REPORTS FROM THE CEYLON MARINE BIOLOGICAL LABORATORY.

No. 1.

THE BIOLOGICAL RESULTS OF THE CEYLON PEARL FISHERY OF 1904,

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WITH

NOTES ON DIVERS AND THEIR OCCUPATION.

BY

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I.—Biological Results relating to Pearl Oysters.

A.—*Details of the Oysters Found.*

THE oysters found during the inspection preceding the fishery were of two distinct generations, the older being from $4\frac{1}{4}$ to $4\frac{3}{4}$ years old, the younger from $2\frac{1}{4}$ to $2\frac{3}{4}$ years. The former were of the same brood as those fished on the Eastern Cheval in 1903, and were therefore of a very satisfactory age for fishing this year. Those of the younger brood will hereafter be termed "immature," not in the sense of sexual immaturity, but in regard to pearl-yield.

The fishable oysters lay as a discontinuous north and south band along the seaward or western side of the Western Cheval. Save for a scattered remnant left over from last year's fishery on the Eastern Cheval and for occasional individuals forming the nuclei of bunches of younger oysters on the parts covered by the immature generation, no other oysters of fishable age were found. Those present last year on the Periya Paar Karai and Vankali Paar were gone, and the huge bed upon the Muttuvaratu Paar, estimated by Captain Donnan in 1902 at a total of 277,000,000 oysters, and which would have been fishable this year, had also disappeared, being partially replaced by a later brood of $2\frac{1}{2}$-year olds.

On the Karaitivu Paar also, none remained of the twenty-five millions of oysters, $1\frac{1}{2}$ to 2 years old, found there in April, 1902, the bank being bare save for a few handsful of 2-year olds. A small bed of this fresh generation of oysters was also discovered on the Dutch Moderagam Paar.

The details respecting the numbers and distribution of these oysters may be summarized thus:—

Number, Distribution, and Sizes of the Fishable Oysters.

The beds of $2\frac{1}{2}$ to 3 years old oysters on the Western Cheval (comprising the South-West, Mid-West, and North-West sections), which I saw for the first time in February, 1902, were found to have the same general disposition, but to have largely decreased in area, and to be represented by several detached patches thickly covered with $4\frac{1}{2}$ to 5-year olds on the South-West Cheval, by a large one of more thinly spread oysters of the same age on the North-West section, and by a third of rather smaller extent on the Mid-West, the southern end of the last-named joining the north-west patch on the South-West section (see Pl. No. 5).

The South-West patches covered in the aggregate an area of 2,754,021 square yards, with an average of twenty-two oysters per dive on 1,778,676 square yards, and of twenty-one on the remainder. As each dive is estimated to account for an area of three square yards, I estimated the

* For "Reports on the Pearl Fishery of 1904," *vide* Sessional Paper XIII., 1904, published at the Government Record Office, Colombo, price 65 cents.

total number of oysters on this section to be 19,500,000, sufficient to give daily loads of 10,000 oysters per boat to a fishing fleet numbering 100 boats for a period of 19½ days, each boat being presumed to have a complement of ten divers.

The oysters on the North-West section amounted to 9,000,000, covering an area of 1,685,460 square yards, a number based upon an average of twenty oysters per dive on 716,100 square yards and thirteen per dive on 969,360 square yards. Although apparently sufficient to give fishing for 100 boats for nine days at an average load per boat of 10,000 oysters, the result of the fishery showed that the number of oysters per dive on certain portions of this bed was too low to give profitable fishing results, with the consequence that the fleet had to be moved off after only five days' fishing and the removal of a little over four millions of the oysters, rather less than half of those present.

The bed on the Mid-West had an area of 992,250 square yards, whereon I estimated there were 6,500,000 oysters, being at the rate of twenty per dive. These oysters were smaller for their age than either those of the South-West or the majority upon the North-West.

The total number of fishable oysters on the three sections of the Western Cheval I estimated at 35,000,000, equal to thirty-five days' fishing for 100 boats.

By far the most important of the beds found, in regard to numbers as well as condition, were the patches on the South-West section, for here, not only were the oysters splendidly grown for their age, but they were absolutely free from commingled young. Everywhere else there was more or less admixture of young of 2 to 2½ years of age, greatest upon the eastern margin of the ground where they marched with the beds of the immature generation. Over those parts of the South, South-East, and South-Central-Cheval, and North Moderagam, occupied by oysters, the older ones, while nearly universally present, were in a very small minority, averaging not more than one to six of those 2½ or 2 years old.

Here and there on the northern edge of the South-East Cheval were small patches of little mixed 4¼ to 4¾-year old oysters, the remnants of the beds fished last year.

As was to be expected, the Periya Paar Karai, ravaged by Rayfish in March, 1903, gave no results, and but a few oysters of no fishery value were found on the Kondatchy Paar—ground that is utterly bad for oyster growth under present circumstances.

The sizes of average samples from the three sections were as follows :—

Name of Bank.	Depth. mm.	Length. mm.	Breadth. mm.
South-West Cheval ...	76·20 ...	69·20 ...	32·32
Mid-West do. ...	72·30 ...	65·25 ...	31·70
North-West do. ...	72·87 ...	66·50 ...	31·57

Some exceptionally fine oysters from a patch at the extreme south end of the Mid-West, a patch lying upon sandy bottom, rose to the high average dimensions of 76·56 by 69·16 by 34·44 mm. If we exclude the last-mentioned series average as being abnormal, we get as the general average of the 4¼ to 4¾-year old oysters fished this year 73·79 mm. by 66·98 mm. by 31·86 mm. During the course of last year's fishery (1903) I found the average size characteristic of oysters on the Eastern Cheval to be 75·51 mm. by 69·18 mm. by 31·18 mm.

Both lots originated from the same brood, and it is significant that, although this year's oysters are a full year older, their size, except in regard to breadth, is decidedly inferior to the average of those fished last year from the Eastern Cheval. This marked characteristic of stunted growth has long been associated with oysters from this particular region, and has frequently been referred to by Sir William Twynam and by Captain Donnan.

Occasionally this stunted growth has been so extreme that the divers and merchants have referred to such oysters as being of the Koddei-pakku variety, a form which is undoubtedly correlated with overcrowding on extensive stretches of rocky bottom.

Number, Distribution, and Sizes of the Immature Oysters.

Immense quantities of immature oysters varying from 2 to $2\frac{1}{2}$ years old cover practically the whole space on the eastern half of the Mid- and North-West sections extending eastwards into the North-Central, Central, and South-Central areas. The South and the South-East Cheval also bear very large quantities, as do also the North and the South Moderagam.

A fair-sized bed plentifully covered with oysters is at present on the Dutch Moderagam Paar, but they are too young to fish for at least a year, as the age of the majority varies from 2 to $2\frac{1}{2}$ years, These oysters represent the young spat that was noted as abundant in November, 1902; their growth has been at the expense of the older that were present that year, and which have been killed off by the more vigorous and numerous young.

The size of those on the North and South Moderagam Paars and those on the South, South-East, and South-Central Cheval is greater than that of those upon the remaining sections, including also the Dutch Moderagam, indicating more vigorous growth and a better food supply. Indeed, many of the oysters have a superficial appearance of being from 3 to $3\frac{1}{2}$ years old. The general superiority of these oysters is well brought out in the following tabulation of the average size of representative oysters from each of the localities named :—

Locality.	Depth. mm.	Length. mm.	Breadth. mm.
South-Central Cheval	$67\frac{3}{25}$ ...	$61\frac{4}{25}$ ...	$27\frac{6}{25}$
North-West Cheval	56 ...	$51\frac{4}{5}$ ...	$23\frac{13}{15}$
North-West Cheval (another locality) ...	$61\frac{1}{3}$ ...	$57\frac{1}{2}$ ...	$23\frac{3}{4}$
Mid-West Cheval	$56\frac{3}{5}$ ...	$52\frac{3}{5}$ ...	$24\frac{3}{5}$
South Moderagam	$68\frac{17}{25}$ ...	$64\frac{4}{25}$ ...	$27\frac{7}{25}$
Dutch Moderagam	$58\frac{19}{25}$ ...	$53\frac{18}{25}$ ...	$25\frac{11}{25}$
Karaitivu Paar	$58\frac{19}{25}$ ...	$55\frac{8}{25}$ ...	$24\frac{4}{5}$

There are few oysters of an age less than two years mixed with these—an important favourable factor, as the fall of abundant spat upon a bed of oysters approaching maturity is one of the most serious dangers that beset the fruition of an oyster bed and one that is most difficult to combat.

B.—*Summary of the Past History of the Oysters Found.*

The oysters fished this year were first seen in March, 1900, by Captain Donnan, who reported that over the whole of the Western Cheval, an area nearly $5\frac{1}{2}$ miles long by 1,000 to 4,000 yards wide. young oysters three to nine months old were thickly spread. The area actually covered was estimated at 5,800 acres.

During the twelve months following an immense decrease took place in the number of oysters present and in the acreage covered, the Inspector reporting that the solid phalanx of 1900 had been broken up into three detached beds, totalling only some 1,685 acres bearing 80,000,000 of oysters.

A year later (February and March, 1902) I first saw these oysters, and noted the marked inferiority of their size to that of oysters of similar age upon the Eastern Cheval. Captain Donnan's estimate of their numbers was 123,357,000 oysters spread over an area of 2,170 acres.

At the same time it was noticed as a disquieting feature that a fresh fall of spat had largely invaded the Western Cheval, a large proportion of the older generation bearing each several young attached to the valves. These young oysters, upon which we now rely for the next immediate fisheries, appeared when first seen (February, 1902) to be from two to six months old.

Besides having invaded the Western Cheval, immense quantities were found on the South-Central and North-Central, South and South-East Cheval regions, and also upon the two Moderagams as well as upon many of the southern banks extending from Negombo to Karaitivu.

In November, 1902, the numbers on the Western Cheval bank were given by Captain Legge as 57,605,000 occupying 936 acres; owing to bad weather the whole of the bank was not surveyed. No other numerical estimate was made till my inspection of this year, when a very careful estimate placed the number remaining at 35,000,000 upon 1,122 acres.

Tabulation of the above facts shows this history clearly :—

Date.	Number estimated.	Age in Years.	Acreage.	Number per Dive.
March, 1900 ...	Too great for calculation	$\frac{1}{2}$ to $\frac{3}{4}$	5,800	—
March, 1901 ...	80,000,000	$1\frac{1}{4}$ to $1\frac{3}{4}$	1,685	21 to 30
March, 1902 ...	123,357,000	$2\frac{1}{4}$ to $2\frac{3}{4}$	2,170	27 to 40
November, 1902 (inspection incomplete) ...	Over 57,605,000	3 to $3\frac{1}{2}$	Over 936	—
February, 1904 ...	35,000,000	$4\frac{1}{4}$ to $4\frac{3}{4}$	1,122	13 to 22

The discrepancy between the estimates for 1901 and March, 1902, appears largely explainable by the estimate of oysters per dive having been either too low for the former year or too high for the latter, estimates being liable to variation with every condition that affects a diver's powers of working. I have known divers bring up from one particular spot but ten oysters per dive when the weather conditions were unfavourable, and yet the following day, the sea being calm and warm, the same men would report double the number. To arrive at accurate estimates the weather conditions, if adverse, should be allowed for and the total number of oysters increased accordingly.

In November, 1902, the encroachment of the younger generation had markedly increased, and with the growth of the smaller ones many portions of the Western Cheval bank—the parts where they were most abundant—had to be transferred from the category of regions bearing maturing oysters to those monopolized by the younger generation.

In February, 1903, no regular inspection was made of these latter regions, but by means of numerous descents in a diving dress I was able to obtain a fair knowledge of the distribution of the younger oysters.

On the Cheval and the North and South Moderagam the young already noted were found well grown and flourishing, and while their actual age was but $1\frac{1}{4}$ to $1\frac{1}{2}$ year, many, especially upon the Moderagams and South Cheval, had the appearance of being two years old.

On the Muttuvaratu and Dutch Moderagam the older oysters had made no increase in size, and were in an unhealthy and miserable condition. Mixed with them were considerable numbers of a younger generation apparently over one year old.

This year, as already stated, the older generation proved to have died off upon the Karaitivu while the younger generation found last year had made fair progress and appeared moderately healthy. Similar conditions, I believe, characterize the Muttuvaratu this year, judging from the rather meagre data at my command.

Rate of Increase in Size.

So little is known with exactitude concerning the rate of growth of oysters that the following tabulation of the observed increase in size of these younger oysters has considerable value :—

Table showing Rate of Growth of Oysters aged $2\frac{1}{4}$ to $2\frac{1}{2}$ years, March, 1904.

(1) *South-East and South-Central Cheval.*

Date.	Age in Years.	Size in millimetres.
March, 1902	$\frac{1}{4}$ to $\frac{1}{2}$ ...	35·0 × 32·0 × —
November, 1902	$\frac{11}{12}$ to $1\frac{1}{6}$ ...	50·57 × 47·52 × —
March, 1903	$1\frac{1}{4}$ to $1\frac{1}{2}$ ...	54·41 × 49·75 × 20·38
March, 1904	$2\frac{1}{4}$ to $2\frac{1}{2}$ ...	67·12 × 61·16 × 27·24

(2) *Moderagam Paars.*

Date.		Age in Years.		Size in millimetres.
March, 1902 ...	...	$\frac{1}{4}$ to $\frac{1}{2}$	...	37·15 × 33·20 × —
March, 1903 (North)	...	$1\frac{1}{4}$ to $1\frac{1}{2}$	...	61·17 × 54·50 × 24·28
March, 1904 (South)	...	$2\frac{1}{4}$ to $2\frac{1}{2}$	...	68·68 × 64·16 × 27·28

(3) *North-West Cheval.*

March, 1902 ...	...	$\frac{1}{4}$ to $\frac{1}{2}$	...	33·50 × 30·75 × —
November, 1902 ...	...	$\frac{11}{12}$ to $1\frac{1}{6}$	...	47·64 × 44·36 × —
March, 1904 ...	..	$2\frac{1}{4}$ to $2\frac{1}{2}$	...	56·60 × 52·60 × 24·56
March, 1904 (another locality)	...	$2\frac{1}{4}$ to $2\frac{1}{2}$	...	61·33 × 57·40 × 23·70

When these records are extended over the remaining life-period of these oysters, we shall have for the first time reliable data as to the relative rate of growth from year to year upon three of the most important of our oyster banks.

The respective increases during the first two annual intervals are as follows:—

Period.	South-East and South Cheval.	North-West Cheval.	Moderagams.
Twelve months from age three to six months ...	mm. 19·41 × 17·75 × —	—	mm. 24·02 × 21·30 × —
Twelve months from age $1\frac{1}{4}$ to $1\frac{1}{2}$ year ...	12·71 × 11·41 × 6·86	—	7·51 × 9·66 × 3·00
Total increase for two years ...	32·12 × 29·16 mm.	27·24 × 24·25 mm. (average)	31·53 × 30·96 mm.

It will be noted that the growth both of the Moderagam and of the South-East and South Cheval oysters has been greater and more rapid than that of those upon the Western Cheval. Of the former, the Moderagam oysters, growing more quickly than those of the South-East and South Cheval up to the age of $1\frac{1}{4}$ to $1\frac{1}{2}$ year and thereby attaining larger size, suffered retardation in the rate of increase thereafter. In the second annual period recorded they made but 7·51 mm. by 9·66 mm. by 3·00 mm. increase, whereas the South-East and South Cheval oysters made 12·71 mm. by 11·41 mm. by 6·86 mm. in the same period and so reduced the disparity in size caused by the more rapid growth of the Moderagam individuals at the earlier age, so much so that the difference between them at the age of $2\frac{1}{4}$ to $2\frac{1}{2}$ year is but 1·56 mm. by 3·00 mm. by 0·04 mm.

This lends support to the belief elsewhere expressed (Professor Herdman's "Report," Part I., page 136) that shell growth is most vigorous during the first two years of life, or, as we may now put it, up to the size of about 60 mm. by 55 mm. by 24 mm. and that thereafter it slackens to a very slow rate, actually coming to a stand, or even retrograding as regards length and depth in the case of the stunted oysters of the Muttuvaratu and the Mid-West Cheval. As example of this slowness of growth in older oysters, take those fished this year from the South-West Cheval. These were the most vigorous and freely grown as regards the general average, and yet the increase made from November, 1902, to March, 1904, was but 5·31 mm. in depth by 3·77 mm. in length, *i.e.*, between the ages of say 3 to $3\frac{1}{2}$ and $4\frac{1}{2}$ to $4\frac{3}{4}$ (size in November, 1902, was 71·25 by 65·39 mm.). Contrast with this the increase *within the same period* (sixteen months) when the oyster is younger, say between the ages of 11 to 18 months and $2\frac{1}{4}$ to $2\frac{1}{2}$ years. In the case of oysters of this age from the South Cheval the increase has been, as shown above, as much as 16·55 by 13·64 mm., and in the case of the North-West Cheval 13·69 by 13·04 mm.,—a remarkable difference indeed.

Again, we see that the disparity of growth is most marked during early life—up to the age of two years—so that oysters situated under exceptionally favourable conditions attain such dimensions that they are liable to be credited with greater age than knowledge of their origin will warrant.

C.—*Causes of Decrease among the Fishable Oysters since March, 1902.*

The factors which tend to reduction in the number of oysters in any bed fall into two categories: (*a*) those which affect spat and oysters under one to two years of age; and (*b*) those which militate against the well-being of those in or approaching the pearl-producing stage.

The first set of inimical influences has been treated of at length by Professor Herdman, and it is only necessary here to discuss the causes which have led to great decrease since 1902 in the older generation of oysters that was fished this year on the Western Cheval and the disappearance of the same generation from the Muttuvaratu, the Dutch Moderagam, and the Karaitivu Paars.

The decrease appears to have arisen from two chief causes, overcrowding and sand disturbance, the ill-effects of which have been intensified by several of subsidiary importance. The former affected the beds in the North-West and Mid-West Cheval sections together with the Muttuvaratu and Karaitivu Paars; the latter those of the South-West Cheval.

Sand Disturbance effected the greatest harm upon the South-West Cheval, as this area has but few stretches of exposed rock surface, while "cultch" is not sufficiently abundant. When this bed was first seen by Captain Donnan in 1900 the whole area was thickly spread with oysters as well on the sand as on the rock and on the cultch-strewn areas. With every recurrent period of stormy weather these oysters suffered thinning by encroachment and overwash of sand, till eventually they were cleared from off the sandy uncultched areas, and only those left that lay on rocky ground and on sufficiently cultch-covered bottom.

A subsidiary cause of destruction was the ravages of the boring sponge, *Clione indica*, which appeared specially active on this section, riddling the valves and sapping the vitality of the oysters by the drain it causes upon the nacre-secreting glands. Out of 400 individuals examined 310 were affected by *Clione;* less than 23 per cent. were free from the infection.

Apart from this the oysters of the South-West Cheval were the healthiest, the organs being plump and well-developed, whereas a considerable proportion of those from the Mid-West and North-West sections were thin and of poor appearance.

The Effects of Overcrowding.—Sand disturbance produced comparatively little numerical reduction upon the North-West and Mid-West sections, these regions possessing more extensive stretches of rocky bottom than any others in this neighbourhood. The reduction was due primarily to the effects of overcrowding; not perhaps so much because of their own numbers, great as they were originally, but rather because of huge deposits of spat in July and December of 1901 along the eastern moiety of these sections, which fell upon the older oysters there present. For the first year the effects were little marked, but little by little as the myriads of newcomers flourished and increased in size the well-being of the older generation was affected, a result that showed itself first by arrest of the growth of the shell, and then later by starvation, lowered powers of reproduction, and wide spread mortality.

Regarding the arrest of growth, we note that the older oysters on the Mid-West Cheval measured 69·42 mm. by 64·54 mm. in March, 1902, when they were $2\frac{1}{2}$ to $2\frac{3}{4}$ years old, while survivors on the same area were but 72·30 mm. by 65·25 mm. in March, 1904, an increase in size of but 4·37 mm. in depth by 2·45 mm. in length in two years, a growth so slight as to justify the conclusion that oysters from the Western Cheval practically attain their maximum length and depth upon reaching the age of three years, increasing thereafter in no appreciable extent save in thickness, which is due to thickening of the valves by deposit of nacre upon the inner surface.

In the case of the Muttuvaratu, the Karaitivu, and the Dutch Moderagam Paars, the disappearance of the oysters has been total, caused not so much by the competition introduced by the presence of myriads of vigorous young, though this also existed, as by the overcrowding set up by their own immense numbers. This had such baneful effect, that when I saw them in March of last year they showed marked deterioration upon their condition four months previously, while their size showed actual decrease in length and depth (58·84 by 54·32 mm. in November, 1902, as against 57·54 by 54·00 mm. in March, 1903).

Again, out of 227 examined, 25 or over 11 per cent. were affected with the "yellow" disease, a malady marking the imminence of widespread mortality.

That the Muttuvaratu oysters should have been entirely cleared away, as against the relatively large number left upon the Western Cheval, is undoubtedly due to stress of overcrowding having been less acute and less widespread in the latter case.

Subsidiary Causes.—The usual general enemies of the pearl oyster were present in their accustomed numbers: starfish, boring molluscs, and the smaller oyster-eating fishes (*Balistes, &c.*). The two former, the starfishes especially, work considerable harm collectively, and their reduction in numbers is one of the benefits to be derived from dredging on a large scale.

The smaller oyster-eating fishes were not excessively numerous upon the Cheval, and are not at present a destructive agency, seeing that the oysters are now too strong and of too large dimensions to be crushed by the small jaws of these fishes. Their ravages are only to be feared when a bank is covered with spat, when these fishes gather from all quarters; if the deposit is limited and the nature of the bottom sufficiently smooth, the attack may involve partial or even entire annihilation. The boring-annelid, *Polydora* sp., was markedly abundant on the South-West Cheval, but I could trace few fatal effects to its tunnelling.

Far otherwise was it with the inroads of the boring sponge (*Clione*) already alluded to. Hundreds of valves were examined, where not only was the substance of the shell riddled by its honeycomb-like tunnels, but more serious, the insertion scar of the adductor muscle was tuberculated and diseased, due to the inferior power of nacre production of the epithelial layer in this region. So great, indeed, was the nacreous tuberculation in some cases that I have seen the natives save these shells with a view to cutting the tubercles off to use in the manufacture of pearl jewellery.

Whenever the inroads of *Clione* were extensive, the sub-epithelial tissue in particular and the other tissues in general were thin and diseased-looking. A fairly large proportion of the dead shells found during the fishery on the South-West Cheval were badly affected; *Clione* must undoubtedly be included among the more destructive agencies with which we have to contend.

There was no evidence of any extensive depredations on the part of rays this year, and so far the destruction by these fish of the Periya Paar Karai oysters last year remains unique in my experience.

Rays were several times seen; on the 27th February a large shoal heading south passed the ship when at anchor on the North-West Cheval. The sight was a remarkable one, the sea for over fifty yards square being one patchwork of yellow discous bodies.

Fair-sized examples of *Trygon walga* were caught from time to time. None of them furnished direct incriminating evidence, the stomachs being filled with crustacean *débris* and fragments of small lamellibranch shells other than those of the pearl oyster.

Like the trigger-fishes, these smaller rays would appear to find the present size and strength of the oysters too great for the power of their teeth and jaws.

D.—*Condition of Spat on the Periya Paar in 1904.*

March 14th was devoted to an inspection of the Periya Paar, with the result than an immense bed of oyster spat* was there discovered. The young oysters were incredibly abundant, spread densely over an area fully five miles in length by from one mile to one mile and a half in width. The age was under three months, so that they must have been spawned not earlier than December of 1903, more probably towards the end of the month than towards the beginning. Alike on sandy and

* The term "spat" is used in these pages in a wide sense to comprise all sizes of attached oysters under the age of four months.

on rocky ground was this profusion found, but on the rocky ground the numbers were notably greater. On the sandy stretches the oysters formed bunches often of large size, the individuals attached in many cases to one another, but generally having a nuclear fragment of small cultch, which most frequently was a cockle shell, a nullipore ball (*Lithothamnion*), or a small fragment of "paar." The spinning mussel (*Modiola barbata*), "suran" as it is called by the Tamil divers, was in places abundant, especially upon some of the sandy ground, but not sufficient to constitute a grave danger to the bed. This discovery of spat paralleled in extent and nature that made by Professor Herdman in February, 1902, when he estimated approximately the numbers of the young oysters at one hundred thousand millions, and which, it will be remembered, had all disappeared when I next re-examined the bank in November of the same year.

A very remarkable fact was that some of the largest of these young oysters when last seen, 3rd April, had already developing gonads filled with reproductive products fully formed and ready to be shed. The average size of these sexually mature individuals was $25\frac{1}{2}$ by $26\frac{1}{2}$ by 9 mm. The smallest was $24\frac{3}{4}$ by 25 by $8\frac{3}{4}$ mm. The extreme age of these cannot be more than $3\frac{1}{2}$ months, and we are fully warranted in considering that sexual maturity is reached by the pearl oyster at or soon after the age of three months. Previous to this the age of six months was the earliest at which reproduction had been observed.

Sexual precocity at such a small size and early age, in itself remarkable, has much practical bearing upon the replenishment of the banks from time to time, a subject that will be treated of on another occasion.

Principal Spawning Seasons.

The gonads of this year's fishable oysters were nearly all in a spent condition during February and March, and this taken in conjunction with the presence of incredible multitudes of very young oysters—so young, indeed, that they could not have been set free earlier than the middle of the December preceding—points to the months of December and January as the period coinciding with one of the two maxima of reproductive activity that characterize the pearl oysters of Ceylon.

In April the gonads began to show sign of increase, and a small quantity of spat was seen. I now believe that the two maxima do not coincide as we at first supposed with the intervals of fine weather and variable winds between the monsoons, *i.e.*, November in the one case, March and April in the other. This year's observations point distinctly to the chief spatting seasons having January and July as the central periods respectively, times when the monsoon winds are blowing steadily and strongly. On *a priori* grounds this particular seasonal activity is also indicated, for wide dispersal of the embryos can be more effectually attained during this boisterous period of strong currents than if they were expelled during the inter-monsoon lulls, characterized by light winds and erratic and circumscribed surface drift.

When stating this as the general rule it must, however, be borne in mind that there are yet many more or less extensive exceptions; small quantities of young oysters are occasionally met with during other months, but such spat falls are sporadic, and do not invalidate the statement that the pearl oyster has two spawning maxima which centre round midwinter and midsummer respectively.

False Spat.

Very frequently in the history of the pearl banks false hopes of future fisheries have been raised by the appearance on the banks of incalculable myriads of minute molluscan spat found clinging in multitudes to sea-weeds and water-plants either floating or rooted to the bottom. For long decades these were confounded with the true spat of the oyster, which they resemble closely. Critical examination has proved them to be the young of a small bivalve, *Avicula vexillum*, closely allied to the pearl oyster. Captain Steuart appears to have fallen frequently into the error of confounding this with pearl oyster spat, as he identified some of the *Avicula vexillum* spat when submitted to him after his retirement as being true pearl oyster spat. Mr. H. Sullivan Thomas, in his valuable report to the Madras Government on the pearl fisheries of Tuticorin (1884), went exhaustively into this question, and appropriately termed these minute shells "false spat," in reference to the falsified hopes of a fishery they so frequently gave rise to.

This present season *Avicula vexillum* is extremely abundant, very young stages being found on fine algæ in four to five fathoms west of Karaitivu island, while older stages up to three parts grown were dredged in wonderful abundance clinging to the fronds of *Halophila* on the sandy ground north-east of Aripu reef.

It is interesting to note that the figures purporting to represent oyster spat in Sir Emerson Tennent's "Sketches of the Natural History of Ceylon" in reality depict faithfully the appearance of this "false spat," and are therefore misleading in respect to the true spat of the pearl oyster.

E.—*Prospects of Future Fisheries.*

The prospects of a large fishery, both next year and in 1906, upon the Cheval and Moderagam Paars, are excellent; the immense quantities of young, 2 to 2½ years old, occupying the Moderagams, the South-East, South, Mid-West, North-West, and the greater part of the three central blocks of the Cheval Paar being ample for two years' fishery. Those on the Moderagams and on the South, South-East, and South-Central Cheval will, I hope, be fit to fish next March, being more advanced in growth than those on the Mid-West and North-West Cheval. Apart from this reason it will be advisable to fish certain of the former sections at as early a date as the valuation of samples may show to be profitable, because as many of the oysters on the beds in question lie loose in bunches on a sandy bottom, they are thereby exposed to the danger of removal and destruction by currents of exceptionally great force, a contingency infrequent, but not unknown, as instanced by the extraordinary fishery of 1888.* By March of 1905 these oysters will be about 3½ years old, and, judging from the rapidity of their growth and their exceptional large present size, by that date they should be sufficiently matured to give a profitable fishery. They will then be practically of the same age as those of the 1903 fishery, which realized just under Rs. 30 per thousand average price.

If fishery be postponed till 1906, the pearl yield would be greater, but were this done, supposing the oysters remained in safety till March, 1906, upon the banks, there would then be too great a quantity to fish in one year, and a moiety would be left for the succeeding year 1907. But in 1907 the remainder would be 5½ years old, and under the conditions prevailing on the Western and Median Cheval, where these remaining oysters would be, it is most improbable that they would be then surviving. Definite decision cannot be arrived at till the next valuation has been made in November of the present year.

The oysters at present on the Muttuvaratu and the Dutch Moderagam Paars should also be ready to fish in 1906, but I do not build confidently upon this; even now these oysters are extremely stunted and sickly looking, and are certain to decrease very largely ere ripe to fish.

Beyond 1906 or at latest 1907 there is likely to be a break in the fishery cycle, a more or less prolonged blank cycle, whereof the duration will be largely dependent upon whether or not large measures of transplantation be resorted to, seeing that there has been no fall of spat upon the Cheval, Moderagam, or Muttuvaratu Paars within the last two years—that is to say, since July, 1902.

The only other hope lies in the possibility that a younger generation may be growing up on some of the paars that have not been inspected of recent years. I therefore trust that I may be given the opportunity to make exhaustive inspections during the next two years. The more I learn at first-hand about the banks and the more I read of the old records, the more convinced I am that limited and narrow-compassed inspections have been the cause of the loss of many valuable fisheries.

* Twynam, "Report on the Ceylon Pearl Fisheries," 1900, pp. 9 and 59

To give a concrete instance of the essential need for thorough periodical examinations of the whole pearl-bank area, the following extract from Captain Donnan's report of the 1878 inspection furnishes significant reading:—

> "While inspecting the Cheval I discovered oysters on a new bank, $2\frac{1}{4}$ miles to the westward of the Cheval, where it has generally been considered that there was nothing but an extensive sandy flat. I saw it recorded in the diary of inspection by Captain Laughton in March, 1802, that he found oysters of four or five years in abundance in nine fathoms rocky bottom, Koodromallai bearing S.E. $\frac{1}{4}$ E.; and being anxious to test if rocky bottom really existed in that neighbourhood, I took all the inspection boats in tow of the launch out to the verge of the bank of soundings, and directed them to dive all the way back to the inspection vessel, so as to cross the position noted by Captain Laughton, and they came upon rocky ground and oysters, where they placed a buoy. On subsequent examination this bed of oysters proved to be about $1\frac{1}{2}$ mile in its longest direction N.N.W. and S.S.E. and about three-fourths of a mile broad at its broadest part, having a depth of water over it of from $8\frac{1}{4}$ to $9\frac{1}{4}$ fathoms and a sandy flat of nine fathoms between it and the Cheval. I believe it to be an extension of the Periya Paar in a S.E. direction. I have duly recorded its position in my diary. The superficial area of the bed is 3,845,935 yards, and the oysters on it average twenty-two to a dive. I estimate the total number of oysters on it at $3\frac{1}{2}$ millions, sufficient to give ten days' fishing for fifty boats with loads of 7,000 oysters each. I found, however, 13 per cent. of dead shells, which is an unfavourable sign, and a large quantity of seaweed growing on the oysters. I have been much puzzled about the age of these oysters, as they appear to be old although of small size. I believe them to be of the description known to the natives as "koddapako," which are said to be a small class of oyster, but rich in pearls. They resemble the oysters of the Chilaw banks, which I know to be four years old now, and therefore they ought to be fit for fishing in March next.
>
> "I can find no record of this bed having ever been inspected since 1802, and it is a curious coincidence (*sic*) that what was then recorded of its condition might be recorded now on its most probably first examination since that time."

The oysters referred to in the above extract were fished the following year, 1879, and the question is at once suggested—how many times between 1802 and 1878, the interval during which this paar received no attention, did oysters mature unknown upon this ground; and, further, how many other oyster-bearing patches have been left in the like neglected state?

The spat upon the Periya Paar will, I fear, vanish during the present south-west monsoon—its all but invariable fate—smothered in sand churned up by the violence of the monsoon seas breaking on this bank, of which the seaward margin forms the edge of the great submarine plateau over which the pearl banks are scattered.

F.—*Pearl Production.*

Parasites of the Pearl Oyster.

Entozoa were plentiful in the oysters fished this year, both nematode worms and encysted cestode larvæ; the former especially were more numerous than I had before seen, and many oysters contained two individuals.

A solitary example of *Aspidogaster* was found; located as usual in the pericardium. Cestode larvæ were particularly abundant in the oysters from the North-West Cheval, and this fact will be referred to again when we come to treat of the relative pearl yield of the three sections.

More light is still needed to enable us to complete our knowledge of the life-history of the pearl inducing parasite, and till I have an opportunity to dissect a number of individuals of the large Sting-Ray, *Trygon uarnak* (Forsk), said to be the oyster-eating *Walwady tirikkai* of the Tamils, there can be no chance to close this important gap in the investigation. No opportunity offered to obtain one of these fishes at the late fishery, my position twelve miles from land precluding access to the fishermen of Pukulam and Marichchikkaddi, the only possible places where I could hope to procure a specimen.

Of *Trygon walga* several small individuals were caught by the inspection boatmen. This species does not however possess teeth sufficiently powerful to destroy oysters more than a few months old, and no cestode parasites belonging to the species found in the pearl oyster were discovered when these fish were dissected.

Besides pearl oysters, a large number of fishes were dissected in search of the adult stage of the pearl oyster parasite, and such work will form the subject of detailed report in the future in the concluding volume of Professor Herdman's Report.

The Yield and Character of Pearls from different Regions.

During the inspection of the Cheval I collected representative samples of mature oysters from the South-West, Mid-West, and North-West beds respectively. From the 7th to the 9th March I was engaged superintending the washing of these samples and the valuation of the pearls picked out. The results showed that the South-West oysters were the richest in pearls, the North-West following closely, with the Mid-West unmistakably much poorer in yield.

The following table will make clear the relative returns:—

Bed.	Quantity.	Total Weight of Pearls.		Weight per 1,000 Oysters.		Valuation per 1,000 Oysters.	Size of Oysters in Millimetres.
		Kalanchu.	Manchadi.	Kalanchu	Manchadi.	Rs. c.	
South-West Cheval.	12,000	7	13·25	—	12·76	36 1	76·20 × 69·20 × 32·34
North-West Cheval.	7,200	2	17·00	—	7·91	33 75	72·67 × 66·50 × 31·50
Mid-West Cheval ...	6,000	2	0·88	—	6·81	20 25	72·30 × 66·50 × 31·57

The weight of pearls per 1,000 was very high in the case of those from the South-West, which fact may be correlated with the size of these oysters being considerably greater than that of the other two lots. In regard to the quality of the pearls, the North-West oysters while yielding a less weight contained a much greater proportion of "cyst pearls" of excellent quality than those from the South-West, which latter owed their greater proportionate weight of pearls to a noteworthy abundance of "muscle pearls."

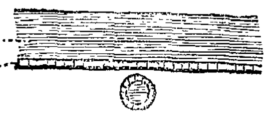
External characteristics give but the most meagre indication of what the pearl yield may be—in regard to "cyst pearls," the abundance or otherwise is connected with the factors which control the relative abundance of the pearl-inducing cestode and those which conduce to its death during encystment in suitable localities within the tissues, problems as yet obscure. The fact is to be noted that dissection showed the oysters from the North-West Cheval to be more extensively infested with cestode cysts than those from the other districts, while the valuation sample showed that cyst-pearls were much more abundant in these oysters than in those from either the Mid-West or South-West Cheval sections.

With regard to muscle pearls, the general fact stands out, deduced from my experience of two fisheries, that the more vigorous and well-grown the oysters may be, the more abundant are the "muscle-pearls."

Shell-pearls.

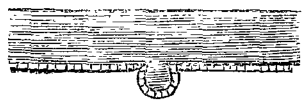
At the close of the inspection, when the valuation samples of oysters had been washed, I seized the unique opportunity thus afforded to examine over 30,000 pairs of separated valves of the pearl oyster. I did this chiefly to see if any considerable proportion of shell-pearls were induced by the irritation caused by perforation of the shell by boring parasites,—sponges, lamellibranch molluscs, and annelids. The result negatived this supposition and showed that these animals have little influence upon pearl production; the sponge, *Clione indica*, causes occasional roughening or even rugged tuberculation at the insertion scar of the adductor muscle, and the annelid, *Polydora*, may produce an occasional discoloured internal excrescence, usually sharp-pointed; more rarely a parasitic nematode, free or encysted, is cemented to the nacre and sealed up in a pearly sarcophagus.

By far the larger number of shell-pearls, fully 90 per cent. of the whole number, are due to the attachment of cyst- and muscle-pearls to the nacreous lining of the shell, consequent upon rupture of the pearl-forming sac upon the outer aspect as well as of the epithelial layer beyond, which is intercalated between the nacreous inner surface of the valve and the pearl sac. This rupture of the tissues is due to the pressure exerted by the pearl as it increases in size, producing primarily a thinning of the containing membranes on the side where resistance is felt, a tenuity which gives way at last placing the pearl in actual contact with the nacre and converting its closed pearl-secreting sac into a pouch-shaped pocket or ampulla, the open neck directed outwards and in continuity with the general epithelial layer upon the exterior surface of the mantle. The process is shown in the following two diagrams :—



a

a.—A cyst-pearl lying free in the sub-epithelial layer of the mantle.



b

b.—The same pearl become attached to the nacre of the shell.

Shell-pearls originating in this manner are at first pedunculated, and at this stage may be detached readily. Little by little the peduncle tends to become obiliterated, and eventually the pearl may be entirely lost in the substance of the shell nacre.

Shell-pearls are in many cases affixed without definite order or arrangement. Examples may be located anywhere, the largest however being usually either in the peripheral region of the nacre or in the central region, where the position corresponds with the lateral surface of the visceral mass. Such irregularly disposed pearls are usually found solitary. Smaller attached pearls are not infrequently located either singly or in a serial row of from two to five along the pallial line, each pearl coinciding in position with a muscle scar. Very rarely small ones may be seen along the edge of the adductor muscle scar.

Most frequent of all are pearl masses of irregular or even botryoidal form attached at or adjacent to the levator insertions. (Pl., 9 fig. E.)

Decalcification of the pearls attached to muscle scars reveals no organic nuclei, whereas the pearls irregularly disposed have cestode embryos as nuclei, exactly as " fine " pearls have.

Examination of these 30,000 shells gives therefore strong confirmatory evidence in support of the theory set forth by Professor Herdman and myself, associating such pearls as have no vermean nuclei—cestode or other platyhelminthian larvæ—with the attachment surfaces of those muscles which have insertion on the shell, especially the small and comparatively weak levator and pallial muscles.

Figs. A to D, Pl. 9, are very instructive in showing the perfect way in which the positions of the shell-pearls there depicted coincide with series of pallial muscle scars.

G.—*Demarcation of the Cheval Paar Region.*

Division into Eleven Sections.

I have definitely adopted in the present report that system of nomenclature for the different sections of the Cheval Paar which I proposed to, and which has been approved by Professor

Herdman. Besides being a present convenience, adherence to a fixed and carefully thought out scheme of nomenclature, coupled with properly defined limits to the sections, will go far to obviate vitiation of inference both in current work and in the historical deductions that will be made in future years by succeeding Inspectors. The sketch plan herewith will form a permanent record of the method of subdivision adopted in the case of the Cheval Paar, the largest and by far the most important of our pearl banks.

I have subdivided this paar into three divisions, the Western, Median, and Eastern. The Western comprises the South-West, Mid-West, and North-West sections or blocks; the Median the South, South-Central, Central, and North-Central; while the Eastern also consists of four subdivisions named respectively the South-East, Mid-East, North-East, and North. The Periya Paar Karai may be said to be a continuation to the N.N.W. of the last named, while the northern limit of the North Moderagam Paar marches with the southern edge of the South-East Cheval.

Each division, and well-nigh each section, has distinctive physical and faunistic characteristics. The Western, save in the South-West section, is essentially a rocky bed; the Median with the exception of the South section is almost entirely a level sand plain; the Eastern partakes of both characters, patches of rock and of sand being intermingled in all proportions.

The South-West, the South, and South-East have much in common, consisting of a rocky framework more or less hidden beneath a layer of sand varying from a few inches to a couple of feet in thickness, with flat-surfaced rocky patches, level with the general surface, here and there. In a good many places an abundance of cultch—dead shells, dead coral, nullipore balls, and small fragments of calcrete—compensates for the scarcity of rocky surfaces, but there are many localities where the cultch is insufficient, and which therefore bear fewer oysters than they would be capable of bearing if effective cultching operations were carried out. Oysters grown upon these sections mature earlier than those on the other sections.

Sand living molluscs, *Mactra*, *Cardium*, and *Venus*, are abundant, with small isolated coral colonies, chiefly Astræids, and fair numbers of the small *Fungia dentata*, a coral that lives free upon the surface of the sand. The black crests of *Spongionella nigra* are very common objects here.

The Mid-West and North-West sections, being abundantly rocky, bear many fixed corals, especially *Turbinaria cinerascens*, bushy but isolated Madrepores, large Astræids, and some *Porites*. Very characteristic is the Kudai-sponge, *Phyllospongia holdsworthi*, which this year, as usual, was common on the valves of the oysters from the Mid-West section. Nearly as common upon the oyster valves were pretty branched colonies of *Madrepora*. *Cidaris*, *Antedon*, and the spicule-bearing Ascidian, *Rhabdocynthia rosea*, are other characteristic organisms.

The Eastern division has fewer distinctive faunistic features, the most characteristic being the magnificent Hydroid Zoophyte, *Campanularia juncea*. On the eastern margin of the Mid-East rosy arborescent Pennatulids are abundant, rooted in the sand.

Comparison of the relative Natural Importance of the Eleven Sections judged by Historical and Biological Data.

Now that cultivation of the pearl banks is to be taken in hand systematically, it is essential to know the relative natural "fertility" of the different sections, *i.e.*, their relative capacity for the successful maturing of spat falling thereon.

Two methods of ascertaining this information exist, the historical and the physico-biological. The former is based upon the information contained in the diaries and reports of former Inspectors of the Pearl Banks, the latter upon the data obtained from the dredging and diving operations carried out during the last two years and a half.

Taking the historical evidence first, we may summarize the facts in the following tabulation obtained and verified by a detailed search through the voluminous records of past fisheries, namely:—

Table showing the Fisheries held since 1820 on the different Sections of the Cheval Paar Region.

North-West Cheval.	Mid-West Cheval.	South-West Cheval.	South Cheval.	South-East Cheval.	Mid-East Cheval.	North-East Cheval.	North Cheval.	North-Central Cheval.	Central Cheval.	Moderagam.	Periya Paar Karai.
1833	1831	1855	1829	1836*	1837*	1835*	1833	1833	1835*	1828 (N. & S.)	1835
1835	1859	1863*	1830	1837*	1888	1887*	1835*	1835*	1836	1836 (N.)*	1836
1881	1874	1888	1836*	1877	1903	1888*	1887	1857	1857	1859 (N.)	1903
1888	1880	1904	1837*	1888	—	1903	1903	—	1859	1860 (N. & S.)	—
1904	1888	—	1858	1903	—	—	—	—	1888*	1877 (N.)	—
—	1904	—	1863	—	—	—	—	—	—	1887 (N.)*	—
—	—	—	1877	—	—	—	—	—	—	1888 (N. & S.)	—
—	—	—	1888	—	—	—	—	—	—	—	—
5	6	$3\frac{1}{2}$	7	4	$2\frac{1}{2}$	$2\frac{1}{2}$	$3\frac{1}{2}$	$2\frac{1}{2}$	4	6	3

* Indicates that the fishery in such year was partial, either upon a small portion of the area of the section or that a fishery of the same brood of oysters was held on the same region in successive years, *e.g.*, 1880 and 1881, on the Mid-West. These are counted as "half-fisheries."

Comparison of the total number of fisheries held on the respective sections shows the marked superiority of the Moderagams and the South Cheval to all the others; next in value appear the North-West and the Mid-West with the South-West, the North and South-East following closely. None of the others have been fished more than three times within the last eighty-four years.

In seeking for the reason of the marked superiority shown by certain of the above regions we will tabulate the principal general physical characteristics of the bottom, and see what light this sheds upon the problem :—

Character of Bottom.	Typical of the undernoted Sections.
Rocky ...	North-West and Mid-West Cheval.
Sandy, without much cultch ..	South-Central, Central, and North-Central Cheval.
Sandy, with fair abundance of cultch ...	South and South-East Cheval and North Moderagam.
Mixed rocky and sandy bottom with variable proportions of cultch ...	South Moderagam, South-West, North-East, and Mid-East Cheval and the Periya Paar Karai.

From this, considered with relation to the evidence furnished by history, it appears that the ground upon which oysters have most frequently matured are (*a*) sandy bottom where cultch is most abundant (*e.g.*, South Cheval and North Moderagam); (*b*) bottom characterized by long stretches of rock surface, with a minimum of sand (*e.g.*, North-West and Mid-West Cheval). The worst bottom is, as seen, the sandy North-Central, Central, and South Central regions, where cultch is not widely distributed, and the mixed ground (rock and sand) on the North-East and Mid-East Cheval. In the case of the two latter localities cultch is scarce on the sand, and in the earlier part of last century inspection here was apparently not carried out in a thorough and systematic manner.

Such conclusions agree generally with those we arrive at if we examine the matter from the biological standpoint and which have been stated elsewhere, namely, that a wholly rocky bottom, other things being equal, will accommodate a larger spat fall than sandy areas, but that if the surface of the latter be well supplied with loose fragments of dead coral, shells, nullipore balls, and calcrete, such will mature a larger quantity of oysters than the rocky bed. And, again, the size attained by the oysters on the well-cultched sandy region will, in a given time, much outdistance that of those upon rock. Oysters from rocky ground are particularly liable to die off about the age of three years, a calamity due to the effects of overcrowding reaching a maximum of pernicious effect at that period.

More definite deductions we cannot at present attempt on account of the great variety and complexity of the other conditions which affect the presence and maturing of oysters upon particular regions. Thus, while certain localities may appear and may actually be better adapted than others for the growth and well-being of oysters, they may, in spite of this, yield fewer fisheries than ground which is decidedly less favourable, the reason being that the interaction of the spat-bearing currents may drift the spat away from the more favourable grounds and thus endow a worse locality with the more frequent spat falls, the favourable ground being denied the seed that is needful to produce the rich harvest which it is capable of producing.

II.—Cultivation of the Pearl Banks.

History of the Proposal to transplant Spat at the 1904 Fishery.

Transplantation of spat with the subsidiary operations which it entails is admittedly the most important cultural means at our disposal for increasing the harvest of the pearl banks, and to make good any deficiency in spat-fall upon the favourable paars.

As noted elsewhere, no fall of oyster spat has occurred upon the Cheval and Moderagam Paars during the last two years, and it therefore behoves us to endeavour to make good the shortcomings of nature by employing artificial means to stock these paars with a fresh supply of oysters, unless we be content to endure frequent series of lean years in our coming fishery records.

With this transplantation scheme in view I took an early opportunity to prospect upon the Periya Paar for young oysters, experience and the historical records of the banks having shown this to be the ground where occur the richest and most frequent falls of spat. My hopes were amply fulfilled in the discovery on the 14th March of a huge bed extending north and south fully five miles and varying in breadth from one mile to one mile and a half. Everywhere the bed was densely covered with pearl oysters less than three months old. The conditions for dredging them up could not have been better, vast numbers lying on sand in densely crowded clusters and bunches. Such an enormous abundance of spat afforded the requisite material for transplantation, and as the history of this bank shows conclusively that oysters do not mature here oftener than once in a century, and but few even then, there can be no hesitation to exploit this supply to the utmost of our power—to remove the largest possible quantity that by any means we can compass, to the end that ground more suitable for the maturing of oysters may be enriched.

The East and North-East Cheval having been fished clear of oysters last year, and being ground proper for maturing purposes, I proposed to Government that sanction should be accorded me to utilize the dredger "Ready" for one month from the 1st April to transplant spat from the Periya Paar to the Eastern Cheval. This proposal was duly sanctioned, as was also one to obtain a large quantity of cultch.

Among other preparations I inspected a likely area on the East Cheval and laid down on the selected ground a set of five mark buoys for the guidance of the Master of the "Ready" when engaged upon the distribution of the dredged spat.

Unfortunately for my carefully thought out plans the dredger by reason of rough weather was able to put in but two days and a half at this spat dredging prior to 9th April, on which date I received instructions to place the "Ready" at Mr. Dixon's disposal for the purpose of dredging mature oysters. When the vessel reverted to me some time later continuous bad weather had set in, rendering it impossible to work upon the exposed Periya Paar. As a consequence I had to cancel the cultching arrangements, and transplanting operations are in consequence postponed probably for an entire year.

With regard to the future of transplantation I can but endorse Professor Herdman's reiterated statement, that *in this lies the true salvation of the pearl fishery*. This being so, if Government approves of such recommendation, it will be absolutely necessary in order to ensure success to give me both permission to arrange for and carry out an extensive programme of transplantation and cultching and to provide me with adequate means for the purpose—that is to say, I should have a dredging steamer at my disposal from the very date of finding young oysters fit for transplanting, and *this steamer should be devoted solely to this work for the whole of the fine weather available and suitable for dredging.* Only by transplantation on the greatest possible scale can success be assured. We have to remember the largeness of the object in view and the huge profit to be made—nothing less than the formation of a bed of oysters of sufficient extent to allow for extensive wastage due to a dozen different causes, and after such wastage to give a fishery of mature oysters calculable in millions.

It is but an obvious truism to say that great results cannot be obtained by the employment of trivial means. To form a bed of oysters that will yield, say, ten millions at a fishery four to five years hence necessitates effort on a commensurate scale.

Necessity for extensive Cultching.

It has already been shown (Section I., A and G) that the sections of the Cheval and Moderagam Paars giving the finest oysters and the most valuable pearl yield are those possessing a well-cultched sandy surface, with somewhat restricted rocky outcrops. Unfortunately such areas are comparatively limited in extent, and the major part of the Cheval—the North, North-East, Mid-East, and part of the South-East and South-West with all the three Central sections—consists of sandy bottom inadequately supplied with material suitable to serve as foothold to oysters.

Many of the oyster grounds cultivated in Europe and America suffer from a like shortcoming; artificial cultching has accordingly been resorted to in order to make good the deficiency. As showing the importance attaching to this remedy, I may mention that at Whitstable three days in each week are given over to cultching and transplanting, and also four hours of each other day.* Hundreds of tons of shells and rubble are utilized for this form of bed surface improvement, oyster farmers willingly paying from 2*s.* 6*d.* to 3*s.* per ton for suitable material.

Again, in France the fishery laws provide that during the dredging of a productive bed all shells, gravel, stones, &c., shall be thrown back on the bottom.†

We now have sufficient knowledge of our own local conditions to see that transplantation must go hand in hand with extensive cultching, if we are to obtain a full return for the labour and money expended on the former operation—indeed, we may go further and say that the transplantation of young pearl oysters will be labour wasted unless adequate cultching operations be carried out concurrently. Appreciation of the vital importance of this fact caused me to apply for authority to obtain several hundred tons of broken rubble for cultching purposes as soon as transplantation was seen to be advisable last March. The proposal was at once sanctioned, and while waiting to begin transplanting I arranged by the kindness of the Public Works Department for the preparation of a trial shipment of 100 tons of broken calcareous sandstone from Kalpitiya. The stone was to be roughly broken to the size of the fist, roughly 3½ by 3½ by 2½ inches. The full quantity had been prepared when the transplanting scheme was arrested, and now lies ready for shipment whenever it be next required.

The Comparative Value of Cultch Materials.

The quantity of cultch needful to cause an appreciable improvement over a considerable area is so great that it is necessary to weigh very carefully the effectiveness of various materials in order to ascertain which is the most truly economical. The ideal cultch material is undoubtedly broken tiles; their shape keeps them from readily sinking into the sand, their non-calcareous composition furnishes no opportunity to the boring sponge, *Clione*, to extend its evil activity, while lastly, their slightly rough surface is excellently adapted for the attachment of the swimming spat when the time arrives for it to settle to the bottom.

* "Report of Commission appointed to inquire into the Methods of Oyster Culture," Dublin, 1870, p. 37.

† *Loc. cit.*, p. 61.

The calcareous sandstone of Kalpitiya, already referred to, probably comes next, its advantages being comparative lightness, a rough surface, and slight liability to damage by the attacks of lime-boring animals, composed as it is of coarse quartz grit interstitially cemented by carbonate of lime.

Oyster and other shells form another good material, and one that Nature avails herself of largely. On the South and South-East Cheval old valves of pearl oysters, cockles, and other lamellibranchs give foothold to hundreds of thousands of oysters.

Gneiss and schist are less suitable materials than the three above named, their heavy weight involving a danger of untimely burial in the sand should it be of any depth.

Regarding the question of price, the quotation given me for the Kalpitiya stone was Rs. 3·75 per ton delivered on the pearl banks, half going in preparation and cartage, the other half in boat freight. Considering the lightness of the stone, which means that it will spread over a considerably greater area than would the same weight of gneiss, this price appears satisfactory, and it is also probable that this quotation may be reduced if material be required regularly.

On the other hand, shell cultch goes three or four times as far as the lightest form of stone cultch on account of the thinness of its substance, and while it has less lasting qualities than the latter, being liable to corrosion by the acids in sea water and to damage by the honeycombing of *Clione*, yet whenever good prices cannot be obtained for the pearl oyster shells accumulated during a fishery the best purpose they can be put to is to be relaid upon the pearl banks during transplantation. I calculate that at the very lowest estimate one ton of shells will furnish as much cultch as three tons of Kalpitiya stone or rubble. As this quantity of the latter costs Rs. 11·25 (3 tons at Rs. 3·75 per ton), I believe that it will be more economical for Government to refuse to sell the shells at any less price than Rs. 10 per ton, and to use them as cultch unless this minimum price be obtained.

On European and American oyster grounds it is the universal practice to return all dead shells to the sea when dredging over oyster banks, care being taken to part the two valves before throwing them overboard, this having the effect of doubling the surface of the cultch available for the attachment of spat. In some places cockle-shells have been utilized with advantage to cultch oyster beds.

Clean Banks essential to successful Cultivation.

In this as in the matter of cultching we may with the greatest advantage profit by the experience of European oyster-culturists, who find it absolutely necessary to check the growth of all organisms upon the banks other than oysters. Not only must those that are active enemies of the oysters (starfishes, whelks, and the like) be destroyed, but also those animals that curtail the area which oysters may occupy, and which also consume food that would otherwise fall to the oysters. Sea weeds, too, are ruthlessly weeded out. As a consequence much of the oystermen's time is taken up in cleaning the beds by means of the dredge. If the beds are in preparation to receive spat, all harmful matter is taken ashore—starfish, whelks, mussels, and the thousand and one animals that may be termed the passive enemies of the oyster—where they find a ready sale as manure. Sea weeds share the same fate, while all solid material that is overgrown with any form of life is regarded as "foul" and laid out on the beach to be cleansed and bleached by the combined influences of sunshine and rain.

Fortunately the Ceylon pearl banks are comparatively clean. No fact struck me so forcibly when first I began to make diving descents than the obvious paucity of life on the better quality of oyster-bearing paars. Wherever oysters were found thriving, wherever they were seen in vigorous growth and perfect health, the bank appeared typically a comparatively dreary waste of sand, bearing clumps of oysters here and there on little patches of flat-surfaced rock or upon fragments of "cultch," with an occasional sponge or small coral at intervals that were few and far between.

Where "foul" areas are found, *i.e.*, where sponges, corals, alcyonarians, echinoderms, and ascidians abound, as on many parts of the Western Cheval and Muttuvaratu Paars, the oysters, while numerous enough, are stunted and poor, suffering by competition with the host of creatures living upon the same diet of microscopical organisms.

The only means to clean a bed is to dredge it thoroughly, separating and treating the materials brought up in the way above described.

In Ceylon the beds are too extensive to permit of dredging being undertaken with this sole object in view, but as this cleansing can and should go on concurrently with the dredging of spat for transplantation or of mature oysters for sale, we have herein one of the chief arguments in favour of taking up dredging on a scale of considerable magnitude. Sight should never be lost of the fact that dredging has four-fold utility, namely, (*a*) fishing oysters, (*b*) cleaning the ground and removing enemies, (*c*) in thinning out overcrowded beds, and (*d*) *spat transplantation.* Its value is not properly assessed if account be taken of the first item alone, or even of the first and the last.

Every live coral removed and replaced by a fragment of clean cultch may mean the addition of three oysters at the next fishery; every starfish destroyed *does* mean scores of oysters saved from destruction; every *Clione*-riddled block of coral bleached on the shore will tend to reduce the widespread havoc this inconspicuous sponge causes amongst the oysters. The immense advantage that accrues from keeping the banks in a state of thorough cleanliness can well be appreciated by an agriculturist who knows how his crops fall off if weeds be allowed to run riot unchecked, if fungoid and insect pests be ignored, if the soil be never disturbed, and if sun and air be excluded therefrom.

The Importance of thinning out Overcrowded Beds.

The evil effects attendant upon the overcrowding of the oysters which so often takes place upon certain of the Ceylon banks have already been laid stress upon, and, I think, sufficiently demonstrated. The remedy already suggested by Professor Herdman consists of thinning out at suitable time. The dredge again is the only remedial agent. Thinning out, transplantation, and cleaning the bank may all proceed conjointly—the thinned out oysters being deposited on unoccupied ground, while the foreign organisms and the cultch materials will be taken ashore, the former to be destroyed, the latter to be bleached.

The Activity of Young Pearl Oysters.

The activity of the pearl oyster during the first six or even twelve months of its existence is very noteworthy. Several instances are given in Professor Herdman's report (pp. 68 and 87), but more remarkable observations than any of those there recorded were made during my inspection of the Tuticorin banks in May last, when on the two occasions when we anchored on the Tholayiram Paar young oysters were found attached to the anchor chain when this was subsequently hove up. In one case, 3rd May, eighteen oysters were picked off from the chain at the anchor end. All were found between the butt of the anchor and a point ten feet up, just where the chain would occasionally rest upon the bottom. The oysters were of the youngest age of those upon the bank, none more than six weeks or two months old. A fortnight later the experience was repeated when we again anchored on this paar, five oysters two months old being found adhering each by several byssal strands to the chain links near the anchor. In both cases the anchor had been down for eighteen hours.

The effects of this restless activity are two-fold; it gives a younger generation great advantage over an older in the struggle for existence, the young ones mounting on the topmost parts of the older ones and intercepting food particles which otherwise would pass to the latter; it aids them also in finding elevated places of refuge when an influx or disturbance of sand occurs.

This advantage of superior activity accounts largely for the diminution and eventual effacement of a bed of old oysters when invaded by myriads of a younger generation, as seen this year in the case of the eastern region of the North-West and Mid-West Cheval Paar.

III.—PHYSICAL AND METEOROLOGICAL OBSERVATIONS.

During the whole time of my sojourn on the pearl banks, from 19th February to 19th April, a continuous record of the temperature and density of the surface water of the sea was kept, observations being taken thrice daily, together with particulars of wind and surface drift.

The same instruments were employed as during the cruises of the "Lady Havelock" in 1902. While these are sufficiently accurate to enable comparisons to be instituted with sufficient approximate accuracy for ordinary purposes, it is advisable, now that the management of the pearl banks is under scientific control, that the present instruments be replaced by others of standard pattern and accurate correction. A special thermometer to ascertain the temperature on the sea bottom should also be obtained; a good barometer is a further desideratum.

Specific Gravity and Temperature of the Sea on the Pearl Banks.

During my stay on the pearl banks the sea temperature at 7.30 A.M., from 81° F. on 20th February and 80° F. on 26th February, rose with occasional slight irregularities to 86½° F. on 19th April, the last day observations were taken upon the banks.

At noon the lowest temperature recorded was 82° F., at which it remained steady from 22nd February to the end of that month. During the early part of March it rose rapidly until the 11th, when it stood at 86½° F. It remained at and between 85° to 86½° F. till 19th April.

The temperature of the sea taken at 5.30 P.M. ranged from 84° to 81° F. during February, rising in March to 85° F., with occasional variations, never more than 1½°. It remained steady at 86° F. during April.

On the Tuticorin banks the temperature of the sea for the first half of May ranged from 88½° to 91° F. at noon, the latter the highest temperature reached and similar to the maximum temperature recorded by Thurston at Rameswaram in July, 1888.*

At 7.30 A.M. the sea temperature ranged off the Indian coast from 87° to 89° F. and at 5 P.M. from 88° to 90° F., the 4th May seeing the maximum with 91° F. at noon and 90° F. at 5.30 P.M.

On the Ceylon banks the total range in temperature from 19th February to 19th April was but 7° F., from 80° F. on the 26th February to 87° F. on 5th April, a range almost identical with the lowest and highest temperatures recorded in 1903, namely, 80¾° to 84¾° F. in February; 83° to 86½° F. in March; 86° to 88° F. in April; a total rise of 7¼° F. during this period.

The *specific gravity* of the water was constant at 1·0236 on the Cheval Paar during February, falling towards the end of March to nearly 1·0230, between which figure and 1·0232 it hovered during April, the variation being due largely, if not entirely, to the alterations in the temperature experienced during this month.

On the Indian banks, where the temperature ran up to 91° F., the average specific gravity was 1·0228.

A corresponding record of the temperature of the air in the shade was kept. At 7.30 A.M. the air temperature from 76° F. on 22nd February, rose to 79½° F. on the 29th, and thereafter moved upwards with slight irregularities to 84° F. on the 31st March, attaining the maximum for this hour at 80 F. on the 17th, 18th, and 19th April.

The lowest noontide temperature was recorded at 82° F. on 22nd February, rising to 88° F. on 29th March. During April it remained steadily between 85½° and 87° F.

From 83° F. at 5.30 P.M. on the 19th February the shade temperature rose to 86° F. at this hour on the 31st March, and remained within 1° F. of this till we left the banks on the 19th April.

On the Indian banks the heat was most exhausting during the early part of May, the highest reading being on the 4th of that month, when as much as 94½° F. was registered at 5.30 P.M., a temperature higher than of noon, which was 92° F.

* "Rameswaram Island and Fauna of the Gulf of Mannar": Madras Government Bulletin No. 3. Madras, 1895, p. 85.

The Weather during the Fishery.

Excellent weather prevailed from the day I left Colombo to the date of beginning the inspection (22nd February), light land and sea breezes alternating morning and afternoon. From 22nd February to 1st March, inclusive, strong north-east winds blew continuously, raising a heavy sea and rendering the work of inspection difficult. On 2nd March typical fishery weather set in, characterized by a breeze from the south-east in the early morning, veering round gradually by the southward to the west by noon, and then on to the north-west in the afternoon—an arrangement admirably suited to the sailing requirements of the diving fleet, which was thus enabled to run out to the fishing grounds with a fair wind in the early morning and to return to the camp in the afternoon with an equally favourable following wind. From about 11 A.M. to noon a dead calm usually prevailed and marked the time of greatest activity in diving work. Early in the evening during this period the wind worked round to the north-east, and later to the east, finally veering to the south-east, where it remained for some hours after daybreak.

Unfortunately the spell of fishing weather was of short duration this year, ending as it did on 30th March.

The following morning broke fine, with a placid sea, perfect conditions for fishing. By 3 P.M. heavy monsoonish clouds banked up to the south-west, and the wind, instead of changing to the usual north-west sea breeze, increased in force from the south-west, raising a rough and ugly sea.

The weather remained variable during the first four days of April, but with a heavy swell from the south-west running continuously accompanied by a strong northerly current, the wind ranging from south to south-west.

The south-west swell made diving distinctly difficult on the twentieth day of the fishery (5th April), and continued with monsoonish vigour thereafter until the close of the fishery, which indeed it directly brought about.

After 4th April the weather was so continuously boisterous, the sea running so high, that from that date onwards only three days were sufficiently calm to permit of dredging by the method adopted by the Dredging Master. Under these circumstances the divers deserve the utmost credit for their perseverance in the face of danger and discomfort. Had they not been keen to work the fishery would have come to a premature end on 7th April by reason of bad weather. As it was it was continued off and on for a further thirteen days beyond the commencement of unfavourable conditions of sea and wind.

Two points of interest were noted in connection with the beginning of the bad weather: the one that the phase of full moon on the evening of 31st March synchronized with the change from fine to bad weather; the second that the next day, 1st April, when, the unfavourable conditions intensified, rain squalls—the only ones experienced during my stay on the pearl banks—occurred from 8 to 9 P.M.

A Phosphorescent Phenomenon.

On the evenings of 9th, 10th, 11th, and 12th April, when at anchor on the Western Cheval, we beheld a repetition of the strange phosphorescent phenomenon witnessed by Professor Herdman on 13th March, 1902. The display began at about the same hour each evening, varying from 8.45 to 9.30 P.M., the sea being dotted with large isolated flashing lights that pulsated and vanished ghost-like at regular and frequent intervals.

The rhythmic and progressive blotting out and rekindling of these phosphorescent fires were as if the sea were swept by regularly recurring searchlight rays. The beginning of each successive light wave appeared to lie to the south; the intervals were approximately of two seconds' duration.

All the four nights were dark, but the weather was variable, one night tempestuous, another fairly calm; a fairly strong swell prevailing the whole time.

The displays lasted approximately for an hour each evening. The cause remains undetermined.

Trichodesmian Calm.

During several days in March vast quantities of the red-brown scum of *Trichodesmium erythræum* lay profuse and filthy upon the surface of the sea. So abundant was this scum that twice did it extend the period of noontide calm, acting precisely as a film of oil does. At midday when the first puffs of the sea breeze came out of the north-west, while the breeze was evident enough otherwise, yet it failed for some time to disturb the surface where lay this scum. Where it was absent or where the progress of the launch broke a lane through the film, the wind raised ripples and wavelets, which little by little spread and encroached upon the *Trichodesmian* calm. This with the gradual freshening of the wind scattered the particles, driving them downwards.

Surface Drift.

Nothing can be done towards the solution of this question without the employment of bottle drifters, except to note the direction of the current from day to day when at anchor on the banks.

This was attended to from 19th February to 19th April, the result being to show that during February the current set in the main to the south and to the south-west in dependence upon the general direction of the wind at this period, which was mostly north-east.

The following month, March, distinguished for its alternate land and sea breezes, showed a to and fro motion of the water upon the banks, the current altering with every change of wind and never attaining any degree of strength.

In April, consequent upon the continuous south-west wind and swell, the current ran strongly northwards, frequently at a rate of from two to three knots per hour.

IV.—RECOMMENDATIONS.

Improved and extended inspection necessary.—The uncertainty as to where oyster spat may fall and subsequently mature, so well brought out by examination of the table on page 9 for the Cheval and Moderagam region, holds good in even greater degree of the southern banks.

There the Muttuvaratu Paar, lost sight of for at least two centuries, gave three consecutive fisheries of great value in 1889-1891, the Chilaw Paar gave fisheries in 1803 and 1884, the Kurukkuppanai Paar in 1815 and again in 1884, while the banks off Karativu gave returns in 1832, 1890 and 1891. Judging by past experience the probability amounts to a certainty that beds of oysters have repeatedly been missed and fisheries lost through imperfect and restricted inspection, through want of good landmarks, and from lack of acquaintance with the biological characteristics of the bottom. It is not enough to survey accurately the regions or paars where oysters are most frequently found, as shown by the case of the "koddeipakku" region of the Periya Paar in 1878* and that of the Muttuvaratu Paar in 1889-91.† Banks not commonly considered fertile may be so occasionally, and therefore wherever the biological and physical features of the ground do not preclude absolutely the growth of oysters, inspection should be made with scrupulous care at the very least once in every three years. On the other hand, time has, I know, been wasted—unwittingly—in the past upon the inspection of banks where the biological factors preclude the maturing of oysters. I recommend therefore that such so-called "oyster paars"—for example, the Anaivilundan and Naddakuda Paars of Captain Donnan's chart—should be ignored. At present, while we know many of these hopelessly unprofitable paars, the work of assessing the oyster potentialities of many of the smaller banks is not complete, and this is one of the duties which the Marine Biologist has to undertake and advise upon. To enable good work to be done, reliable charts, conspicuous landmarks, the best of instruments, and picked and experienced assistants are necessary.

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* *Ut supra*, page 10.

† It is however by no means certain that this paar is not fairly fertile, as till Captain Donnan re-discovered it we have no information regarding its previous history under European control.

Fairly satisfactory charts of the pearl bank region we have, thanks to the care and foresight displayed by Captain Donnan, and when I shall have completed the detailed biological survey of the bottom from Aripu to Negombo, which I have already begun, I propose to incorporate such data in a series of revised charts, showing (a) the areas where rock, well cultched sand, and bare sand respectively preponderate; (b) contour outlines of the localities capable of maturing oysters and the regions where spat-falls occur.

Landmarks.—This subject has already been treated of at length, the conclusion being reached that a beacon on Aripu coral reef is the most urgent present need, together with the raising of Kutiramalai trigonometrical tower.

Instruments.—The ss. "Ready," if employed again, should be supplied with a reliable and properly adjusted compass as well for the safety of the ship as for the accuracy of the work to be done. A barometer is also urgently required for the use of the Inspector, together with a set of tested thermometers, including one for taking temperature on the sea bottom.

Cultural Requirements.—The chief requirement needful to give permanent prosperity to the pearling industry consists of a scheme of transplantation upon a liberal scale, the oysters relaid having an ample supply of cultch provided whereto they may attach. This with careful cleaning of the ground from active and passive enemies during dredging for transplantation and for market, and with judicious thinning out when inspection shows a bed to be overcrowded, summarize the main points.

Transplantation.—When a bed of oysters of suitable age for transplanting be discovered the necessary quantities may be obtained in either of two ways: by dredging or by utilizing native divers. At present we have no data whereby to compare these two methods financially.

In any case no divers would be obtainable whenever a fishery might take place coincidently with the need for transplantation, while they have ever shown reluctance to work during November, because of the chilliness of the atmosphere and of the sea at that period. Hence dredging appears the sole practicable means at our disposal whereon reliance may be placed.

The best time to carry on transplantation is during February, March, and April, that being the period when we have the longest spell of good dredging weather. This, too, is the time when the probability of finding suitable young oysters is greatest, as has been proved repeatedly; instance the Periya Paar in March, 1902 and 1904.

In November the chance of finding oysters in a suitable position relatively to the ground where they are to be relaid is less, and the available extent of fine weather is so short and uncertain that the work of a single steamer would be, I fear, insufficient to give any adequate results. I consider that one steamer continuously employed for twenty-six working days is the minimum that will produce a useful return for the labour and money expended.

What I recommend may be summarized as follows :—

That preparations on a liberal scale be made for carrying out a very extensive transplantation of young oysters during February, March, and April next year, if suitable oysters be found. The Inspector should be allowed to spend the first few days of his inspection in January—say from 25th to 30th January—in searching for a bed of spat or young oysters within a radius of 20 miles from the Eastern Cheval.

A steamer fitted specially for dredging and trawling should be ready to take up the work immediately, should the required discovery be made, in which case this steamer should be devoted wholly to such operations—on no account or pretext should the dredging be interrupted by detachment from this service even temporarily; only by incessant labour will it be possible for one steamer to do an adequate amount of transplantation, and any interruption while fine weather lasts would in all probability entail utter failure, with consequent waste of the money spent. Only by continuous work during every available day of fine weather, all too brief, can success be attained.

This consideration of the difficulty which a single steamer employed upon transplantation will experience in getting through an adequate amount of work in the necessarily limited time available makes me reluctant to advise transplantation at the November inspection. The weather then is noted for its uncertainty, and I am none too hopeful of having at that time a continuance of dredging weather lasting for the twenty-six days which I consider the minimum of usefulness.

On the other hand, if the oyster spat which was present in incredible abundance on the Periya Paar last March survive through the south-west monsoon, the oysters will be almost a year old in November next, and will be many times more valuable and suitable for forming a new bed of oysters on the Cheval than had they been moved in the stage of spat (under three months old). Therefore, every day's work during November would be ultimately of great financial importance to the pearl fishery revenue of future years. If work be done in November it would be resumed and amplified in the February following, for the oysters having survived the dangerous south-west monsoon period might be relied upon to live till the spring.

I recommend that a steamer fitted for dredging and trawling be got ready to accompany me when I set out to inspect the beds in October next, and, if young oysters be found, that it be employed wholly upon transplantation duties so long as the weather will permit.

Should no transplanting be done, the steamer need not remain idle; it may be employed in the experimental dredging of mature oysters, the thinning out of overcrowded beds of young, or in aiding in the inspection of the banks by running dredging traverses over the southern banks which have not been examined since November, 1902. The dredger's time would in no way be wasted: I can always fine more useful work than there would be opportunity to complete.

A second steamer would be required for the purpose of towing the inspection barque from place to place and for the laying out and taking up of buoys.

Cultching.—The question of cultching should receive early consideration, in view of the many preparations that become necessary if a large scheme of transplantation be authorized eventually. In such case a further supply of cultch should be at once got ready, say a total of 300 tons, inclusive of the 100 tons of rubble now piled at Kalpitiya jetty. If possible a portion of this quantity should consist of broken tiles, in order to test the respective advantages of this material as against rubble.

As I do not care, however, to recommend the preparation of the further 200 tons till it be known if there be oysters to transplant, I should have permission to utilize 500 tons of oyster shells left from the last two fisheries at Marichchikkaddi, pending the preparation of the rubble and tiles. With 500 tons of shells and 300 tons of rubble and tiles, after the lapse of a year we would be able to judge by experience whether it be more economical to sell or to relay the shells. Meanwhile I strongly urge the inadvisability of disposing of the present stock of shells at a lower price than Rs. 10 per ton.

The Pearl-inducing Cestode.—The Marine Biologist should be given opportunity to further investigate the life of the spherical cestode so abundant in the pearl oyster, and which is the inducing agency in the formation of cyst-pearls ("fine pearls"). The problem is far from solution, and will entail much unpleasant and trying labour before a satisfactory conclusion can be hoped for.

During inspection and fishery the Marine Biologist has no opportunity to obtain specimens of the larger predatory fishes, and I recommend therefore that he be allowed several weeks at Negombo or other likely large fishing station for the purpose of procuring and dissecting specimens of all animals there available which are likely to throw light upon this important problem.

Surface Drift Investigation.—The importance of an accurate knowledge of the movement of the water over the pearl banks has already been urged repeatedly by Professor Herdman. I can add nothing to what he has said, save to say that the more intimate my knowledge of the banks becomes, the more important does this investigation appear. Without this knowledge we cannot form even an approximately accurate idea of the source whence comes the spat that from time to time replenishes one or other of our banks. So long as we are in the dark upon this subject, we cannot define in what location a reserve of oysters should be maintained to produce the most useful results. There must be banks so situated as to be normally of no breeding value, of no importance in replenishing the banks which are our reliance; conversely, certain banks must be of supreme importance in the conservation of our beds, and it is obvious that information on these points is of vital importance in the farming of the banks. We want to know also whether we owe any proportion of the spat that settles on the Cheval to the oyster banks on the Indian side of the Gulf of Mannar; whether we supply any part of their spat; or, again, whether there be mutual interchange.

The plan offering the greatest advantages is to obtain the co-operation of the Madras Government in order to secure both uniformity of method and mutual assistance in carrying out this investigation. I recommend that batches of small sealed bottles, each containing a post card inscribed in English, Tamil, and Sinhalese, be thrown into the sea at intervals and places yet to be determined on both the Indian and the Ceylon side of the Gulf of Mannar; and that small rewards be given to those finders who place the cards in the hands of the nearest revenue officer or native headman, who would despatch them to me with particulars of the date and place of recovery.

After investigation on these lines has been carried out systematically for two or three years, it will become possible to determine the place of origin of much of the oyster spat, and we will be enabled to trace the course of its wanderings while in the larval swimming condition, and in consequence know where to conserve breeding reserves of oysters for the further replenishment of the banks.

Suggested establishment of a Chank Fishery.—On the Tinnevelly and Madura coasts a chank fishery of considerable profit to the Madras Government is carried on annually. I have no particulars of the revenue obtained of recent years, but during the seven years ending May, 1883, a nett profit of Rs. 124,677 was earned, an average annual return of Rs. 17,725.*

In Ceylon, while a large chank fishery employing a large body of divers exists north of Mannar and round the coasts of the Jaffna peninsula as far as Mullaittivu on the north-east coast, the law† forbids any fishery for chanks, bêche-de-mer, or coral on the pearl banks between Mannar and Kalpitiya, an enactment based upon the apprehension that such a fishery would encourage poaching on the oyster banks and militate against the well-being of the banks.

Sir William Twynam states ‡ that this prohibition came into force about 1832; prior thereto chank fishing did take place in the neighbourhood of Aripu and Silavaturai, the district which was appropriately termed the "fishery coast" in Portuguese times.

During the recent fishery I saw many chanks both in the shallows at Aripu and at Pukulam. They were also dredged in deeper water—three to six fathoms—in the same districts, of good size and healthy condition.

To prohibit fishing *in toto* appears to me a needless waste of the resources of the Colony; ample safeguards can be provided against abuses in this instance.

I therefore submit for the consideration of Government the question of the amendment of Ordinance No. 18 of 1890 in the following particulars, namely :—

(*a*) That fishing for chanks, bêche-de-mer, and coral be permitted at such seasons and in such places between Mannar and Tallaivilla as the Marine Biologist may recommend to Government from year to year; that this permission be granted only during those seasons when no mature (fishable) pearl oysters be present upon the banks in the vicinity, notice of the limits of time and place to be published as soon as possible after the completion of the inspection of pearl banks in November of each year.

(*b*) That the fishing be carried out under Government control, the Government to license a certain number of boats and to buy the chanks fished at a fixed price after the manner adopted at Tuticorin.

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* H. Sullivan Thomas's "Report on Pearl Fisheries and Chank Fisheries, 1884." Madras, 1884.

† Ordinance No. 18 of 1890.

‡ "Report on the Ceylon Pearl Fisheries." Colombo, 1900; page 21.

The provision that chank fishing be not carried on when mature oysters are present in quantity would be no hardship on any men settled on the fishery coast for this purpose, seeing that if mature oysters be present a pearl fishery will ensue during the only weather suitable for diving, and at which these men would be employed more profitably than they would in chank fishing. This plan, if adopted, would probably induce some of the Kilakarai Moormen to settle permanently at Marichchikkaddi or at Aripu, and, as Sir William Twynam says, "lead to the training of a body of Ceylon divers, whose services would be available at a pearl fishery, while the profits on the sale of the chanks would go far towards paying the expenses incurred on account of inspecting and guarding the banks."*

In the same report Sir William Twynam states that "the difficulty experienced in fishing the banks during recent fisheries (arose), in a great measure, from want of a sufficient number of divers."

The closing of the proposed chank fishery in pearling years would have the effect of supplying a close season for the chanks, working automatically, and would result in keeping up the quality as well as the quantity of these shells.

If the proposal be eventually approved a great deal could be done by the Marine Biologist to increase the supply of chanks, principally by collecting the egg-capsules and hatching the young out in roughly constructed tanks, where protection would be afforded till it became necessary to establish them in suitable places along the coast.

Withdrawal of the prohibition to fish for bêche-de-mer would also be of advantage, and if this were done a small item of revenue might accrue from those so frequently dredged up by the Government steamer. There are places, as on the Vankali Paar, where from twenty to thirty fine specimens are dredged up in nearly every haul, and, considering the good prices obtainable for this delicacy, it were a pity to see these returned to the sea, as the law as it stands now compels.

Synopsis of Recommendations.

(*a*) Improved and extended inspection.

(*b*) The provision of a beacon on Aripu reef and the improvement of Kutiramalai tower.

(*c*) Transplantation on an extensive scale by means of steam dredging whenever blank spaces occur upon the Cheval coincident with the presence of young oysters in the neighbourhood within a radius of 20 miles.

(*d*) Cultching to go on concurrently with transplantation. If these operations can be carried out within the next twelve months, 500 tons of oyster shells and 300 tons of Kalpitiya stone to be provided for the former purpose.

(*e*) The thinning out of overcrowded beds by means of the dredge.

(*f*) The cleaning of the oyster banks by means of the same agency.

(*g*) Further investigation of the life-history of the pearl-inducing cestode.

(*h*) A series of drift bottle experiments in conjunction with the Madras Presidency officials.

(*i*) The establishment of a chank fishery on Government account and under Government management in the neighbourhood of the Aripu pearl banks.

JAMES HORNELL,
Marine Biologist to the Government of Ceylon
and Inspector of Pearl Banks.

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* "Report on the Pearl Fishery of 1881" (Sessional Paper No. XI. of 1881).

APPENDIX A.

Tables of the Dimensions of Representative Oysters examined.

(*a*) Measurements of Oysters aged $4\frac{1}{4}$ to $4\frac{3}{4}$ years, South-West Cheval Paar, Southern Edge.
Date: March 3, 1904.

No.	Depth in Millimetres.	Length in Millimetres.	Breadth in Millimetres.
1	80	73	34
2	78	69	31
3	80	76	35
4	85	73	35·50
5	67	61	25
6	81	75	35
7	80	71	31
8	76	68	34·50
9	75	71	33
10	90	83	35·50
11	78	75	35·50
12	69	62	30
13	69	61	37
14	76	68	32
15	73	67	28
16	75	66	30
17	76	67	30·50
18	70	69	31
19	80	71	32·50
20	81	70	33·50
21	73	68	33·50
22	79	78	31
23	67	59	31·50
24	70	60	30·50
25	77	69	32
	1,905	1,730	808

Average, 76·20 mm. by 69·20 mm. by 32·32 mm.

(*b*) Measurements of Oysters aged $4\frac{1}{4}$ to $4\frac{7}{8}$ years, North-West Cheval Paar.
Date: February 28, 1904.

No.	Depth in Millimetres.	Length in Millimetres.	Breadth in Millimetres.
1	78	70	32
2	80	68	32
3	75	75	30
4	85	70	33
5	78	70	27
6	70	63	31
7	76	73	34
8	67	58	30
9	68	60	32
10	68	63	30
11	70	65	34
12	73	70	36
13	70	63	27
14	68	65	29
15	67	63	29
16	72	68	32
17	73	68	32
18	76	74	32
19	70	60	35
20	75	65	31
21	78	65	32
22	69	63	31
23	68	63	30
24	70	64	30
25	80	76	34
26	66	63	32
27	68	59	31
28	82	78	34
29	81	65	34
30	65	68	31
	2,186	1,995	947

Average, 72·87 mm. by 66·50 mm. by 31·57 mm.

(c) Measurements of Oysters aged $2\frac{1}{4}$ to $2\frac{1}{2}$ years, South Moderagam Paar.
Date : March 5, 1904.

No.		Depth in Millimetres.		Length in Millimetres.		Breadth in Millimetres.
1	...	65	...	60	...	29
2	...	67	...	59	...	27
3	...	58	...	58	...	26·50
4	...	69	...	65	...	26
5	...	78	...	73	...	31·50
6	...	73	...	64	...	25·50
7	...	70	...	69	...	29
8	...	65	...	58	...	25·50
9	...	72	...	69	...	28·50
10	...	67	...	65	...	26
11	...	67	...	63	...	27
12	...	77	...	69	...	27
13	...	64	...	60	...	26
14	...	63	...	59	...	28
15	...	69	...	63	...	28
16	...	68	...	67	...	28
17	...	62	...	58	...	26
18	...	73	...	72	...	29
19	...	82	...	79	...	30
20	...	69	...	59	...	24
21	...	69	...	65	...	27
22	...	61	...	53	...	26
23	...	70	...	68	...	28
24	...	69	...	60	...	26·50
25	...	70	...	69	...	27
		1,717		1,604		682

Average, 68·68 mm. by 64·16 mm. by 27·28 mm.

(d) Measurements of Oysters aged $2\frac{1}{4}$ to $2\frac{1}{2}$ years, Mid-West Cheval Paar.
Date : March 1, 1904.

No.		Depth in Millimetres.		Length in Millimetres.		Breadth in Millimetres
1	...	66	...	58	...	26
2	...	55	...	53	...	23
3	...	58	...	55	...	27
4	...	57	...	54	...	25
5	...	51	...	46	...	23
6	...	58	...	51	...	27
7	...	51	...	51	...	22·50
8	...	60	...	54	...	26·50
9	...	55	...	50	...	25
10	...	56	...	52	...	26
11	...	53	...	48	...	21·50
12	...	60	...	58	...	24
13	...	60	...	57	...	26
14	...	60	...	55	...	23
15	...	58	...	56	...	25
16	...	50	...	46	...	22·50
17	...	46	...	44	...	23·50
18	...	57	...	52	...	22·50
19	...	59	...	53	...	23
20	...	57	...	52	...	24
21	...	58	...	49	...	25
22	...	55	...	54	...	26
23	...	56	...	51	...	26
24	...	61	...	57	...	25
25	...	58	...	59	...	26
		1,415		1,315		614

Average, 56·60 mm. by 52·60 mm. by 24·56 mm.

(*e*) Measurements of Oysters aged $2\frac{1}{4}$ to $2\frac{1}{2}$ years, North-West Cheval Paar.
Date : February 28, 1904.

No.	Depth in Millimetres.	Length in Millimetres.	Breadth in Millimetre
1	60	55	22
2	63	57	23·50
3	61	60	25·50
4	61	58	23
5	60	61	25
6	59	55	22
7	63	60	25
8	61	60	23·50
9	56	56	23
10	60	57	24
11	53	55	19·50
12	60	55	24
13	58	56	21
14	64	59	24
15	55	50	20
16	66	66	25
17	67	65	23
18	61	55	23
19	67	58	27
20	63	55	26
21	64	60	25
22	59	53	22
23	64	58	23
24	60	58	29
25	60	57	23
26	58	56	23
27	65	58	25
28	65	56	24
29	60	53	21
30	67	60	27
	1,840	1,722	711

Average, 61·33 mm. by 57·40 mm. by 23·70 mm.

(*f*) Measurements of Oysters aged $2\frac{1}{4}$ to $2\frac{1}{2}$ years, Dutch Moderagam Paar.
Date : March 12, 1904.

No.	Depth in Millimetres.	Length in Millimetres.	Breadth in Millimetres
1	57	52	23
2	57	52	21·50
3	64	58	24
4	66	59	24·50
5	52	50	22
6	56	50	22·50
7	54	49	22
8	50	47	22·50
9	53	48	22
10	62	56	29
11	65	64	29·50
12	62	52	28
13	67	63	32
14	56	54	23
15	55	50	22·50
16	55	51	24·50
17	58	55	25
18	57	53	25
19	57	50	24
20	67	56	31
21	60	55	26·50
22	62	56	30·50
23	60	56	26·50
24	57	53	26·50
25	60	54	28 50
	1,469	1,343	636

Average, 58·76 mm. by 53·72 mm. by 25·44 mm.

APPENDIX B.

Notes on Inspection and Valuation.

I.—*Method of Inspection.*

The principal method of inspection adopted was that introduced by Captain Donnan, modified in details. The essential features may be stated as follows:—Three flag-buoys are laid out by the attendant launch or tug-boat in the direction of each cardinal point of the compass at distances apart of a quarter of a mile, the inmost buoys taking their distance from the inspection vessel, which is anchored to serve as a pivot mark in the centre of the area to be inspected.

Four inspection boats (modified whale boats), each manned by a crew of six, together with three divers and two munducks, under the charge of an experienced coxswain, take up equidistant positions between the ship and the first buoy on the north line and row slowly round the ship, retaining their relative positions the while. At regular intervals the crews rest on their oars to allow the divers opportunity to make descents. The result of each dive is reported to the coxswain of the respective boat, who records it upon a diagram with which he is provided.

The four boats having each performed a complete circuit are next ranged in line abreast in the same manner as before, between the quarter and the half mile buoy and each makes a second circuit. The day's work is completed by a third and last circle, in this case between the buoys distant respectively half a mile and three-fourth mile from the ship.

The boats make a total of twelve concentric circuits, each boat making three. The results shown upon the coxswains' diagrams—each of which has three concentric circles drawn upon it (see plan No. 1) representing the three circular paths covered—are transferred by the Inspector to a final diagram or plan furnished with twelve concentric circles. When this has been done the distribution of old and of young oysters is graphically shown for a circular area having a diameter of a mile and a half. (Plan No. 2.)

After calculating in square yards the area occupied by oysters, the approximate number of oysters thereon may be estimated by taking the average number of oysters per dive (ascertained by scrutiny of the divers' results) in conjunction with the average amount of ground which a diver is credited with being able to clear at one descent. Usually this area is considered on average ground to be from two and a half to three square yards. By assuming the area per dive to be three square yards the danger of an over estimate is avoided. Inspection estimates are usually less than the total of oysters obtained at the ensuing fishery. Thus, at the 1904 fishery I estimated the number of mature oysters to be 35,000,000, whereas the number actually fished from the area in question was roughly 37,000,000 (41,000,000 minus the amount of immature oysters fished on 2nd April).

Sketch plan No. 4 shows graphically the course and extent of the work done between the 23rd February and 4th March on the Cheval Paar, while upon plan No. 5 are plotted the areas then found to be covered respectively by old and by young pearl oysters.

II.—*How the Valuation Sample of Pearls is procured.*

During intervals in the inspection three large samples of oysters of fishable age were collected from the three western blocks of the Cheval, partly by means of divers and partly by the use of dredges. Superintendence of the washing of these samples and the valuation of the contained pearls detained me on shore for the three days ending 9th March.

The washing of the oysters and the sifting and subsequent valuation of the pearls were carried out in the usual way, the two former processes by the Government divers and munducks, the latter by three Mohammedan pearl merchants. All the processes received my personal and continuous supervision, Mr. V. Vraspillai, the able Adigar of Musali, giving me valued assistance during the last stage.

As an era of improved methods appears to have commenced in the history of our pearl fisheries, it may be useful if I here record briefly an outline of the method employed hitherto to separate the pearls from the pearl oysters obtained for this purpose, lest this primitive system give way before the innovations of labour-saving devices.

When the samples are brought into the Government kottu, a palisaded enclosure, the sacks of oysters are preferably emptied into dug-out canoes or "ballams" and covered carefully with mats. In this state they are left under guard for a period of from seven to ten days. Bacterial putrefaction is not relied upon to get rid of the flesh, the maggots of a species of blow-fly being the agency desired. Under favourable conditions at the end of seven to ten days, the so-called rotting period, the fly maggots should have eaten their way through everything and have left nothing but empty shells and pearls behind. When the oysters are rotted in sacks, the time for washing is rendered evident by the pile of brown chrysalis cases—full and empty—that litter the ground immediately around the pile of sacks as well as encrust the sacks themselves.

The time to wash having arrived, the covers are removed from the ballam and coolies fill it to the brim with water. As the water level rises to the edge a mad race for the points above the flood ensues among the maggots, which float up in myriads from the lower recesses. The washers range themselves in line along either side, squatting on anything convenient—a canoe outrigger, an overturned tub, empty kerosine tins, and the like. They are stripped to the loin-cloth, and are not allowed to take their hands out of the water save to drop out the empty shells.

The first process is to rinse the shells thoroughly, to separate the valves, and by rubbing the outside of one valve against that of the other to remove any *detritus* in which a pearl might lodge. The men scrutinize the nacreous lining for attached or shell pearls, placing any found in a special basket. The other shells after a final rinse are dropped outside the ballam at the washers' feet.

After the quantity is reduced somewhat, the floating maggots are skimmed off, lifted by hand, and some of the water is baled out through a sieve, the solid matter that remains therein being carefully returned to the ballam, lest a pearl might be contained or entangled in the dirt. More water is added and the process of washing continued. At last all the shells are removed, and the men are then free to stand up and stretch their cramped limbs.

A fresh supply of water is poured in till the ballam overflows—a rough method of decanting. Time after time this is repeated till the bulk of the lighter filth is got rid of. Then the remainder of the water is decanted and the heavy *débris* in which the pearls are mingled is exposed on the bottom. More water is repeatedly poured in, the sediment dirt, or "sarraku," the while being kneaded and turned over and over again. When this apparently interminable cleansing process comes eventually to an end every scrap of sarraku is removed with scrupulous care to a cotton cloth and bundled up. One ballam full of oysters will usually furnish from two to three bundles of pearl-containing dirt. The bundles of sarraku are later opened and spread to dry in the sun, undergoing a preliminary search at the beginning and, if wished, at intervals during the drying. These early searchings yield usually the largest and therefore the most conspicuous of the contained pearls.

When dry the material is sifted out into several grades, and each is gone over time after time by the men employed. The final search—after it appears that even the dust pearls, the *masi-tul*, have been removed—is carried on by women and children, and it is amazing to see what a large quantity of small pearls their keen eyes and fine touch enable them to obtain, chiefly by winnowing. After the pearls are picked out it is the custom to offer the apparently exhausted dirt for sale, and ready buyers can always be found.

APPENDIX C.

NOTES RELATING TO DIVERS AND THEIR OCCUPATION.

I.—*Racial Types represented among the Divers.*

Four distinct types were represented among the divers both at last year's fishery and at this: Coast Tamils, chiefly from the Madras Presidency; Moormen or Lubbais drafted largely from Kilakarai and the neighbouring villages on the Madura coast of the same Presidency; Malayalam men from the southern portion of the Malabar coast (Travancore principally); and lastly, a compact body of some 250 so-called Arabs from Colombo and Jaffna. The first two groups comprised the bulk of the diving community (including both divers and munducks), accounting for 1,989 and 3,732 respectively out of a total of 7,408 who attended at last year's fishery (*vide* Report on Fishery of 1903 by Mr. R. W. Ievers, C.M.G.).

The Tamil divers, almost without exception, are Roman Catholics, owing the conversion of their caste to Christianity to the zeal of St. Francis Xavier and his followers in the middle of the sixteenth century. To this day at Pinnacoil on the Tinnevelly coast, a chapel where this prince of missionaries is reputed to have preached, is held by these people in especial sanctity. Scapularies are carried hung round the neck by the more zealous, and their lips may often be seen moving in muttered prayer prior to the beginning of the day's work.

The Moormen—the term applied in Ceylon to the Mohammedans inhabiting the coast of Southern India, and who are also found scattered throughout Ceylon—are physically finer men as a body than the Roman Catholic Tamils, but how far this is a result of habit and environment, sobriety, superior food, and personal cleanliness, or how far an infusion of a superior race stock can be invoked to account for it, is at present difficult to say, and requires prolonged anthropometric and other investigation to settle definitely. As it is, there is no question of the superiority, physically, of these Kilakarai Mohammedans to the Tuticorin and Rameswaram Catholics. I am inclined to think the differences are not racial, or at least that the proportion of Arab blood is so diluted as to be infinitesimal. Still, that a wave of Arab immigration flowed along the western coast of India is an historical fact. On the other hand, wholesale conversions are known to have been made of the natives at many points, and the Arab immigrants, probably with few exceptions, took natives to wife. The distribution of Arab blood must therefore be irregular among the Moor settlements, and without anthropometric details of the inhabitants of villages we cannot say whether any particular Moormen are the descendants of mere converts or have a true Arab strain in them. In this connection the extraordinary virility and persistence of the Arab type has to be borne in mind, and, although I have seen men of typical Arab physiognomy and form among the Ceylon Moormen, I certainly have not seen any appreciable Arab bodily characteristics among the Kilakarai divers, whom therefore as I have said I expect will be found to be of Tamil extraction, the descendants of Islamic converts.

Their co-religionists, the so-called Arabs, exhibit a wide range of racial type—from the hook-nosed, long-visaged, and light coloured true Semite type through all grades to the bullet-headed, wooly-haired, flat-nosed African negro of sable hue and grinning visage. Most hail originally from the Persian Gulf, having received their training on the Bahrein pearling grounds, controlled by the wealthy Arab Sheikhs who rule there under British protection, and who would be far from gratified did they know that the mongrel divers in question were masquerading under the name of "Arabs" at a Ceylon pearl fishery. However, mixed breed as they are, these men, whatever their tint and type, agreed equally in religious devotion to the Prophet's laws, and in the afternoon after diving was over took each an early opportunity to turn his face Meccawards and recite the accustomed religious formularies.

Malayalam Type.—At the 1903 fishery a large contingent of Malayalam divers attended from the Travancore seaboard; as this locality forms part of that portion of the western shore-line of India known as the Malabar coast, these men are frequently known as "Malabars." This year few were present, due to a triple conjunction of adverse circumstances: (1) the abrupt announcement of the fishery after word had gone round the diving community that none was to be held; (2) the prevalence of sickness at last year's camp; and lastly, (3) the fact that the depth of the water on the Western Cheval, averaging $7\frac{1}{2}$ to 8 fathoms, is said to be too great for them to work in with comfort, accustomed as they are to dive in 5 and 6 fathoms only.

II.—*Comparative Diving endurance of the different Types.*

Most extravagent statements have been current regarding the period a diver can remain under water. Even the staid and conscientious "Encyclopædia Britannica" asserts that while the average submersion is from 50 to 80 seconds, it may exceptionally be as much as six minutes! Ribeyro's statement, dated 1665,* that the pearl diver remains below while two *credos* can be said is picturesquely worded, but also exceeds the truth, the maximum appearing to be not over 90 seconds.

Far ahead of all the others in endurance are the Arabs. During the first day's fishing 70 to 75 seconds under water was their general average. They informed me that after two or three days' work, as they became accustomed to the pressure, they would be able to stay down longer, a fact which I verified later, when I timed them frequently from 80 to 87 seconds. In an extreme case I timed one of these men at 89 seconds from the moment of his descent to that of re-appearance.

The Tamils' average under water is 45 seconds; rather better than this is the average of the Moor divers of Kilakarai, which I put at about 50 seconds.

The Malayalam divers from the Malabar coast, who, in contradistinction to all other native divers, plunge headforemost from a spring board hung over the boat's side, are notably the least capable and least intelligent men who attend the Ceylon pearl fishery. Comparatively poor in physique and of little staying power, their average under water is but 35 seconds. The majority are brought to the fishery from Quilon and the vicinity by boat owners, who advance money for the expenses of the journey, and who recover it with usurious interest during the fishery. These Malabars are usually the first men to leave the fishery, always very ready to break away as soon as they have amassed one or two hundred rupees.

The number of pearl oysters brought up per dive varied extremely even at the same anchorage, a fact that follows naturally upon the great range of physique and skill characterizing divers from widely separated districts and of different races. The Arab, as may be inferred, had easy pre-eminence, bringing up on good ground 40, 50, and even 60 oysters per dive, as against the Dravidian Tamil's 25 to 35 oysters. Somewhat superior to the Tamil divers are the Moormen, whereas the average catch of the Malayalam men is distinctly smaller.

Having bearing upon the superior staying power of the Arabs is the habit they have of taking the greatest possible care of themselves while working, a care shown in several ways. They nearly all possessed voluminous warm brown cloaks, wherein they made themselves comfortable during the run to the banks in the raw chill mornings. Then, in the intervals of rest between spells of diving, they were always very careful as soon as they came out of the water to dry their bodies thoroughly with towels—really fine bath towels in many instances. Were it early in the morning, and the sun not yet powerful, they might next be seen huddling over tiny fires made in small wooden packing cases half filled with sand. Spreading their hands over the embers they would rest till they felt ready once more to re-commence their labour. At a later hour in the day, after a hearty towelling, they would stretch themselves out in the sunshine in evident relish of the comforting heat rays.

* "History of Ceylon," English translation, by Lee. Colombo, 1847.

Another device was to pass either a cheroot or a huge cocoanut-bowl pipe having a long curved stem to the men in the water, who in turn took a few whiffs between their dives. Sometimes I have seen a cigarette pass in turn from mouth to mouth of a group of four or five divers.

III.—*Behaviour at the Fishery.*

The behaviour of the divers was generally excellent, especially with regard to the Arabs and the Mohammedans (Moormen or Lubbais) from Kilakarai. These men worked energetically and without complaint even in rough weather. Of the Arabs, I cannot indeed speak too highly; in a word they were indefatigable.

At the fishery of 1903 there was much apparently purposeless sailing about; casting anchor for half an hour and then sailing away to another place, where another short spell of work would take place preparatory to another move. More particularly were the Tuticorin Parawa divers guilty of this irregularity, which, I believe, was done to mask and give opportunity for wholesale and illicit opening of oysters for the purpose of extracting the best pearls.

This year there was extremely little of this suspicious manœuvring, the few offenders being again the Parawas, who, Christians though they be, are undoubtedly the greatest rogues attending the fishery as divers. In self-restraint they are much inferior to the Mohammedans, wasting their earnings largely upon arrack.

Regarding the illicit opening of oysters referred to above (the one great drawback to the employment of native divers under present arrangements), I have strong reason to believe that at this fishery it was not carried on upon nearly so extensive a scale as has usually been the case. The excellent retail prices obtainable for their share had probably much to do with this unusual rectitude on the part of the divers. The strong winds usually prevailing in the afternoon were another contributing factor, as the men had thereby less time and opportunity at their disposal.

IV.—*Fisher and Diver Castes.*

The connection between fishermen and divers would appear at first sight most direct and intimate, and while it is true that in certain districts men may be alternately fishers and divers according to the season of the year and its opportunities, it is of great interest to note that in the Rameswaram district the Fisher or Kareiyar caste does not furnish the supply of divers hailing from that locality. On the contrary, it is to the despised Kadeiyar caste, whose members are primarily occupied in lime-burning and chunam-selling, that the Rameswaram divers belong. Possibly we may trace in this connection between diving and lime collecting and burning a clue to the manner in which pearl fishing originated in this district. It is probable that lime-burning antedated pearl fishing here; and it is conceivable that as the demand for lime sent the men of this caste wading on the reefs for coral or shell material, and as we know from the *Mahawansa* how highly esteemed were the shells of the pearl-oyster for the manufacture of the chunam used in the decoration of palaces and temples, these Kadeiyar men finding the shells abundant in the deeper water would gradually advance from dives of a few feet to dives of several fathoms. With the discovery of gem-like bodies of great beauty embedded in the flesh, the industry of oyster fishing for pearls would begin and thereafter rapidly evolve.

The fishermen of Rameswaram and the neighbourhood belong to the Kareiyar caste, from which the Sinhalese name "Karawe" for one of their fisher castes evidently directly originated, a derivation from Tamil paralleled by several other caste names among the Sinhalese.

On the Tinnevelly coast—Tuticorin, Pinnacoil, and other centres—both the fishers and the divers belong to one caste, the Paravar or Parawa caste, which is described in the Government Minute of 23rd June, 1869, as comprising "those who live on the seashore." It does not, therefore, confine its members either to diving or to fishing; they may enter on any coast trade. Many of them act as boatmen, and practically all the men who man the inspection boats belong to this caste. The Parawas are all Roman Catholics.

The present hereditary head of this caste is Don Gabriel de Croos Lazarus Motha Vaz, known officially as the Jati (or Jadi) Talaiva More, or Jati Talaivan ; he resides at Tuticorin, and is largely the intermediary between the Government and the men of his caste. His predecessors under the Dutch and Portuguese exercised authority over the divers, as well at the Ceylon as at the Tuticorin pearl fishery, but under early British rule the Ceylon duties were delegated to a local headman. In addition to exercising caste authority, the Jati Talaivan is the repository of native knowledge and tradition relating to the pearl banks, and in the days before the British occupation, both in Ceylon and India, he and his representatives largely directed the periodical inspections of the banks.

With the growth of experience on the part of the European Inspectors and the production of reliable charts based upon Admiralty survey, the assistance of these headmen became less important, till upon the Ceylon side their services have been wholly dispensed with.

At the Tuticorin inspections, owing largely to the charts used being as yet imperfect in regard to the accurate delineation and plotting of the banks and of the landmarks, to the more primitive methods of inspection employed, and other causes, the Jati Talaivan is still required to accompany and assist the Inspector upon his visits to the pearl banks.

V.—*Longevity of Divers.*

During the fishery I made inquiries with a view to ascertain if diving as an occupation tends to shorten life. A difficulty meets the inquirer at the outset in the uncertainty which the older men show regarding their age. Thus, in the case of the Government staff of divers, we have two, who are father and son, hailing from Mannar, and have both been divers since boyhood. The son Saverimuttu Anthony is the finest man in the lot, well built and in good condition. His appearance tallies perfectly with his statement of his age as thirty-two. The father is at least fifty-two, but he is uncertain as to the exact figure, believing it, however, to be greater. He, too, is fit for several years' more work ; he states that diving has had no ill-effect upon his constitution that he is aware of. The grandfather was also in his time a Government diver, and lived to the reputed age of eighty-five. He was working, according to his son's statement, at diving to within two years of his death. Another of the divers, Anthony Muttu, was employed when a youth as a diver at the inspections conducted by Captain Donnan's predecessor in office, which therefore places the beginning of his career as a professional diver at a date over forty years ago, Captain Donnan having assumed office as Inspector in 1863. This man is still reckoned one of our best men, he works well, and comes regularly to inspections and fisheries.

Again, when at Kilakarai, the centre whence comes the chief supply of our local divers, I made further inquiries, and had a number of the older divers brought forward. It proved impossible however to obtain reliable figures, but judging by comparison and general appearance there could be little or no doubt of several of the men who attended this year's fishery being at least sixty years old. The whole consensus of opinion among the divers is that their calling, *per se*, does not conduce to shorten life, and this, too, is my own conclusion drawn from daily observation during actual fishery time.

It must, however, be borne in mind that a natural elimination of the unfit takes place among youths who propose to take up diving as their life's occupation, the weakly discovering their inability to withstand with impunity the pressure experienced when on the bottom. Such more weakly men usually perform the duties of munducks at a fishery.

On the whole, I am strongly inclined to the belief that an expert naked diver experiences less strain and fatigue after a day's work—say, the collecting of a thousand oysters—than a man of equal physique attempting the same task attired in a diving dress. One point which I think is in the naked diver's favour is that in his case the pressure is confined to the outer surface of his body, whereas in the case of the diver in armour the pressure penetrates to the lungs with the air he breathes. The Arab divers fasten a horn clip upon the nose, while the Indian divers merely close the nostrils with the fingers during descent.

Hyatt* states that in the Mediterranean the naked diver goes to greater depths than men using diving dress, and apparently with less danger to his life. In Ceylon the working depth seldom exceeds eight fathoms, ranging principally between six and eight fathoms, depths which are easily negotiable by natives of ordinary physique.

VI.—*The Hearing of Divers.*

Native divers in this part of the world universally hold the belief that air passes out through the ears when they are under water. This, they say, is accompanied by a crackling sound, and if this sound be absent in a man beginning to learn diving, it is considered a sign that he is unfitted to continue. Were this belief that air passes out to be true, it would mean that perforation of the tympanic membrane or drum of the ear has taken place, and this would entail a marked degree of deafness. Against this has to be set the fact that in the vast majority of cases the hearing of divers is normal, as I know from daily intercourse with them. Indeed, it is doubtful if one has to raise the voice even slightly above the usual pitch when conversing with them.

I have also the direct evidence of my eyes. In my own diving excursions I have met naked divers on the bottom, and there was never the slightest issue of air bubbles from their ears : all came —usually when the men were ascending to the surface again—from mouth or nostrils.

As to the crackling in the ears, that also would be absent were the tympanic membranes ruptured. The sound, which is due to the vibration of the membranes, indicates that they are intact and are responding readily to differences in the pressure.

VII.—*The Blind and the Crippled at a Fishery; Physical Disabilities met with among Divers.*

Sir William Twynam, K.C.M.G., has recorded (Sessional Paper XII. of 1891) the participation in the fishery of 1891 of a Malayalam diver, who had lost a leg by the bite of a shark when chank fishing near Cochin, and of three blind divers, one of Periyapatam near Kilakarai and two from Tuticorin.

The present fishery also had its contingent of blind and crippled divers. To my own knowledge three blind divers attended from Kilakarai, a fourth hailing from Tuticorin. Ophthalmia, which appeared to me to be very prevalent in Kilakarai, was, I believe, the cause of the loss of sight. Another diver who attended the fishery, and whom I examined while at Kilakarai, had lost one leg, and was in addition blind of one eye. The man was a most pitiable object, sickly in appearance and miserably thin, helping himself along with the aid of a crutch. Well could I believe that his catch of oysters was meagre; the wonder was that he had the energy to attend the fishery and make the attempt, even though poverty was the impelling power. He had managed to obtain a pittance, and took home a few rupees. I was told that this man lost his leg by shark bite while engaged in chank fishing on the Indian coast some years ago.

His blind *confrères* did rather better, but their catches were good only upon ground where the oysters were thickly spread, such as on certain regions of the South-West Cheval. When on the sparsely covered North-West section, their earnings were greatly inferior to those of the other divers. I should mention that their blindness is not congenital—sight was lost years after they had taken up diving.

VIII.—*Types of Pearl-fishing Boats.*

The picturesque appearance of the pearling fleet when under weigh has been described times without number—picturesqueness that depends partly upon the great number of boats engaged, partly upon the hugeness of the sails they carry, and, when seen near at hand, largely upon the diversity of the types of boats and sails.

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* "Commercial and other Sponges," Boston, 1883, page 34.

At the fishery of this year the fleet was separable into five component divisions, the boats in each characterized by sharp and distinct differences in hull, rigging, and sails. These five types belonged respectively to five different ports or groups of ports, namely:—

(*a*) Large-sized sailing cargo lighters from Tuticorin.

(*b*) Large dhoneys from Jaffna, Kalpitiya, and other ports in the North of Ceylon.

(*c*) Narrow canoe-like boats with balance board from Kilakarai and the neighbouring villages on the Madura coast.

(*d*) Long three-masted canoes from Adirampatnam and Mutupet on the Tanjore coast.

(*e*) Square-sterned Paumben boats of lugger rig.

Besides these, there were a few boats of miscellaneous types hailing from Colombo.

The Tuticorin lighter, the Jaffna dhoney, and the Kilakarai canoe are all single-masted, bearing huge lug sails. The first-named is by far the largest type of boat taking part in the fishery, varying in tonnage from 20 to 35 tons capacity. Clumsy looking as they are, they sail splendidly in a favourable breeze, their solid build permitting the employment of a great sail area. The stern is sharp, practically both extremities are alike. All are copper-bottomed.

In some cases as many as thirty divers went out in one of these boats, and as each diver requires an attendant munduck, there were as many as 64 or 66 men aboard, the extra number being accounted for by the crew and the Government boat guard.

The Kilakarai canoes also run sharp at either end, the bow being usually curved upwards and inwards to form a small ornamental prow with a crudely painted symbol of an eye on either bow. They sail extremely well, as, although they are particularly narrow, satisfactory stability is obtained by the employment of a balance board placed amidships, to which the mast is stayed. In a breeze this board is run out to windward and live ballast distributed along its length. On several occasions towards the end of the fishery I have seen as many as six men standing and squatting on the portion projecting beyond the side, the boat tearing through the water at a grand pace. These craft could in most cases easily outpace the other types in the race for the camp.

The boats hailing from Kilakarai itself are painted bright colours—red, or green, or yellow; those of similar type hailing from the neighbouring villages of Vaipar, Vembar, &c., often attempt in addition a decoration of the sides in rude geometrical pattern.

The great canoes from Adirampatnam and Mutupet are the strangest craft of the fleet—long and narrow, with curved and ornamented prow. They carry three masts, of which the foremast is a diminutive pole bearing a correspondingly small sail answering the purpose of a jib. They are not furnished with balance boards, although otherwise they appear to have been evolved from a common origin with the Kilakarai boats. They employ powerful leeboards.

The Jaffna dhoney is too familiar to require description. Comparatively broad for their length, they are roomy craft and sail well. Their usual colour is black; less frequently blue or green.

The three last described types all affect a very heavy and peculiar-shaped rudder—so shaped and so substantial that a man can easily squat upon the upper edge.

The fifth type, the Paumben boat, approximates in hull and rig to a somewhat clumsy European lugger; indeed we may fittingly call it a lugger, as it is fitted with the three distinctive lugger sails—a gib, a large lug on the mainmast, and a small one on the mizzen. The stern is square, with European style of rudder.

IX.—*Share system in use among the Divers.*

(Extract from the Report of Mr. J. P. Lewis, Superintendent of the Pearl Fishery of 1904. Ceylon Sessional Papers, 1904. No. XIII., p. 6.)

"There are always on a diving boat, in addition to the tindal and the divers and munducks, of whom there are two of each to each stone, a samátti (which is supposed to be a contraction of sámän vattai), who is the representative of the owner, and a todai, whose duty it is to attend to the baling of the boat, an important function, and to take charge of the food and drinking water.

"The custom is general among all classes of divers that each diver gives one dive of oysters per day to the samatti, tindal, and todai, respectively, *i.e.*, they each receive two divings from each stone.* Their shares are given to them in the boat, and they hand over the Government share in the kottu themselves and retain the balance.

"The divers' share of the oysters are divided as follows :—†

"(1) *By Erukkalampiddi Men.*—One-sixth of the oysters for hire of boat; one-third of the balance to munducks and two-thirds to divers.

"(2) *Tuticorin Men.*—One-fifth of the oysters for hire of boat; one-third of the balance to munducks and two-thirds to divers.

"(3) *Arabs (from India).*—Same as Tuticorin men.

"(4) *Arabs (who are settled in Ceylon).*—For boat hire each diver gives Re. 1·50 per day. The oysters are divided as follows :—Two-thirds to divers and one-third to munducks.

"(5) *Kilakarai Men.*—One-fifth or one-sixth, according to arrangement, for boat hire; one-third of the balance to munducks and two-thirds to divers.

"Thus, if an Indian, Arab, or Tuticorin boat brings in 10,000 oysters, divers' shares will, at Rs. 50 per 1,000, fetch Rs. 500 :—

	Rs.	c.
One-fifth for boat	100	0
One-third of balance to munducks	133	33
Two-thirds to divers	266	67

"I may add that in some cases the Arab divers at this fishery hired boats from the owners for fixed sums of money, such as Rs. 250 or Rs. 230 for use of the boat during the fishery, without any handing over to them of shares of the oysters, and that in the Kilakarai boats each diver gave one dive for the Kilakarai mosque, in addition to the dives given to the samatti, tindal, and todai."

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* These shares were made compulsory on divers by Government regulations published in 1855. (See Report on Pearl Fishery of 1880, Sessional Papers, 1880, No. XV. p. 119.)

† From notes supplied by Mr. Denham.

APPENDIX D.

Tabulation of the Comparative Yield and Value of Pearls from the Chief Samples of Pearl Oysters lifted from the Ceylon Pearl Banks during the Fifty Years ending 1904.

Date of lifting Sample.	Bank taken from.	Number of Oysters lifted.	Total Weight of Pearls produced, including Shell Pearls. Kalanchu.	Manchadi.	Average Weight of Pearls per 1,000 Oysters. Kalanchu.	Manchadi.	Total Value of Sample.	Value per 1,000 Oysters.	Age of Oysters.	Remarks.
							Rs. c.	Rs. c.	Years.	
November 1854	Cheval ...	4,000	1	—	—	5	70 72	17 68	4	Age accurately known. Increase in weight of pearls is equal to 60 per cent. per annum for these four months.
March 1855	do. ...	4,500	1	10	—	6	60 87	13 75	$4\frac{1}{3}$	
November 1856	do. ...	10,000	6	1	—	13	100 60	11 6	—	
February 1857	do. ...	10,000	4	16	—	9	140 0	14 0	4	These Cheval oysters were all of the same brood. Ages given are approximate. The increase in weight of pearls per 1,000 oysters was 166 per cent. between fourth and fifth year and 89 per cent. between fifth and sixth year.
November 1857	do. ...	12,000	9	—	—	15	195 72	16 31	$4\frac{3}{4}$	
February 1858	do. ...	12,000	14	13	1	4	260 40	21 70	5	
November 1858	Moderagam ...	12,000	12	17	1	1·50	182 16	15 18	—	
Do. 1858	Cheval ...	10,000	17	8	1	15	317 0	31 70	$5\frac{3}{4}$	
March 1859	do. ...	10,000	22	15	2	5·50	446 60	44 66	6	
Do. 1859	Moderagam ...	12,000	19	2	1	12	295 68	24 64	5	Of the same brood. Increase in weight of pearls between fifth and sixth year of age 100 per cent.
November 1859	do. ...	1,220	weight not		given		42 95	35 21	$5\frac{3}{4}$	
March 1860	do. ...	6,500	20	$19\frac{1}{2}$	3	4	469 75	72 27	6	
November 1862	Cheval ...	12,000	29	13	2	9	540 0	45 0	—	
March 1863	do. ...	12,000	31	12	2	13	516 0	43 0	5	Age approximate.
November 1863	do. ...	12,000	31	1	2	12	584 40	48 70	6	
Do. 1873	do. ...	10,000	3	15	—	7·50	333 35	33 33	—	
February 1874	do. ...	10,000	5	8	—	11	365 0	36 50	4	Age accurately known. The same brood. Increase in sixteen months 177 per cent. or 132·75 per cent. in one year.
November 1876	do. ...	10,000	4	$6\frac{14}{20}$	—	8·75	266 99	26 70	$3\frac{2}{3}$	
March 1878	do. ...	7,781	10	$3\frac{1}{4}$	1	5	318 $68\frac{1}{2}$	39 86	5	
Do. 1878	Koddeipakku ...	1,100	—	$5\frac{1}{2}$	—	5	5 52	5 2	—	Same brood. Shows increase in weight of pearls in one year of 166·25 per cent.
November 1878	do. ...	13,125	10	$7\frac{1}{5}$	—	15·69	225 $85\frac{3}{4}$	17 21	—	
February 1879	do. ...	16,000	10	$13\frac{1}{16}$	—	13·33	297 56	18 59	—	
November 1879	North-West Cheval ..	12,000	3	$1\frac{7}{16}$	—	5·08	77 21	6 43	$4\frac{3}{4}$	An increase in weight of pearls in one year of 249·05 per cent.
Do. 1880	do. ...	16,200	14	$8\frac{8}{16}$	—	17·79	346 27	21 $37\frac{1}{2}$	$5\frac{3}{4}$	
February 1881	do. ...	15,200	13	—	—	17	331 48	21 80	—	
April 1884	Karukupanai .	3,000	—	$16\frac{1}{2}$	—	5·50	35 25	11 75	—	
March 1887	North-East Cheval ...	10,253	3	$19\frac{1}{8}$	—	7·68	114 $17\frac{1}{2}$	11 14	$3\frac{1}{4}$ to $3\frac{1}{2}$	
November 1887	do. ...	12,053	8	$16\frac{12}{16}$	—	14·66	218 0	18 9	$4\frac{1}{4}$	
March 1887	North-West Cheval ...	10,508	2	$14\frac{11}{80}$	—	5·15	72 60	6 91	$3\frac{1}{4}$ to $3\frac{1}{2}$	
November 1887	South-West Cheval ...	12,100	8	$13\frac{7}{16}$	—	14·33	212 0	17 50	$4\frac{1}{4}$	
Do. 1887	South-East Cheval ...	12,060	7	$13\frac{6}{16}$	—	12·72	172 0	14 27	$4\frac{1}{4}$	
Do. 1887	North-West Cheval ...	12,180	8	$19\frac{15}{16}$	—	14·77	225 0	18 45	$4\frac{1}{4}$	
Do. 1887	Mid-East Cheval ...	12,016	3	17	—	6·41	78 25	6 51	$4\frac{1}{4}$	
March 1887	Moderagam ...	10,550	3	$14\frac{29}{80}$	—	7·05	104 $15\frac{7}{8}$	9 87	$3\frac{1}{4}$ to $3\frac{1}{2}$	

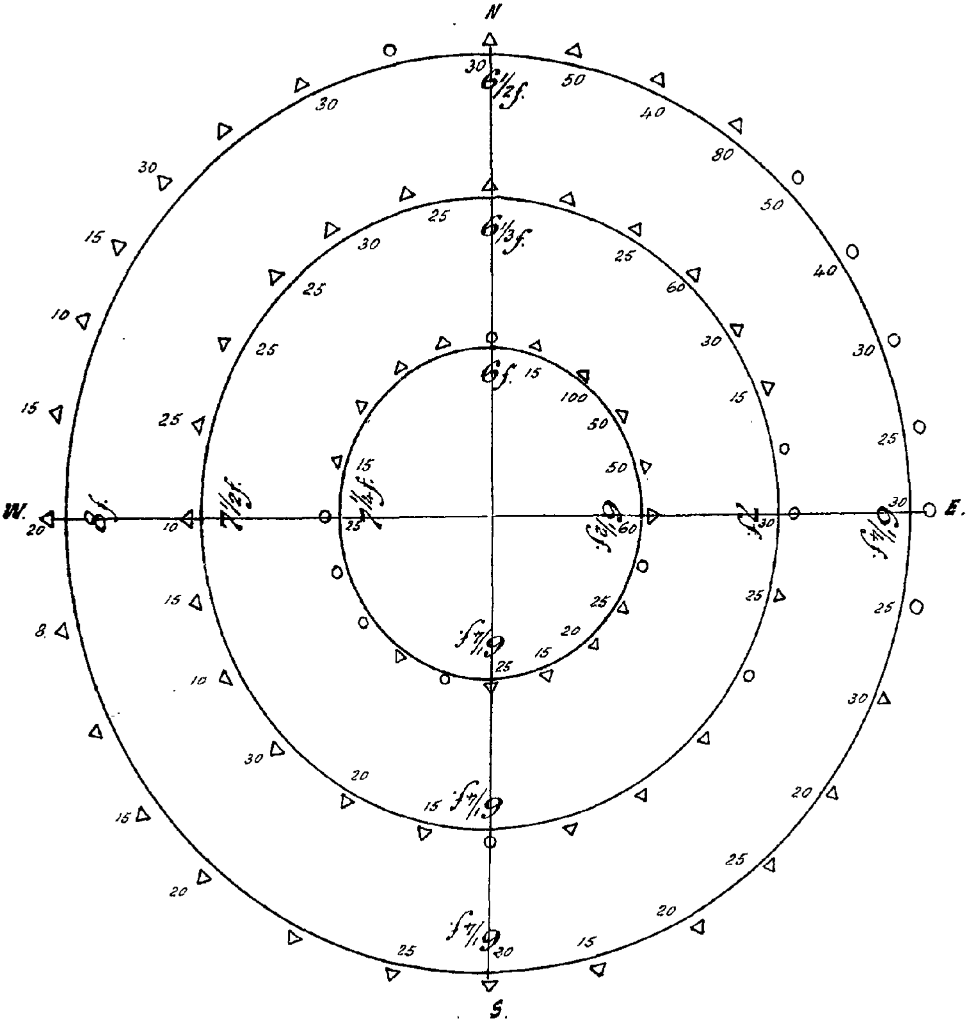
November	1888	Muttuvaratu ...	12,000	3	$10\frac{18}{16}$	—	5·84	122 0	10 16	—	
February	1889	do. ...	12,650	4	$18\frac{13}{16}$	—	7·81	142 0	11 $18\frac{1}{2}$	—	
November	1889	do. ...	15,000	10	$2\frac{12}{16}$	—	13·51	300 0	20 0	—	All from the same brood.
February	1890	do. ...	16,000	10	$19\frac{15}{16}$	—	13·74	271 10	16 $94\frac{3}{8}$	—	
November	1890	do. ...	15,200	17	8	—	22·89	550 0	36 11	—	
November	1889	Karativu ...	8,250	4	14	—	11·39	175 0	21 21	—	
February	1890	do. ...	10,000	4	$3\frac{14}{16}$	—	8·40	93 $44\frac{1}{2}$	9 $34\frac{1}{2}$	—	All from the same brood.
November	1890	do. ...	10,400	9	$1\frac{8}{16}$	—	17·44	267 0	25 67	—	
Do.	1902	Periya Paar Karai* ...	2,000	—	$5\frac{26}{32}$	—	2·91	26 50	13 25		
Do.	1902	South-East Cheval ...	12,000	2	$17\frac{3}{16}$	—	4·76	123 0	10 25		
Do.	1902	Mid-East Cheval ...	1,000	—	$5\frac{7}{32}$	—	5·22	18 17	18 17	$3\frac{1}{4}$ to $3\frac{1}{2}$	
Do.	1902	North-East and Northern Cheval ...	2,000	—	$9\frac{5}{32}$	—	4·58	46 25	23 $12\frac{1}{2}$		
February	1903	North-East and Northern Cheval ...	4,000	1	$4\frac{26}{32}$	—	6·20	99 89	25 0		All the same brood.
Do.	1903	Periya Paar Karai ...	3,000	—	$15\frac{19}{32}$	—	5·19	66 73	22 25		
Do.	1903	South-East Cheval ...	15,000	4	$14\frac{14}{32}$	—	6·29	290 0	19 27	$3\frac{1}{2}$ to $3\frac{3}{4}$	
Do.	1903	Mid-East Cheval ...	6,000	2	$4\frac{16}{32}$	—	7·41	121 54	20 26		
Do.	1904	South-West Cheval ...	12,000	7	$13\frac{4}{16}$	—	12·76	432 14	36 1		
Do.	1904	North-West Cheval ...	7,200	2	17	—	7·91	243 0	33 75	$4\frac{1}{2}$ to $4\frac{3}{4}$	
March	1904	Mid-West Cheval ...	6,000	2	$\frac{14}{16}$	—	6·81	121 51	20 25		

* From this valuation forwards the weight of shell pearls was excluded from the total.

No. 1.

Mid West Cheval Paar,

No. of Boat ..... 4 ..... *Date* ... 25th *February, 1904.*



Numbers above the line indicate Old Oysters.
— „ — *below* — „ — „ — „ — *Young Oysters.*
△ *indicates flat rock.*
x — „ — *Oysters too young to count.*
○ — „ — *a sandy bottom.*

No. 2

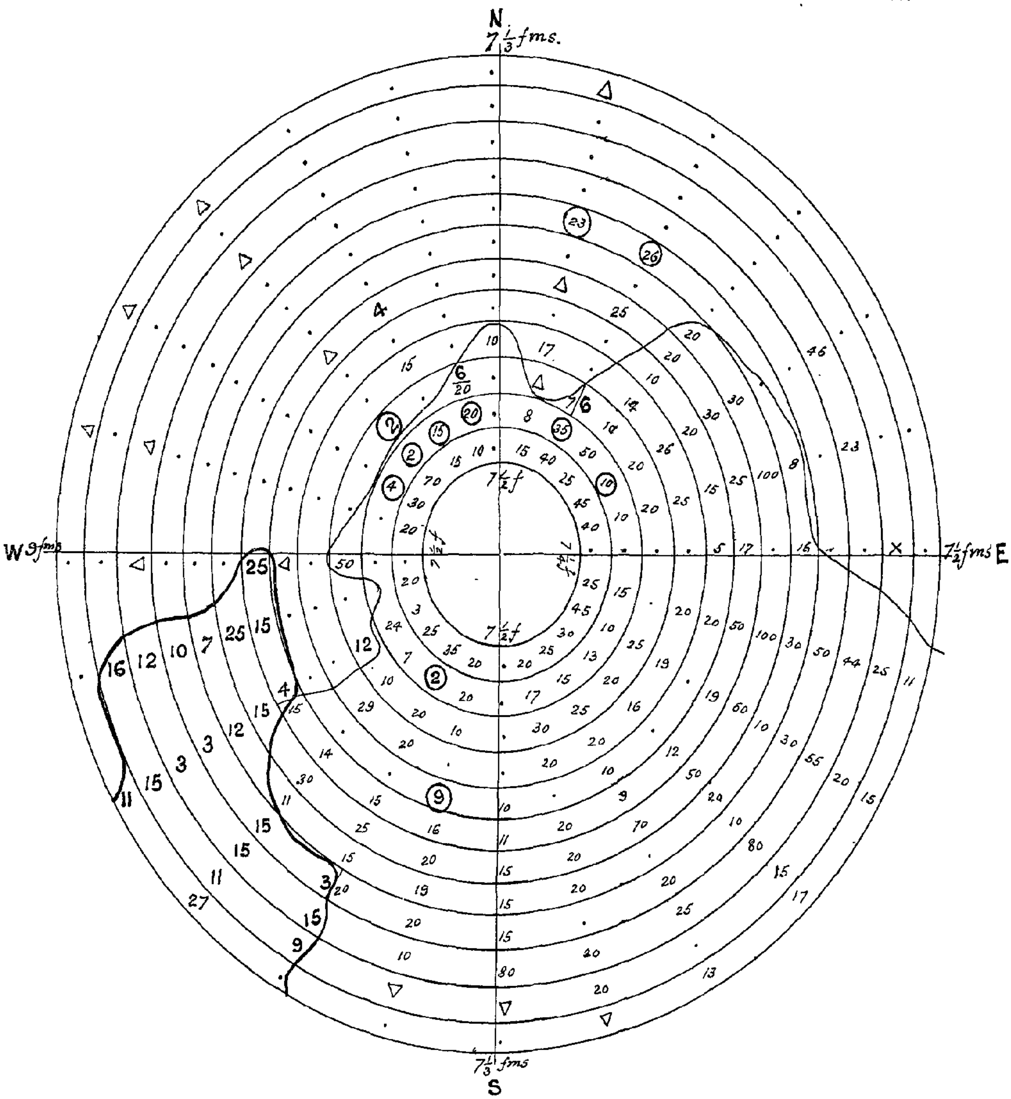
Date 27th and 28th February 1904. N. W. Cheval Paar.

Bearings of landmarks from centre are :-

....

....

....



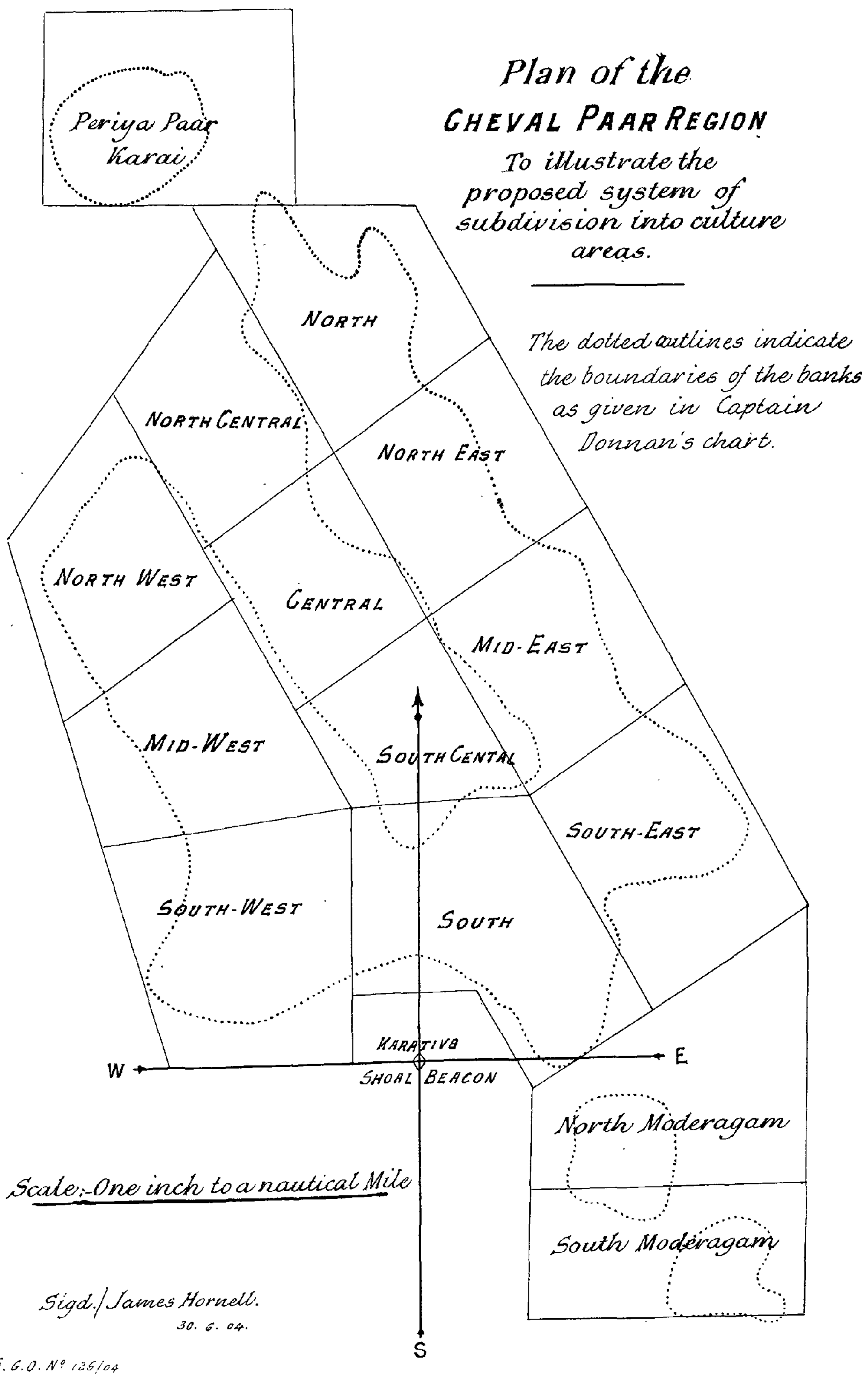
24. Numbers indicate Old Oysters .... } Upon Rock when the figures stand alone

12. Numbers indicate Young Oysters ..... } Upon Sand when contained within a circle

× indicates Oysters too young to count...

Δ indicates that the bottom is flat rock } When Oysters are wanting.

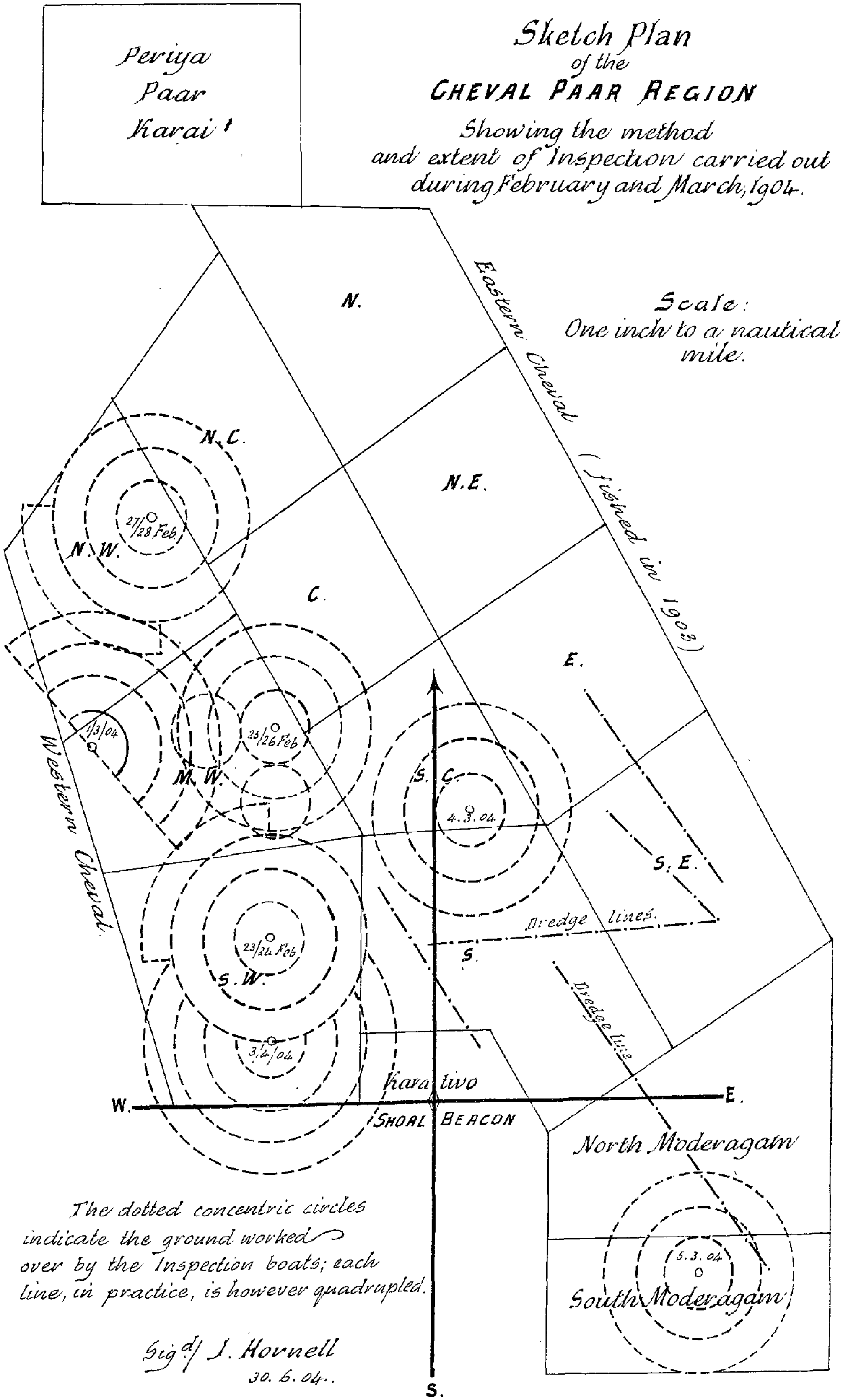
· " a sandy bottom ....


Plan of the
CHEVAL PAAR REGION
To illustrate the proposed system of subdivision into culture areas.
The dotted outlines indicate the boundaries of the banks as given in Captain Donnan's chart.
Periya Paar Karai
NORTH
NORTH CENTRAL
NORTH EAST
NORTH WEST
CENTRAL
MID-EAST
MID-WEST
SOUTH CENTAL
SOUTH-EAST
SOUTH-WEST
SOUTH
KARATIVU
SHOAL BEACON
W
E
S
North Moderagam
South Moderagam
Scale:- One inch to a nautical Mile
Sigd./ James Hornell.
30. 6. 04.
S. G. O. No. 125/04

No. 4.

Sketch Plan of the CHEVAL PAAR REGION

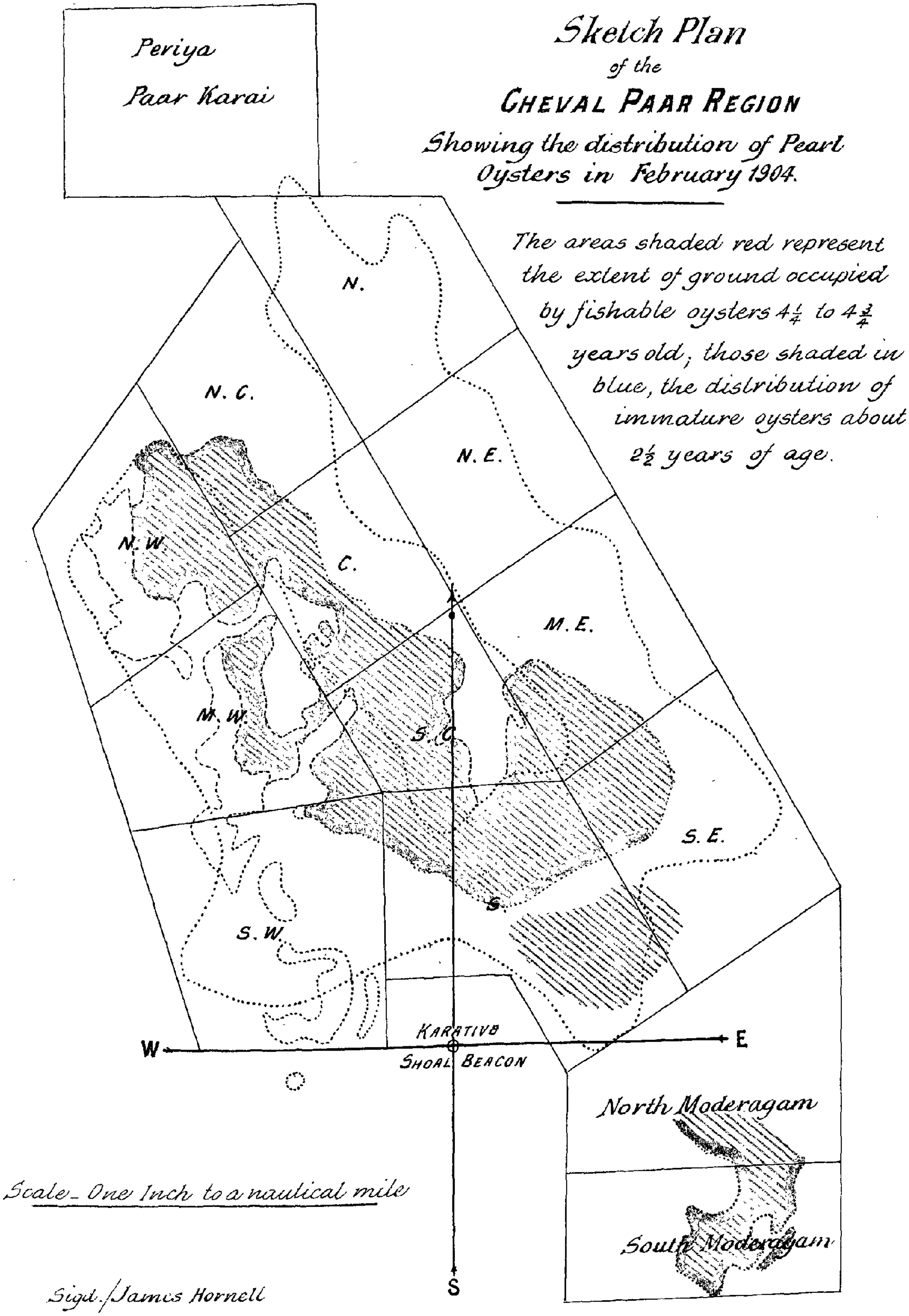
Showing the method and extent of Inspection carried out during February and March, 1904.



The dotted concentric circles indicate the ground worked over by the Inspection boats; each line, in practice, is however quadrupled.

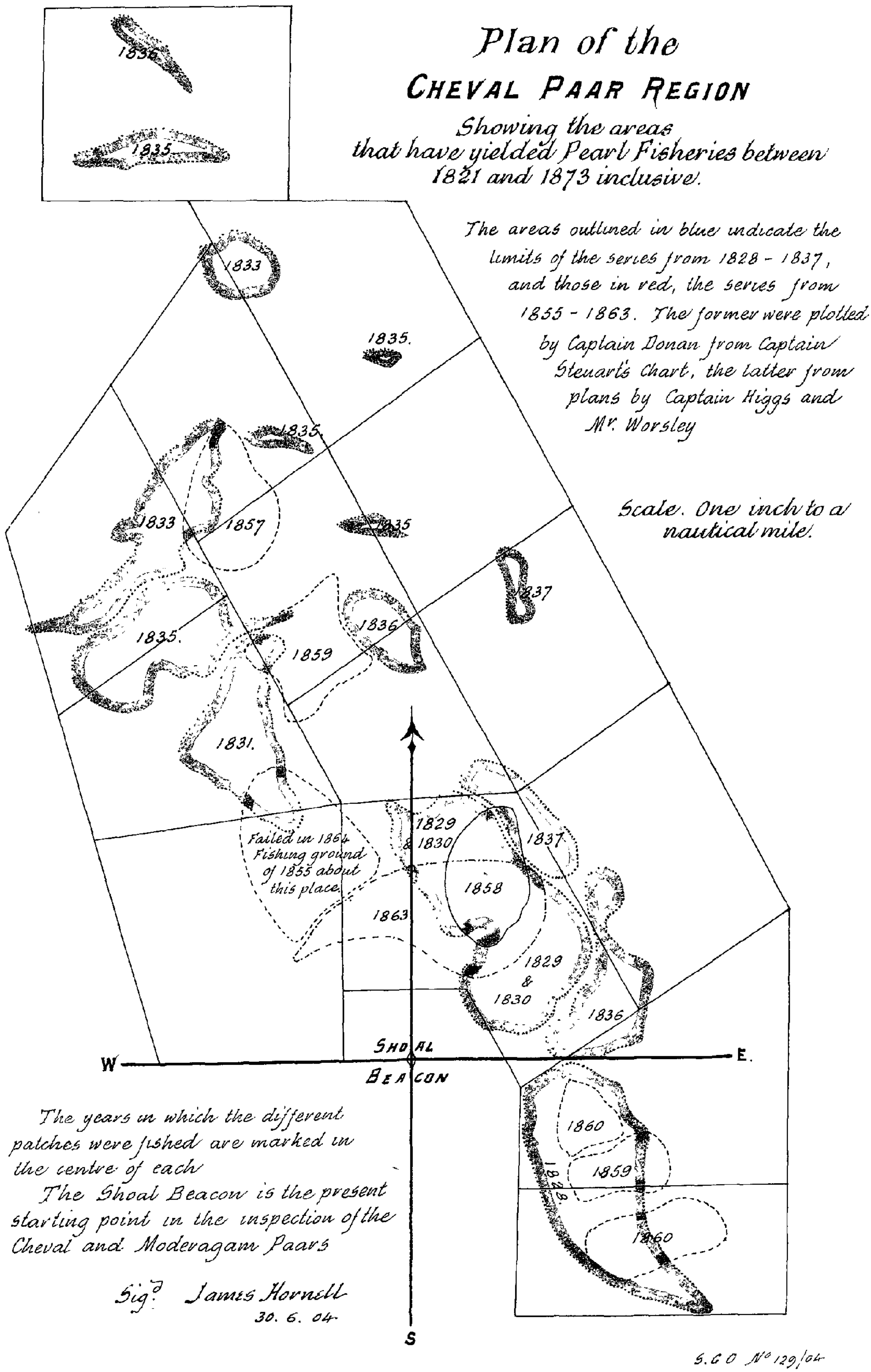
Sig.d/ J. Hornell
30. 6. 04.

No. 5.



S. G. O. No 128/04.

Nº 6.



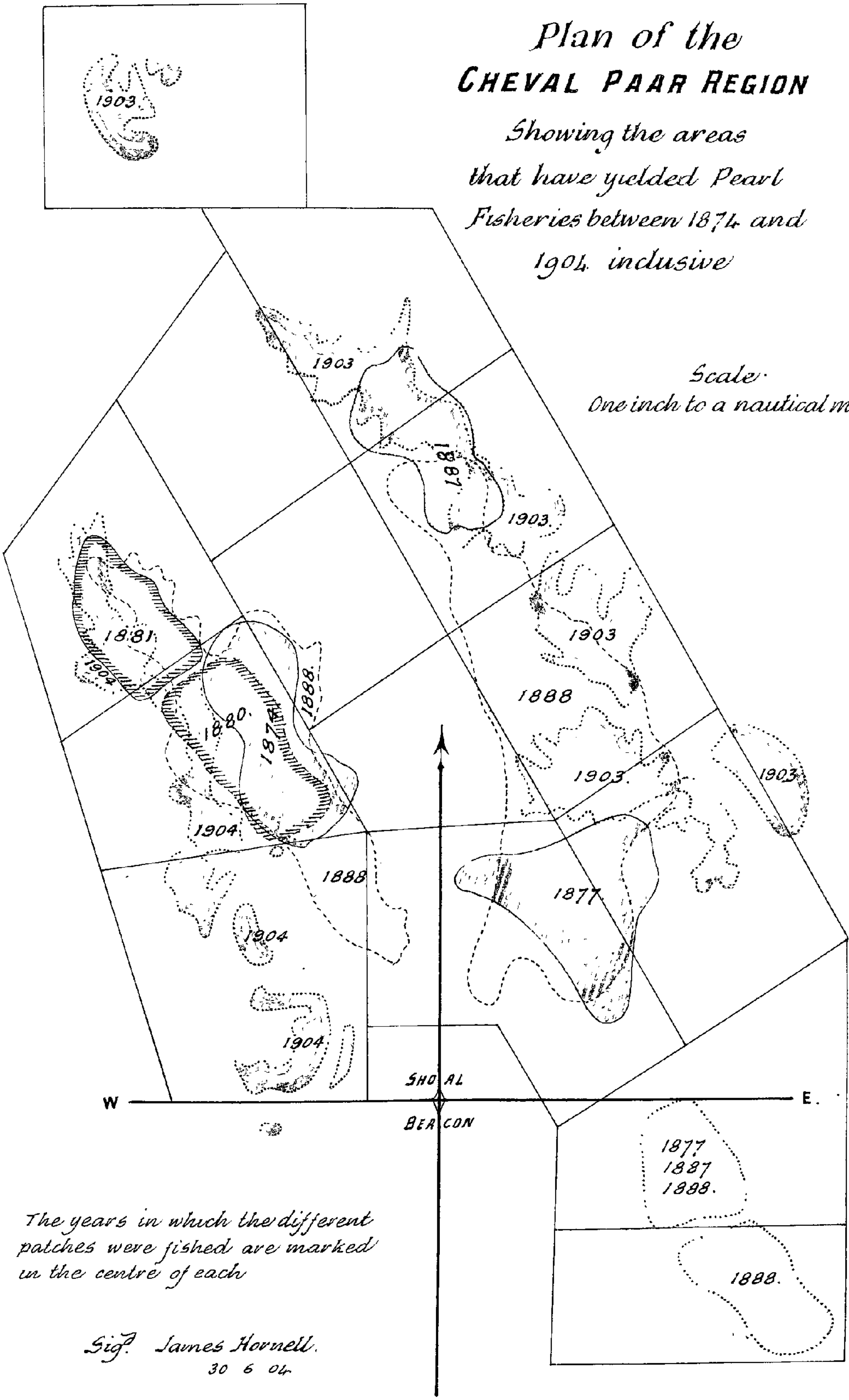
S.G.O Nº 129/04

No. 7

Plan of the CHEVAL PAAR REGION

Showing the areas that have yielded Pearl Fisheries between 1874 and 1904 inclusive

Scale: One inch to a nautical mile.



The years in which the different patches were fished are marked in the centre of each

Sig^d. James Hornell.
30 6 04.

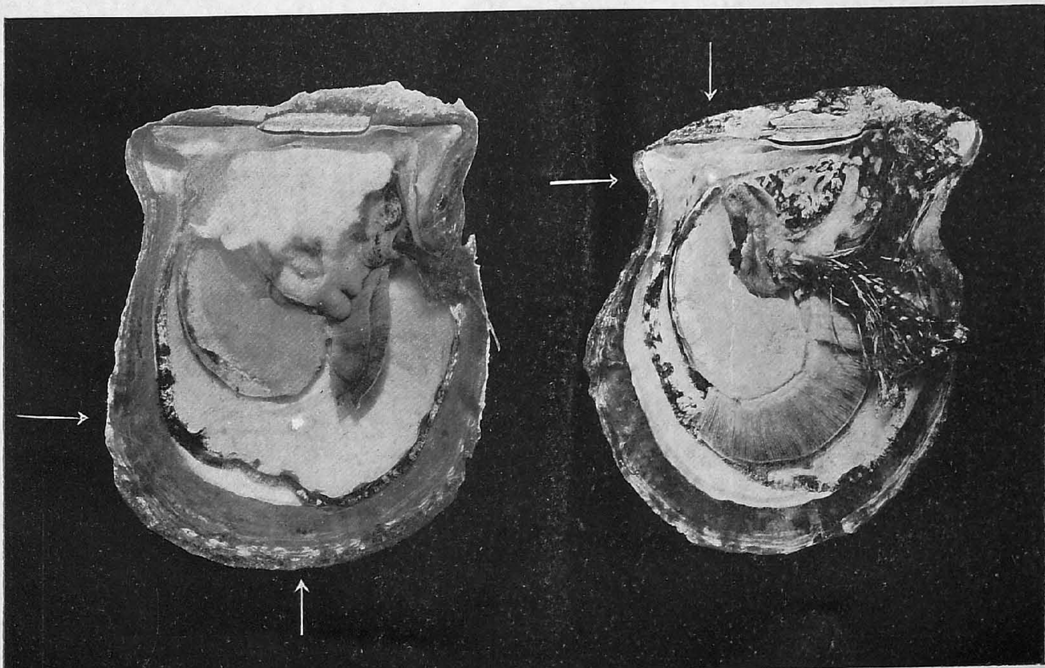
S G O No 130/04

No. 8.

A.

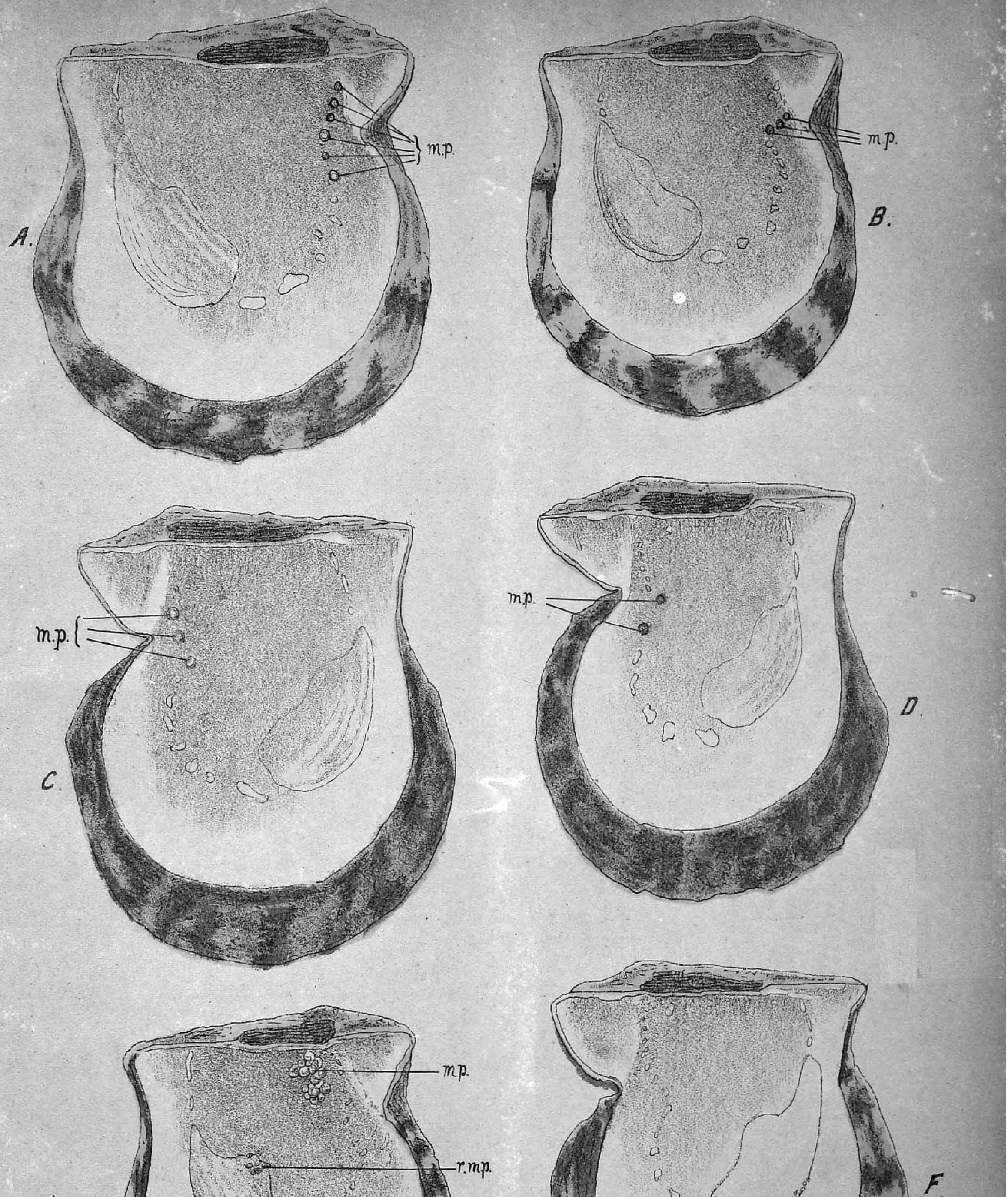
GOVERNMENT DIVERS ENGAGED IN PICKING OUT PEARLS FROM OYSTER-WASHINGS.

B. C.



TWO DISSECTIONS OF PEARL OYSTERS SHOWING CYST-PEARLS *in situ.* [Photo. by James Hornell.

No. 9.



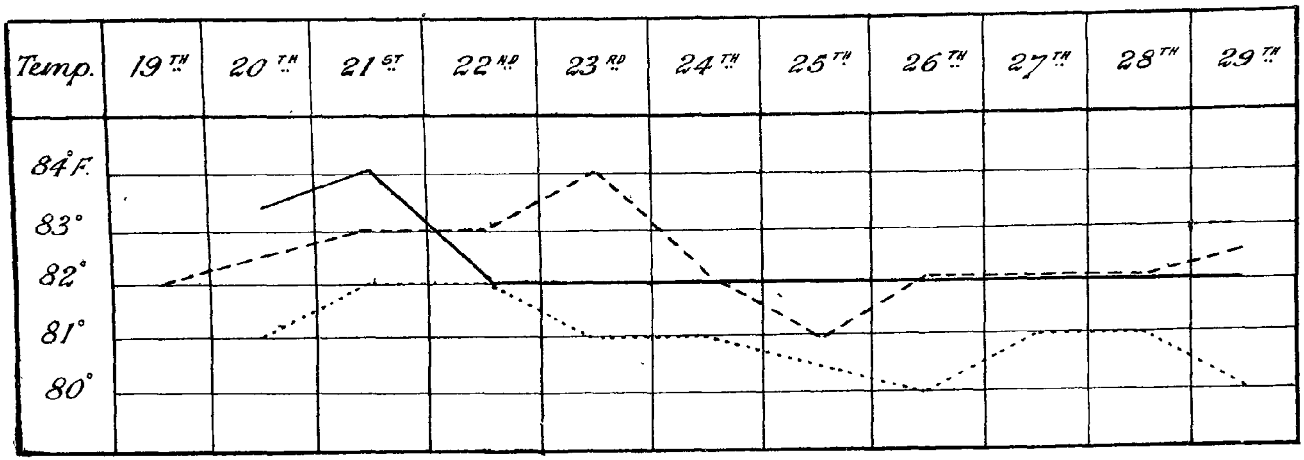
Attached Muscle-pearls.

James Hornell
30. 6. 04

No. 10.

Ceylon Pearl Banks.

Temperature of the Sea during February 1904.



.... denotes temperature registered at 7.30 a.m

———— " " " " noon

– – – – – " " " " 5 30 p.m.

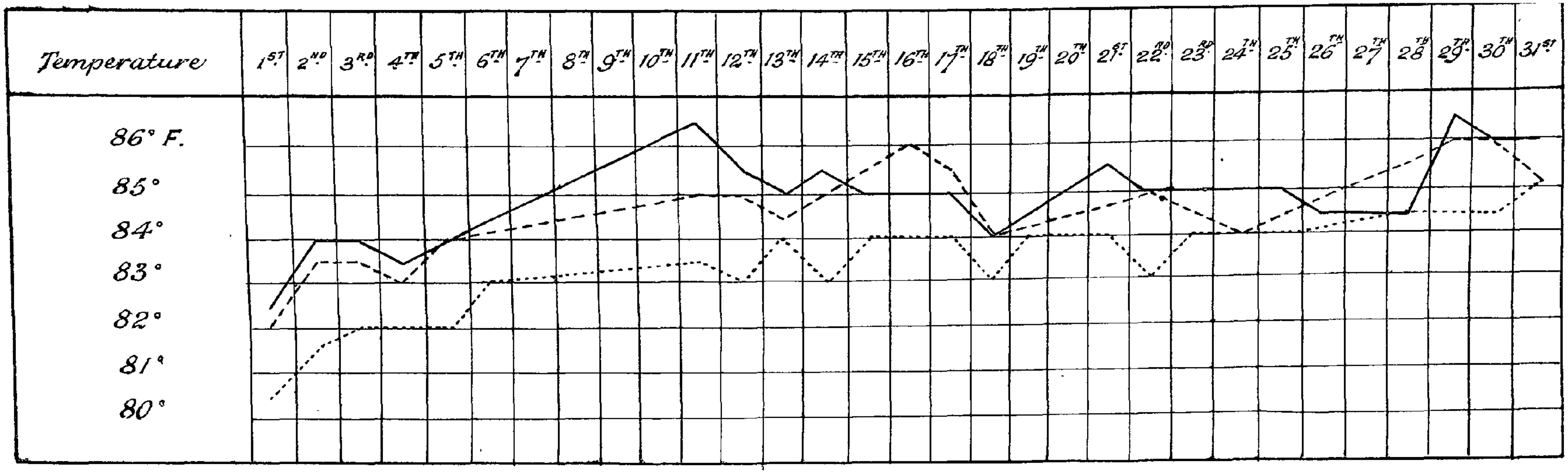
In all cases the temperature was taken at a depth of 2 feet below the Surface.

S G O. No 132/04.

No. 11.

Ceylon Pearl Banks.

Temperature of the Sea during March 1904.



.... denotes Temperature registered at 7.30 a.m.
——————— " " " " noon
- - - - - - - - " " " " 5.30 p.m.

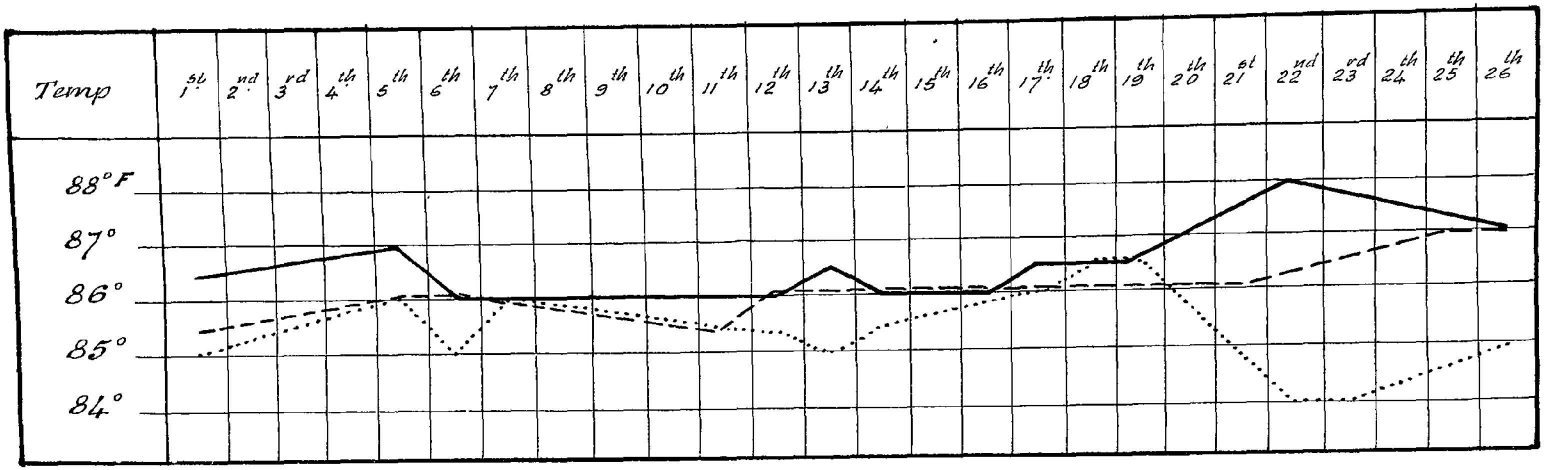
In all cases the temperature was taken at a depth of 2 feet below the surface.

S. G. O. No. 133/04

No. 12.

Ceylon Pearl Banks.

Temperature of the Sea during April, 1904.



.... Denotes temperature registered at 7·30 a.m.

———————— " " " noon

— — — — — — " " " 5.30 p.m.

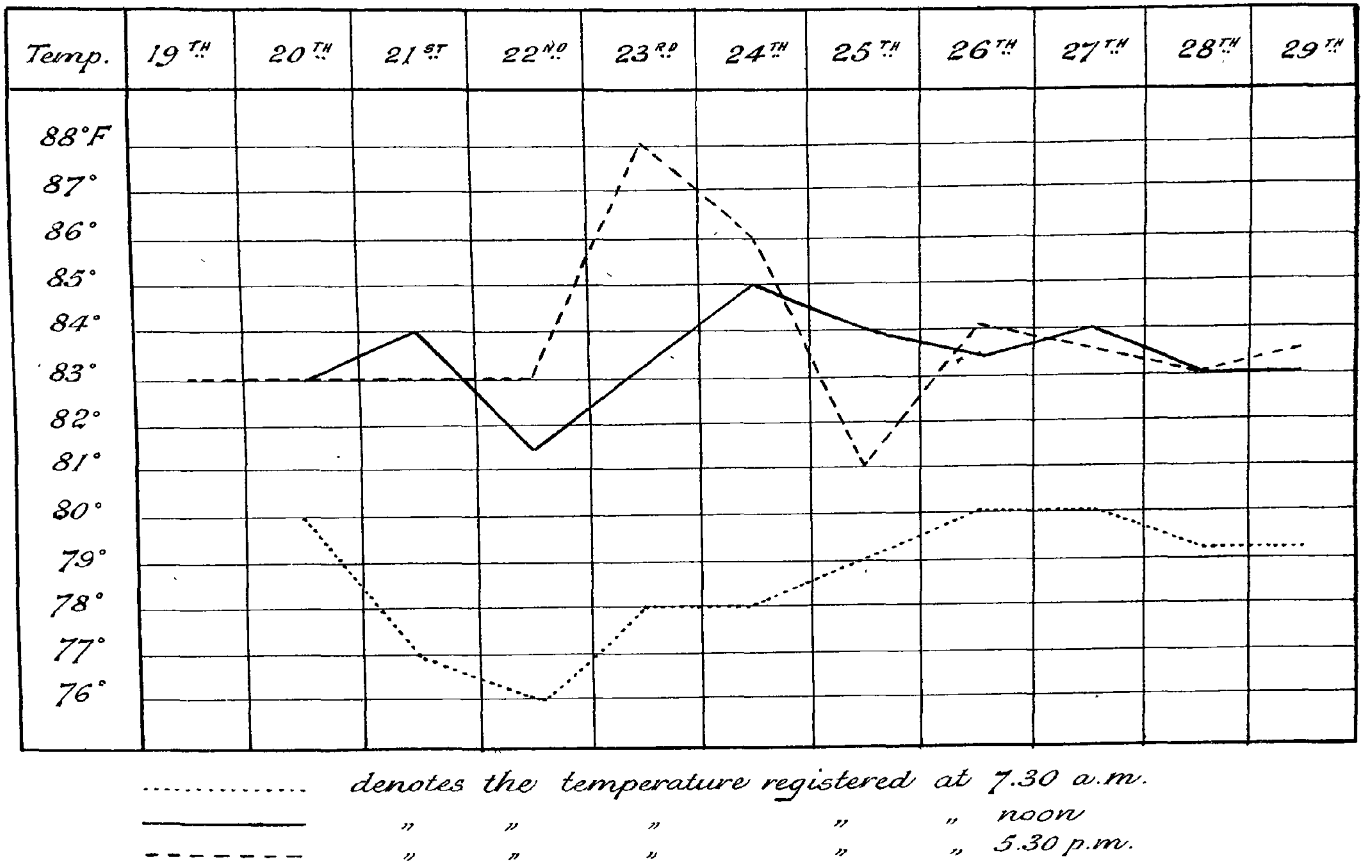
In all cases the temperature was taken at a depth of 2 feet below the surface.

S G O No 134/04

No. 13.

Ceylon Pearl Banks.

February 1904 Temperature of Air in Shade.

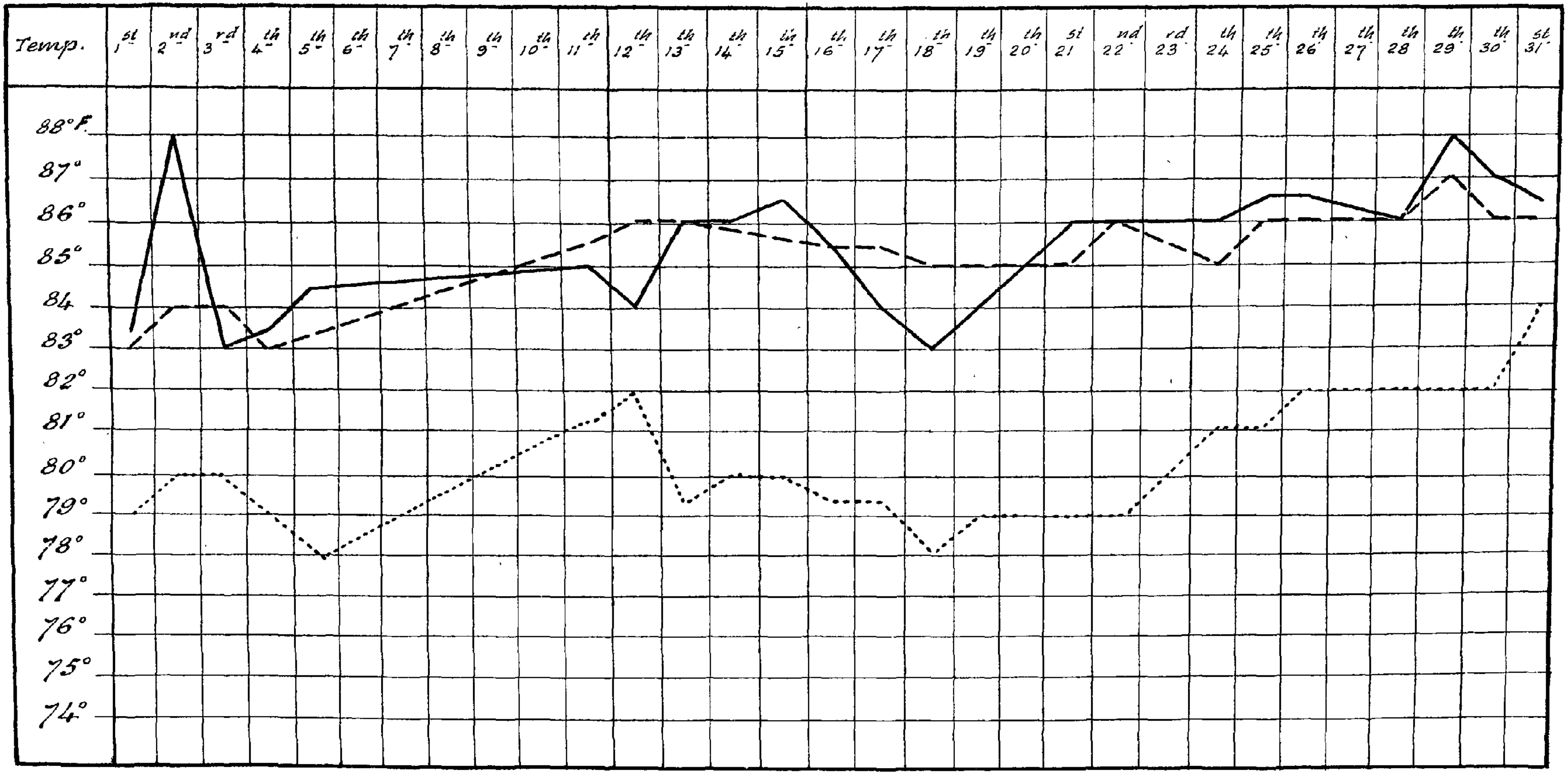


S G O. N 135/04.

No. 14.

Ceylon Pearl Banks.

Temperature of Air in Shade, March, 1904.



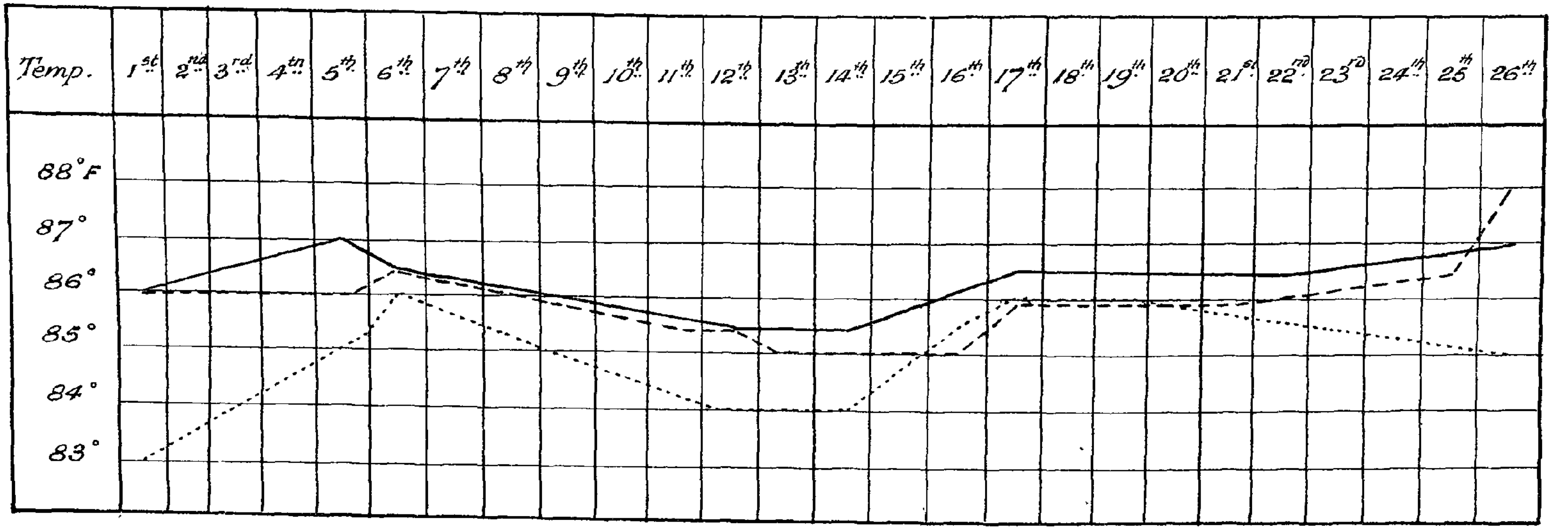
.... Denotes temperature registered at 7.30 a.m.
——— " " " noon
– – – – " " " 5-30 p.m.

S G O No 136/04.

No. 15.

Ceylon Pearl Banks.

April 1904. Temperature of Air in Shade.



.... denotes temperature registered at 7.30 a.m.

———————— " " " " noon

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S.G.O No. 137/04

Reports from the Ceylon Marine Biological Laboratory.

PART II.] [VOL. I.

No. 2.

REPORT ON THE PLACUNA PLACENTA PEARL FISHERY OF LAKE TAMPALAKAMAM.

With one plate and two sketch-plans.

By JAMES HORNELL, F.L.S.,

THE beginning of a long deferred biological survey of Lake Tampalakamam was made in May of this year; before proceeding to detail the results obtained with regard to the present condition of the *Placuna* pearl beds which give this bay its local importance, it will be well to furnish some particulars of the principal topographical and physical peculiarities of the locality in question, together with what few notes I have been able to gather regarding the history of the Tampalakamam pearl fishery.

The time and means at my disposal did not permit the making of an exhaustive collection of the fauna and flora, but the detailed knowledge gained of the topography of the lake will greatly facilitate further work, for, as has been my usual experience in Ceylon, the best charts and plans available for out-of-the-way places are miserably inadequate when identification of landmarks is requisite; the makers of such charts as I have had to use appear to have been remiss beyond belief in this essential of good cartography, for in the comparatively few cases where names are attached to places of topographical value they are, as a rule, rendered incorrectly. Who, for instance, can recognize Periya-ar in Kerni-aru, Semmalai in Chamaimalai? After this we think nothing of finding Nachchikuda masquerading as Narche Coudar, Kakamunai as Çorkamunny, and Malay Cove as Maly Cove.

Most of these initial topographical difficulties I have smoothed out, and the attached sketch plan of the lake (Annexure III) will, I hope, enable my notes to be followed with comparative ease.

When the faunistic collections are completed they will be distributed to specialists in the different groups to be reported upon in detail.

I.—TOPOGRAPHY AND PHYSICAL CHARACTERISTICS OF LAKE TAMPALAKAMAM.

Tampalakamam Lake, usually corrupted into Tamblegam Lake or Bay, is a shallow, land-locked tidal bay of great extent opening by a narrow neck-like mouth to the sea on the west side of Great Bay, Trincomalee. It lies south-west of the harbour of Trincomalee, separated therefrom by a tract of densely wooded hilly ground channeled by ravines, which in a few instances widen into short stretches of low-lying land.

The main axis of the lake lies in a north-east and south-west direction and measures $4\frac{1}{4}$ nautical miles. The breadth varies from one to two miles, the greatest width being midway between the two extremities. In general outline the lake, if shorn of the seaward entrance and the branch inlet of Nachchikuda adjoining thereto, is roughly that of a parallelogram set south-west and north-east, the entrance and Nachchikuda being at the south-east angle

Three main divisions may be made out—an *eastern*, comprising the mouth and the northward-running inlet of Nachchikuda; a *south-western*, comprising the whole of the bag-like or cæcal western end, separated from the central division by an arbitrary line connecting the headland of Peyaddaimunai on the north shore with Kakamunai on the south. The third or *central region* lies between the line named on the west and the mouth of Nachchikuda on the east.

Except in the channel near the entrance and in the mouth of Nachchikuda, the bottom is remarkably level, maintaining a depth of from 6 to 9 feet over the whole area, save as one approaches the shore and over well-marked banks or *kallams* which rise here and there close to the surface. Immediately within the mouth of Nachchikuda we have, however, depths from 3 to $3\frac{1}{4}$ fathoms. Generally the lake is slightly deeper off the north shore than off the south and south-west shores, where open the chief rivers and streams falling into the lake; off the mouths of several we have distinct sand spits formed; the principal is the long cockle-bearing sandbank that stretches far into the lake in a north-west direction from the mouth of the Periya-ar.

The principal streams emptying into the lake taken in order from east to west on the south shore are: Katti-ar, Periya-ar, Sembian-ar, Polokarai-ar, Periya Palamput-ar, and Tampalakamam-ar, the three latter opening through a maze of mangroves.

Along the north-west stretch of shore we have only the Sinna Palamput-ar and the Manal-ar; the latter, which is called Coppotary-ar (Kapalturai-ar) on the Admiralty chart, is of little importance.

No other streams and but a few small creeks break the line of the north-east shore and that of Nachchikuda.

The whole of the great south-west pocket of the lake, into which open the two Palamputs and the Tampalakamam-ar, is shut in by a low deep-green wall of mangroves straddling out into the shallows on grotesque stilt-roots. The north coast is generally higher than the south, and with a backing of stately hills and a diversified array of forest trees and jungle in the foreground, its appearance is picturesque and attractive—a pleasing contrast to the dark and stagnant swamp land on the opposite margin, hidden beyond which, however, there stretch miles of fertile paddy fields supporting a considerable and industrious population.

The general bottom of the lake is a dark grayish-black mud, known as *mei seru* or "ink mud," intermixed in places, and towards the shore generally, with more or less quartzose sand. True sand banks, almost or entirely dry at low water, occur in various places, and are known as *kallams*.

Among the more noteworthy of these are *Muttikallam* and *Amaikallam* lying between the Sinna Palamput-ar and Peyaddaimunai on the one hand and Kakamunai on the other; *Muttikallam* is a sand-bank awash at low water and the home of edible shellfish (*Mutti*, Tam., a general term embracing *Cardium*, *Venus*, and other cockles and clams), while *Amaikallam*, the "Turtle Bank," characterized by a fairly uniform depth of half a fathom, bears abundance of vegetable life (Algæ and *Halophila*), and thereby is a favourite resort or feeding ground for the turtles of the neighbourhood.

The place names of the lake are almost entirely all descriptive of some natural or physical characteristic—commonplace in the extreme. As instances in point, we have *Semmalai*, the Red Hill; *Vellai Kalumunai*, White Stone Point; *Serukuda* or Muddy Bay, and *Kannamunai*, a promontory where Kanna trees are abundant.

The name of one spot has a minor historic interest—Kapalturai, literally "Ship Harbour." The vicinity of this place is a good locality for snipe shooting, and in consequence it used to be a well-recognized rendezvous for shooting parties from the men-of-war stationed or calling at Trincomalee.

As is to be expected from the configuration and shallowness of the lake, the temperature of the water rises rapidly during the day; during the period of my last visit, May 18th to 24th, while the temperature varied from 82° to $82\frac{1}{2}$° F. at 5 A.M., by noon it attained 89° F., falling to 88° and even 85° F. by 4 P.M., according to the strength of the cold wind from the inland hills to the south-west that prevailed at this time of day.

The air temperature in the shade varied from 82° F. at 5 A.M. to 88° and 89° F. at noon, falling to 86° and $86\frac{1}{2}$° F. at 4 P.M.

On February 11, 1902, the temperature of the lake was 80° F. at 9 A.M., while when I visited it in the October following it ranged from 87° to 90° F. between 10 A.M. and noon. The general average for noon may be taken as approximating to 88° F. throughout the whole year.

The salinity of the lake is not so low as might be expected, ranging from 1·015 in the western section, where a considerable volume of fresh water is emptied into the lake, to 1·019 in the eastern division and in the median part of the central section, at temperatures from 86° to 90° F. These figures are however for the dry season; it will be necessary hereafter to make a study of the conditions which prevail during the wet season of November, December, and January and of the effect then produced upon the inhabitants of the lake.

II.—The Nature of the Placuna Pearl Fishery of Lake Tampalakamam.

The shell which furnishes this unique pearl fishery is *Placuna placenta*, L., a peculiar Lamellibranch mollusc excessively compressed laterally and furnished with white translucent valves, discous in outline. The valves are asymmetric, the left being very slightly convex, while the right is quite flat. It possesses no relationship with the true pearl oysters (Aviculidæ), being closely akin to the strange Horse-shoe oyster (*Anomia ephippium*) of British waters. But whereas *Anomia* lives firmly attached to rocks and shells by a calcified byssus passing through a circular and median aperture in the right valve, *Placuna placenta* has no byssus in adult life and lives free, preferring as its chosen habitat the muddy flats of such shallow tidal bays as Lake Tampalakamam.

The usual position is almost prone on the muddy surface, the hinge region slightly sunk in the mud, which lightly covers the dorsal third of the shell. Occasionally they are sunk more deeply, and they may even be found, though rarely, planted vertically after the manner of *Pinna*.

In the young condition, during the first year at least, the valves are perfectly transparent—the general anatomy of the animal can be clearly seen even to the beating of the heart. The very young up to the time they reach a diameter of two inches, not infrequently exhibit ray bands of palest pink diverging from the hinge and broadening as they approach the free edge of the shell. A few are almost entirely suffused with this pale pink tinge; others, and these are the majority, exhibit no colour, clear and transparent as the finest mica flakes, which indeed they resemble closely, even to the readiness with which they can be split into further lamellæ.

Towards the age of two years the shells as they become more massive gradually turn white and translucent in place of being clear and transparent.

From the observations I have been able to make, having visited the lake in 1902, 1903, and 1905, I conclude that three years constitute the life-span of this species; within this time they attain the size of 7 inches in length by 6 inches in depth (or height). This confirms Kelaart's statement:—" I am not able from my own observations (having been only a few months engaged in these researches) to say, in how many years this oyster arrives at perfection. But from the appearance of shells of all sizes, and the history of the Tamblegam pearl fisheries since 1839, I should say, that in three years this bivalve mollusc attains its adult age; and, after that, it dies." *

During my last visit I measured representatives of the different broods met with (see Annexure No. I.), and this record will enable the rate of growth to be ascertained with exactitude by means of further observations next year.

The shells of this mollusc are said to be used on account of their clear translucency as a substitute for window glass in China and in the Portuguese territory of Goa—whence arises the term " window oyster " as applied to this species, the " *Vitre chinoise* " of French writers.

In Ceylon such glazed windows would be a superfluity in native dwellings; the reason for the fishery of these oysters lies entirely in the abundance of small pearls yielded by full-grown individuals.

* " Report on the Tamblegam Pearl Oysters," 8vo., 6 pp., Trincomalee, 3rd October, 1857.

Of the past history of the fishery little is known, save that during last century a small and gradually diminishing revenue was drawn by Government from the rental of the fishing rights.

In 1857, Dr. E. H. Kelaart furnished a short preliminary report on the fishery (*loc. cit.*), wherein he states that during the two days he spent at Kinniei in 1857 there could not have been less than 30,000 oysters fished on each day. He adds: "More than two-thirds of this number were young and had better have been left in the lake for another year or more...... The Tamblegam Wanniah, and all the divers, whom I questioned on the subject, stated, that in the early part of the present year more than 50,000 oysters were fished daily...... At the lowest calculation, in three years there must have been fished from this bank upwards of 18 millions of oysters, supposing that there were only 200 fishing days in each year."

During the period of the three years in question the rental paid to Government by the lessee was £901, while for the eighteen years preceding 1857 the average annual rental was £344, rather higher than that of the final triad of years.

Between 1880 and 1890 the fishery, according to the Kachcheri records, was leased out three times, viz.:—

Year		Lessee.			Amount of Rent. Rs.
1882–1884	..	Annamalai Chetty	..	..	3,000
1885–1887	..	do.	..	..	7,000
1888–1890	..	Arumugan	..	..	5,000

The fisheries during Arumugan's lease were carried on most thoroughly; in consequence, the long threatened complete exhaustion of the beds came about, and since 1890 no fishery has been held. The rent for 1897–1898 was indeed sold for Rs. 1,850, but the lessee dying, the lease was abandoned by his representatives, and on account of poor prospects it was not resold, no fishery taking place in consequence.

The beds have taken from 1890 to the present to make a partial recovery; they will require very careful treatment, largely protective, to ensure continuance and the distribution of further deposits over a larger area. The beds are still so restricted in extent that fishery greed if uncontrolled may easily bring about another long series of blank years, while on the contrary, if the fishery be carried on systematically and providently, it should become the source of a fairly regular annual revenue to Government of from Rs. 10,000 to Rs. 12,000, possibly even more.

Up to the present time the fishery in Tampalakamam Lake has invariably been leased by Government to native speculators—Chetties from Trincomalee and Jaffna—for periods of three consecutive years. The divers receive one-half the catch as their remuneration, but they are bound by custom to open their oysters fresh and to sell the pearls they find to the renter virtually for whatever he may like to give.

The renter also opens his oysters fresh, employing coolies to do this. I am informed that the pay is usually at the rate of some 12 cents per hundred.

The divers claim that each makes from 300 to 500 dives per day; they consider the yield satisfactory if they obtain an average of one large oyster per dive. When the oysters are abundant one man may fish from 2,000 to 3,000 per day.

The Kinniei divers distinguish between the true pearl oyster (*Margaritifera vulgaris*) and the window oyster by terming the former *Silavattai chippi*, the "pearl fishery oyster," and the latter *Muttu chippi*, the "pearl oyster."

The causation of the pearl in the window oyster and other details are dealt with on pages 48-49.

III.—INSPECTION OF THE PLACUNA BEDS, MAY, 1905.

With a view to the systematic exploration of the lake, I laid off the area to be examined into four sections—(*a*) Nachchikuda, (*b*) the southern half of the central division, (*c*) the northern half of the same, and (*d*) the south-western division.

To each I devoted at least one day, running series of soundings and dives along the lines marked upon Sketch Plan No. 2 (Annexure IV.). Several hundreds of dives were made, and where the results of those adjacent to one another are identical with regard to the organisms found and the character of the bottom I combine them under the same number, as marked on the plan.

Those stations where *Placuna* was found are underlined.

IV.—SUMMARY OF RESULTS.

Except at the inner end of the entrance to the lake and on the *kallams* or banks already alluded to, the general bottom of the lake is a fairly stiff grayish-black mud ; both fauna and flora are scarce, few organisms having adapted themselves to life under such environment. The two principal animals that have so succeeded are *Placuna placenta* and the peculiar Suberitid sponge which I found first in October, 1902, and which Professor Dendy is describing as a new species. The latter goes by the name of *Kadalpalam* (sea fruit) among the divers of Kinniei—an appropriate designation as it is roughly pear-shaped in form, with a ground colour of pale yellow, blotched on the larger end with red.

It lives rooted in the mud by silky tufts of spicules ; its abundance is associated in the minds of the divers with replenishment of the *Placuna* beds, which they aver is preceded by the appearance of this sponge. Probably this belief arises from imperfect observation, as when *Placuna* is not plentiful these men have no occasion to make acquaintance with the condition of the non-edible fauna of the bottom.

Algæ are scarce on what we may term the *Placuna* mud. Here and there a branched *Codium* clings to a perambulating gastropod shell inhabited by a hermit crab, or a stout fan-shaped species may occasionally be found rooted in sandy mud by bulbous base. Otherwise, save for crawling gastropods, there is little conspicuous life present.

Four distinct *Placuna* beds were found, one at the head of Nachchikuda, one off Kapalturai, a third fronting the coast between Kakamunai and the mouth of the Sembian-ar, with a fourth in the southern half of the south-west section of the lake.

That in Nachchikuda consists of very young individuals, none exceeding the size of a crown piece. The divers whom I had with me did not know of the existence of this bed, and were extremely pleased to find it, for, as they said, no sign of oysters had been seen here for very many years; the augury they inferred is of the best.

The bed off Kapalturai is also composed of young individuals, older by some three months than those of Nachchikuda. The average size is 3·33 inches by 2·92 inches, and over the greater part of the bed they lie in great profusion, from 10 to 22 being commonly brought up at one dive.

Another bed largely composed of similarly aged oysters was found to extend south-west of Kakamunai and to occupy the greater part of the bay off the mouths of the Tampalakamam-ar and the Periya Palamput-ar. Some older oysters of $4\frac{1}{2}$ inches by 4 inches were mixed with them, and in places there were considerable numbers of the very young, $1\frac{3}{4}$ to 2 inches in diameter.

The bed lying off the south shore, from Kakamunai eastwards to the mouth of the Sembian-ar, is by far of the greatest immediate value, for, while the age appears sufficiently advanced to admit of a fishery next year, their abundance is great enough to make such a fishery profitable so far as numbers are concerned.

Two ages are present, the one probably over 2 years old, and measuring $155\frac{1}{8}$ mm. by $142\frac{2}{8}$ mm. ($6\frac{1}{8}$ in. by $5\frac{5}{8}$ in.) and another considerably more numerous of from $1\frac{1}{2}$ to $1\frac{3}{4}$ year, measuring from $111\frac{5}{12}$ mm. by 102 mm. ($4\frac{3}{4}$ in. by 4 in.) to $125\frac{1}{5}$ mm. by 115 mm. (5 in. by $4\frac{1}{2}$ in.).

V.—PRINCIPAL DETAILS OF RESULTS.

A dug-out canoe pulled by four boatmen was employed for the first three days; work therefrom was most inconvenient in the high wind and choppy water which prevailed after 8 A.M.; during the latter part of my stay, by the courtesy of Mr. W. B. Gregson, the District Engineer of Trincomalee, I was enabled to use his roomy and more manageable cutter greatly to the improvement of the work performed both by the divers and by myself.

The divers of Kinniei are all Moormen, generally of poor physique and low intelligence. They do not care to dive in greater depths than three to four fathoms; none attend the pearl fishery in the Gulf of Mannar, neither do they take any part in chank fishing. Some of them in the season dive for beche-de-mer in Trincomalee Harbour; others employ themselves in net-fishing, and all do more or less work in the paddy fields of the district.

The first day's inspection was devoted to an exploration of Nachchikuda, a sleeve-like bay at the extreme eastern end of Tampalakamam Lake. A series of dives was made across the mouth and then continued up the western side. At the north end, where hillside jungle gives place to a fringe of mangrove swamps, a number of traverses were made, and here it was that the bed of 6 weeks old *Placuna* was located. Thence we returned homewards, keeping a course parallel with the eastern shore.

Stations 1 to 5 across the mouth of Nachchikuda :—

Station 1.—15 yards from the shore at Semmalai; 10 feet depth; bottom shelly sand with some gravel, fragments of dead *Ostrea*, also rock.

Station 2.—3 fathoms; fine brown muddy sand.

Station 3-3-3.—2 fathoms; dark coloured gritty mud with subfossil shells of a small species of *Turritella* abundant. A few fan-shaped stout algæ rooted in the sand, with some *Codium* on live gastropod shells.

Station 4.—Close to the shore at Vellai Kalumunai, 2 feet; gravel and pebbles mostly of white quartz, with small edible oysters in quantity; the latter are known locally as *kavatti* and corruptly as *quatti*; both forms are much in evidence in local nomenclature along the coast line of Tampalakamam and Trincomalee.

Large *Cerithium* shells inhabited by Pagurids are very abundant on the gravelly portions of the shore line.

Station 5.—About 40 yards there, from the along the western coast of the bay; $\frac{3}{4}$ fathom; bottom fine sandy mud, bearing an abundance of phanerogamic plants, chiefly *Halophila*

Station 5*a*.—At the head of the bay; 5 to 6 feet; black mud, with great abundance of very young *Placuna placenta; Halophila* present, but not abundant; nearer the shore the bottom becomes very soft and highly charged with organic matter

Station 6.—A shallow *kallam* with less than 2 feet of water over it; gravelly muddy sand, largely calcareous. Small clams, *Venus* sp., extremely abundant. Every hut on the adjacent shore has a pile of dead shells of this species outside its door—a veritable kitchen midden.

Station 7.—1 to $1\frac{1}{2}$ fathom; muddy sand.

The second and third days were occupied in the examination of the central division of the lake, during which two beds of *Placuna* were located, the one covered by the station numbers 8, 28, and 10: the other by stations 14 and 13.

These days' work brought out most clearly that the suitable bottom for *Placuna* is the soft, pasty black " ink mud," *mei seru*, that covers almost the whole of the bottom in this division in depths over half a fathom. Wherever an exceptional admixture of sand occurs, as for example towards the shore off the mouths of the Sembian-ar and the Polokarai-ar, no window oysters are present, though a hundred yards away on the *mei seru* they are brought up 12 to 16 at a dive! The particulars are :—

Station 8-8.—$\frac{3}{4}$ to 1 fathom; black mud; abundance of oysters.

Station 9-9.—1 fathom; black sandy mud; no oysters.

Station 10-10, which is known to the divers as *Sembian-ar velangu*, was particularly prolific in fine, well-grown oysters from 10 to 16 to a dive lying on soft black mud; depth 8 feet.

Station 11 occupies the whole of the central portion of the division; depth 1 to $1\frac{1}{4}$ fathom; *Kadalpalam* (the peculiar new species of Suberitid sponge already mentioned) in quantity on soft black mud; no living oysters, but a large number of dead valves.

Station 12.—1 fathom, hard muddy bottom with sand admixed.

Stations 13 and 14.—1 fathom, muddy bottom; great quantities of oysters measuring $3\frac{1}{3}$ by 3 inches, with a few of $6\frac{3}{4}$ by 6 inches, 7 to 22 per dive.

Station 15, in the mouth of Serukuda or Muddy Bay, a mangrove-lined inlet having an exceedingly soft muddy bottom, so soft that walking over the surface one sinks to the middle at every step. A second name is Settakuda (Dead Bay), as window oysters settling here invariably die before attaining even medium size. Depth $\frac{1}{4}$ to $\frac{1}{2}$ fathom.

Near the mouth of Serukuda is Kumladdai maddam, now an uninteresting ruin of a small roadside resting place. The old road to Kandy passed this spot.

Stations 16 to 19.—1 to $1\frac{1}{4}$ fathom; muddy bottom.

Station 20.—Off the shore between Korrinjavat and Vellai Kalumunai. Depth 5 to 6 feet. Sand and mud; towards the south end some Kadalpalam. No oysters since leaving station 14.

The remaining part of the lake, the south-west division, took a further two days to survey. Combining the results we may summarize them as follows.—

Proceeding westwards from a point north of Kakamunai we passed south of the Amai-kallam; we found at station 21, 5 feet, the same conditions as at the adjacent station 8, black muddy sand without any oysters, but with some *Halophila*.

Station 22 and the three sections of station 23, all of 1 fathom, gave black mud with plenty of oysters at 22, 23*a* and 23*b*, 3 to 5 to a dive, varying in size from $6\frac{1}{2}$ to 6 inches down to 3 by $2\frac{1}{2}$ inches.

At station 24, 1 fathom, half a mile off the mouth of the Sinna Palamput-ar, bottom black sandy mud, no live oysters were met with, but large numbers of dead shells $1\frac{1}{2}$ inch in diameter. The proximity of the river mouth will account for this mortality

Station 25.—1 fathom; black sandy mud; no oysters.

Station 26.—On Muttikallam, a cockle-bearing sandbank nearly awash at low water.

Station 27.—Similar to station 11.

Station 28 —Similar to station 10

Station 29.—On Amaikallam, a curious bank in half a fathom of water, lying midway between the mouth of the Sinna Palamput-ar and Kakamunai (see Sketch Plan No. 1, Annexure III.). Unlike Muttikallam, where the bottom is comparatively clean sand, that here is a dirty black sand charged with a considerable quantity of decaying vegetable matter and bearing a great abundance of *Halophila* and of algæ of various species. Turtles (*amai*) are said to resort here in January and February to browse on this vegetable life. No window oysters are ever found on this or any other *kallam*.

Station 30.—6 feet; black mud; a very few oysters $3\frac{1}{2}$ by 3 inches at station 30*b*.

Stations 31 to 34.—$\frac{1}{2}$ to 1 fathom; black mud with varying quantities of young oysters, mostly of the $3\frac{1}{2}$ by 3 inch size, seldom more than three or four to a dive.

Stations 35 to 38.—$\frac{1}{2}$ to $\frac{3}{4}$ fathom; no window oysters; bottom a black mud with some brown dichotomously branched algæ bearing a slender zoophyte in fair quantity.

VI.—Pearls and Pearl Causation in Placuna Placenta.

Value and uses of these pearls.—Allusion has already been made to the great abundance of pearls in full-grown individuals of *Placuna placenta;* Kelaart states (*loc. cit.*) that while the pearls they produce are about two-thirds less in value than those from the Gulf of Mannar pearl oyster (*Margaritifera vulgaris*), the quantity obtained in one thousand *Placuna* oysters is at least treble what is yielded by a similar number of the other species. He adds that oysters of upwards of two years of age (*i.e.*, about 6 inches in diameter) were worth, in 1857, at least ten shillings a thousand, but if there be any competition among purchasers the price may rise to fifteen shillings a thousand.

So far I have seen but very few of these pearls ; all were small, the larger being more or less irregular in form. I am told, however, that occasionally they are found sufficiently large and well shaped to be utilized in the manufacture of jewellery, nose ornaments and earrings principally.

The small size and imperfect shape of the vast majority entail quite other uses—uses that depend entirely upon Eastern customs, for who in Europe would at the present day think of using pearls as a constituent of a chewing mixture, as medicine, or as a passport or travelling provision for the dead? The only purpose for which they can have a sale in Europe is for the manufacture of a pearl facepowder or enamel, a demand for which has arisen within recent years ! It has been the former uses, however, which have made the Tampalakamam pearl fishery a source of revenue to Government and a livelihood to some hundreds of divers in that district. Practically the whole supply of these pearls is exported to India, where the majority are calcined and made into a luxurious form of chunam, affected by the wealthy and ostentatious when partaking of their dearly loved betel.

A proportion are employed medicinally, chiefly in China, in powder or in solution, pearls having a recognized place in the ancient Eastern pharmacopœias. Another use is where a small quantity of these pearls is placed in the mouth of the dead before burial, in the same way that rice grains are occasionally similarly disposed, and with the same end in view as had the ancient Britons and early Saxons when they placed food and the requisites for a lengthy journey in the graves of their chieftains.

Of three of the oldest oysters met with in May, the average measure being 155 mm. by 142 mm. ($6\frac{1}{8}$ by $5\frac{5}{8}$ in.), one contained three minute pearls located in the free portion of the mantle. All were about midway between the pallial margin and the visceral mass, the same location where we find the finest class of pearls in the true pearl oyster.

The lustre of the smallest of those I have seen is good, but that of the larger ones is very inferior, while the indentation of the surface with a network of shallow furrows and grooves renders the pearls somewhat botryoidal in appearance. However, I have seen but four of a size larger than a pin's head, and I am told that all are not equally inferior. At the best, even if smooth skinned and of fair lustre, they cannot compete with *Margaritifera* pearls, as their substance is much less hard. A steel point scratches a pearl from *Margaritifera* with some difficulty—the resultant scratch is shallow and clean edged; a scratch made in similar manner on the surface of a *Placuna* pearl is easily effected, deeper and wider : where a mere line would be made in the one case, a gash results in the other. This is exactly what we should expect, arguing from the difference in the nature of the two shells, that of *Placuna* being micaceous or talcose in appearance according to age, and having hardness approximating rather to that of these minerals than to that of ordinary calcite.

No investigation whatever has hitherto been made into the causation of pearls in *Placuna placenta ;* no suggestion even has been hazarded so far as I know. Therefore, considering how divergent the environment in which *Placuna* lives from that of the true pearl oyster, I was not prepared to find the cause to be identical. This, however, proves to be the case ; out of five minute pearls which I have found in the tissues of *Placuna* I have so far sacrificed two, dissolving the investing coats of carbonate of lime with weak hydrochloric acid. In each case the nucleus proved to be the dead remains of a minute Platyhelminthian larva of the same stage and species as that which forms the nucleus of cyst pearls in *Margaritifera vulgaris.**

The next step was to ascertain under what conditions this parasitic worm exists in the tissues. For some time my search was fruitless ; none of the opaque white cysts of this larva so conspicuous in the liver and upon the gills of *Margaritifera vulgaris* were to be seen, but finally I located a number of the

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* Shipley and Hornell, "The Parasites of the Pearl Oyster" in Professor Herdman's "Report on the Pearl Oyster Fisheries of the Gulf of Manaar," part II , 1904.

cysts within the dorsal portion of the visceral mass just above the stomach. Searching in the same locality in other individuals, similar groups of cysts were noticed in every case.

In details of form and structure these larvæ appear identical with the spherical larvæ found in *Margaritifera vulgaris;* in size and grouping they show marked divergence. In *Margaritifera* I have never found them in definite groups of numerous individuals as here (see Annexure II., fig 2); in the former case, although I have occasionally come across small clusters of two and three, the rule is for the cysts to be scattered singly through the tissues most affected. In *Margaritifera vulgaris* many of the cysts are a full millimetre in diameter, while some even exceed this size—conspicuous to the naked eye; in *Placuna* the larvæ are all very minute, averaging from 0·2 to 0·4 mm. in diameter, and aggregated into populous groups of as many as 50 individual cysts.

These cyst groups are tightly packed, the membranes of many cysts actually in contact. Moreover, there is a great range in size, some being but one-quarter the diameter of others.

With such an abundance of material I passed some hundreds in review under the microscope, hoping to settle some of the minor points of detail yet in doubt. In all particulars they tallied with the form already studied, the only point of additional structure made out being that in the larger forms the terminal excretory pore was seen to be lined with bristle-like cilia (Annexure II., fig. 3) in a similar manner to that described for the excretory funnel in the advanced larvæ of *Tetrarhynchus unionifactor*.*

A much more important observation, and one throwing light on the still obscure and puzzling life-story of this economically valuable parasite, was my finding parthenogenesis to be taking place within the bag-like bodies of these encysted larvæ. In three different instances a miniature reproduction of the parent was seen within the bladder-like posterior division of the body. So far as my observations go only one secondary larva is produced at a time; the structure of the latter appears identical with that of the mother. Calcareous corpuscles were already present within the asexually produced stage, though of proportionately smaller size (Annexure II., fig. 1).

It appears to me probable that the young individuals which arise in the manner described eventually make their way through the body wall of their parents and form separate cysts; in this way the numbers in the cluster or group gradually increases and will account for the large numbers present without the necessity to invoke individual infection repeated scores of times.

The parthenogenetic reproduction of this particular pearl-inducing parasite enables us to understand the hitherto puzzling fact that true cyst-pearls in *Margaritifera vulgaris* are quite frequently found in small clusters of two, three, and even four or more, for while this mode of increase in numbers has not yet been signalized in that oyster, such I have now no doubt does there occur also, and furnishes a satisfactory explanation of the occurrence of clustered cyst-pearls.

The only other entozoon found in *Placuna* proved to be the handsome Nematode *Cheiracanthus uncinatus*, which is also common in the true pearl oyster. As in the latter, it finds its lodging encysted within the adductor muscle and is in the larval stage.

VII.—Conclusions and Recommendations.

The outstanding conclusions with regard to the causes which have involved a suspension of the Tampalakamam pearl fishery for many years, with gradual deterioration for a long preceding period, are more readily arrived at than is the formulation of a scheme for the efficient protection of the beds and the profitable conduct of future fisheries. The causes of dearth in the one case and the difficulty of regulation in the other, both spring from the peculiar situation of the beds—from the fact that they lie in a comparatively restricted area of shallow water whereby overfishing and related malpractices are facilitated. But if the regulation of this fishery be difficult it is far from being impossible, and I shall now try to show how the desired end may be attained.

* Hornell, "Report on the Operations on the Pearl Banks during the Fishery of 1905," in Ceylon Sessional Papers (XXXIII.) for 1905.

Unrestricted fishing in the past, coupled with a total disregard of the most elementary biological axioms, have been the sole causes of the suspension of the fishery. Only the wonderfully prolific reproductive powers of the oyster delayed the temporary extinction of the beds, for so long ago as 1857 we find Kelaart writing :—" The banks have become overfished. The Natcha Cooda bank is completely destroyed. The renter in 1856 left scarcely any oysters behind, and this portion of the bank will consequently be unproductive for many years."

Further on he states that he observed the renter, free from any remonstrance on the part of the Government Agent, to be "bringing up daily 5,000 to 6,000 oysters scarcely more than eight months old, and which cannot yield more than sixpence worth of pearl in each thousand, if they do that."

The chief faults of the control here, as also with regard to the Gulf of Mannar pearl banks, have been the total disregard shown in past years by the authorities to the absolute necessity to preserve adequate breeding reserves and to afford, in the case of Tampalakamam, protection to the immature oysters. In respect of the latter safeguard, Kelaart put the matter bluntly but truly: " The Government Agents who could have acted so unwisely as to lease out to native renters a small bank of pearl oysters for three consecutive years, without any stipulation as to the size of the oysters to be fished, must have lost sight of the natural laws of reproduction and multiplication of species, known even to the native divers."

The whole of the evil has arisen from this obnoxious system of leasing the banks without control as to the number of oysters to be removed or the size at which they should not be fished. The remedy lies in the recasting of the methods of management and the enactment of rules for the regulation of fishing.

The remedial measures which I recommend for adoption are :—

I.—The enactment of an Ordinance vesting the rights to this fishery wholly in Government, that is to say placing the Government monopoly of this fishery on a legal basis, whereby the authorities may make such bye-laws for the conservation of the beds and the regulation of fishing as they may deem fitting. Hitherto the right of Government to lease out the fishery has been based solely on prescriptive usage: there appears to be no enactment conferring exclusive rights upon the Government. In consequence it might be difficult for the authorities to sustain at law any prosecution for infringement of regulations relating to illegal removal of oysters. Without such enactment the appointment of watchers can have little or no value.

I may mention here that any enactment made with regard to the protection of the *Placuna* pearl beds will not affect the local fishermen's prescriptive right to fish edible oysters, as none are found in the vicinity of the pearl beds. The latter are all in the central and south-western divisions of the lake; the edible oysters solely on the rocks at the entrance.

II.—Fishery on Government account should be substituted for the system that has hitherto prevailed of renting out the fishery for periods of three years. Probably the best plan would be for the Government to have an enclosure or kottu put up in the vicinity of the bed to be fished, whereto all oysters must be taken each day. In view of the comparative smallness of the fishery it would be unnecessary to sell the oysters daily. It would probably be adequate if the Government Agent attended (say) once a month and then put up to auction the oysters to be fished during the ensuing month, the price to be not a lump sum, but a rate per one thousand, as customary at the Marichchukaddi auction. This method of sale, I believe, would have the two-fold effect (*a*) of stimulating competition and thereby ensuring better prices, as by the smaller rental involved a larger number of capitalists would be enabled to enter the field; and (*b*) of making the transaction one of legitimate business, and not a mere speculation or gamble, as it has been hitherto. In the past the sale of the fishery for periods of three years led to the preferment of many claims against Government by the lessees for alleged losses sustained. Some of these claims no doubt were *bona fide*, but many were, I believe, misrepresentations, and as the Government had no satisfactory means to check the statements made, remissions of part rental were not infrequent, with consequent loss to the Government.

Another fraudulent device alleged against past renters is the one of obtaining cancellation of the lease with subsequent resale, a relative of the original renter stepping in to purchase at a greatly reduced figure!

III.—A clause in the terms of sale should require that the renter shall buy the whole of the divers' share of the daily catch at the same rate per thousand as he may be paying to Government.

Hitherto an unfair practice has prevailed compelling the divers to open their share of the oysters while fresh and to sell to the renter all the pearls found at a fixed rate, which the renter takes good care is well below the market value. It is not advisable that there should be much huckstering of oysters or of pearls in the village, but it is, I think, the duty of Government to see to the removal of a very real grievance and so help to ensure to the toiler a proper return for his labour and protection against the wiles of the Chetty.

IV.—If the disposal of the divers' share be placed on a more equitable basis, the proportionate amount of their share should be reduced if possible from one-half of the total catch, at which it has stood hitherto, to one-third, thereby bringing the remuneration given into line with that prevailing at the Marichchukaddi fishery.

There is no comparison between the ease of fishing oysters in the two places—the water over the beds in Tampalakamam seldom exceeds six feet—and there is no reason for so large a proportion of the catch falling to the divers' share other than the unfair custom that has prevailed of giving less than market price for the produce of the share. Were the divers to be paid a fair price for a one-third share, they would be very much better recompensed than under the rule of receiving a half, to be disposed of at a rate fixed by the renter.

V.—It has been the renter's custom to prosecute the fishery off and on for the greater part of the year. I recommend that fishing be limited to the period between January 15 and May 15. Fishing during the rest of the year must be at best more or less desultory on account of the weather; it will be more profitable to prosecute the fishery vigorously during the period of favourable weather and to close it entirely for the rest of the year. When the men are in a position to earn a good wage by straightforward work, there is not the same inducement present to indulge in underhand practices that there is when the weather makes the catches small and the work arduous.

If direct Government supervision be given to the fishery, this will be a further reason to curtail the duration of the fishery, seeing that such supervision spells expenditure.

VI.—A minimum size at which the oysters may be fished must be specified; penalties for contravention should be severe, and every effort made to enforce respect for such a bye-law. The size which I suggest is 5½ inches in shortest diameter.

Such are the principal modifications in the manner of conducting this fishery which I propose for consideration. Later, at a future date, when our knowledge of the life-conditions of the window oyster become more exact, further means may be taken to make the harvest of the beds more abundant—simple cultural methods may be introduced, such for example as the transplantation of young from unfavourable positions, together with the stocking of other of the muddy tidal lakes so numerous on the Ceylon coast line. I see no reason why profitable *Placuna* beds should not be formed in Batticaloa and Puttalam lakes to the advancement of the local prosperity and the good of the general revenue. But working experience and investigation on the spot must precede such stocking, and for such I have had as yet no opportunities.

At the present time there is no bed of oysters in Tampalakamam Lake ready for fishing. The most advanced bed, that off Kakamunai and the Sembian-ar, will not be ready at earliest till February of next year. The pearl yield is just now insufficient to tempt poaching on any extensive scale, and for this reason I recommend that the present watchers be discharged.

Early in January next the Assistant Government Agent at Trincomalee should be requested to draw a large sample, say of not less than 1,000 oysters, and to have the pearl yield therefrom valued by a local merchant. The result will decide the advisability or not of holding a fishery during the ensuing three months.

Should the weight or the value f the pearls appear sufficiently satisfactory to justify a fishery, then it might be useful to re-employ a couple of reliable men as watchers, but unless really trustworthy men be obtainable it would be preferable to have none. Personally I do not think that poaching is likely to take place on a large extent so long as the Wanniah does his duty; were it prosecuted on an extensive scale the matter would become notorious and easily traceable, while so long as it is restricted little or no harm is done My experience of watchers or " guards " at the Marichchukaddi fishery prejudices me against the class, and inclines me to think their presence is dear at the wages they receive.

The best way to obviate poaching lies, in my humble opinion, in the exercise of such foresight and care in the management of the beds as will ensure a lucrative annual fishery and by showing the men of the district that the Government is exploiting the beds not merely as a revenue milch cow, but as a local industry deserving of fostering care.

VIII.—Synopsis of Recommendations.

(1.) The discharge of the present watchmen appointed to look after the pearl beds.

(2.) The enactment of an Ordinance vesting the monopoly of the fishery for window oysters (*Placuna placenta*) in Government and giving the authorities power to make by-laws for the protection of the beds and the proper conduct of the fishery.

(3) The abolishment of the old system of renting out the fishery for periods of three years; the substitution of a fishery on Government account, with periodical auction sales of the oysters at a rate per thousand.

(4.) The divers' share of the daily catch to be reduced to one-third; but

(5.) Protection to be given the divers to ensure that they receive as good a price for their oysters as does the Government.

(6.) Limitation of the fishing season to the period between January 15 and May 15.

(7.) No oysters to be fished of dimensions under 5½ inches in shortest diameter.

(8.) Further study of the life-history of the window oyster with a view to the stocking of other tidal lakes therewith and the creation therein of pearl beds similar to those at Tampalakamam.

In conclusion, I have to record my great indebtedness to Mr. W. L. Kindersley, Assistant Government Agent at Trincomalee, and to Mr W. B. Gregson, District Engineer, for much kindly help and advice, without which I should have been unable to complete the investigation satisfactorily in the limited time at my disposal. Mr. Kindersley, I believe, views my various proposals favourably, and if there be a fishery at Tampalakamam under his direction, the great personal interest which he takes in the establishment of the industry on a stable and enduring basis should go far towards ensuring success.

Mr. Gregson took an equally keen interest in the prospective development of the fishery. He suggested the utilization of the great mounds of shells littering the margin of the lake, relics of former fisheries, for the purpose of lime manufacture, and had I been able to stay at Tampalakamam a few days longer we should have made a trial burning. At present the Public Works Department requires considerable quantities of lime for use in this district, and in the absence of a local supply considerable transport charges have to be incurred. I see no reason why these shells, composed of calcium carbonate as is the case with all mollusca, should not make excellent lime; Mr. Gregson was making arrangements to have a quantity calcined experimentally at the time I left Trincomalee.

LIST OF ANNEXURES.

No. I.—Dimensions of three series of *Placuna placenta* from Lake Tampalakamam, 19th May, 1905.

Plate I.—The pearl-inducing worm larva of *Placuna placenta* :—

Fig. 1.—A larva from the liver of *Placuna* extracted from the cyst membranes and showing within the posterior part of the body a young individual (*p.l.*) of a second generation produced parthenogenetically.

Fig. 2.—A group of cysts containing larvæ of similar species to that shown in fig. 1; *p.l.*, parthenogenetic larva within the body of the mother.

Fig. 3.—A larva of the same stage as fig. 1; an excretory funnel is present at the posterior extremity, lined by stiff bristle-like cilia (*cil. ex. f.*)

Plate II.—Sketch Plan (No. 1) of Lake Tampalakamam showing the disposition of the beds of *Placuna placenta* in May, 1905.

Plate III.—Sketch Plan (No. 2) of Lake Tampalakamam showing the route followed in the inspection of the pearl beds and the position of the various stations.

JAMES HORNELL,
Marine Biologist to the Ceylon Government
and Inspector of Pearl Banks.

Colombo, June 15, 1905.

ANNEXURE I.

Dimensions of three series of Placuna Shells (Living) taken from Kakamunai Bed, Tampalakamam Lake, 19th May, 1905.

Series I.

No.	Length. mm.	Depth. mm.
1	158	138
2	155	147
3	150	122
4	159	143
5	134	146
6	160	145
7	165	150
8	160	147
	1,241	1,138

Average, $155\frac{1}{8}$ mm. by $142\frac{1}{4}$ mm.
Approximately, $6\frac{1}{8}$ by $5\frac{5}{8}$ inches.

Series III.

No.	Length. mm.	Depth. mm.
9	110	104
10	116	115
11	105	92
12	116	109
13	112	92
14	110	104
15	111	100
16	110	107
17	117	102
18	100	95
19	109	99
20	121	105
	1,337	1,224

Average, $111\frac{1}{12}$ mm. by 102 mm.
Approximately, $4\frac{3}{4}$ by 4 inches.

Series II.

No.	Length. mm.	Depth mm.
1	119	110
2	110	110
3	120	110
4	124	119
5	129	113
6	126	109
7	127	111
8	125	123
9	133	124
10	131	123
11	119	108
12	115	115
13	125	114
14	125	114
15	119	114
16	122	117
17	118	101
18	125	108
19	127	113
20	116	105
21	124	104
22	122	106
23	120	120
24	139	120
25	120	110
26	129	118
27	143	129
28	125	122
29	144	120
30	130	124
31	130	124
	3,881	3,564

Average, $125\frac{6}{31}$ mm. by $114\frac{30}{31}$ mm.
Approximately, 5 inches by $4\frac{1}{2}$ inches.

ANNEXURE II

Fig 1.

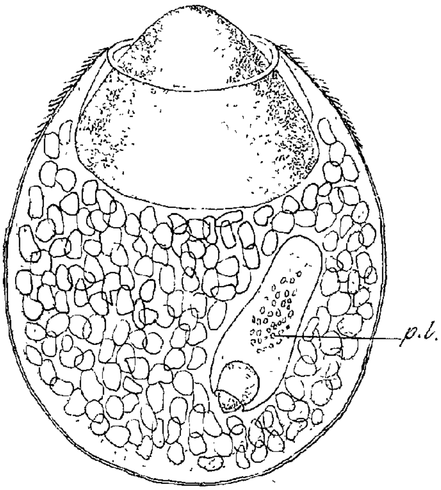


Fig. 2.

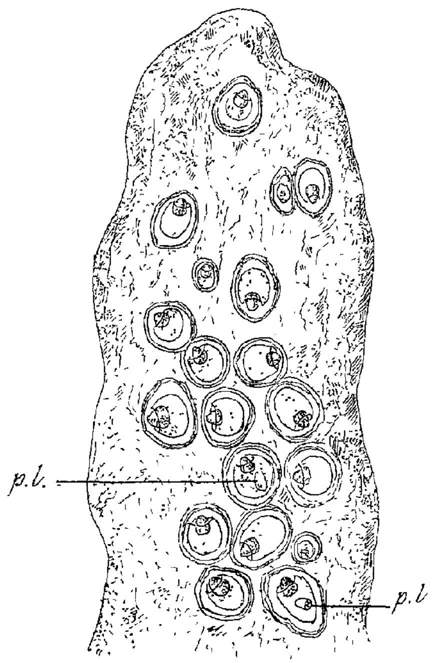
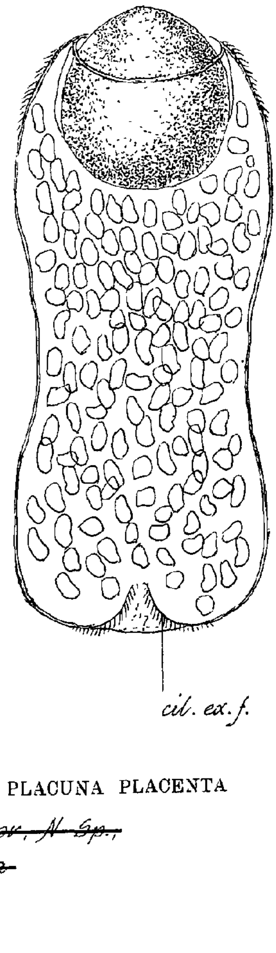


Fig. 3

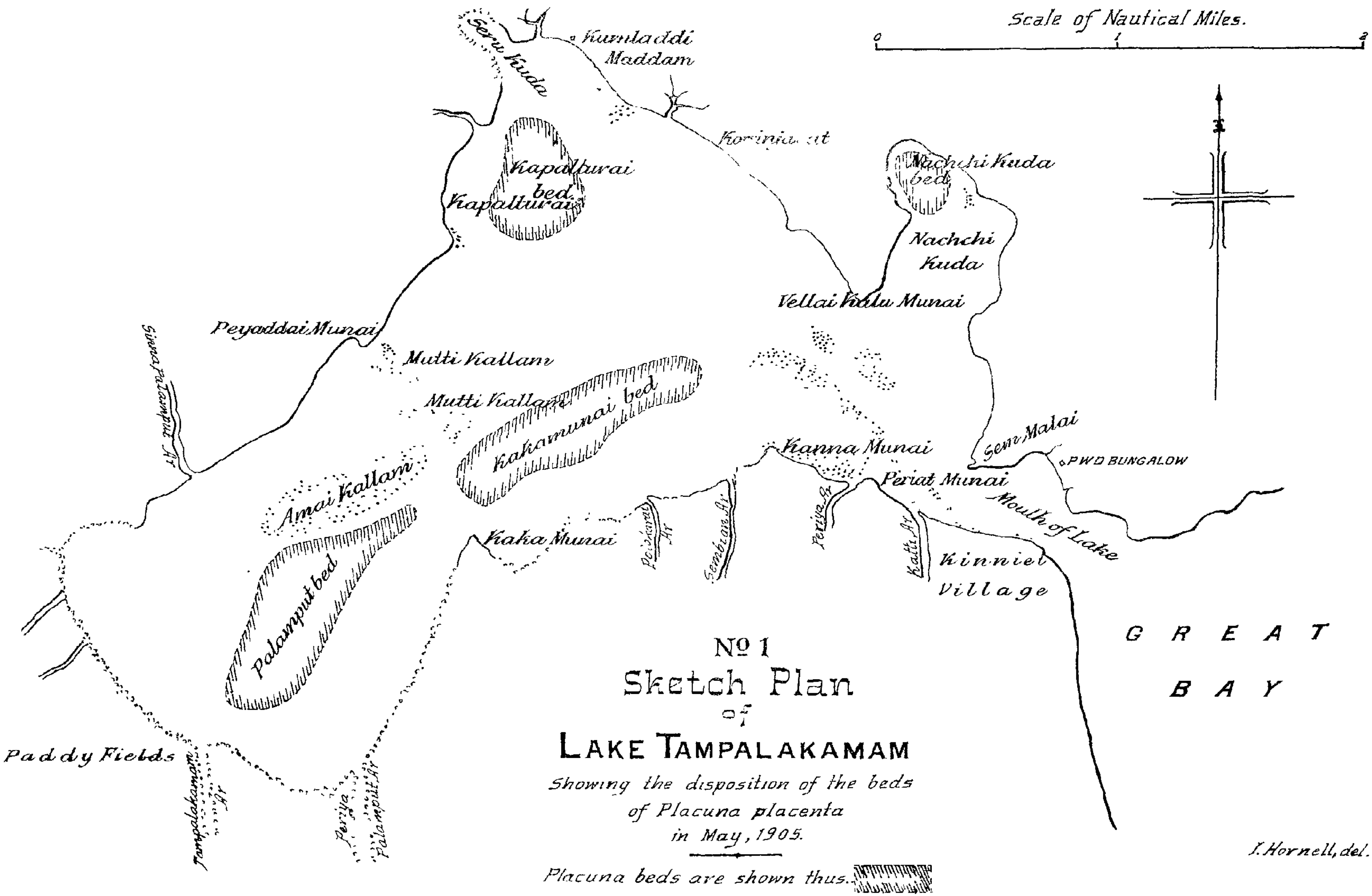


THE PEARL-INDUCING WORM LARVÆ OF PLACUNA PLACENTA

~~Distomum Margaritifactor, N. Sp.,~~
~~from Placuna Placenta~~

J Hornell, del

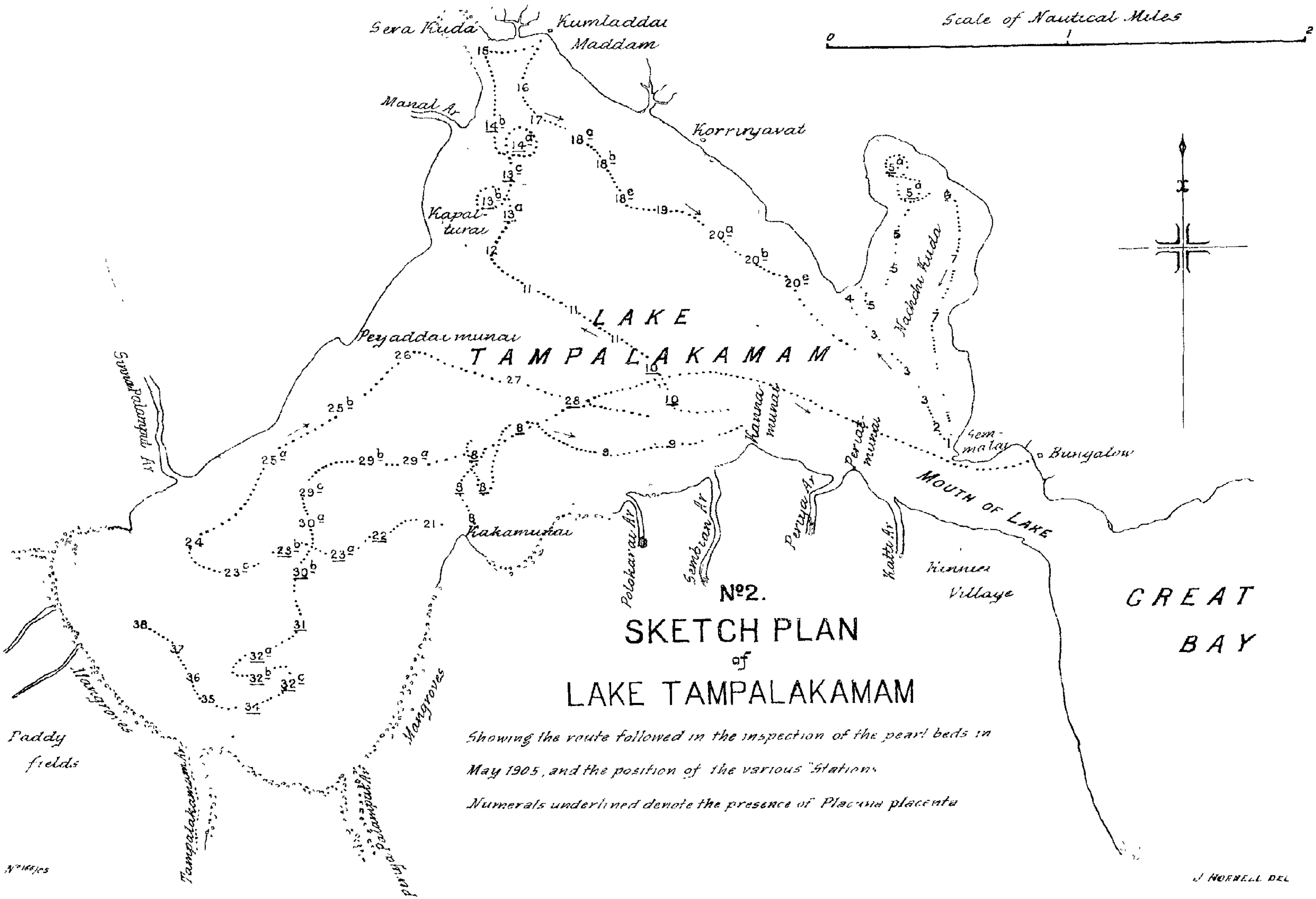
S G O No. 164/05.



No 1
Sketch Plan
of
LAKE TAMPALAKAMAM
Showing the disposition of the beds
of *Placuna placenta*
in May, 1905.

Placuna beds are shown thus.

ANNEXURE. IV



Nº2.
SKETCH PLAN of LAKE TAMPALAKAMAM

Showing the route followed in the inspection of the pearl beds in May 1905, and the position of the various "Stations"

Numerals underlined denote the presence of Placuna placenta

Lith S.G.O. Nº166/05

J. HORNELL DEL.

No. 3.

REPORT ON THE OPERATIONS ON THE PEARL BANKS DURING THE FISHERY OF 1905.

With one sketch-plan.

By JAMES HORNELL, F.L.S.

I.—THE FINAL INSPECTION PRIOR TO THE FISHERY.

(a) DISTRIBUTION, AGE, AND NUMBER OF THE OYSTERS FOUND.

CONSEQUENT upon the report made in December of last year upon the facts ascertained in the course of the November inspection concerning the state of the maturing oysters on the pearl banks, Government decided upon the proclamation for fishing in 1905 of the beds lying on those sections of the pearl banks respectively known as the South-West Cheval, Mid-East and South-Central Cheval, South Cheval, and North and South Moderagams. It was further decided that the commencement of the fishery should be accelerated as far as possible, in view of the large number of oysters to be fished and the uncertainty pertaining to weather conditions at the fishing season. 20th February, therefore, was decided upon as the day when the fishery should begin, this being considered the earliest date on which we could count upon the attendance of divers and merchants.

This proposed acceleration of the opening of the fishery reduced the time available for the final inspection, while as weather conditions precluded the date of the commencement of the latter earlier than the last week in January, it was not till 26th January that I was able to leave Colombo on this duty aboard the barque "Rengasami Poravi." The steamer "Violet," fitted up as an oyster dredger, left in company, having received a thorough overhaul and additional equipment in the interval since her return from the pearl banks at the end of last year.

Headway was slow owing to strong contrary winds from the north and north by east; it was the afternoon of 28th January ere we reached our destination. The next day was spent in landing stores, making arrangements for the subsequent watering of the vessels, and other matters incidental to the inception of an inspection. All else was in order and ready for an immediate start; the "Serendib," which was allotted to me as attendant launch for the purposes of towage and the laying out and lifting of the inspection buoys, had arrived, and the staff of divers were already aboard the barque, having travelled to Colombo by British India steamer from Paumben, instead of *viâ* Mannar as heretofore, the recommendation to this effect made in my November report having been sanctioned.

The actual work of inspection began on 30th January and continued for ten days. Within this time a careful examination was made of the banks to be fished, the approximate numbers of oysters estimated as accurately as the means available permitted, the contour of the oyster-bearing area laid down upon the chart, boundary buoys placed in position, and valuation samples of oysters collected from the beds to be fished. I was anxious to examine the ground outside the bank limits, but the time at my disposal was too short to allow this to be done.

The results as regards the distribution, numbers, and condition of the oysters were as follows:—

South Cheval Paar.

The general condition of the oysters remained the same as when examined in November, 1904. The individuals were in the main remarkable for vigorous growth, clean, healthy appearance, and freedom from disease. The bed was large and compact; oysters were distributed over the whole of the section, except for two deep barren indentations on the west side. To the north the bed merged with the oysters on the South-Central and Mid-East blocks; on the north-east a narrow neck connected with the irregular bed of the South-East section, while to the south of this point the bed extended some distance eastwards beyond the arbitrary boundary between the South and the South-East sections.

The great majority of the oysters were from 3 to $3\frac{1}{2}$ years of age with irregularly scattered patches, varying considerably in extent and density, of an older generation, whose age I estimated to be from $5\frac{1}{4}$ to $5\frac{3}{4}$ years. These also were lusty in growth, and obviously held excellent pearl-producing potentiality. The irregularity of their distribution rendered the gathering of a fair representative valuation sample a matter of considerable difficulty, and, as will be seen later, entailed eventually much additional trouble.

An extremely careful calculation of the extent of the oyster-bearing area of the South Cheval bank, together with the bordering bed lying on the west side of the South-East Cheval, gave the total as 6,700,000 square yards. In the southern region, over an area of 3,900,000 square yards, the oyster population was the more crowded, giving an average slightly over twenty-six per dive. Over the northern third of the bank, where the oyster-bearing area was approximately 2,800,000 square yards, the average per dive dropped to fourteen. The combined areas gave a total of fishable oysters of 47,500,000, made up of 40,500,000 on the South Cheval and 7,000,000 on the portion of the South-East Cheval which marched with it.

The small bed of brood oysters noticed in November at the centre of this bed is now practically non-existent. In November forty-six dives recorded brood oysters. In the same section in February young oysters were recorded on four occasions only. This signifies the virtual disappearance of the patch.

Mid-East and South-Central Cheval.

Mature oysters were found occupying the same areas on these two sections as was indicated in the report of last November. On the north and north-west portions of the conjoined bed considerable apparent decrease in the number of the older oysters had taken place, principally owing to the rapid growth of the associated brood oysters, which were still exceedingly abundant; wherever these brood oysters occurred, the older oysters, principally $3\frac{1}{2}$-year olds, were poor in condition and lacking that vigorous growth characteristic of their fellows on the South Cheval. A natural decrease in the oyster population was undoubtedly in progress, and the utmost estimate I could frame of their numbers was 9,000,000 spread irregularly over an area of 1,900,000 square yards with oysters ranging from five to twenty-five per dive.

A considerable number of the oysters of this region showed brown spots and blotches on the nacre, due to inflammatory conditions in the mantle, thereby denoting a critical state of health and indicating the need for the early fishing of this bank.

South-West Cheval.

The small remnant of 3,000,000 of 6-year old oysters discovered on the South-West Cheval last November was next sought for. Two days were spent in thoroughly exploring the ground, with disappointing result. Of the 3,000,000 present in November, less than a million (900,000) remained in February. These were scattered sparsely over 140,000 square yards, and varied from two to ten per dive. Such poverty of numbers, coupled with very irregular distribution, made their fishing impracticable, and prevented even the lifting of a valuation sample. Old age was at work, and seven years may be taken as the utmost span of the Ceylon Pearl Oyster's existence, *pace* John Christopher Wolf, who states* that fourteen years are necessary to the ripening of pearl oysters and the production of "perfect pearls."

Time did not permit of a further examination of the isolated bed on the South-East Cheval, this being immaterial, as the fishery thereon is postponed till next year. I estimate, however, that the number of mature oysters present in February, 1905, was 13,000,000.

North and South Moderagam Paars.

The condition and numbers of the South Moderagam oysters were practically unchanged. The main bed, which alone I had time to examine, had an oyster-bearing area of 2,750,000 square yards: the average of oysters was seventeen per dive, and as I reckon a dive to clear $2\frac{1}{2}$ square yards on this particular ground, the total number here was 19,700,000, a decrease of 1,300,000 since November. On the south-east side, however, the bed extended beyond the limit of the ground inspected, and there was therefore a probability that the actual numbers would prove considerably in excess of the estimate.

Brood oysters were again exceedingly abundant, crowding on the valves of the old and rendering the continued existence of the latter most precarious. As with the similarly circumstanced oysters of the Mid-East Cheval, the older generation showed the evil effects of this overcrowding in arrest of growth, stunting of the internal organs, and a general tendency to the development of inflammatory centres in the tissues of the mantle. The two cushion-stars, the variable *Pentaceros nodosus* and the lovely crimson-lake coloured *Pentaceros lincki*, were present in extreme profusion, due, I believe, to the sickly condition of the oysters rendering them an easy prey to these greedy devourers. The spat on this bank I consider sufficiently abundant to have ample margin for all the wastage likely to occur and as promising to yield a fishery in 1908.

The *North Moderagam* received greater attention than it did in November; a considerable extension to the north was traced; in consequence the oyster-bearing area was increased to 1,500,000 square yards bearing 10,000,000 oysters, ranging from ten to forty per dive, with a general average of eighteen per dive. The health of these oysters was very indifferent; various burrowing enemies, especially sponges and worms, were numerous, and some four per cent. were affected by the "yellow" disease. Everything pointed to the advisability of fishing these oysters as early as possible, but unfortunately they were also the poorest in size, appearance, and pearl yield, and likely to fetch but poor prices at auction.

SUMMARY OF THE RESULTS OF THE INSPECTION.

Paar.	Oyster-bearing Area in Square Yards.	Number of Oysters per Dive	Estimated Number of Oysters.
South Cheval	6,700,000 ...	From 14 to 26 ...	40,500,000
South-East Cheval (portion bordering east side of South Cheval) ...			7,000,000
Mid-East and South-Central Cheval...	1,900,000 ...	5 to 25 ...	9,000,000
South-West Cheval	140,000 ...	6 ...	900,000
North Moderagam	1,500,000 ...	18 ...	10,000,000
South Moderagam	2,750,000 ...	17 ...	19,700,000
			87,100,000
For fishery in 1906:— Add for unexamined portion of South-East Cheval, approximate estimate			13,000,000
Grand Total of Fishable Oysters ...			100,100,000

* "The Life and Adventures of John Christopher Wolf, late Principal Secretary of State at Jaffnapatam in Ceylon" English Translation, London, 1785. He naively remarks: "A connoisseur in these matters can tell the age of an oyster as exactly by looking at it, as the dealers in cattle can that of an ox by looking at his horns. But during these fourteen years there is always some fresh oyster seed deposited under (*sic*) the old, and consequently in every fishery they get pearls of all sorts some large and perfect, some middling, and some small."

For the same series of banks the aggregate of the estimate of November, 1904, was 106,770,000, an approximation in results that was most satisfactory as a guarantee of the general accuracy of the method of numerical estimation employed. The number available for fishing in 1905 as above shown, after deduction of the 900,000 on the South-West Cheval, was 86,200,000. (The number actually fished was 81,876,520!)

(b) Valuation Results.

On 10th February the inspection being completed I returned to Marichchukkaddi, landed the last collected sample of oysters, and set about the washing of those first gathered. By the 15th the work was ended, and the various samples of pearls ready for the valuers. The results are tabulated as follows:—

Number of Oysters.	Paar.	Weight of Pearls obtained.		Weight of Pearls per 1,000 Oysters.		Total Value in Rupees.	Value per 1,000 Oysters.
		Kalanchu.	Manchadi.	Kalanchu.	Manchadi.	Rs.	Rs. c.
10,000	South Cheval	3	$5\frac{1}{16}$	—	6·5	127	12 70 *
2,400	Mid-East Cheval	—	$13\frac{4}{16}$	—	5·52	49	20 $41\frac{2}{3}$
5,000	North Moderagam	—	$16\frac{8}{16}$	—	3·3	40	8 0
6,000	South Moderagam	2	$1\frac{12}{16}$	—	6·96	99	16 50

Comparison with the valuation of the samples gathered three months previously shows that while the Mid-East Cheval oysters had made a most satisfactory pearl increase from Rs. 13·21 to Rs. 20·41$\frac{2}{3}$ per 1,000 oysters, and while those of the South Moderagam remained virtually unchanged in value, the valuation of the South Cheval was most disappointing. The irregular distribution of patches of rich 6-year old oysters over this ground has already been indicated, and it was very evident from the result of the valuation that the boats had been unfortunate in the ground they ranged over when collecting the second sample. As it was felt that the latter did not furnish a fair indication of the true value of the oysters on this section, a third sample was gathered from the central region of the South Cheval under my personal supervision. This proved thoroughly satisfactory in results, giving a valuation of Rs. 31·10 per 1,000 oysters. Probably the average of the three valuation results (Rs. 24·65, Rs. 12·70, and Rs. 31·10), Rs. 22·82 per 1,000, is the most accurate index of the true relative value of the oysters over the entire bed, a conclusion borne out by comparison of the relative average prices given during the fishery for oysters from the different beds.

Examination of the prices which ruled for oysters throughout the fishery gives the impression that these sample pearls were very greatly under-valued. It has to be remembered, however, that these latter valuations were given prior to the opening of the fishery, and that the market value of pearls became greatly enhanced within a few days after the beginning of fishing operations. I have evidence that pearl values became at least trebled within the period mentioned.

This enormous enhancement of values during the course of the fishery enables us to understand why merchants eagerly vied with each other to pay from Rs. 60 to Rs. 124 per 1,000 for oysters which had been valued prior to the fishery at from Rs. 20·41 to Rs. 24·65 per 1,000. The high prices paid were quite consistent with the reaping of fair profits, provided the oyster merchants sold while the pearl market remained inflated. I am strongly of opinion that the original holders of pearls were on the whole considerable gainers during the fishery; the eventual losers are likely to be the "bulls," those who have bought pearls at high prices and are now holding. The situation so far as they are concerned is an ordinary gambling speculation, and has ceased to be legitimate trade.

(c) Recoupment of Expenses from Sale of Valuation Pearl Samples.

In the course of the November, 1904, inspection, 87,500 oysters were collected by the Government staff of divers. Of this quantity, 66,750 were washed by the men under my supervision, and during the recent fishery the pearls therefrom were sold at auction by Mr. Lewis. They realized the sum of Rs. 3,120, made up as follows :—

Quantity.		Locality.		Valuation. Rs. c.		Proceeds of Sale. Rs.
15,000	...	Mid-East Cheval	...	198 20	...	580
5,250	...	South-East Cheval	...	56 50	...	136
1,500	...	North-West Cheval	...	—	...	72
15,000	...	South-Moderagam	...	268 0	...	731
20,000	...	South Cheval	...	335 86	...	1,500
10,000	...	Muttuvaratu	...	31 67	...	101
				890 23		3,120

To this amount must be added the value of the remainder, 20,750, handed to Mr. Dixon to be put through his washing machinery. I do not know what they realized, but if valued *pro ratâ* with the hand washed, we should add for—

750 from South-East Cheval	...	...	...	19
20,000 from South Cheval ..	...	...	...	1,500
87,500		Total	...	4,639

This sum of Rs. 4,639, although it goes to swell the gross proceeds of the present fishery, was earned by the inspection staff, and constitutes a revenue that more than recoups the expenditure upon the inspection of November, which, including all salaries, wages, and stores, did not exceed Rs. 3,500 in all. Properly and economically conducted, the inspection of the pearl banks may frequently be made self-supporting, as in the instance now indicated.

II.—THE PEARL FISHERY OF 1905.

Summary of Results.

As already indicated, the beds fished this year were the—

South Cheval and bordering part of South-East Cheval, estimated to bear	...	47,500,000 oysters
Mid-East and South-Central Cheval, estimated to bear ...	...	9,000,000 „
North Moderagam, estimated to bear ...	...	10,000,000 „
South Moderagam and ground south thereof, over ...	...	19,700,000 „
A total of over	...	86,200,000 oysters

The aggregate number of pearl oysters actually fished by the divers and the dredger "Violet" approximated very closely to the estimate, being 81,876,520, by far the greatest number fished in any one year of which we have record. It all but equals the combined totals of the two great fisheries of 1903 and 1904, and is not far from double the highest number taken in any other fishery concerning which we have authentic information, namely, 44,311,441 in 1891 The following is a tabulation of the particulars of the daily takes by the divers.

Table showing the Place of Origin of the Oysters fished, February 20 to April 25, 1905.

Date.	No. of Boats engaged.	Total Number of Oysters lifted by Divers.	From what Beds obtained.					
			South Cheval.	Mid East Cheval.	South-East Cheval.	North Moderagam.	South Moderagam.	Kutira-malai Paar.
1905.								
February 20 ...	251	1,955,167	—	—	—	—	1,955,167	—
” 21 ...	297	1,742,400	—	—	—	—	1,742,400	—
” 22 ...	301	4,574,460	—	—	—	—	—	4,574,460
” 23 ...	233	4,377,225	—	—	—	—	—	4,377,225
” 24 ...	303	4,978,685	—	—	—	—	—	4,978,685
” 25 ...	305	4,706,389	—	—	—	—	—	4,706,389
” 27 ...	310	4,394,879	—	—	—	—	—	4,394,879
” 28 ...	313	2,888,470	—	—	—	—	—	2,888,470
March 1	315	1,689,945	—	—	—	—	—	1,689,945
” 2 ...	315	4,188,135	—	—	—	—	4,188,135	—
” 3 ...	315	3,443,092	—	—	—	—	3,443,092	—
” 4 ...	305	3,471,877	1,157,293	—	—	1,157,292	1,157,292	—
” 6 ...	309	3,315,877	3,315,877	—	—	—	—	—
” 7 ...	296	3,119,475	3,119,475	—	—	—	—	—
” 8 ...	314	2,874,810	2,874,810	—	—	—	—	—
” 9 ...	315	2,464,732	2,464,732	—	—	—	—	—
” 10 ...	313	2,781,458	2,781,458	—	—	—	—	—
” 11 ..	315	3,539,992	2,789,992	—	750,000	—	—	—
” 13 ...	315	2,106,907	2,106,907	—	—	—	—	—
” 14 ...	310	1,992,780	1,992.780	—	—	—	—	—
” 15 ...	307	1,691,670	941,670	—	750,000	—	—	—
” 16 ...	303	1,388,235	1,388,235	—	—	—	—	—
” 17 ...	311	2,530,748	843,583	—	—	1,687,165	—	—
” 18 ...	300	1,104,233	1,104,233	—	—	—	—	—
” 20 ...	231	466,098	466,098	—	—	—	—	—
” 22 ...	161	396,621	—	—	—	396,621	—	—
” 24 ..	157	1,019,212	—	—	—	1,019,212	—	—
” 25 ...	175	1,346,820	—	—	—	1,346,820	—	—
” 27 ...	171	1,162,380	—	—	—	1,162 380	—	—
” 28 ...	155	383,415	—	—	—	287,562	95,853	—
” 29 ..	174	725,865	—	725,865	—	—	—	—
” 30 ...	73	99,075	—	99,075	—	—	—	—
April 3 ..	93	336,502	—	336,502	—	—	—	—
” 4 ...	104	555,547	—	555,547	—	—	—	—
” 5 ...	102	441,690	—	441,690	—	—	—	—
” 6 ..	101	578,130	—	78,130	—	—	—	—
” 7 .	99	349,192	349,192	—	—	—	—	—
” 8 ...	91	137.946	—	—	—	68,973	68,973	—
” 10 ..	68	264,712	264,712	—	—	—	—	—
” 11	92	298,590	298,590	—	—	—	—	—
” 12 ..	96	318,720	79,680	239,040	—	—	—	—
” 14 ...	16	41,168	40,013	—	1,155	—	—	—
” 15 ...	83	185,130	185,130	—	—	—	—	—
” 17 ...	78	259,402	259,402	—	—	—	—	—
” 19 ...	34	196,290	—	—	—	196,290	—	—
” 20 ...	47	158,962	—	—	—	54,127	104,835	—
” 21 ...	12	73,282	—	—	—	—	73,282	—
” 25 ...	—	975	—	—	975	—	—	—
	9,684	81,117,365	28,823,862	2,975,849	1,502,130	7,376,442	12,829,029	27,610,053

To these totals have to be added the number of oysters dredged by the ss. "Violet" from 30th January to 29th April, amounting to 635,210 from the South Cheval, 1,460 from the South-East

Cheval, 102,485 from the South Moderagam. The respective yield of the individual beds may be compared with the estimates thus:—

Name of Bed.	Total Number of Oysters landed.	Estimated Amount opened by divers (Minimum).	Balance left on Bank.	Inspection Estimate prior to Fishery.
South Cheval and adjoining part of South-East	29,383,444 ...	7,000,000 ...	10,000,000 ...	47,500,000
Separate part of South-East Cheval ...	1,503,590† ...	500,000 ...	10,000,000‡ ...	13,000,000
Mid-East Cheval	2,975,849 ...	750,000 ...	5,000,000§ ..	9,000,000
North Moderagam	7,280,817 ...	1,500,000 ...	1,000,000* ...	10,000,000
South Moderagam	12,931,514 ...	2,000,000 ...	4,500,000§ ...	19,700,000
Kutiramalai‖	27,610,053 ...	4,000,000 ...	8,000,000* ...	Not estimated
	81,876,520	15,750,000	38,500,000	

(b) Historical Note on the Sections fished.

The South Cheval and the two Moderagams have a record for fruitfulness superior to all other Ceylon banks. The former has yielded during the past seventy-seven years no fewer than nine fisheries; the latter seven. The South Cheval has provided fisheries in the years 1829, 1830, 1836, 1837, 1858, 1863, 1877, 1888, and now again in 1905, while the Moderagams have been fruitful in 1828, 1859, 1860, 1877, 1887, 1888, and 1905.

The Mid-East and South-Central Cheval have in comparison but an insignificant record, the present year's fishing ground having previously given oysters only in the years 1837, 1888 (doubtful), and 1903.

There can be no doubt that the South Cheval is the section possessing the greatest inherent or natural qualities suitable for the growth and well-being of pearl oysters in the whole of the Gulf of Mannar, but it is difficult to say precisely wherein such consists. Probably they lie in a combination of three factors—special abundance of suitable food material, a well-cultched bottom affording favourable holding ground, and a position sheltered in large measure from the violence of the south-west monsoon by the long tongue of Karativu shoal. The last-named has been put forward by some as a sufficient explanation in itself, but standing alone it is undoubtedly inadequate; other beds enjoying equal and even greater shelter have nothing like equal fertility. This, then, is the ground that unquestionably offers the greatest possibilities for the successful prosecution of cultural methods. The major portion of the area is in addition admirably suited for dredging, the middle and northern thirds being practically free from any obstructions; the southern third alone is somewhat difficult, but with the aid of a few mark buoys even this may be fished when necessary by the dredge.

With regard to Kutiramalai Paar, the name I propose to apply to the northern half of the sandy area lying between the South Moderagam Paar and Kutiramalai Point, I can find no reference to mature oysters having ever been fished or seen there; I cannot even trace any indication of the ground having ever been inspected, the area in question being blank in the inspection chart at present in use, although favourable ground closer to Kutiramalai Point as well as a muddy area within the mouth of Portugai Bay received attention.

This year's results emphasize once more the good grounds there are in favour of my contention that fisheries have been lost in the past through inadequate inspection. To cope with the

* Much scattered, almost certain to disappear this year.

† This is the number which I estimate was filched by the divers from that portion of the South-East Cheval which was not meant to be opened to fishing this season.

‡ A solid bed, giving fair promise of remaining; the number certified by inspection subsequent to the fishery.

§ Divers will not fish these oysters on account of the abundance of associated young which have to be separated; the majority will die off this year.

‖ I propose to give this name, Kutiramalai Paar, to the area lying south of the South Modaragam Paar. It consists wholly of sandy ground, and has never previously been fished so far as I can ascertain.

uncertain distribution of spat-falls consequent upon the complexity and changeability of the currents over the pearl bank area, as well as to take account of the fact that the ground where spat-falls occur may vary from time to time in regard to its potentiality to bring the young oysters to maturity, necessitates periodical inspection upon the widest possible scale. The unlikely places must be examined equally with the likely, though naturally it will be proper to pay primary attention to the latter.

(c) THE PROGRESS OF THE FISHERY.

The fishery began punctually as advertised upon 20th February, falsifying the belief hitherto prevalent that it is hopeless to expect divers to attend until the first week of March. The abundant promise of specially lucrative fishing, coupled with the knowledge that from 1,000 to 2,000 Arab divers were either at the camp or on the way thither, influenced the Kilakarai and Tuticorin men to depart from the trammels of old habits, and by 19th February it was seen that vigorous fishing was assured from the date specified. Still it was with considerable astonishment that I saw at daybreak of 20th February a fleet of 251 diving boats anchored round the inspection barque, the men eagerly awaiting the moment when the mounting sun should be sufficiently high to justify the firing of the signal gun for the commencement of the day's work.

The bank opened to fishing on the first day was the south half of the South Moderagam Paar properly so called. The greater bulk of the oysters thereon were covered with young some six months old ; these the divers avoided as far as possible, but I was pleased to see that separation was carried on whenever the boats anchored on such ground, the young being thrown back into the sea. In spite of this difficulty the day's catch amounted to 1,955,377, by far the highest total on record for an opening day. The next day the number of the boats engaged rose to within three of 300 ; the catch, however, was reduced owing to the delay caused by the necessity to separate the young oysters from the old.

On 22nd February a considerable number of boats fished on the ground to the south of that portion of the South Moderagam inspected earlier in the month The whole of this area is composed of purely sandy bottom whereon lay oysters free from commingling with any of a younger generation ; all were a little over three years old. In some places they lay in loose bunches ranging from five to twelve individuals in each ; elsewhere the oysters clung to the projecting edges of large wedge-shaped shells of *Pinna bicolor*, rooted upright in the sand by the narrow end. The former condition delighted the hearts of the divers ; the latter gave those unprovided with protecting finger-stalls considerable trouble, the sharp edges of the Pinna shells inflicting frequent cuts and scratches on the hands tearing them from their sandy foothold. In both cases the divers filled their bags with remarkable celerity, forty seconds in many cases sufficing to fill the diver's bag with 60, 70, and even 100 oysters. As a result the day's catch, aggregating the enormous total of 4,574,460 oysters, broke every known record. Light wind made progress to the shore slow, the boats straggling along in loose order ; many had to use paddles, and one sighed for the assistance of a couple of powerful tugs, whereof the cost, to say nothing of the convenience, would be covered time and again by the safeguard this help would be against illicit opening of oysters, a malpractice which flourishes especially on days when the run to land is unduly prolonged.

Work on this sandy area continued with feverish activity for the remainder of the week. The daily catches never fell below 4,000,000 per day, while on 24th February high water mark was reached with the enormous take of 5,005,685 oysters. Such a huge total for one day's fishing establishes a record that is likely to remain unsurpassed for many years to come.

The loads taken ashore each day showed no great falling off till the last day of February, when indications began to point to the impending exhaustion of the bank ; the next day there was further reduction, the total for 295 boats being little over $1\frac{1}{2}$ million.

In consequence I opened a fresh section of the bed on the north side of the South Moderagam. Oysters there were plentiful, but the area being circumscribed I was not surprised to find that two days' strenuous fishing sufficed to cream the bank.

For some days previous to this the divers, rendered greedy and exacting by their initial good fortune, had had their thoughts and desires fixed on the South Cheval bed as their land of promise, and on 4th March, taking advantage of a temporary absence of the patrol steamers, they scattered northwards, a third of their number on the North Moderagam and a third on the South Cheval. Accordingly, as the North Moderagam oysters were relatively poor in pearl yield, it was considered expedient to postpone fishing that bank and to open the South Cheval, for which the merchants as well as the divers were clamouring.

Sunday, 5th March, I spent in marking out the fishing boundaries with lines of bamboo buoys bearing red flags, while the centre of each of the chief oyster patches was marked by a white flag as in last year's fishery. The following day saw all the boats at work on the South Cheval, and for four days the work proceeded smoothly, the men giving little trouble.

This bank greatly disappointed the divers, who, being accustomed to the easily gathered loose oyster bunches of Kutiramalai Paar, did not appreciate the trouble entailed in wrenching the oysters individually from the rock, the condition wherein they are found on the South Cheval. Superior quality was little or no compensation in their eyes; their ambition is always quantity rather than quality. A flagrant instance of this occurred about this time. On 9th March one diving boat anchored on that patch of the South-East Cheval lying separate from the South Cheval bed; the men subsequently reported to their comrades in the fleet that the oysters there lay in bunches. The next morning the whole fleet settled down with one accord on the South-East bed, and it took two hours of incessant objurgation to get them away and back to the proper fishing ground. The Arabs, I must say, behaved best, while the Kilakarai Moormen were the most troublesome, making but a pretence of discontinuing work when remonstrated with, re-commencing diving immediately the launch passed on. As a consequence of this invasion of a bed of oysters of inferior pearl yield the prices fell from Rs. 65·73, given on 9th March for South Cheval oysters, to Rs. 38·16 for those of the succeeding day on account of the admixture with these South-East Cheval ones.

Discipline in the fleet once broken was thereafter difficult to maintain, the men quickly grasping the fact that the fleet was too large to be effectually controlled by the means at my disposal. There was for a week thereafter a continual game of hide-and-seek proceeding, the boats watching for any chance to pass beyond the boundaries set to their labours, while I, on my part, was kept on continuous patrol driving trespassers away from the forbidden ground. Eventually the divers gave in, finding the loss of time they sustained in this conflict insufficiently compensated otherwise.

Varied with the excitement attendant upon these occasional excursions, fishing on the South Cheval proceeded prosperously till 18th March, the last day whereon 300 boats participated in the fishing.

The weather hitherto, while not strictly typical "pearl-fishery weather," had been well suited to sailing and diving requirements. On 18th March conditions changed, marked by a south-west swell with wind from the same quarter. By next fishing day, 20th March, the disturbance had gathered considerable force, rendering diving so difficult and arduous that, although 231 boats came out, the day's catch totalled less than half a million oysters, a number surprising indeed to those who watched the acrobatic performances of the boats when at anchor; by noon the wind and sea appeared to be increasing, when, feeling anxious for the safety of the fleet, I gave the signal to cease work and sent the launches to help those of the boats that were crippled.

It is under conditions such as these that the attendant launches prove their value; on this occasion a divers' boat having capsized, with the timely assistance of the ss. "Active," which I sent to render help, the men were all saved and the dhoney towed to Marichchikkaddi. Accidents to the rudder are the most frequent of the minor damages entailed by a rough day on the banks, and during the latter half of the fishery it was no uncommon occurrence for the launches to have from two to five of these crippled craft to tow to port.

From this time forth work was carried on with increasing difficulty; owing to the changeable and frequently boisterous weather, the working of the fleet became intermittent and punctuated with idle days spent in port. 18th March may be counted as marking the end of the fishery proper. The great bulk of the oysters had then been removed, and influenced by this and the unfavourable nature of the weather a third of the boats took their departure. Proceeds thereafter never once reached Rs. 27,000, whereas prior to this date the lowest had been over Rs. 49,000.

The South Cheval being creamed, fishing on the North Moderagam Paar was begun on 22nd March, and was continued with fair success both as regards quantity of oysters and prices realized for four days—a high sea running the while.

The last section to be fished was the bed on the south side of the Mid-East and South-Central sections of the Cheval Paar. Fishing there commenced on 29th March, when 174 boats lifted a quarter of a million oysters from the south side. The weather that evening again became stormy, the inspection barque continually dragging her anchor during the night, pitching and rolling so violently that sleep became an impossibility. So bad was it that my astonishment was great to see 73 boats struggle out at daybreak; the weather was absolutely unfit for them both as regards safety and utility. The Government share on this day amounted to a paltry 66,000 oysters. The launches again did excellent work, towing being an absolute necessity, as many of the boats were unable to beat against the wind and were in danger of driving ashore at Kallar.

Three days of idleness followed marked by another exodus of divers, who, with plenty of money in their possession and because of the hardship of their work under the prevailing adverse weather conditions, were now careless whether the fishery continued longer or not.

Our weather prophets had, however, prophesied a change for the better three days before new moon; sure enough on 3rd April, two days prior to that phase, the sea and wind so improved that fishing was resumed. This and the next succeeding day sufficed to remove the bulk of the oysters on the Mid-East that were not masked by the presence of myriads of a younger generation, and which the divers virtually refused to fish.

For the remainder of the fishery the boats were engaged in gleaning over the whole ground already fished; from the heavy loads taken when good fishing weather prevailed, it is evident how unevenly and imperfectly fishing proceeded so long as the full fleet of over 300 boats were at work.

With the renewed onset of high wind from the south-west on 19th April, the tindals of the diving boats began to raise objection to putting to sea, and chiefly on this account the fishery came to an end on 21st April, when eleven diving boats were all that came out. The fishery ended sixty days from the opening on 20th February; fishing actually proceeded on forty-seven days, constituting thereby one more record to the credit of this phenomenal fishery.

Illicit opening of Oysters; the extent and the remedy.

There is not the slightest doubt that great numbers of oysters were opened by the divers and manduks and even by the "boat-guards" on the run home, especially on those days when calms and light airs gave several hours of unrestricted freedom wherein such malpractice could be carried on with ease and celerity.

During the 1903 fishery there were opened, according to Captain Legge's estimate, no fewer than 9½ millions of oysters, against 41 millions landed and accounted for at Marichchukkaddi. From the personal knowledge I have of the fishery in question, I believe this estimated loss of 23 per cent. to be by no means exaggerated. The percentage this year has been, I consider, somewhat less; it was however variable, greater on the banks further from shore and on those where the oysters were difficult to gather.

On Kutiramalai Paar it was comparatively slight. Prices were good considering the age and the abundance of oysters there, while the bank was within seven miles from the camp. It paid the divers better to sell these oysters than to open and steal the pearls. I do not think that many more than 4 millions were opened on this bank, as against the 30 millions taken ashore.

Contrary conditions prevailed on the South Cheval. On that bed there was a considerable, though variable, admixture of valuable 5 to 6-year old oysters very rich in pearls; the bank was some miles further from shore, and the oysters were troublesome to gather, the majority being firmly attached to rocky patches on the sea bottom. I estimate that some 25 per cent. of the oysters fished there were opened on the run home, certainly not less than 7 millions, and probably a good many more. The loss sustained by Government is, however, far from limited to the loss of its two-thirds share of such illicitly opened oysters; the divers choose the largest and oldest individuals for their operations, and as the great majority of the best oysters are thus weeded out of the day's catch, the remainder, which goes to the Government kottu, is depreciated greatly in value. This the merchants are well aware of, and it is this knowledge that induced them willingly to give much higher prices for oysters dredged by the "Violet" than they would give for oysters from the same locality fished by the divers; the buyers knew that the former were exactly as brought up, that no tampering with them had taken place, and that therefore each bag contained its due proportion of large oysters.

An incident connected with the confiscation of a boat load of oysters on 4th April first showed me with what deliberate method some at least of the divers pursue this operation. The boat in question had fished beyond the boundary line and had disregarded all warnings; at 11 A.M. I had it brought alongside the barque and the oysters removed and provisionally confiscated. The oysters were found disposed partly loose and partly in bags. To ascertain the number taken, the bags had to be emptied, and as the bagged oysters formed one heap and the loose ones another, a difference in the size of those in the one from those in the other was obvious to the most casual observer. The inference was clear that the smaller oysters, which had been packed neatly in bags, were intended for the Government kottu, while the large ones lying loose were intended for opening on the run home.

The best practicable safeguard that I can think of is to provide one or two powerful tugs to tow the whole fleet to port as soon as diving has ceased at 1 P.M., the men being made to lie down on the decks of their boats during the whole time. The cost would not be excessive, for even the "Violet," a vessel not designed for such work, is able to tow fifty diving boats at one time. She actually did tow thirty-nine on one occasion, and there was ample power available to have taken another eleven.

If either the "Goliath" or the "Samson" can be spared at the time of the next fishery, I strongly recommend employment on the duty indicated; the saving or profit would be so high as to be wholly out of all proportion to the cost involved. As above-mentioned, I believe the number of oysters opened during this fishery to have exceeded 15,000,000. If, however, it has not been more than 12,000,000, and we make first an allowance of 3,000,000 for the number which might still, in spite of this precaution, be opened illegally, and then from the remainder, 9,000,000, deduct the divers' share of one-third, we still have a total of 6,000,000 oysters, which at the lowest computation might have been added to the Government share had provision been made for the towage of the fleet from the banks to the camp. 6,000,000 oysters at Rs. 50 per 1,000 (roughly the average price at the fishery) would amount to Rs. 450,000, to which must be added the enhanced value of the general catch consequent on the greater proportion of large oysters left among the oysters landed, and the wages which otherwise would be paid to boat-guards.

I have no faith in the employment of boat-guards of the class hitherto employed. They are venal, I believe, without exception, and this perhaps cannot be wondered at considering that their pay is but Re. 1 per diem, and that a contribution of 50 cents from each of the fifteen divers—a low average per boat—means a bribe of Rs. 7·50 per day. The pay of boat-guards during the present fishery cost approximately Rs. 9,000 per month, which of itself would go far to pay the expenses of a powerful tug of the "Samson" class.

(*d*) CASUALTIES.

It is satisfactory to record that this fishery was marked by immunity from any fatal accident, contrasting favourably with its predecessors of 1903 and 1904. A half-breed Arab diver had, however, a very narrow escape; he collapsed while on the bottom, and was not drawn up by his comrades for some minutes. He was taken to the inspection vessel thereafter, and in my temporary absence Lieut.-Col. K. M. Foss took charge of the case; his long-continued and persistent efforts to restore animation were successful, and when we eventually gave him back wrapped in a blanket to his friends we had the satisfaction of knowing that he was in a fair way to recovery. He certainly owed his life to Col. Foss.

Another day an Arab came aboard suffering from the effects of a wound in the thumb inflicted by the poisonous spine of a small fish. The hand and forearm were considerably swollen, and the man appeared to suffer great agony. Knowing the beneficial effect of permanganate of potash as an antidote in the case of snake bites, I had the small wound slightly enlarged and introduced therein a crystal of this substance. The result was quite satisfactory; the pain and swelling rapidly subsided, and after an hour's rest the man asked to be sent back to his boat in order to resume diving! Before he went he begged to be given a few of the magical crystals.

Other accidents occurred through boats colliding while fishing; the wonder was that such were not more numerous. In spite of rough weather towards the termination of the fishery no fishing boats were lost; a few capsized, but such were salved and the men all rescued. In the towage of the boats during rough weather the tindals of both the "Nellie" and the "Active" behaved very well; indeed, I wish to record my particular satisfaction with the tindal of the "Nellie," who exhibited excellent initiative and energy in the performance of the duties assigned him.

(*e*) THE NEED FOR FISHING REGULATIONS.

The unwritten laws of custom have hitherto ruled the operations of the divers when fishing on the banks; such were perhaps adequate when the fleet was restricted in its numbers, and when divers from distant parts did not participate. But the old order changeth or rather should change in accordance with new conditions, and during the fishery under review I found the difficulties incident to the management of the work on the banks rendered unnecessarily troublesome by reason of the want of a code of simple rules for the regulation of the diving operations.

What I consider as desirable is the issue of printed instructions in English, Tamil, and Arabic defining the rules which the owners and tindals of the diving boats shall observe at sea while under the control of the Inspector of Pearl Banks; the consequences that shall follow disobedience of these rules should also be stated, in order that the men shall be aware what penalties may accrue if they be contravened.

(*a*) *Numbering of the boats.*—In these instructions the men should be informed how and where to display upon the sail and upon the hull of the boat the fishery number allotted to their craft, with the penalty for neglect in either particular. (The numbering of the boats at this fishery was carried out in so slovenly a way that many numbers were undecipherable, while others were obliterated wholly or in part within a couple of days from the opening of the fishery.) Under the present absence of system it is in practice impossible to check the numbers of those boats that take up fishing.

(*b*) *Fishing beyond limits.*—Particulars of the method adopted by the Inspector of Pearl Banks in the marking of the fishery limits by means of flag buoys should be detailed; power to inflict summary punishment in particularly flagrant cases of disobedience in fishing outside the boundaries should, I consider, be given to the Inspector, the nature and extent of the punishments being defined if thought necessary. It is of the greatest importance that punishment for disregard of boundary limits should follow swiftly. My experience this season has shown clearly that the men in many cases were willing to take the risks when they found that my power extended no further than the report of their conduct to the Government Agent. It is obvious that a penalty exacted in full sight of their comrades immediately upon the commission of an offence has salutary effects that are wanting from punishment deferred and inflicted amid the turmoil and distractions of "Pearl Town."

(*c*) *Daily verification of the numbers of the boats engaged in fishing.*—The present absence of system renders it, in practice, impossible to check day by day the fishery or register number of each boat engaged in fishing; it is difficult therefore to be assured that no boats without passes are at work. Such an occurrence as the latter I can scarcely imagine ever to happen, but if no check exists a premium is offered to adventurous spirits to attempt such a flagrant act of poaching. The further advantage accrues from daily verifying the registration of all boats that, if the tindal of each is bound to report arrival to the Inspector, the latter has better control of the boats' movements and can issue to the tindals any special directions necessary from day to day. I recommend therefore that besides the numbering on the hull, the fishery number of each boat be painted on a loose square of cotton which shall be sewn to the sail in such position as may be directed by the Inspector. The size and colour of the figures should at the same time be specified. This being done at the time each boat first joins the fishing fleet, the tindal should be ordered by the fishing rules, before beginning each day's diving, to sail past such specified point or points at the rendezvous upon the fishing ground as the Inspector may decide upon and notify from time to time. At each of these points an inspection boat in charge of a Government coxswain would be stationed, and as each diving boat passed, displaying its number conspicuously, the coxswain would note the same. At the close of the day's fishing the Inspector would make up a list of boats thus checked and despatch it to the Superintendent ashore, who by comparing this with the list of boats which return from fishing would be able to trace any discrepancy, should there be any.

(*d*) *Towage.*—Rules might well be framed to obviate the unnecessary trouble that is frequently occasioned to the launches when about to take diving boats in tow by the indifference of the men aboard the latter to the need to put their boat in a proper position and their neglect to help in the operation. On several occasions during the past fishery the boats were manœuvred to cross the path of the steamer, and when right across her bows sail was lowered and the steamer had difficulty to avoid a collision, the crew of the diving boat standing idle the while. Further, each boat should be required to carry a lantern, to be lit after dark should calms or contrary wind prevent her making port before sunset, in order to serve as a guide to the patrolling launches sent to render assistance.

(*e*) *Accidents.*—Any accidents or illness that may occur should be reported to the Inspector with the least possible delay, especially in the case of men who have collapsed while under water. Delay in the latter instance is practically certain to be fatal to the subject, whereas if reported at once aboard the Inspector's ship measures would be taken immediately to restore animation.

(*f*) *Cessation of fishing.*—Ready obedience to the "cease work" signal should be exacted, the Inspector being given power to cause the rule to be respected. Dilatory observance of this signal frequently occasions the waste of much of the time of the attendant launches, which have to be sent round to hasten the movements of laggard boats, thereby detaining them from other more important duties.

(*f*) The Weather during the Fishery.

True north-east monsoon conditions still prevailed at the time of our departure from Colombo on 26th January, and the strong northerly winds made progress slow on the journey to Marichchukkaddi. From 21st January until 20th February similar winds continued, blowing from north and north-north-east in the morning, veering to north-north-west and north-west in the afternoon.

Cessation of these steady northerly winds coincided with the opening of the fishery on 20th February; thenceforward for a duration of two months there prevailed the usual inter-monsoon period of variable wind currents. This seasonal interval, while it extended to greater length than it did last year, was noteworthy for the frequency with which spells of rough weather interrupted fishing, and which repeatedly gave rise to the fear of an unexpectedly early oncome of the south-west monsoon. The latter did not set in, however, till 18th April, from which date the wind blew continuously from the south-west, accompanied by a more or less heavy swell from the same quarter.

The particulars of the inter-monsoon period are so variable that they may best be set forth in diary form as follows:—

Period. 1905.	Character of the Weather.
February 22 to March 1	... Alternate land and sea breezes, with rain squalls on the afternoons of February 22 and 23.
March 2 to 11 ...	... Continuous northerly breezes ranging from E.N.E. through N. to N.N.W.
March 12 to 14 ...	... The wind from S.W. and W.S.W., accompanied by a heavy swell from the S.W.
March 15 to 17 ...	... Resumption of land and sea breezes; general fine weather.
March 18 to April 2	... South-west conditions prevailed throughout this period with rough weather, save on March 27 and 28, a heavy S.W. swell the whole time. Fishing was greatly interfered with.
April 3 ...	... The native weather prophets foretold that about three days before full moon (April 5) an improvement in the weather would take place; sure enough on April 3 there was cessation of the S.W. winds experienced continuously during the fortnight preceding, with a reversion to land and sea breezes and calm from 10 A.M. till noon.
April 4 to 17 ...	... A period of excellent fishery weather so far as the mornings were concerned marked by the prevalence of light winds and calms which made diving easy. The lightness of the wind hampered greatly the arrival and the return of the fleet, and on several occasions the boats did not reach the camp till after sunset; indeed, a considerable number of those engaged in fishing on April 12 did not return to port till 10 A.M. the succeeding day, the boats having drifted a considerable distance up the coast. In the mornings during this period the wind came generally from the E.S.E. and S.E., veering gradually round to W. and S.W. in the afternoon, with dead calm at noon and in the early afternoon. Rain squalls from the N.E. were frequent in the afternoons, and during this period the fleet ceased work each day soon after midday in the hope of getting to shore before the advent of these squalls. They seldom succeeded.
April 18 and onwards	... South-west monsoon conditions of wind and swell. Weather generally fine.

(g) SURFACE DRIFT.

When we left Colombo on 26th January we experienced a fairly strong current setting to the southward, retarding our progress considerably. Throughout February and until 11th March it ran steadily in the same direction, gradually weakening till with the advent of southerly winds on 13th March it changed direction and ran to the northward. It so continued the next day, but on 15th and 16th March it was so weak that wind and tide made the direction extremely variable.

From 17th March to 2nd April the current ran towards the north with strength, accompanied by a heavy swell. South and south-east currents prevailed from 3rd to 7th April, while from the 8th to the 17th of the same month the drift was notably variable and usually of little or no force. From 18th April onwards a current setting to the north prevailed, gradually gaining in force till on our return towards Colombo on 1st to 3rd May its strength must have been fully two knots per hour.

So far as I know there was no spat fall from the oysters during the period of weak and variable currents in March and April; the only oyster spawn shed this year (Eastern Cheval), I judge from its size, was liberated from the gonads between the middle of January and the middle of February. At this time the current was running to the southward in the locality of the Ceylon pearl banks.

Abstract of Observations on Surface Drift.

Period.		Direction of Drift.
January 26 to March 11	...	To the south ; strong.
March 13 to March 14	...	To the northward ; weak.
March 15 to March 16	...	Variable ; weak.
March 17 to April 2	...	To the north ; moderately strong.
April 3 to April 7	...	To the south and south-east ; weak.
April 8 to April 17	...	Variable ; calm.
April 18 onwards	...	To the north ; increasing rapidly in strength.

An occurrence worthy of record in connection with the investigation of surface drift in these waters arose through the drifting from position of one of the flag buoys placed on the Cheval Paar on 7th February. This particular buoy, which had two red pennants attached, appears to have been too lightly weighted, and disappeared from the bank immediately after being placed. The next heard of it was from a report made by the Master of the ss. "Ranza" that he observed a "bamboo upright, about 20 ft. high, with two new red pennants attached in lat. 8° 3′ N. and long. 73° 51′ E." The "Ranza" arrived in Colombo on 16th March, and we may infer that the bamboo was sighted on the 14th or 15th of the same month, thirty-five or thirty-six days after being placed on the Cheval Paar. As its original position on the latter was lat. 8° 42′ N. and long. 79° 48′ E., it travelled approximately some 364 nautical miles in thirty-six days, or ten knots per day. The place where the pennants were seen by the "Ranza" was about 3° 41′ west of the meridian of Cape Comorin and almost due west thereof, so it would appear that after travelling southwards towards Colombo for some time the bamboo came within the influence of a strong current setting westwards in the direction of Minicoy.

III.—THE DREDGING OPERATIONS OF THE SS. "VIOLET."

(a) ACCOUNT OF THE WORK ACCOMPLISHED.

When reporting upon the results of the pearl banks inspection of November, 1904, reference to dredging operations was purposely omitted, as it would have been premature to attempt to draw conclusions from the scanty data then available.

After the fishery of 1904 the intention was to re-employ the ss. "Ready" for the purposes of further oyster dredging, if it were found possible to effect certain radical alterations affecting the hold and deck plan to allow of the provision of additional dredging equipment. The requirements of the Harbour Works Department, the owners of the steamer, were however such as to preclude these alterations, and thereby to bar her further employment on pearl fishery duties. The Government, desirous to give the oyster-dredging scheme a fair test, had therefore to look elsewhere for a suitable vessel, and thus it was that the suitability of the steam-trawler "Violet" came up for consideration.

This vessel belonged at the time to Mr. T. A. J. Noorbhai of Colombo, who had brought her out some two years previously with a view to the introduction of fish-trawling in Ceylon waters; unfortunately for Mr. Noorbhai a variety of causes, not, however, due to any lack of good trawling ground, led to the abandonment of the enterprise, and the vessel at the time I refer to was on the market for sale. The vessel is a typical North Sea trawler, built for a Grimsby firm in 1896, and was fully as readily adaptable to dredging purposes as any trawler that could have been obtained at the time in England.

The real choice lay between taking this steamer, and thereby having her at our immediate disposal, or of sending to England to have one built to special design.

The advantages of the former course are abundantly manifest, as a steamer built to order would not have reached Ceylon in time to take part in the fishery of 1905, far less in the November, 1904, inspection. Besides this, as was pointed out by Mr. E. B. Denham, whose sympathetic assistance and well-considered advice in this matter, as in all others connected with pearl fishery work, have been of the greatest support to me, while the "Ready's" experiments had shown us the general lines upon which the design for special fittings should be based, many details were yet doubtful. He dwelt specially on the advantages to be gained by taking a vessel that was available for work during the approaching inspection and fishery, when we should have ample opportunity to test the various special improvements in equipment and arrangement which I contemplated introducing. It was not as if steam dredging on the scale proposed and under the special and peculiar local conditions prevailing in pearl fishing in Ceylon had ever before been tested; the work would be unique in character, and we could not expect marine architects at home to furnish a suitable design; the main lines must be elaborated in Ceylon, and for this further experiments were necessary. Because of these reasons the ss. "Violet" was eventually purchased by the Government, the price being Rs. 50,000, a reasonable enough one considering that the vessel was immediately available and generally in good and serviceable condition.

The dimensions and the particulars of construction are as follows:—

Length between perpendiculars	... 95 feet
Breadth	... 20 feet 6 inches
Depth	... 11 feet
Draft laden	... 12 feet
Tonnage	... 150 gross, 57 nett
Speed	... 10 knots
Coal consumption	... $3\frac{1}{2}$ tons per 24 hours
Cargo accommodation	... About 150 tons

The engine is of the triple condensing marine type of 40 horse-power nominal.

The principal alterations which were carried out at my suggestion consisted in the fitting on either side of four dredging davits with their necessary fairleads and the provision of a second steam winch. Each winch was to wind in two dredges at each haul, thereby allowing four dredges to be used at one time, the same number as used on the "Ready." I was also desirous of operating some from the stern of the vessel, but as this would have necessitated the fitting of a steam capstan requiring several extra weeks for construction, such had to be postponed for the time being.

Mr. C. H. S. Jelstrup was appointed to the post of Master on 1st October, 1904, and twenty-five days later the vessel left Colombo for the pearl banks.

The beginning was sufficiently discouraging, two separate outbreaks of fire occurring in the bunkers during the first fortnight's operations, each of which compelled a return to Colombo with consequent loss of a valuable portion of the available fine weather, as well as involving considerable unremunerative expenditure.

The most important section of the dredging scheme is the transplantation of young oysters from unfavourable to favourable situations on the banks; in November, 1904, this was found to be temporarily unnecessary, as an immense spat fall had taken place over nearly the whole of the Cheval Paar and over part of the South Moderagam. I was thereby enabled to utilize the steamer to dredge mature or fishable oysters for the sake of the contained pearls. From 7th November to 17th December, the date when stormy weather compelled a retreat to the harbour of Colombo, 322,468 oysters were dredged and delivered to Mr. G. G. Dixon to be treated by his patent oyster-washing machine. This number was, I consider, fairly satisfactory, seeing that the crew were new to the work, and that the Master had to grope his way after success, as he had had no previous experience in dredging, and had only my instructions for his guidance.

During the progress of the operations I gave very careful attention to the working of the gear, and on my return from the banks early in December, 1904, I submitted a scheme for further alterations, and for the provision of considerable additions to the equipment with a view to increase materially the dredging capacity of the vessel. The chief of these suggestions were the installation of a steam capstan aft, the addition of two sets of dredging gear at the stern, of two additional on the quarter, and of a number of larger and heavier dredges. The Government treated the report in the most liberal spirit possible; the whole of the recommendations were sanctioned and ordered to be put in hand immediately. Mr. J. H. Rhodes was also appointed as dredging mate to lighten Captain Jelstrup's responsible and arduous labours.

I am glad to be able to record that the alterations were amply justified by results, the daily takes being doubled and even trebled during the subsequent dredging operations, increasing steadily day by day as officers and crew gained in experience, till during four days towards the close of the period wherein the vessel was engaged in dredging mature oysters for sale purposes, the average was 34,774 per day, reaching 38,250 as the maximum for one day's catch. Annexure No. VII. gives a statement of the daily progress of the work during the period when the vessel was engaged exclusively in dredging mature oysters, while the succeeding table (Annexure No. VIII.) furnishes a record of the quantities of mature oysters fished incidentally during the course of transplantation operations, together with the prices and proceeds of such as were sold.

On 15th March enough of mature oysters had been removed by the divers from the central *portion of the South Cheval to permit of the commencement of operations for the establishment* there by transplantation of a bed of young ones. Accordingly, I instructed Captain Jelstrup to dredge for young oysters aged about six to seven months, which I knew to be in profusion on the South Moderagam Paar, to convey them to the South Cheval and there to throw them overboard within the limits which I defined by a series of mark buoys.

The method adopted was to bag all the young oysters taken, to keep them in a cool place covered with wet sacks, and to steam twice a day, noon and evening, to the South Cheval, throwing them out as the vessel manœuvred between the flags. The young oysters stood the treatment well; there was practically no mortality, as I ascertained by sending divers down from time to time to ascertain the condition of these young and to bring me samples.

The total quantity transplanted was upwards of ten millions. I propose to concentrate attention upon this bed during the next season, in order to give the experiment fair treatment. I hope to transplant thereto in November next an additional 10 to 15 millions; after that we may hope that enough work shall have been accomplished to ensure a small fishery two years later—a result that would be due entirely to cultural methods, and not to the fortuitous interaction of currents and other natural influences.

During the course of the dredging a great amount of good was done by the capture and destruction of large numbers of starfishes and carnivorous gastropod molluscs, noted enemies of the pearl oyster. Frequently between 200 and 300 starfishes were taken and destroyed in one day. By my instructions these were retained on board for twenty-four hours in order to insure that life should of a certainty be extinct when they were returned to the sea.

Chanks.

A considerable number of chanks (*Turbinella rapa*) were dredged from the South Moderagam Paar, confirming my opinion that the dredge may be used to great advantage in chank fishing as well as demonstrating the presence of a chank bed between Marichchukkaddi and Kutiramalai. The shells obtained were sent ashore periodically, and were sold by auction at the close of the fishery. There were, in addition, considerable numbers taken ashore by the divers during the time the Moderagam Paars were being fished; little groups of three or four laid out for sale were familiar objects in the by-ways of the camp.

(*b*) Financial Results of the Dredging Operations.

Turning now to the financial aspect of the dredging operations subsequent to the acquisition of the ss. "Violet," I am confronted with the initial difficulty that by far the greater part of the oysters dredged were not offered for sale publicly, being supplied to Mr. G. G. Dixon to experiment with in his oyster-washing machine, and that no particulars are available yet of the proceeds realized from the sale of the pearls obtained from such oysters. In any case Mr. Dixon's work was in itself experimental, and may or may not be financially more profitable than open sale of the oysters. The profit and loss account of the dredging should certainly not be subjected to the hazard of the machine washing being unduly expensive or otherwise unsatisfactory; the most satisfactory and simplest plan will be, I consider, to take the average rate per 1,000 of the dredged oysters actually sold at auction, and to value the remainder at a similar rate. If anything, this will under-estimate the money returns that would have resulted from open sale, as the dredged oysters supplied to Mr. Dixon were of a finer quality, and contained a larger proportion of pearls than did those dredged ones which were sold. In the former case the oysters were from the South Cheval, in the latter from the South Moderagam. The former sold during the fishery at the average price (approximately) of Rs. 62 per 1,000, the latter at Rs. 42 only. From this it will be seen that as I credit the "Violet" for her catch on the South Cheval at the rate of the average for the inferior oysters of the South Moderagam, I am in reality under-stating the value of the dredged oysters by Rs. 20 per 1,000 oysters on the amount fished upon the South Cheval, namely, 977,563, which number at Rs. 20 per 1,000 gives a total under-valuation of, say, Rs. 19,550.

During the latter part of the fishery, when the dredged oysters were offered for sale in the same way as those obtained by the divers, it is of importance to note the great partiality shown by the merchants for those furnished by the "Violet." An average of fully Rs. 20 more per 1,000 was maintained consistently. The reason was that the dredged oysters being bagged under European supervision, buyers could rely that no illicit interference had occurred, such as is normal in the case of those sent in by the divers. As explained in my report on the progress of the fishery, it is the regular custom of the native divers to select the largest and most likely oysters for the purpose of opening during the run homewards after the cessation of diving.

The cost of dredging oysters also compares most favourably with that of the share system in vogue with divers. During the recent fishery it certainly did not exceed 20 per cent., as against the $33\frac{1}{3}$ per cent. of the divers' one-third share. But in reality the divers' share is close upon 50 per cent., when we make allowance, as we ought, for the great proportion of the finest oysters opened by the divers before they reach the shore. Dredging is economically a more sound method of fishing than is diving, and I look forward with increasing confidence to the developments it promises as gear and methods improve; both are capable of great and material improvement.

The picture of the ideal fishery steamer that I should like to have the opportunity to design is often before my eyes: a steamer capable of dredging 100,000 oysters per day during a fishery, and of transformation into an efficient steam-trawler when pearl fishery operations are at a standstill. Such a craft should ensure pearl fishing upon such economical lines as would hugely enhance the profits derivable from a fishery.

From the following particulars of the expenditure to date and of the valuation of the oysters dredged and other work done, the favourable financial outcome of the experiment is clearly demonstrated :—

A.—Abstract of Expenditure upon ss. "Violet."

Capital Account.

	Rs.
Purchase price of the vessel and gear	50,000
Repairs, alterations, and additions to equipment	17,382
Total capital expenditure ...	67,382
Current or working expenses (wages, coal, stores, and minor repairs) for the seven months, from 1st October, 1904, to 4th May, 1905	23,803
Total amount at debit of the ship Rs.	91,185

NOTE.—The working expenses were under Rs. 4,500 per month for the five months spent in commission, equal to Rs. 160 per day at twenty-five working days per month. At 35,000 oysters per day the proceeds at Rs. 70 per 1,000 amount to Rs. 2,450 obtained, as seen above, at a cost of Rs. 160. The same quantity of oysters fished by divers would cost at the least Rs. 816, a difference in favour of dredging on this comparatively small quantity—one day's work—of at least Rs. 656.

B.—Abstract of Earnings of the "Violet" from 1st October, 1904, to 4th May, 1905.

		Rs. c.
Dredged Oysters.		
Proceeds of 104,060 sold at auction at an average price of Rs. 71·81 per 1,000 (excluding those dredged after close of fishery)		7,183 0
Estimated value of 977,563 oysters delivered to Mr. Dixon at the same rate as the auctioned ones, viz., Rs. 71·81 per 1,000 ...		70,198 80
Rs.		77,381 80
Other Services.	Rs. c.	
Towage of diving boats on several occasions to and from the banks, say three days at Rs. 160 per day ...	480 0	
Towage of the barque to and from Marichchukkaddi in January and May respectively, four days at Rs. 160 ...	640 0	
Laying out buoys and towage of barque on bank during absence of the "Serendib," five days at Rs. 160 ...	800 0	
		1,920 0
Total of estimated earnings Rs.		79,301 80

NOTE.—No credit has been allowed for the transplantation, from which great eventual profit is due.

C.—Comparison of Expenditure and Earnings.

	Rs. c.
Capital expenditure	67,382 0
Working expenses	23,803 0
Total of expenditure	91,185 0
Amount of earnings as above	79,301 0
Balance, being the total amount at the debit of the ship on 4th May, 1905 ...	11,884 0

The foregoing figures show that the earnings of the vessel during the short time she has been at work, after paying off the working expenses, are sufficient to reduce the capital charge from Rs. 67,382 to Rs. 11,884. If the vessel were to become a total loss to-day, the actual sum lost would be represented by the latter amount.

That Rs. 79,301 should be earned during less than five months of actual work upon a gross expenditure of Rs. 91,185 and a capital sum of Rs. 67,382, is a profit large enough, I think, to satisfy the most captious of critics. The knowledge of such success is, I hope, very gratifying to Mr. E. B. Denham, who shared with me the responsibility involved in an advocacy of the purchase of the ss. "Violet." I should add that the earnings, Rs. 79,301, after deduction of the working expenses Rs. 23,803, and depreciation at 15 per cent. per annum on Rs. 67,382 for seven months (Rs. 5,900) give a nett profit of Rs. 42,000, equivalent to a profit of nearly 75 per cent. for less than five months actual working, part of which was employed upon transplantation, for which no credit is taken in assessing the percentage of profit. Had the work to be done over again, the further experience gained would enable much better results to be obtained, with a proportionate increase both in the amount of the proceeds and in the percentage of profit. Where 1,081,263 oysters were lifted, fully 1,750,000, and not improbably 2,000,000, could now be taken in the same time and under similar circumstances.

For the next five months the steamer will be laid up in Colombo Harbour, failing employment on duties other than those of the Pearl Fishery Department. And there is one of great utility and of some urgency. I refer to the utilization of the steamer in her original *rôle* of fish-trawler. It has already been mentioned that trawling was attempted in 1902 on the Ceylon coast with discouraging results. Were I a capitalist I should, however, be content, armed with my present knowledge of local conditions, to renew the effort. I am confident that worked upon rather different lines and in co-operation with native fish-curers and fish merchants, the enterprise would be a huge success and of far-reaching benefit to the Island.

I submit, therefore, that modern and up-to-date fish-trawling gear be obtained and installed on the "Violet;" that a capable trawling master be obtained from England; and that the steamer be sent to explore the rich fishing grounds which I know to exist off the north-east coast of Ceylon.

This trawling exploration would be conducted during the continuance of the south-west monsoon, when pearl fishery work is necessarily in abeyance. Other Governments, notably that of Cape Colony, have shown the way to local enterprise in the manner I recommend should be followed locally; their work, as I would suggest should also be the case here, was entirely pioneering. In the seas alluded to neither scientists nor fishermen knew the fishing potentialities of the sea bottom save that immediately adjacent to the shore line; banks had to be sought for, and the presence in paying quantities of marketable fish had yet to be demonstrated.

Here in Ceylon the Government is now in a position to carry out such prospecting more efficiently and cheaply than any private individual, being in the possession of a suitable craft and with a Marine Biological Department sufficient to provide the necessary scientific direction.

As the trawling would take place off a sparsely populated coast at a distance from any large distributing centre, it would be preferable to arrange to cure the catches rather than make any attempt to preserve by refrigeration. I recommend that prominent fish-curers should be invited to co-operate; from inquiries I have made I do not anticipate any difficulty would be experienced in coming to a satisfactory arrangement whereby any fish caught by the trawler would be taken over at specified rates by one or more curers and cured by them, thereby relieving the Government of much trouble and risk.

The Sinhalese fish contractors are an enterprising class, endowed with keen business aptitude. I believe that they require only a demonstration of the lucrative character of trawling as a source of supply for their fish-curing yards to induce them to take the matter up on their own account. We have the precedent of other Governments before us, precedents which show that the work suggested lies well within the sphere of duties devolving upon the administration of a progressive Colony.

IV.—CULTURE OF THE BANKS.

It is unnecessary here to do more than give a brief summary of this branch of my work during the past fishery, as a separate and detailed report will be furnished at the close of this year, when, after visiting the banks in November, I shall be in a position to record whether their condition shows any improvement consequent upon the means taken to such end during the past fishery.

The work done falls under three heads :—Transplanting, thinning out, and cultching.

(*a*) *Transplanting.*—For some time after the beginning of the fishery there was no suitable place whereto young oysters might be transplanted ; accordingly, the ss. "Violet" was very profitably employed in dredging mature oysters until the time came when the central portion of the South Cheval Paar was fished sufficiently bare by the divers, and thereby rendered fit to accommodate a new generation. From 15th March until the end of the season I caused the "Violet" to dredge over the South Moderagam Paar, where is the greatest profusion of young oysters, and to transfer what were dredged to the South Cheval. Twenty-one days in all were devoted to this work, the result being that a small bed of healthy six months old oysters has been formed at the spot named. The number transplanted amounted to a total of 10,120,000.

Prior to leaving the banks I directed the Government divers to examine the area in question. They reported young oysters apparently numerous; the individuals they brought up were in good health, exhibiting no ill-effects consequent on the transplanting operation. Some had attached to fragments of cultch rubble laid out during the course of the fishery.

(*b*) *Thinning out.*—This operation went on concurrently with transplantation, the abundance of young oysters on the South Moderagam being so inordinate as to constitute, through overcrowding, a grave danger to their own continued prosperity. Transplantation, by entailing a reduction in the numbers upon the South Moderagam, should react favourably, and if the density of population be found still too great when next the bed be inspected, further transplantation should be resorted to. So great is the present profusion that the numbers taken in the dredges upon the last day appeared as great as on the day transplantation was begun, and indicated no appreciable diminution in the fertility of the bed.

(c) *Cultching.*—During the fishery a quantity of rubble obtained from the indurated limestone strata of Kayts, near Jaffna, was laid down, principally upon the sandy portion of the South-Central Cheval, a region which has never yet yielded a pearl fishery. The quantity contracted for was 180 cubes; unfortunately the contractor experienced such difficulties in obtaining vessels to convey the stone to its destination that he was able to deliver less than half the specified quantity although I helped him materially by extending the time limit by a week.

The stone, on the whole, was satisfactory in quality, and likely to prove a durable cultch material. In size the blocks approximated 3½ in. by 3½ in. by 2½ in., but several consignment, contained a proportion of blocks of excessive dimensions, and these I rejected.

The total amount laid down was just under 300 tons. Some 40 tons of the friable semi-calcareous sandstone of Kalpitiya was also used. The greater part was deposited on the South-Central Cheval, some 20 tons on a sandy patch near the centre of the South Cheval, and about the same quantity on the north-east quarter of the South Moderagam Paar, a locality where there is no outcropping rock on the bottom. Several times towards the end of the fishery I received fragments of this cultch from the divers with young oysters attached to the surface.

V.—MISCELLANEOUS.

(a) Inspection of Sea Marks.

During the course of the fishery I employed Sundays, the only free time at my command, in an inspection of the beacons and marks which serve to give bearings when searching for and demarcating pearl beds.

Karativu pile beacon, erected over twelve months ago, is in good condition, save for the slackening of two of the wire stays, a matter that will be put right at the first opportunity. No movement whatever of the piles has occurred; the structure retains its perpendicular with exactitude, especially satisfactory considering the severe weather it had to sustain during the past year and the short distance—six feet—the piles are driven into the shifting sand of the shoal. The depth of water remains the same as it was last year. The condition of the ironwork is satisfactory; during their spare time I employed a number of boatmen in scraping it and thereafter in applying two coats of paint. I propose in future to re-paint it twice each year, in November and in March.

Kutiramalai trigonometrical tower was visited in company with the District Engineer of Mannar, who wished me to point out a suitable site for the higher fishery beacon which it is proposed shall be built on Kutiramalai hill. A good path from the shore of Portugal Bay* leads to the old tower. I went provided with the necessary instruments wherewith to take a series of bearings and angles of the various other beacons in sight; to my great disappointment they could not be used, as jungle of 15 feet in height surrounded the base of the tower, while the rude scaffolding giving access to the summit was too rickety and rotten to permit of an ascent. A blank wall of jungle shut out the prospect on all sides.

I selected a site for the new tower about an eighth of a mile due north of the present one. I pointed out to the District Engineer the great advantages for observational purposes from the sea, if lanes be cut in the jungle in certain particular directions from the base of the beacon, say, one in line with the bearing of Karativu pile beacon (approximately N.W. by N.), another in line

* Portugal or Portugai?

with the cocoanut tope of Kurusadai Mondal on Karativu Island, bearing approximately W.S.W. A third might be cut due northwards. Such open lanes would render the beacon more conspicuous on the bearings of greatest importance and thereby increase its usefulness and diminish the risk of error, which hitherto has been so great as to contribute to the occasional loss of a fishery.

I strongly recommend that a permanent stairway be constructed within or around the new tower to give ready access to the summit, that observations may be made therefrom when necessary. Possibly an iron ladder would suffice.

Kallar beacon is in good condition, and one of the most useful marks we have.

Kurusadai Mondal was also visited. The bearing of Kutiramalai tower was taken from the cocoanut tope there; it was found not to coincide with that given on the fishery chart, thereby confirming my belief that there is an error in the construction of the latter, one that calls for the attention of the Survey Department at an early opportunity.

(*b*) Deficient Watering Facilities for the Fishery Steamers.

The lack of suitable facilities for the supply of water to steamers and other vessels employed in work on the pearl banks remains the one great disadvantage pertaining to Marichchukkaddi as the headquarters of the pearl fishery. No arrangement whatever exists to convey water from any of the tanks to the beach; as a consequence vessels are under necessity to proceed to Silavaturai for this purpose, or else a special boat has to be chartered as water tender.

The latter alternative was employed during the recent fishery, but the arrangement proved wholly inadequate to meet requirements, the service being carried out inefficiently by the boatmen employed. The latter were, I understand, Government employés brought from Paumben; lazier and more troublesome men I have seldom met. Not only did they take an inordinate time over each trip, but constant watch had to be maintained lest they supplied a mixture of salt and fresh water. They did supply this abominable mixture on two occasions at least, to my personal knowledge, vouched for by taste and by hydrometer!

Instead of five trips in two weeks, which might easily have been made, there were several occasions when they came but once in the whole week. Fines imposed by the Government Agent appeared to have no effect, and eventually the whole crew deserted. The service was the source of continual trouble and anxiety to me; I was ever in fear lest the work of the "Violet" should be interfered with because of the shortage of water. As it was, the launches could never obtain a supply from the water boat, and were under the necessity to go periodically to Silavaturai to water. As a consequence quite a considerable proportion of their services was frittered away amounting approximately to one-eighth of their time. As their charter cost Rs. 175 per day, the water service by its inefficiency became in consequence an extremely costly one.

The remedy lies in the construction at Marichchukkaddi of a pipe line from one of the tanks to a small reservoir near the shore, where water casks might be filled and rolled thence to the beach. The cost of this would be comparatively little, and fully covered in one fishery by the saving effected by the non-employment of the present water boat service and by the increased efficiency of the steamers engaged in the fishery service.

(*c*) Experiments in Net Preservation.

In January of this year, while living at the fishing station on Dutch Bay spit, I obtained much preliminary knowledge of nets and fishing methods. Among other items I found that the men employ no special preservative for many of the finer nets, especially those of the kind known as "gill-nets"; mangrove cutch (*kadul*) used for the stronger nets cannot be employed because of the objectionable dark brown-red colour which it imparts, and which would scare fish away.

I remembered that the sardine fishers of the French coast, who employ gill-nets in their work, are reported to use nets tinted either blue or green; it occurred to me that the solution which gives a pale green colour to Willesden canvas, and which is employed not because of the colour, but on account of its preservative qualities, would be very suitable for applying to our local gill-nets, and would have the double advantage of ensuring less visibility and of serving as a useful and much-required preservative. Having knowledge of a method giving a similar colour and rot-proof quality, I explained it to the Sinhalese fish-curer with whom I was staying; he welcomed the suggestion, and promised to make practical experiments upon his own nets if I would obtain the requisite materials and show him exactly how to proceed when I should meet him at Marichchukkaddi during the fishery.

Accordingly, I demonstrated the method one Sunday in March, greatly to the satisfaction of the assembled fishermen, who were especially pleased with the resulting colour. Indeed, I suspect they think more of this attribute than of the preservative quality of the method. I divided the materials I had left among them, and left full instructions written in Sinhalese. They on their part promised to furnish me with particulars of the results obtained. One of the inspection coxswains has also been shown the method, and as he has the control of many fishing nets at Kilakarai and is a most intelligent man I expect a valuable report from him in the course of a few months. I can rely upon him giving the method a fair trial.

(*d*) Biological Notes.

I propose to incorporate the details of biological work carried out on the pearl banks during the fishery in an annual report to be issued at the end of the year, as the publication of results at intervals of twelve months has many advantages over a more frequent issue of observations that must in consequence be frequently incomplete. It will suffice for the present to say that valuable additions were made to the data being accumulated with regard to the rate of growth of oysters on the different banks: hundreds of measurements were made and recorded, together with weights and other particulars. Regular examination and dissection of samples of oysters from the different localities inspected and fished were carried out, and several interesting new facts were made out in regard to the diseases and parasites of the pearl oyster as well as some additional points in anatomy.

(1) *New Parasites of the Pearl Oyster.*

Two new parasites were found, one a small species of leech adhering to the edge of the mantle, the other an immature stage of a new species of Tetrarhynchid worm living in the middle region of the intestine. It is of a smaller size than the young of *Tetrarhynchus unionifactor* common in the same host, differing from the latter in the hooks arming the introverts being conspicuously slender, of a different form, and more numerous. The surface of the body is smooth and entirely free from warting, so characteristic a feature in *Tetrarhynchus unionifactor*.

The life-history of this latter worm was advanced another stage; I found immature individuals present within the second or ascending portion of the intestine in two out of every three pearl oysters examined. All were of the same form and size as those which I have taken from cysts previously. They lie in the intestinal cavity anchored by means of the proboscidial hooks to the intestinal wall; this discovery confirms the opinion expressed a year ago,* that this armature is probably already functional while yet the parasite is lodged within the oyster. The meandering pattern upon the surface of the narrow terminal region of the body was well shown in all, while the immobile bristle-like cilia already signalized as present upon the posterior extremity were clearly seen in some. In others, however, the ciliation appeared absent, a fact which already had been remarked, and which had puzzled me greatly; the explanation is that the large excretory cloaca which exists there, and into which the excretory trunks open, is lined with stiff cilia and is more or less eversible. When partly everted the spinous cilia show as a crown around the posterior extremity in

* Shipley and Hornell, "The Parasites of the Pearl Oyster," p. 85, in Part II. of Professor Herdman's "Report on the Pearl Oyster Fisheries of the Gulf of Manaar," London, 1904.

the manner depicted already in various drawings.* Much attention was also given to the entozoa of fishes: a great number of specimens were collected and drawings made thereof. The report upon the collection will appear in Part IV. of Professor Herdman's "Report on the Pearl Oyster Fisheries of the Gulf of Manaar."

(2) *Function of the Crystalline Style.*

Observations made during dissections of pearl oysters upon the relationship existing between the anterior extremity of the crystalline style and the contents of the stomach have fully satisfied me that Barrois' view of the function of this style—a view hitherto considered doubtful—is undoubtedly the correct one. Thus, specimens examined within a few minutes after being taken from the sea showed, when opened carefully, the anterior extremity of the style surrounded by a sub-globular bolus of food material permeated with viscous matter, which imparted loose adhesion between the food particles. The appearance was as in the annexed figure (fig. 1). The apical part of the style when freed from the adhering food particles is distinctly attenuated (fig. 2), exactly the appearance we should expect to see if a gradual wasting process be in operation. So thoroughly permeated is the bolus mass capping the anterior end of the style with the viscous waste of the latter that I was enabled to remove and preserve the bolus *in situ* on the style in several instances. This positive observation must be considered in conjunction with the fact that out of hundreds of living oysters examined immediately after removal from the beds, and including individuals diseased as well as healthy, not one was found to be without a crystalline style of normal form.

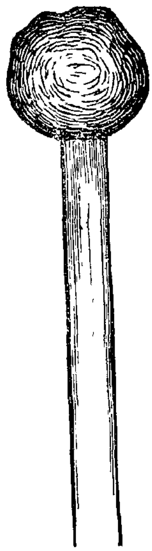


Fig. 1

Fig. 2

These facts go far, I think, to establish the truth of Barrois' theory, that the function of the style is to yield a viscous material for the binding together of food particles within the stomach into a bolus-mass, wherein the sharp points of sponge-spicules, diatoms, and the like may be lost and rendered harmless to the delicate wall of the intestine. Compare the analogous secretion of mucus matter by definite regions of the alimentary canal in the case of certain fishes which feed upon lamellibranch molluscs, and which thereby injest large quantities of sharp-edged shell fragments.

* *Loc. cit.* pl. II., figs. 19 and 20.

(3) *Breeding-time of Chanks and Octopods.*

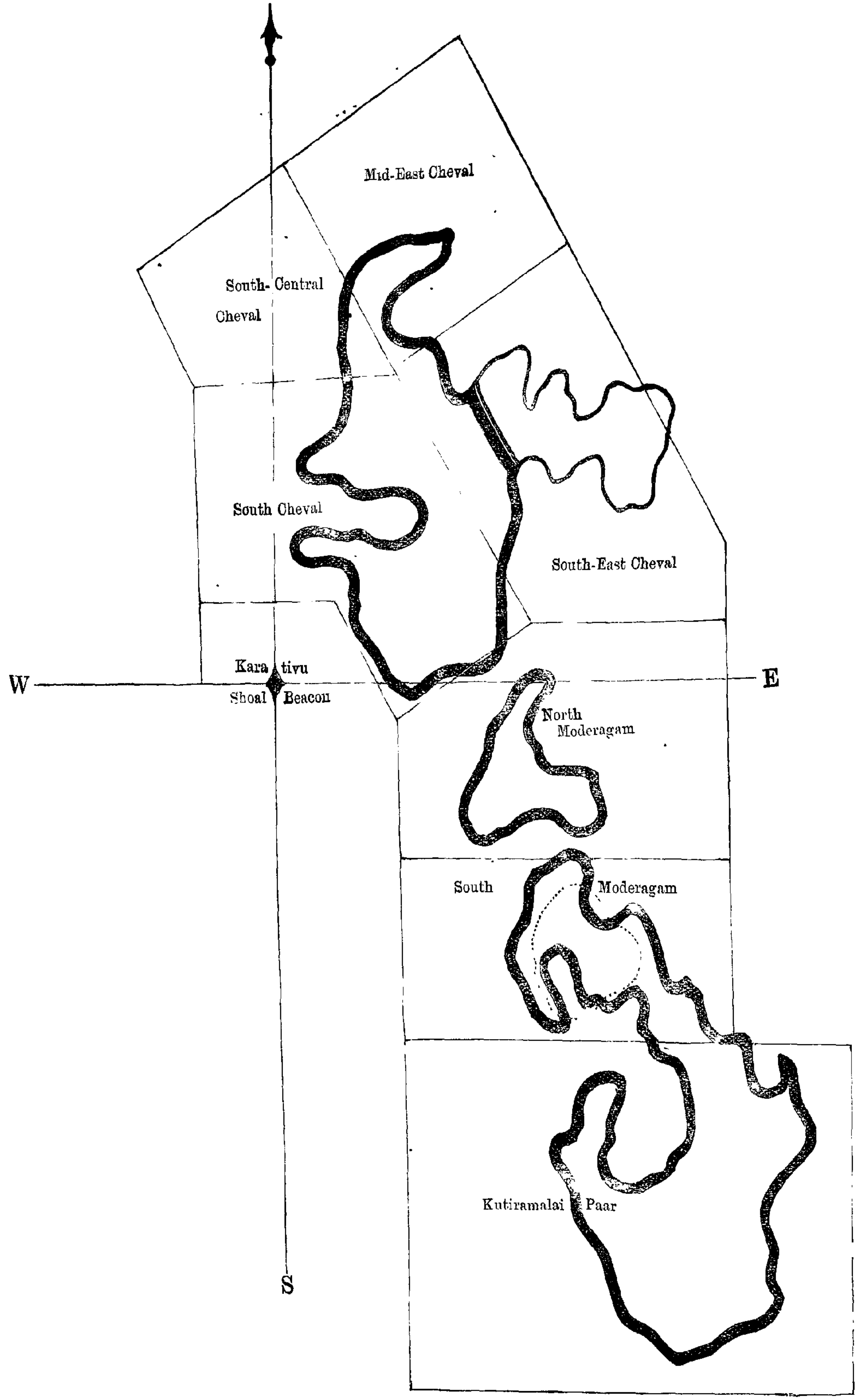
During February large numbers of female Octopod Cephalopods (*Polypus* spp.) were met with carrying strings of embryos; the ram's horn egg-capsules of *Turbinella rapa* (the common chank) were also common on the South Moderagam ground at the same time.

CONCLUSION.

In concluding this report I must not do so without expressing my very grateful thanks for the courtesy and consideration shown me by the staff ashore, and particularly by Mr. J. P. Lewis, Government Agent and Superintendent of the Fishery, who, with Mrs. Lewis, was ever mindful of the discomforts of life afloat, and did much to lighten the monotony which is inseparable from shipboard conditions. I have also to record my satisfaction with the way in which my clerk, Mr. F. O. Assauw, and the four inspection coxswains performed their respective duties. I should add that the latter had a considerable accession of work during the fishery, as I laid upon them the charge of attending to the proper disposal of cultch rubble over specified areas.

JAMES HORNELL,
Government Marine Biologist and Inspector of Pearl Banks.

Colombo, May 17, 1905.



Sketch Plan of the Fishing Ground of 1905.

Scale :—One nautical mile to the inch.

Explanation.—The thick lines show the area fished in 1905; the thin line the area remaining unfished (the oysters thereon are now 3½ years old); and the dotted line the ground occupied by six months old oysters on the South Moderagam Paar.

No. 4.

REPORTS ON THE MARINE ALGÆ OF CEYLON.

No. I.—ECOLOGICAL AND SYSTEMATIC STUDIES OF THE CEYLON SPECIES OF CAULERPA.

By NILS SVEDELIUS, Ph. D.,
Docent in Botany at the University of Uppsala.

I.—INTRODUCTION.

The investigation of the marine flora of Ceylon, of which this is the first part published, was carried out by myself during the years 1902 and 1903 with the help of a grant from the Regnell Botanical Travelling Scholarship at the University of Uppsala. My stay in the island lasted, with a short interruption, from November, 1902, to August, 1903, and for the greater part of the time I stopped at Galle, on the south coast, which place showed itself to be the most convenient centre for algal studies in Ceylon. Thus, here are to be found close under the ramparts one of the greatest coral reefs in Ceylon, which together with the rocks adjacent offers a rich marine flora living under partly varying external conditions, and at the same time a rich material for studies in various branches of algology. Here, too, I had the great advantage, through the courtesy of the Ceylon Government, of being allowed to carry on my investigations in the newly established Ceylon Marine Laboratory, by which my studies were greatly facilitated. It is with great pleasure that I seize this opportunity of expressing my sincere thanks to Mr. James Hornell, F.L.S., Marine Biologist to the Ceylon Government and Inspector of Pearl Banks, for the never-failing interest he showed and the great assistance he afforded me in the prosecution of all my algal investigations in Ceylon.

After making myself tolerably familiar with the Ceylon marine flora within a limited district, I extended my knowledge of the algal vegetation by journeys along the coast. So I visited Weligama, Matara, Dondra Head, and Tangalla, in the south; Gintota, Ambalangoda, Kosgoda, Bentota, Beruwala, Colombo, and Negombo, in the west. The marine vegetation in the north of Ceylon is known to me by studies at and excursions about Jaffna and by visits to Paumben on the Island of Rameswaram. This little island does not belong to Ceylon, but to India; its situation, however, since it bounds the Gulf of Mannar in the north, justifies it in being included in the Ceylon marine flora district. The vegetation of the east of Ceylon is known to me through a lengthy stay at Trincomalee, on the east coast. Naturally, it was predominantly the littoral flora that was the object of my studies. As far as was possible for me I tried, by dredging, to get to know the sub-littoral vegetation; but my knowledge of it is unfortunately rather fragmentary, since dredging required a much more complicated apparatus than was at my disposal. Dredging, moreover, is exceedingly difficult to carry out on the open Ceylon coasts with their often difficult bottoms, the more so as the outrigger canoes of the natives are too narrow a craft for such work, which requires broader and more roomy boats. At smaller depths one can conveniently make use of native divers, but the yield from this source is invariably poor. My knowledge of the sub-littoral flora is thus rather fragmentary, and the best material I got from deeper water came from the pearl banks in the Gulf of Mannar, and for that I am also indebted to Mr. HORNELL, who collected it during his official journeys for the study of pearl oysters.

Important sources for studies in the marine flora of Ceylon are the collections of HARVEY and FERGUSON. W. H. HARVEY stayed in Ceylon from September to December, 1853, and visited Trincomalee, Weligama, and Galle. Of his collections, which are preserved in Trinity College, Dublin, there are duplicates in the collections of the Royal Riksmuseum in Stockholm and in the Algal Herbarium of J. G. AGARDH in Lund. The rich collections of marine algæ made by W. FERGUSON are preserved in the British Museum, but duplicates of them are also in the Herbarium at Peradeniya and in the Herbarium of J. G. AGARDH in Lund. Through the courtesy of Dr. J. C. WILLIS, Director of the Botanic Gardens, Ceylon, the FERGUSON collections in the Peradeniya Herbarium were placed at my disposal at Uppsala, and this considerably assisted me in my studies. I am deeply indebted to Dr. WILLIS for this material help From the Botanical Museum of Copenhagen and from the Botanical Department of the Royal Riksmuseum in Stockholm I was also allowed to borrow rich collections of Caulerpas, which were kindly lent me as material for comparison, and for which I here beg to thank the Directors of those Institutions, Professor E. WARMING and Professor C. A. M. LINDMAN Finally, I beg to express my thanks to Professors O. NORDSTEDT, B JÓNSSON, and S. MURBECK in Lund for their kind assistance during my studies in J. G. AGARDH'S valuable Algal Herbarium in the same town.

The extent of my material has forced me to publish my studies in several parts, and if I begin with *Caulerpa* it is because the plants of this genus, interesting from so many different points of view, have hitherto been studied so little in their natural state from an ecological point of view—*i.e.*, their biology. Hence it seemed to me that a real gap in our knowledge of these interesting plants remained to be filled, and that this should be done as soon as possible. It is clear that a study of this nature introduces such difficult questions as the relationship and variation of the species, their geographical distribution, and the like. To try to give an account of the Ceylon Caulerpas from these points of view is the aim of the present essay.

Uppsala, April, 1906.

II.—ON THE MODE OF LIFE OF THE CAULERPAS.

The Relation between Habitat and Organization.—Do Caulerpas show any Examples of Adaptation?

1.—DO ALL CAULERPAS GROW UNDER SIMILAR EXTERNAL CONDITIONS?

Concerning the ecology of the Caulerpas, there are in botanical literature very few, indeed practically no reports. This may be chiefly attributed to the fact that so many of those who have studied the tropical algæ had no opportunity themselves of observing them in nature, but examined them exclusively from material collected by others. Thus, for instance, C. A. AGARDH and J. G. AGARDH, who were the first to give a detailed monographical account of the genus *Caulerpa*, had themselves never collected or even seen any living Caulerpas.

On the other hand also, the algologists who, as HARVEY, had themselves travelled and collected much, only devoted themselves casually to the observation of the habitats of the algæ, of which, as a rule, only short notices were communicated.

Of those who, more recently, have dealt with the Caulerpas monographically, Madame WEBER v. BOSSE and Professor REINKE, only the former had collected her material herself, during travels in the Tropics; but still it is remarkable how entirely her great work, "Monographie des Caulerpes," is lacking in information about the habitats, vertical distribution, &c., of the different species. Hence, too, it is fully explicable that Professor REINKE, in his discussion of the Caulerpas, almost starts *a priori* from the assumption that they all live under practically quite similar circumstances. Thus, in speaking of the problem of the surprising diversity of the organisms ("Ueber Caulerpa," pp. 55, 88), he mentions precisely the genus *Caulerpa* as an example of a large genus with some 50 species that offer considerable dissimilarities, but which nevertheless live among identical external conditions. The differences between the species are therefore not to be considered as due to adaptations, and in this he finds a support for his theory of exclusively inner causes, "determinants," for the motley multitude of the organisms. As a kind of confirmation of how this conception of the independence of external conditions among the variable Caulerpas prevails in literature, we may mention what Madame WEBER V. BOSSE in a later work ("Etudes sur les Algues de l'Archipel Malaisien," p.128) has uttered in connection with the question about the vegetative propagation of these plants "La facilité avec laquelle les Caulerpes se multiplient végétativement et *varient sous des influences qui échappent à notre perspicacité** est à mon sens indice de plus qu'une reproduction sexuée ou par spores leur fait défaut."

OLTMANNS however rightly points out (in "Morphologie und Biologie der Algen," I., p. 312) that in this matter we must, for the present, bide our time until the different species have been studied in detail in their natural localities, as well as the external factors that affect them there.

That Caulerpas actually live under very different conditions can already be concluded from various notices in the literature of the group Thus, for instance, the only European species, *C prolifera*, which was almost exclusively the form that was the object of detailed investigations and which has therefore been the physiological *Caulerpa par préférence* and has been made the type for the whole genus, is in the Mediterranean apparently a pronounced still-water form, which even if it can occur at the surface (0·5 metre BERTHOLD) yet seems to prefer deeper localities down to a depth of about 15 m.† That it lives under the same conditions in the West Indies follows from COLLINS's note (in "The Algæ of Jamaica," p. 245), that it is not to be found at Jamaica except washed ashore. On the other hand, there are notices in literature about other Caulerpas, which tell us that they live on rocks amongst corals or also in pools; of others, again, that they live in sand and mud, often at no considerable depth (cf. for instance, the above mentioned paper of COLLINS; REINBOLDS; the Marine Algæ in "The Flora of Koh Chang"; A. VICKERS' "Contributions à la Flore algologique des Canaries" and "Liste des Algues marines de la Barbade," &c.).

Therefore, to judge from certain statements in the literature, the Caulerpas do not live under such quite *identical external conditions* as is commonly supposed And that the Ceylon species of *Caulerpa* occur to some extent under greatly different external conditions, and that this, in its turn corresponds with evident differences in organization, I hope to show in the following pages.

In examining whether, among a group of plants, the different forms or species really show examples of adaptations to their surroundings, or to employ a term first used by DETTO, they are ecologisms ("Okologismen"), we can proceed in different ways Since, just as in the following case, direct experiments were out of the question, the comparative method is the only one which analytic ecology can adopt We can, then, compare either widely different species, *i.e.*, such as have different characters of organization ("Organisations-Merkmale" to use NÄGELI V. WETTSTEIN'S expression), but which still live amid similar surroundings, in order to examine whether, besides these characters, others of similar kind (*i.e.* adaptations to the similar surroundings) occur; or, following DETTO, examine whether they may be examples of ecological convergence (DETTO, *loc. cit.*, p. 146). But we can also go to work in another way; we may compare one species, which occurs very plentifully in one district in many forms and amid different surroundings, in order to study the changes it undergoes in the different situations and endeavour to find out whether these may be considered as adaptations to environment.

Of the some 20 species of *Caulerpa* that I found in Ceylon, some are very rare and to be met with in only few specimens; others, it is true, have very limited distribution, but show abundant local occurrence; some, finally, are very widely distributed, and occur in plentiful closely related forms which are hard to distinguish. To the very rare species which are only found in scanty specimens

* Italicized by the author of the present paper.

† FALKENBERG mentions *C. prolifera* in the Gulf of Naples at a depth of from 2-15m. Cf also A. VICKERS "Contribution à la Flore algologique es Cdanaries," p. 30.

belong, for instance, *C. scalpelliformis*, *Freycinetii*, *cupressoides*, *Fergusonii* In abundant individual occurrence, but with very limited distribution, we have *C. verticillata* and *lætevirens.* Lastly, to the commonest and most widely distributed belong *C. clavifera*, *uvifera*, *peltata*, *imbricata*, and others; in a word, all those species belonging to the very critical *racemosa group*, according to WEBER v. BOSSE's definination, a variable group very difficult to define.

If we compare the different situations in which the Ceylon species of *Caulerpa* grow from the point of view of the character of the substratum, we shall find in a preponderating number of cases that it consists of firm rocky or coral ground. But, very commonly, too, *Caulerpa* grows on soft bottom, in sand or coarse gravel formed by decomposition products of the reefs, remains of corals and lithothamnia, or again in soft mud carried out to sea by rivers and streams

2.—DIFFERENT ECOLOGICAL TYPES AS DISTINGUISHED BY VARYING DEVELOPMENTS OF THEIR ROOT-SYSTEM.

(A.) *C. verticillata type.*

Do the Caulerpas show any differences in their organization and mode of growth upon the different bottoms ?

Let us first examine *C verticillata* (fig. 1), which I observed at the mouth of a river on rocks partially and at times, during the south-west monsoon, entirely covered by sand and mud carried out to sea, as was the case at Galle. The tufts grow in very thick masses which all arise from more or less deep growing axes, now horizontally (fig. 1*a*), now obliquely growing upward (fig. 1*b*), and which higher up form side axes which grow out horizontally. Evidently this mode of growth is very favourable to a *Caulerpa* growing in localities exposed to the danger of being covered by sand, and this whole mode of growth is quite analogous with that of the dune grasses or certain bog mosses, which are characterized by a continuous succession of dyings-off in the basal parts in proportion as they sink deeper down. This comparison, first suggested by REINKE, is really very striking, and is strengthened by the fact that down in the mud we find remains of verticil branches which have been killed and buried in the sand.

Through the stimulus to upward growth which the over-sanding exercises, this plant can always keep its assimilation branches in the light where they stick up out of the mud and wave to and fro in the swell. Thus *Caulerpa verticillata* seems to show, in its system of shoots, an example of an organization adapted to the surroundings in which it lives. The information about the situations wherein this plant lives in other countries is very scanty. Both JOHS. SCHMIDT ("Flora of Koh Chang," IV., p. 104) and COLLINS ("Algæ of Jamaica " p. 245) only mention that it grows on coral reefs without any further specification.

Mlle. VICKERS (" Liste des Algues marines de la Barbade," p. 57) only says, " Flaques, abritées, à basse mer." Remarkable, on the other hand, is COLLINS's note on the *f. charoides*, which is closely related to the main species, *C verticillata* He says of it (*loc. cit.*, p. 245) that it grows " in soft mud near Mangrove swamp," consequently in localities to some extent similar to those where *C. verticillata* occurs at Galle. But if, in other respects, there can be discovered any analogies in the formation of the shoots, cannot of course be determined as far as this form is concerned, any more than is the case with the other related Caulerpas belonging to the *Vaucherioideæ*- and the *Charoideæ*-group, all of which are distinguished by finer and weaker shoot systems than are to be found in other Caulerpas. In *C. verticillata*, therefore, we have found a type of *Caulerpa* which grows in soft, muddy bottom, where the danger of oversanding is present, and I have not seen another *Caulerpa*-species in Ceylon belonging to the same biological group, nor do any other Caulerpas occur together with *C. verticillata* in the localities where it grows.

(B.) *Sand Caulerpas.*

Another type of the Caulerpas that grow in a movable substratum is represented by such species as *C. Freycinetii*, *cupressoides*, *Lessonii*, and *Fergusonii*. The figure of *C. Lessonii* (fig. 11) gives us a good idea of this rhizome type, which seems to be rather common among the Caulerpas and of which

REINKE has figured several, as, for instance, *C. flagelliformis* (REINKE, *loc. cit.*, fig. 10), *prolifera* (fig. 11), *Freycinetii* (fig. 38), *paspaloides* (fig. 52), and others. The characteristic of these species is that the rhizome is rather coarse, sparsely branched, grows more or less deep in the sand, out of which only the assimilation branches stick up in long rows, with small or great intervals between them. Of *C. Freycinetii* we consequently only see as it were ball-shaped bundles of assimilation branches entangled together. In Ceylon this type of *Caulerpa* is only met with in the north, around Adam's Bridge and the islands about Jaffna, where the shore is always sandy. On the coral reefs and rocky shores of the south-west, this type is scarcely to be met with. To judge from certain indications, this *Caulerpa* type consists chiefly of still-water forms, which therefore often prefer somewhat deeply situated habitats. Thus *C. Lessonii* has only been observed on the pearl banks at a depth of several metres. *C. Fergusonii*, too, does not belong to the upper littoral zone, either. *C. Freycinetii* has been collected by me in the upper littoral zone, it is true, but since it only appears there occasionally we are tempted to assume that its main distribution lies deeper down. That this is not a mere chance guess, and that it has some justification is supported by the fact that JOHS. SCHMIDT collected *C. Freycinetii* in the Gulf of Siam at no depth less than 2 metres, and as for *C. cupressoides* we are told that it occurs in such localities as lagoons (BÖRGESEN), which points to its being a still-water form.

Besides being distinguished by its mode of growth—*i.e.*, half hidden in the sand—this type is distinguished also by its root branchlets being very long and especially very closely and finely branched, and between the fine root branches the particles of sand are pressed so tight that large lumps accompany the plant when it is pulled up from the bottom. REINKE has described this type and given several illustrations of it in his paper (*loc. cit.* figs. 20, 38, 42, 52, 73). As ecological adaptations to the conditions of the life of these plants in the sand, we may consider their long-creeping rhizome axis and especially the development of their root system. Such repeated branching in a great number of fine filaments which fasten themselves firmly to the grains of sand may be taken as an excellent anchoring apparatus for a plant living on a sandy bottom. *In this type there is no organization of the shoots to neutralize the danger of being oversanded*—a danger which is not to be feared in such places as those where this plant is to be found. Approximating to this type are such species as *C. crassifolia*, *C. dichotoma* (fig. 23), *C. uvifera* (fig. 15), and others, which if not invariably, at least most generally, have a mode of growth analogous with that of the sand Caulerpas just described.

(C.) *Rock and Coral Caulerpas.*

The most numerous Caulerpas belong to a group which grows preferably on stones, corals, and in general, fixed substrata But here the conditions may be of most dissimilar nature, owing to the different degrees of exposure to the swell, to the other local conditions affecting vegetation, to the presence of Actinians and living corals, and so forth.

(*a*) *C. lætevirens type.*

Among these rock Caulerpas, *C. lætevirens f. laxa* (fig. 19) takes a unique position inasmuch as this species grows by preference in exposed localities, where it constitutes the sole vegetation (forming a special *C. lætevirens* association), and covers large areas, as at Galle, on the boulders north of Victoria Park.

C. lætevirens f. laxa there forms a typical algal association of a kind that has been described from northern seas, and that has been called "boljslagsformationer" by GRAN ("wave-beat formations" is the literal rendering), in "Kristianiafjordens algflora," p. 9. Such formations or associations are, for instance, the *Nemalion* formation of the west coast of Sweden (KJELLMAN, "Algenreg. und Algenformationen," p. 11), the *Bangia-Urospora* association of the Faeröese coasts (BÖRGESEN. "The Algæ-Vegetation of the Faeröese coasts," p. 719) and the *Gobia-Dictyosiphon* formation from the Baltic (SVEDELIUS, "Ostersjóns Hafsalgflora," p. 29). What characterises all these formations* is that they are very exposed to the swell and hence are in continual movement, waving to and fro, covered one moment, free the next, in never-ceasing alternation.

* This use of the term "formation" is analogous with the sense in which it is employed in Geology.—ED.

Such algæ must, of course, be firmly fixed to their substratum. Whereas the European forms of this type are characterized by smaller or greater adhesive discs, *C. lætevirens* has quite a different method of fastening to the rock. In this we find, as in the other Caulerpas, a creeping rhizome, but here much more developed than in the species in general. The assimilation axes, on the other hand, are few and placed at comparatively long intervals, and hence the root system, since it develops numerous fine root branches that fasten themselves to the smallest crevices, corners, or irregularities in the rock, becomes in these plants, in proportion to the assimilation system, much greater than in the other *Caulerpa* species. To this must be added—and this seems to me by no means the least characteristic feature of this species—that the assimilation branchlets or pinnules have a strong tendency to grow out into root-forming branches (fig. 19), whereby the whole plant is still more firmly fastened to the rock. That assimilating shoot branches change their character, become procumbent and take root, is, as Weber v. Bosse has pointed out (" Monographie des Caulerpes," p. 249), not a rare phenomenon. I have given a picture of such a case in *C. Fergusonii* (fig. 51 a, b). But in *C. lætevirens* it is the branchlets or pinnules (fig. 19, f–i) that grow out into haptera-like rhizomes, and this has become very common in this particular species. As for the shoot system in general, we refer to the description of this species in the special section of the present work. That all this organization is highly advantageous to a species exposed to strong swells, and to the resultant danger of coming loose, is evident; and *C. lætevirens f. laxa* must therefore indisputably be considered as an ecological adaptation to such surroundings.

Very remarkable is the changed appearance this plant assumes (figs. 21 and 22) when it grows in somewhat deeper localities not so directly exposed to swells. I have called this biological form *f. cæspitosa*. It becomes tufted owing to the assimilation branches growing very close together. They are moreover shorter, coarser, and especially more rigid (fig. 22), so that they cannot wave to and fro in the water. To this contributes also the fact that this *f. cæspitosa* grows squeezed between other tufted algæ. Its rhizome and root system are normally developed, not stronger than in the other Caulerpas, and the branchlets, moreover, show no tendency to grow out into root-taking branches. The small, short assimilation-branches are not so pliant in *f. cæspitosa* as in *f. laxa*, but more rigid. They are often clavately swollen at the tops, or sometimes flattened. In the last-named case torsion often occurs (fig. 22, b, c), so that the flattened sides are turned up to the light. It is evident that both the clavate form and the torsions of the branchlets produce the same effect, viz., as great a number of chloroplasts as possible are exposed to the light falling from above. It is interesting that this happens only in *f. cæspitosa*, the rigid form with the stiffer branches. The *f. laxa*, on the other hand, in which the branches wave to and fro, thereby receiving the light from every side, shows no such peculiarities in the organization and position of the branchlets. In this, too, both these forms show differences in their organization that are to be looked upon as ecological adaptations.

We shall reach a similar conclusion if we compare *C. lætevirens* with *C. dichotoma* (figs. 23, 24). As will be pointed out in the more detailed description of this species, it is closely allied to *C. lætevirens*, from which it differs chiefly in its broad flattened dichotomous assimilation branches, commonly arranged in two rows along the main axis. This organization means a considerable increase in the assimilating surface, but at the same time it entails a number of disadvantages to an alga exposed to strong swells. *C. dichotoma* is consequently not found in the upper littoral region in places which are so characteristic for *C. lætevirens*, but at Weligama it grows at a depth of about 2 metres on sand. The horizontal axis and the root system also corresponds far more in coarseness with the sand Caulerpas than with the fine creeping axis of *C. lætevirens*.

Also in *C. dichotoma* the easy transition from assimilation-branches to haptera is entirely lacking, the reverse of the case in *C. lætevirens*, wherein this is so closely connected with its mode of growth. Hence, we see that the characters of these related species are undoubtedly in complete correspondence with their mode of growth and with the closely connected surroundings.

It is remarkable that *C. lætevirens* seems to live under similar conditions on the coast of Western Australia as in Ceylon Thus HARVEY says (in "Phycologia Australica," I., Pl. XXX.) about *C. cylindracea*, SOND. (= *C. lætevirens f. cylindracea* (SOND) WEBER v. BOSSE) : "This plant is excessively common on all the reefs at Rottnest Island, growing in shallow, exposed tidepools, as well as in sheltered spots below low-water mark, and it varies much in luxuriance according to the locality."

From these remarks it follows in any case that *C. lætevirens* in Australia forms a special association with its environment, especially in exposed localities, but that it also grows in deeper and more sheltered places. And, just as at Galle, the different forms also seem to be dependent on the different localities. In what way these make their influence felt HARVEY does not mention. He only speaks in a few words of the variation of *C cylindracea* "in luxuriance according to the locality."

(*b*) *The remaining rock and coral Caulerpas.*

If, now, *C. lætevirens f. laxa* is a pronounced, even though rare, example of a rock *Caulerpa* growing in strongly exposed localities where no other alga happens to occur, on the other hand we find a preponderant number of other species also growing on rocks, but in more sheltered places, where they occur in company with other algæ, and especially with living corals and small Actinians.* I have frequently observed that amongst living corals and Actinians the Caulerpas must be considered as a characteristic occurrence. With their long rhizomes they creep among the Actinians, and only the assimilation branches are visible where they shoot up between the animal colonies. Such is the case with several forms of *C. clavifera*, *nummularia*, &c. Especially noticeable is *C. longistipitata* (fig. 45) with its long rhizomes creeping on rocks and among other algæ, even if it does not occur on such strongly exposed localities as *C. lætevirens f. laxa.* All these have a root system without the very fine branching present in the sand Caulerpas, the root-branches, on the contrary, are fewer but coarser, and often as if flattened at the top where they are fastened to the stones But that there is no hard and fast difference between such a root system and the one that occurs in the sand Caulerpas is best proved by the fact that the same species has now the one, and now the other, depending on the substratum. REINKE has already pointed this out (*loc. cit.*, p. 58).

3.—DIFFERENT ECOLOGICAL TYPES AS DISTINGUISHED BY THE VARYING DEVELOPMENT OF THEIR ASSIMILATION SYSTEM.

If, then, as we have already seen, there is a great difference in the root systems or adhesive organs in general, at least within certain *Caulerpa* groups, the difference is much greater in the assimilation branches and the shoot system It is really with reference to this difference that REINKE ("Ueber Caulerpa," p. 67) seems to have been led to the opinion that the genus *Caulerpa* offers a special point of interest, because it shows that even under similar external conditions and with essentially similar inner organization, the external form can yet be variable. "Alle Caulerpen sind dem Lichtleben in Wasser angepasst: jede Art ist ein Spezialfall dieser Anpasung, und alle sind verschieden geformt. *Diese Verschiedenheit beruht aber nicht auf besondere Anpassungscharakteren.*† Die Assimilationsarbeit lasst sich bewerkstelligen eben so gut mit gleichartigen feinen Faden der *C. fastigiata*, wie mit den breiten ungetheilten Blättern der *C. prolifera*, den grossen fiederspaltigen Blättern der *C. taxifolia* und den kleinen einfachen Blättern der *C. racemosa* und *Lycopodium*".... and again we read. "Wer es liebt, auf die Unterscheidung von morphologischen und Anpassungsmerkmalen Werth zu legen, der wird daher die Speziescharaktere von *Caulerpa* sowhol zu den ersteren wie zu den letzteren rechnen müssen." But none the less REINKE has a feeling of the possibility that the Caulerpas may be, for all that, more or less adapted in their main functions to their surroundings, and he adduces as an example how a fine-leafed species—as *C. hypnoides* — has greater possibilities of profiting by and making the fullest use of the light in every situation than for instance a *C. taxifolia* or *C. prolifera*, and these advantages show themselves chiefly in moving water.

* These are chiefly Zoanthids —ED.

† Italicised by the present author.

If we examine the assimilation system in the Ceylon Caulerpas, we shall find several different types and variations. They may be roughly divided into two groups, viz., such as have the assimilation system very strongly branched (always a system of short shoots, pinnules), and such as in their assimilation organs have a measure of correspondence with, or at least some outward resemblance to, the leaves of the higher plants. To the latter group belong such forms as *C. scalpelliformis* (fig. 2), *crassifolia*, *taxifolia* (figs. 4, 5), &c. ; to the former such as *verticillata* (fig. 1), *clavifera* (fig. 13), *uvifera* (fig. 15), *lætevirens* (fig. 19), &c. But a division of this kind is of course incomplete and vague. For it could also be expressed in this way : the one group (the leafy one) is characterized by its assimilation branches being bilateral, the other by its axes being radial But here it is to be observed that only the main axes are radial, the lateral axes or the short shoots may afterwards assume the most variable shapes. They, too, can be radial, *i. e.*, cylindrical as in *C. lætervirens f. laxa*, cylindrical with spherical point as in *C. loncistipitata* (fig. 45), *crassicaulis* (fig. 47), *clavifera*, *uvifera*, *&c.*; finally, disciformly flattened, as in *C. nummularia* (figs. 35, 36), *imbricata* (fig. 30), and others. The questions now arise whether in these various leaf and shoot forms we can see any adaptations to their different surroundings ; whether one can be considered in any way more perfect than another, or whether they are all equally good for the purpose, and whether really the great variability is only to be ascribed to formative energy in the plant that escapes our direct observation. We will deal with these in that order.

(A).—*The bilateral leaf-like Caulerpas.*

It seems to me indisputable that the leaf-like flat Caulerpas are derived from radial forms as being the more primitive ones ; that they are very closely related is shown already by such a species as *C. flagelliformis*, of which there are both radial and flattened forms, very similar to one another and often passing over from the one to the other. Such a fine leaf-like species as *C. prolifera* can even be transformed, as KLEMM has shown, into the cylindrical form, exactly in the same manner as several species of *Opuntia*.

A comparative examination of the assimilation axis of the bilateral species shows moreover that the bilateral axes are often radial at the base, and there form branchlets round the axis. This by no means rare case is illustrated in this work by *C. Lessonii* (fig. 11, the branches to the left of the picture), by *C. taxifolia f. tristichophylla* (fig. 5), and also by *C. dichotoma* (fig. 24, *a*) where some branches at the base show weak indications of radial arrangement. It is evident that by the lateral arrangement a surface increase has been gained, the advantage of which for the work of assimilation is self-evident. So far, as great an increase of surface as possible were desirable, provided no disadvantage were involved. But such is undoubtedly present; the large flattened leaf-like organ, without any special mechanical elements or tissues, runs a great danger of splitting if exposed to too violent a strain, in the form of ground-swell or the like. That *Caulerpa prolifera* is actually very susceptible to this, and cannot withstand a too turbulent sea follows very clearly from JANSE's notes ("Bewegun. d. Protoplasma von *Caulerpa prolifera*," p. 166) on broken Caulerpas in the Gulf of Naples after very stormy weather, which has stirred up even the quiet depths where *C. prolifera* lives. It is evident, therefore, that if such broad-leafed forms are to have any chance of living it must be in sheltered places, and, of course, especially at considerable depths that are not disturbed by heavy seas In this respect how does the matter stand with the other leaf-like Caulerpas ? It has already been pointed out above that *C. prolifera* is by preference a deep water form, both in the Mediterranean and in the West Indies. The same may be asserted of *C. scalpelliformis*. In the littoral zone I only found it once, at Paumben, and for the rest it is wanting in the littoral zone of Ceylon. As, however, it has been noted from the pearl banks in the Gulf of Mannar (E. S. BARTON, "List of Marine Algæ collected. . . . at Ceylon," p. 165), and has moreover been obtained by JOHS. SCHMIDT at as great a depth as 15 metres and more in the Gulf of Siam ("Koh Chang," IV., p. 104), and as it is mentioned by HARVEY ("Phycologia Australica," I., Pl.17) as growing "a few feet below the low-water mark," we may consider ourselves justified in not counting *C. scalpelliformis* among the typical algæ belonging to the upper littoral zone, but as a Caulerpa which prefers somewhat deeper regions.

The same may be said of *C. crassifolia*. I only found it once in the littoral zone of Ceylon, and then in its deeper parts at a depth of about 2 m. On the other hand it does not seem to be rare on the pearlbanks in the Gulf of Mannar. No detailed information as to locality is present from other places. It is highly probable, by reason of its appearance in Ceylon, that this species also belongs to those which prefer somewhat deeper regions. On the other hand *C. crassifolia* is, even if evidently bilateral and provided with rather broad and flat main axes, so lobed that the danger of splitting is not really serious in this species, even if it grows in exposed places in the upper littoral zone. What is true of *C. crassifolia* is true also of *C. taxifolia* (figs. 4, 5) and its different forms. It avoids exposed localities when it grows in the upper littoral zone, where it is to be met with in pools. On the other hand, it is plentiful on the pearl banks in deeper water. COLLINS only knows this alga from Jamaica as "washed ashore." The deep-water form, *f. asplenioides* (fig. 4), has somewhat broader but shorter pinnules, directed straight outward, the surface form smaller but longer, and sickle formed branches bent upwards. Remarkable is HARVEY's note on this species ('Phycologia australica,' III., Pl. 178): "There is fully as much difference among my Friendly Island specimens, between those collected in the quiet waters of the lagoon and those from the outer reef, as I find in those from opposite hemispheres."

HARVEY thus remarks in this species variations according to different situations, but without characterizing the nature of the changes.

An examination of the occurrence of *the larger bilateral Caulerpa* forms both in Ceylon and on other coasts, where anything is known of them, consequently shows that in any case they have *not* their main distribution in the littoral zone—even if isolated specimens occur there—but that this *must be located in deeper and quieter regions.*

(B).—*The radial Caulerpas—The Analogy between the C. clavifera-uvifera type and the C. nummularia-peltata type.*

Where do we find, on the other hand, the Caulerpas which have radial structure of their assimilation system in the form of short-branches?

Of the *Caulerpa* species of Ceylon, besides the *C. verticillata* and *lætevirens* which have already been dealt with, we have in this group *C. longistipitata, sedoides, clavifera, uvifera, peltata, nummularia, parvula, imbricata*, and *Chemnitzia*. It should be observed at once that all these species occur in the littoral region, and several of them belong to the commonest algæ in the upper littoral region. Some species with wide distribution are also to be met with deeper down, and these show very instructive and interesting changes of form. More of this later on. A few species, as *C. longistipitata* and *C. sedoides*, have only been found in relatively very few places; but as JOHS. SCHMIDT ("Flora of Koh Chang," IV., p. 105) also mentions them only from the littoral region, they seem most probably to be at home in this region.

Under what conditions do these forms live, and can we see any adaptations to their surroundings in their organization?

Let us first examine *C. clavifera* (fig. 13). In the special part the characteristic mode of growth of this species is dealt with. The form which is pictured in fig. 13 is a pronounced surface form, which at low water is often only laved by the waves. Its characteristic is its extended—almost flattened—mode of growth, which depends on the vertical axes being so short and having only a small number of side branchlets. When, at the same time, the root system and the horizontal axes are strongly developed, the whole plant is firmly fixed to the rock, while the small short vertical axis offers few points of attack to the swell. It is to be noted that as a rule no Caulerpas at all—with the possible exception of *lætevirens*—are ever met with in the littoral region in really strongly exposed localities, but *C. clavifera* can sometimes grow in places which, even if the sea there cannot be described as violent, are yet exposed to wear and tear of a kind. In such places we often come across *C. clavifera* and others with similar construction, as *C. nummularia* and others. It is rather remarkable that these Caulerpas are so often to be found among small living corals and small colony-forming Actinians. The horizontal axes creep amongst the Actinians and fasten on to them. *C. clavifera* then often gets somewhat longer vertical axes, and the whole plant assumes an appearance more closely resembling TURNER'S *Fucus clavifer*, Pl. 57, vol. I., and WEBER v. BOSSE'S, fig. 4, Pl. XXXIII.

If it grows directly on the rock and more isolated, it appears as in fig. 13. That for such a pronounced littoral alga, which grows squeezed in between Actinians and corals, such a mode of growth offers certain advantages, seems evident to me. Partly because, as mentioned above, the surface exposed to the waves is relatively small compared with the well-developed adhesive system, partly because the exposure of the assimilation system—and this, I think, is worthy of special note—becomes under such circumstances the most favourable, since it is practically spread out in one level and thereby as many branchlets as possible are exposed to the light. That, for instance, the taller vertical axis with pronounced uviform shape, as *C. uvifera* (fig. 15), cannot be a suitable form amongst corals will easily be understood, for if these vertical axes are squeezed in between equally high corals, only the uppermost branchlets, that is the points alone, can be exposed. Therefore short axes with few side branchlets must be considered as especially suitable shapes for such habitats. The reduction in the assimilation system that results from the diminished number of branchlets is compensated by their being larger and coarser. It is also in such localities that we meet with forms with very large ball-shaped branchlets, KÜTZING'S *Chauvinia macrophysa.*

These observations of mine concerning the occurrence and mode of growth of *C. clavifera* in Ceylon, correspond with Madame WEBER v. BOSSE'S note on *C. clavifera f. macrophysa* ("Monographie des Caulerpes," p.362) where we read : "J'ai recueilli la plante sur des recifs de corail : la fronde de la *v. clavifera* était enclavée entre des morceaux de corail, les ramules s'étaient par conséquent tournés du côté de la lumière, s'étaient rapprochés du côté frontal de la fronde et en meme temps agrandis." This seems to indicate that the assimilation branches were all as in a level at the same time as they were enlarged.

I have therefore come to the conclusion, as a result both of my own observations and of such notices in botanical literature as the above, that *C. clavifera* may be characterized as the coral reef Caulerpa *par préférence.*

The changes *C. clavifera* undergoes when it grows deeper down can in general be characterized by the vertical axis, as well as the cylindrical parts of the assimilation branchlets, being lengthened. The *f. remota* (fig. 14), described by myself, is such a pronounced form from a deep pool. Its vertical axes are very lengthy, are not recumbent, nor root-taking. Between this and the surface form intermediate forms can be found. The *f. remota* as a form living in deep pools is never exposed to the tearing influence of the swell to the same extent as the main form. Its root system is relatively weaker, but the assimilation branchlets are longer, slenderer, and more pliable, so that when they wave to and fro they also can derive every benefit from the light.

That these various forms arise directly through the influence of light, so that, for instance, obscuration favours the lengthening of the axes, while bright or intense light causes shortening of the axis system, seems very probable. But this can only be determined by direct experiments. A comparative examination shows, in any case, that the one type is almost exclusively at home in the upper littoral region, the other in somewhat deeper localities. For analytical ecology, however, it is sufficient to state that both kinds of forms in this organization have certain advantages suitable to the different surroundings amid which they live, and can therefore with good cause be considered as adaptations or ecologisms.

This *C. clavifera* organization shows itself still more closely an ecological adaptation if we compare it with *C. uvifera*. In the special section I have dealt in more detail with the differences which exist in Ceylon between these two species. In this place I may call special attention to the fact that *C. uvifera* will be looked for in vain on the coral reefs of the south-west of Ceylon. It is this species however that seems to be the commonest in the north. At the present time I do not venture to decide whether this different distribution of the two forms is to be exclusively attributed to the different nature of the shores ; viz., that on the south-west and south coasts there occur only cliffs and rocks, which are favourable to the growth of *clavifera*, whereas such formations are rare in the north. There the shores are more sandy, with very scanty vegetation in the upper parts of the littoral region, and with algal life beginning only a little further down. That *C. uvifera* is closely allied to the sand Caulerpas, I have already pointed out. Though it is chiefly the rhizomes and the root system in which this appears, yet even the assimilation axes point to its being predominantly a deep form. For the assimilation axes are much longer than in *C. clavifera*, and especially very thickly covered with branchlets, which show a firm cluster-shaped formation (fig. 15). That such an organization is very unsuited to exist amongst corals and Actinians has already been pointed out above; it would be equally unsuited to strongly exposed localities. Deeper down in sandy bottom, however, it has a more suitable habitat, and the long vertical axes wave to and fro in the currents so that the whole axis gets exposed to the light from every side. As JOHS. SCHMIDT (*loc. cit.*, IV., p. 105) also only found *uvifera* at a depth of from "1-2 fathoms water (coral sand)," the opinion I formed about this plant in Ceylon is strengthened: the opinion, namely, that it is a sand Caulerpa from somewhat deeper regions.

With respect to the variations of *C. uvifera* and their ecology I need not take up much space, since I have only collected *f. planiuscula* myself. It differs only in that its upper branches show a tendency to flattening out (fig. 16), while the vertical axes at the base have rather few side branchlets. This change seems to be favourable to the reception of light coming directly from above, but about the special habitats of this plant my notes unfortunately do not afford me any help. It occurs only in the north of Ceylon, with about the same distribution as the main species.

C. longistipitata (fig. 45) and *C. sedoides f. crassicaulis* (fig. 47) have a similar organization to that of *C. uvifera*. As far as *C. sedoides* is concerned, at least, the resemblance seems to apply also to its mode of growth, for at Weligama it grew inside the reef at a depth at low-water of about 2 metres together with *C. taxifolia* and *sertularioides*, anyhow not in the upper exposed part of the littoral region. At Matara it occurred in rock pools. It also seems capable of variation in the length of its shoot axis, some branches being very short (fig. 47), analogous with those in *C. clavifera*.

C. longistipitata, on the other hand, seems to show some analogies with *C. lætevirens* in its lengthy root system that creeps along the stones, and its long, slender, and weak assimilation branches. It occurs at Paumben in the upper littoral region, but not in any exposed places. Seeing that I only observed it in that place, I will not venture to express any opinion as to where this form is really at home, but JOHS. SCHMIDT (*loc. cit.*, IV., p. 105) also informs us that he only found it in the littoral region.

Of the remaining species that occur in the littoral region, *C. peltata, nummularia, parvula, imbricata*, and also *Chemnitzia* may be considered as a very uniform and closely related group, distinguished by all their short branchlets being more or less pronouncedly disciformly flattened.

Of these species *C. nummularia* (figs. 35, 36) occurs in about the same localities as *C. clavifera, i.e.*, in the upper littoral region, not rarely together with corals. The organization of the shoots is also quite analogous with that of *C. clavifera*. The branches are all recumbent, root-taking, and creep among corals and on stones. These branches are dorsi-ventral and form disciform assimilation branchlets on the upper side only. The whole plant resembles a matty tuft (fig. 36) with the assimilation system in one level. Thus we here find an organization quite analogous with the one we have already described in *C. clavifera* (fig. 13), and which is characterized by the relatively strongly developed root system in comparison with the shoot system, and by the shortening of the shoot axis, whereby the assimilation system is flattened out so that it receives the whole light vertically from above. *C. clavifera* and *C. nummularia* are both pronounced light algæ from the upper littoral region, growing in localities with frequent changes of water and often somewhat exposed to the swell. These analogies in the outward conditions of life correspond to pronounced resemblances in mode of growth. Therefore, too, these forms might with reason be characterized as ecological adaptations; they are, as DETTO says ("The orieder direkten Anpassung," p. 146) *examples of ecological convergence.*

What is true of *C. nummularia* is also true of *C. parvula* (fig. 43), which in its mode of growth and occurrence is quite analogous with *C. nummularia.*

In the same way as in the series with the ball-shaped branchlets, *C. clavifera* is a surface form, and the more long-branched *uvifera* is a deep form ; similarly, in the series with disciform assimilation branchlets, the surface form *C. nummularia* (fig. 36) has an analogous form in the relatively deep form *peltata* (figs. 31, 32, 33). The changes in form in the *nummularia-peltata* series are also quite analogous with those in the *clavifera-uvifera* series. *C. peltata* has long vertical branches with the side branchlets placed all round and their flattened assimilation discs obliquely directed upwards (figs. 31, 32, 33), whereas *C. nummularia* has recumbent axes with assimilation discs on the upper side only (fig. 35). It is evident that with this position the exposure of these branchlets to the light is the most favourable one for vertical axes when they have branchlets all round them, for horizontal ones when they have them dorsiventrally developed. That some transition forms with both radial and dorsiventral axes can be found (fig. 32) will be pointed out by me in the description of the different species.

Just as *uvifera* was predominantly a deep form, so too this *C. peltata* is only to be met with deeper down in rock pools and other places not too strongly exposed.

What applies to the different types of the *clavifera-uvifera* series as far as their advantages and disadvantages are concerned, applies also, of course, to the *nummularia-peltata* series. *Thus we see that between C. peltata* and *C. uvifera there is a similar ecological convergency to that between C. nummularia and C. clavifera.*

Finally, with regard to *C. imbricata* and *C. Chemnitzia*, the latter, in its organization, mode of growth and occurrence, corresponds exactly with *C. uvifera.* The differences are only of a morphological nature, and only apply to the form of the branchlets, *i. e.*, *C. Chemnitzia* (fig. 27) has quite cylindrical branchlets at the base of the vertical axis. *C. Chemnitzia* is also, in accordance with its organization, a form which occurs by preference in still water deeper down often together with *C. uvifera.*

C. imbricata (figs. 37—42), on the other hand, is a species which seems to prefer the upper littoral region. It is as a rule closely tufted (fig. 37), which gives it a certain likeness to *C. nummularia.* It might be characterized as a *C. peltata* in which the branches have contracted, so that the vertical axes are very short as are also the branchlets, while they are almost pressed together, thus forming an almost continuous assimilation surface. The detailed description of the species will also show that there are certain transition forms between *C. imbricata* and *C. parvula.*

This *C. imbricata* grows on coral reefs together with *C. clavifera* and *C. nummularia*, but is far less frequent, and does not occur on strongly exposed parts. So, on the reef at Galle, this species was only to be met with on the more sheltered rocks below the Clippenberg Bastion and the Neptune Bastion. It is evident that the form points to a surface enlargement of the assimilation system, if we compare it with *C. nummularia* and *parvula*, since isolated branches grow up vertically and become covered with assimilation discs (figs. 41, 42). But this also involves greater danger of laceration, as the strain is increased. It seems, therefore, as if *C. imbricata* may be conceived as a variant of the *nummularia* type that has increased its assimilation system, and that occurs where the external circumstances do not stand in its way.

(C).—*C. sertularioides type.*

It follows from what has been said above that the bilateral *Caulerpa* forms in common are to be met with in deeper regions, whereas the radiate forms in general have their main distribution in the littoral region. Certain of the radiate species are replaced in the uppermost littoral zone by more or less dorsiventral species.

It is to be noted, however, that in the Ceylon marine flora a typically bilateral Caulerpa also occurs in the uppermost parts of the littoral region, viz., *C. sertularioides* (figs. 7-10). I have already pointed out above the advantages and disadvantages which are connected with the bilateral shoot form in general, which may be shortly characterized as follows :—the assimilation surface is extended, but this, on the other hand, is accompanied by an increased risk of laceration. As a matter of fact, all the bilateral

Ceylon *Caulerpa* forms are more or less lobed, even the deep water forms. Furthest in this respect goes *C. sertularioides*, which has very fine branchlets, whereby the whole shoot axis has the appearance of a feather (fig. 10), to which it owes its former name of "*plumaris*." Strictly speaking *C. sertularioides* is closely allied to the radiate forms in that its branchlets are cylindrical and subulate, and it need only develop these radially as in *f. Farlowi* or *C. Selago*, for the organization to be perfectly radial.

C. sertularioides occurs on the shores of Ceylon in a number of different forms. It is very common in the uppermost exposed littoral region on coral reefs and rocks in the south-west. It is often of low growth with the branches at the top as if chopped off sharp (*f. brevipes*, fig. 7). The branches are now very fine, now somewhat coarser and with coarser rhizomes. The latter seems to be the case especially on sandy bottom as at Jaffna. Sometimes it also seems able to form small tufts (fig. 8). It often grows, as we have said, in very exposed places, and the feather-like axes wave to and fro in the swell. It is clear that such fine subulate branches are very well adapted to a species with such a mode of growth. In this respect *C. sertularioides* corresponds with *C. lætevirens f. cylindracea*, of which it also reminds us in its mode of growth, even if it does not occur in such exposed places as the latter.

C. sertularioides also occurs in the deeper parts of the littoral region, as for instance at Weligama, from a depth of about 3 metres. JOHS. SCHMIDT has also collected this species in 1-2 fathoms of water. In this case it has a somewhat different appearance (*f. longiseta*). It is longer, weaker, and not chopped off sharp at the top (fig. 10). I observed quite similar forms in dark cavities in coral masses on the reef at Galle, so that it seems very probable, in my opinion, that this lengthening of the axis in dark localities and its shortening in intensely bright must be attributed to the influence of light.

4.—ON THE DIFFERENCE BETWEEN MORPHOLOGICAL AND ADAPTATIONAL CHARACTERS IN CAULERPAS.

It should follow from what has been said above that *Caulerpa* can scarcely, in contrast to other plants, lay claim to be able to show a multitude of variable types in which no correspondence can be traced between the outer form and the surroundings, which REINKE has presumed. As I think I have shown, several *Caulerpa* species, *e.g.*, *lætevirens*, are as evident ecologisms as one could wish, and different localities are characterized by different *Caulerpa* types.

The different localities are characterized by differences in the bottom (sandy bottom or rock), by different degrees of exposure to the swell, by different depths, and by different intensities of light—and all these differences in environment correspond with differences in organization. Thus, the sand Caulerpas (*C. Freycinetii, cupressoides, Lessonii, Fergusonii*, and others) are distinguished by their long creeping rhizomes with finely branched roots, whereas the coral and rock Caulerpas (*C. clavifera, nummularia*) are often far less elongated, and their root system consists of adhesive roots with rather few and short branches. Then we find that in more exposed localities—besides that the adhesive organs are more strongly developed—the assimilation axes approach the cylindrical, at the same time being very narrow, *i.e.*, offer the least possible opposition to the tearing power of the waves (*C. verticillata, lætevirens, f. laxa, sertularioides*). On the other hand, the branchlets are numerous and cylindrically arranged so that complete exposure is favoured by the continuous movements in the swell. The different depths at which the Caulerpa lives is reflected in the organization; the deep forms are often leaf-like and reach the highest dimensions (*C. scalpelliformis, pinnata, taxifolia*): the surface forms have a shortened axis system, while at the same time the whole assimilation system is extended at the sides in one level (*C. clavifera, nummularia, parvula*), whereby also the assimilation discs themselves strive, as it were, to extend horizontally (*C. nummularia*).

REINKE, as is well known, is of the opinion that in Caulerpas there is no difference between so-called "morphologischen und Anpassungsmerkmale," so that "Wer es liebt, auf die Unterscheidung von morphologischer und Anpassungsmerkmale Werth zu legen der wird daher die Speziescharaktere von *Caulerpa* sowohl zu den ersteren wie zu den letzteren rechnen müssen." ("Ueber Caulerpa," p. 68.)

But in this connection we need only refer to the parallel between *C. clavifera*, *C. uvifera*, and their forms on the one side, and *C. nummularia*, *peltata*, and *parvula* on the other, to prove that REINKE'S assertion cannot be justified, for the "Spezies-character" in the former group is the *ball-shape* of the small assimilation branches, in the latter their more or less *disciform* shape. But the "Anpassungs-charactere," on the other hand, are the different lengths of the rhizomes and axes which form the analogy between *C. clavifera-nummularia* and *C. uvifera-peltata*. And between them as a transition form, or rather as a primary form common to both, stands *C. Chemnitzia*, which in its organization shows a faculty to develop in the one or the other direction, thus less markedly differentiated or adapted than the other two groups.

If what REINKE says about *Caulerpa* were really a fact, it would be most remarkable and would alone justify these algæ in taking an exceptional place in the vegetable kingdom. For the opinion of the biologists of our day is inclined to recognize that it is justifiable to distinguish between organization characters and adaptational characters. So, for instance, Professor GOEBEL said in his lecture at the Congress of Arts and Sciences in St. Louis, 1904, "The Fundamental Problems of Present Day Plant Morphology" ('Science' N. S., Vol. XXII. No. 550, 1905): "In reality it seems to me that morphological comparison as well as experiment shows that the distinction between organization and adaptational characters is justified." This principle may be said to hold good, as I have tried to show, also of the many changing forms of the genus *Caulerpa*.

III.—ON THE DIFFERENT KINDS OF VARIATION IN CAULERPA.

1. CONTINUOUS VARIATIONS IN SHOOT BRANCHLETS (PINNULES) FROM BASE TO POINT.

The variations often point to a surface increase.—Comparison with the heterophylly of the higher plants.

In the foregoing I have shown the differences in the organization and structure in the shoots of *Caulerpa*, which are to be looked upon as adaptations to different modes of life. Thus we have seen that the shoot systems of many surface living Caulerpas are closely connected with the conditions of the light and the exposure to sea and wind that exist in the littoral region, and that when the Caulerpas grow in deeper and calmer water they assume other larger and more branched and taller forms. In all these cases the relation between organization and locality is evident.

But in this genus there is another kind of variation in the shoots, between the forms of which and the external conditions of the plant no such direct relation can be traced. It is the multitude of these variations that seems to have caused the difficulties in determining the definitions and limitations of the species in this genus. That Madame WEBER v. BOSSE has kept in sight these different variation types can be seen from what she says on p. 245 in the "Monographie des Caulerpas:" "La question sur la valeur des espèces......est d'autant plus difficile à resoudre puisque le thalle à structure continue de ces algues, subit une grande influence du milieu où il pousse, et que la même plante adopte en outre des formes très diverses, sans qu'on puisse trouver une raison quelconque pour expliquer l'apparition de formes si variées au même stolon." It is precisely this variation that has been so sharply accentuated, both by Madame WEBER v. BOSSE and by Professor REINKE, that the variations according to localities have been almost entirely overlooked.

The variations that are not directly dependent on locality are mentioned by Madame WEBER v. BOSSE on p. 246, and are either characterized by the branchlets or pinnules of an assimilator being of a different form at the base than at the point, or there shoot out from the same horizontal axis dissimilar assimilators, in that some have exclusively one kind, other exclusively another kind of branchlets. Lastly the variation can also consist in the branchlets being arranged in a varying number of rows, though the branchlets be similar among themselves.

Here it may happen either that assimilators with a different number of branchlets shoot up from the same horizontal axis, or that one and the same assimilator may have branchlets with a number of rows varying at the top and at the base.

For a discussion of these different variations and their nature it is perhaps advisable to begin by describing some special cases. Let us, therefore, examine some Ceylon Caulerpas which show a variation of this kind.

Among other forms of *C. uvifera* from the islands around Jaffna I observed one which I have described under the name *f. planiuscula* (fig. 16). It shows a series of transitions in its branchlets. At the base they are all ball-shaped, without exception, but a little higher up they begin to grow more and more flattened, at first hardly noticeable, afterwards very evident. At the top of the assimilators the greater number of the branchlets are more or less flattened, whereas at the base no such branchlets at all are to be seen.

An analogous variation of the branchlets is to be observed in *C. corynephora f. complanata* (fig. 18). The main axis is flat, with the branchlets in two rows. At the base these are of the same width, but higher up they swell out at the points, so that they have the appearance of being somewhat constricted. The transition between the different kinds of branchlets is gradual, without sharp contrasts.

To some extent of the same kind is the variation in *C. dichotoma* (figs. 23, 24), in that in this species too the basal branchlets are simple and the dichotomous ones only begin higher up, but in this species we have, besides this, to note that the branchlets at the base are arranged radially around the axis, whereas the bifurcated branchlets higher up are arranged predominantly in two opposite rows, whereby the whole assimilator becomes bilateral. Moreover it sometimes happens that some assimilators have only simple radially arranged branchlets. *C. dichotoma* thus shows an example of different kinds of variation of branchlets.

C. peltata (figs. 31-33), on the other hand, shows somewhat different kinds of variation ; either an exclusive increase in the assimilation discs, the intervals being then longer, at the same time as the branchlets only develop from the upper side of the side branches, which thus become dorsi-ventral (fig. 32), or some branchlets develop in the direction of the spherical form, showing a tendency to swell up (fig. 33). The larger assimilation discs in the former variety, as well as the swollen ones in the latter, occur at the tops of the shoots, whereas the base is surrounded by the more numerous but smaller assimilation branchlets.

Of about the same kind is the metamorphosis of the branchlets or pinnules in *C. Chemnitzia* (fig. 26–30). At the base they are more or less pronouncedly cylindrical (fig. 27), of about the same shape as in *C. lætevirens* ; higher up they become trumpet-shaped at the top and as if abruptly cut short. At the very top the branchlets are either disciform in certain varieties (fig. 29), which have a tendency in the *peltata* direction, or spherically swollen in others which thus approach the *racemosa-uvifera* series (fig. 30).

In all the forms of variation in the branchlets described above it is a common feature that the variation proceeds more or less regularly, step by step, and furthermore that a tendency to surface increase is apparent, though it is effected in different ways ; for it is evidently shown in *C. corynephora f complanata* (fig. 18), *dichotoma* (figs. 23, 24), *peltata* (fig. 32), *Chemnitzia* (fig. 27), and also to some extent in *uvifera f. planiuscula* (fig. 16).

Reinke, in his treatment of the variations of *Caulerpa* (*loc. cit.* p. 87), has distinguished between such as pass over " allmahlich " and such as pass over " sprungweise," *i.e.*, " gradually " or by " leaps and bounds." The variations in question are apparently identical with those Reinke has characterized as " allmählich."

It is indisputable that this metamorphosis of the branchlets reminds one in many respects of the heterophylly of the higher plants. It can, however, be of an essentially different kind, in that the difference between the younger and older leaves is bound up with different conditions of life during different phases in the life of the plant, or else such different conditions do not occur, but the heterophylly depends on the first developed leaves being arrestment stages ("Hemmungsstadien") of the fully developed ones.

Are they then arrestment stages of the same kind as the primary leaves, as for instance the simple leaves of Leguminoseæ with otherwise normal compound leaves? Yes, to a certain extent they are quite analogous with them. Thus, the basal branchlets of *C. dichotoma* (figs. 23, 24) are undoubtedly much simpler than the later dichotomous ones, and there is nothing that debars our considering these simple branchlets as arrested stages of the other ones. The same may be said to apply to *C. corynephora f. complanata* (fig. 18) and *C. Chemnitzia* (figs. 24, 29) and other species with simpler branchlets at the base.

But, on the other hand, certain reasons offer definite testimony against our explaining all the differences in the development between base and top as arrestment phenomena. So, for instance, *C. Lessonii* offers an example (fig. 11) of the branchlets at the base being arranged in many rows, *i.e.*, are more numerous at the base than higher up. The same is also the case with the *f. tristichophylla* of *C. axifolia* (fig. 5) and several *cupressoides* forms. For in these *more* rows of branchlets are developed at the base than higher up, and this can scarcely be characterized as an arrestment, but rather the reverse. Every case, therefore, mentioned above must not be looked upon as an arrestment stage.

But cannot the different forms of branchlets at base and point be explained phylogenetically? That is, a *Caulerpa* rhizome, which for some cause or other has entered on a new course of development as far as the form of the assimilation branches is concerned, has returned to the more primitive branch form. But by reason of the exclusive propagation of *Caulerpa* by the formation of shoots, the difference between phylogeny and ontogeny is practically *nil*, provided the latter term is not meant to express the history of the limited development of each assimilation axis (= assimilator, REINKE).

There is scarcely any reason to consider indisputable arrestments as reminiscences of phylogenetic evolution. GOEBEL, in his work "Vergleichende Entwicklungsgeschichte der Pflanzenorgane" in SCHENK's 'Handbuch der Botanik' (III., 1), has pronounced against such an opinion. Thus on p. 261 he says: "Derartige Erscheinungen (=Hemmungsstadien der Laubblätter) phylogenetisch aufzufassen, dazu liegen glaube ich, kein Grund vor, ich sehe in jenen einfachen Primärblättern nur Hemmungsbildungen, deren Ursachen in Eigenthümlichkeiten des Wachstums oder der Zusammensetzung embryonaler Sposse liegt." In the cases where no objection can be raised against considering the different branches as simply arrestment forms—and such cases exist, as we observed above, also in Caulerpas—there is no valid reason for the hypothesis that phylogenetic phenomena has played a part, but both cases are so similar and analogous that what is the cause of the one kind may well be supposed to be the cause of the other. Experiments alone can decide the point.

But as for the shoots in which the basal branchlets are so far from being arrested that the very opposite is the case, it seems that there is no other explanation possible than phylogeny. It cannot be denied that the resemblance between the basal branchlets of *C. dichotoma* (fig. 23) and the branchlets of *C. lætevirens* (fig. 19) is perfect. The same holds good to almost the same extent of the corresponding branchlets of *C. Chemnitzia* (figs. 26, 27, 28, 29) and *C. lætevirens*. And the basal branchlets of *C. uvifera f. planiuscula* (fig. 16) are typical *uvifera* branchlets, just as basal branchlets of *C. taxifolia f. tristichophylla* (fig. 5) are *C. falcifolia* branchlets, and the basal branchlets of *C. Lessonii* (fig. 11) are *C. cupressoides* branchlets. Examples of the same thing are not uncommon among the Caulerpas in general. Thus *C. plumaris f. Farlowi* (WEBER v. BOSSE, "Monographie," p. 295, Pl. XXIV., 4–6) is a form with branchlets running in every direction and is to *C. plumaris* as *C. falcifolia* is to *taxifolia*.

In this respect *C. mamillosa*, regarded by Madame WEBER v. BOSSE as a variety of *C. cupressoides*, is especially remarkable (WEBER v. BOSSE, *loc. cit.* p. 332, fig. 6, Pl. XXVIII.). Its base is surrounded by globular branchlets, which forcibly remind one of certain forms of the *pedicellatæ* group (for instance, *C. lentillifera*, compare fig. 6, Pl. XXVIII. and fig. 2, Pl. XXXIV. in WEBER v. BOSSE, *loc. cit.*). Similar examples could be multiplied. These examples show clearly how the development of the branchlets may be conceived as having taken place. Whatever the factors were that produced them, the changes (metamorphoses) proceed precisely as in other plants, in that these factors must be considered to have exercised a transforming influence upon the embryonal substance in the growing point itself, and this results in a successive transformation of the branchlets in some direction which then is either a direct surface increase of the assimilation system (*C. dichotoma*, figs. 23, 24) or a transition of the assimilation from several branchlets placed in many rows round a cylindrical axis to only a few but opposite rows of branchlets on a flattened but broader main axis. It follows then that a study of the metamorphosis of the branchlets can give us some serviceable hints for the solution of the question of the evolution of the different *Caulerpa* species, and hence of the system and phylogeny of the whole genus.

Thus, for instance, it seems to me that such a form as *C. lætevirens*—at least as far as its assimilation branchlets are concerned—is a very primitive type, because this form of branchlets reappears at the base of so many other forms, as *C. dichotoma*, *Chemnitzia*, and several of WEBER v. BOSSE's *uvifera* and *clavifera* forms, which must thus be considered as younger than and derived from *lætevirens*. (Cf. figs. 3, 8, 18, &c., Pl. XXXIII., WEBER v. BOSSE, *loc. cit.*). In the same way forms with the branchlets radially arranged around cylindrical axes must be considered as more primitive than the bilateral forms, because one often meets with axes with the branchlets at the base radially arranged, higher up bilaterally, but not the other way about. Also some Caulerpas with articulated base, but for the rest with very varying and different shape, show, in my opinion, that the articulation is a very old and primitive character, while their form otherwise must be considered as something that has arisen in relatively recent times. In any case they are undoubtedly younger than the truly articulated species of *Caulerpa*.

In general, the earlier stages phylogenetically are very strongly pronounced in such plants as have been developed under extreme conditions, very different in nature when compared with those under which their ancestors lived. So Xerophytes, Hydrophytes, and climbing plants are often characterized by a pronounced heterophylly, the explanation of which must be looked for in their phylogenetic evolution, even if the plant's present mode of growth can be an explanation for its being so differently organized at different periods of its life.

As for the Caulerpas, it seems that no such sharply pronounced difference exists, with respect to their external conditions of life, as may explain the cause of the different development at base and point. But, in the foregoing, we have seen that the localities of the species of *Caulerpa* can vary not inconsiderably. So *C. lætevirens* is confined to strongly exposed localities where its position is not threatened by any other *Caulerpa*, and we have seen that its organization is an adaptation to precisely such surroundings. It is highly probable that this or some similar form under altered conditions of life has given origin to forms, such as *dichotoma*, and *Chemnitzia*, both of which could be derived from *lætevirens*. In both these species in the upper branchlets an increase of the assimilation surface takes place, but it is produced in different ways : in *dichotoma* (figs. 23, 24) by the cylindrical branchlets being flattened out and becoming leaf-like and, finally, bifurcated at the top; in *Chemnitzia* (figs. 27, 29) by the branchlets expanding trumpet-like, being more sharply cut short at the top, and finally being perfectly disciform. In both cases very similar results are produced, but in different ways. To this we must add that both these forms, *C. dichotoma* and *Chemnitzia*, are still-water forms in comparison with *C. lætevirens* and the gradual metamorphosis of the branchlets can thus be seen in connection with the changed conditions of life, which allow a surface increase of the branchlets that in *C. lætevirens* is perhaps made impossible by its mode of life, *i.e.*, by the external conditions in which it grows. Therefore, of course, the external conditions can very well be considered in this genus too as the factors that produce a transforming influence on the growing-point by irritation, and through that the whole organization of the plant. Why the development in the one case takes the direction of flattened leaf forms, and in the other of trumpet-like ones, is a question that cannot, of course, be answered by deductions from the above facts. Now, at the base of the branches in the derived species, branchlets are still developed of the more primitive kind which entirely covered the axis system of the parent form, in the same way as *Acacia* seedlings *in their youth* develop primary leaves like those in other species of *Acacia* and only develop phyllodes later on. It, therefore, seems that, also in Caulerpas, the base of the shoot has retained most of the character of the parent form.

The differences in the formation of the shoots, which I have just dealt with, are characterized by the different kinds of shoots originating successively in the same main axis ("allmählich erfolgend," REINKE) or, in other words, they are an example of differences in organogenesis at different stages of development in the life of the shoot, *ergo*, analogous with the early forms (" Jugendformen ").

Closely allied are the cases in which, from the same horizontal axis, vertical axes shoot out, each with its several special kind of branchlets (a " sprungweise erfolgende " variation, REINKE); for, usually, the different vertical axes are to some extent individualized, so that the branchlets in different axes are transformed at unequal rates. Thus, for instance, we can see one axis in which the primitive form of the branchlets covers the axis rather high up, another in which they only occur at the base and abruptly pass over into the definitive form (Cf. fig. 11 of *C. Lessonii*, the branchlets to the left).

If, now, the case occurs that in one axis the primitive forms are very few, or even entirely wanting, and that the opposite is found in another, that is to say, that there is nothing but primitive forms, it results that from one and the same horizontal axis quite different vertical axes may derive. In this form of variation, however, there are always transition forms, which show how the different axes may have arisen. The same is the case when the difference between the vertical axes only consists in their branchlets having developed in a dissimilar number of rows (Cf. fig. 45 *a*, *b*, of *C. longistipitata*). It is precisely these differences that REINKE has kept in view in distinguishing the variations in the two kinds " allmähliche " and " sprungweise " (*loc. cit.*, p. 87), and he characterizes the difference thus, that in the one we have to deal with a little, in the other with a big bound (" sprung "). According to him, there is no other difference.

It is one very characteristic trait in all the shoot variations we have been speaking of that they occur successively, *i.e.*, with transitions that may be more or less pronounced; another that they may to some extent be connected with changes in the mode of life, to which they can be conceived as adaptations or " ecologisms." The more primitive forms of branchlets at the base may be explained by the base of the shoot having kept more of its primitive character, a character more closely allied to that of the ancestral form. Therefore they must be explained phylogenetically.

(2) *Discontinuous Variations—Atavistic reversions or mutations?*

Quite different from all the other kinds of variations are those that occur in *C. Lessonii f. uticorinensis* (fig. 12). Here we have three different kinds of branches, narrow ones with two-sided and three-sided branchlets, like those in *C. cupressoides*, and furthermore, and this is the most noticeable point, considerably broader ones whose very presence shows their affinity with *C. Lessonii*. The last-named kind occurs abruptly without any intermediary transition form, and corresponds in this respect, as REINKE has pointed out ("Ueber Caulerpa," p. 85) in a striking way with the bud variations we know in such higher plants—especially trees—as can be referred to under the name of " sporting plants " (DARWIN).

Another example of the same phenomenon is the plant I have called *C. sedoides f. mixta* (figs. 49, 50). The branchlets are, as a rule, ball-shaped with or without stalk, but among them shoots out occasionally a perfectly cylindrical branchlet, three or four times as long as the others, and without any transition at all. *C. sedoides f. mixta* thus shows an example of an abrupt variation of branchlets or pinnules, whereas *C. Lessonii* shows an example of similar variation but of long branches or whole assimilators. That these variations are of quite a different kind to all the others I have dealt with in the foregoing chapter is evident, and the difference lies not only in the abrupt transition, but rather in that no correspondence with any external conditions at all, no adaptations, can be traced in this metamorphosis.

Bud variations (DARWIN) or the so-called vegetative mutations have been dealt with at length in DE VRIES' "Mutations-theorie" (Band, II., p. 670). According to him, these can be divided into three different groups: bud variations due to the vegetative cleavage ("Spaltung") of bastards; bud variations due to vegetative atavism in so-called middle races ("Mittelrassen"); thirdly, the real bud variations, which again may be of two kinds, viz., such as are of atavistic nature and such as are not of atavistic nature but are progressive mutations (vegetative mutations).

As no other propagation than by shoot formation occurs in the Caulerpas every kind of variation due to bastard formation is, of course, absolutely out of the question. There remain, consequently, bud atavism and real mutation. If, now, it is of the former kind, the changes that take place in the appearance of the shoot must therefore correspond with those of ancestral forms. Since no absolute certainty can be arrived at in this matter, we must content ourselves with examining whether possibly any now living species normally possesses branches of a kind which in another species appears as bud variation. If so, it would support the supposition that atavistic phenomena are present.

If we now examine *C. sedoides f. mixta* (fig. 50) which afforded us an example of such a bud variation, it will appear that its elongated or irregular branchlets have the very same form or, at least, are very similar to those in *C. ambigua*, which belongs to the same group as *C. sedoides* (Cf. my fig. 50 and Pl. I., figs. 4, 6, 7, 14 in Okamura, "On the Alg. of the Ogasawara-jima" (Bonin Islands).

It thus seems by no means improbable that *C. sedoides* is derived from a species which has been very closely allied with or similar to *C. ambigua.* That cylindrical branchlets (= pinnules) are more primitive than spherical ones I have already tried to show in the foregoing, while dealing with the question of relationship between *C. racemosa, lætevirens*, and *Chemnitzia.* In complete analogy with this is, too, that such species as *C. ambigua* must be considered as more primitive than *sedoides f. crassicaulis.* Everything, therefore, points to the conclusion that the bud-variation in *C. sedoides f. mixta* should be regarded as an atavistic reversion.

Whether the same is the case with *C. Lessonii f. tuticorinensis* is somewhat more difficult to decide. The form which I have indicated as the main species of *Lessonii* (fig. 11) shows at the base branches with three-sided branchlets; thus, in conformity with the opinion I have attempted to vindicate, it s derived from a species with three-sided branchlets, *i.e.*, from one of the *cupressoides* forms. *C. Lessonii f. tuticorinensis* (fig. 12) also has the prevalent number of branches of the common *cupressoides* form; two-sided as well as three-sided, and the great majority of the branches never have a different appearance. But amidst these branches the broad flattened ones with their two-sided branchlets are formed just as bud variations. These are from the very beginning two-sided, and not, as often in *Lessonii*, three-sided at the base. It is therefore impossible to say that the broad flat branches in *C. Lessonii f. tuticorinensis* are reversions to *Lessonii*, for that would mean that *Lessonii*, that is the broad flat leaf form, were more primitive than the *cupressoides* branches. But this is contradicted by *C. Lessonii* itself, in which the development shows the exact contrary (fig. 11). This does not seem to support the atavistic nature of these shoots; yet it seems impossible to look for any definite solution of this problem at the present time. It may be possible for *Lessonii* and *C. Lessonii f. tuticorinensis* to be in the nature of parallel forms of equal rank, both deriving from a *cupressoides* form and with a tendency to form flat bilateral branches. But in the one (*Lessonii*) this tendency is the predominant, and has so to speak become the normal one, while in the other one (*tuticorinensis*) this tendency is more latent and only rarely reveals itself. This is of course a pure speculation, and for the solution of this, as of so many similar questions touching variation in *Caulerpa*, experiments and cultures are necessary which the traveller in the Tropics has difficulty in arranging.

That both these forms go together seems to me indisputable, and I have wished to give expression to this by calling one form the *f. tuticorinensis* of the other, *Lessonii.* But with this I do not imply that *Lessonii* is necessarily more primitive, for here, as in so many other cases, the first form to be distinguished becomes the main species, the later ones the variations, though with equally good reason the reverse might have taken place.

3. *Dwarf Forms.*

Stunted dwarf forms are often looked upon as a special kind of variation. These, too, are not rare among Caulerpas. Dwarf forms in general are produced by poor nourishment, and it is to be assumed that this has also in some way occasioned the *Caulerpa* dwarfs. And it seems to be clearly the case in *C. taxifolia f. interrupta* (fig. 6), in which stunting has perhaps been produced by lack of light, owing to the great depth, for *Caulerpa*, at which it grows (more than 10 m.). In the other cases there are, on the other hand, no directly apparent external circumstances which could justify our calling the cause poor nourishment. On this point, however, it is impossible to pronounce with any degree of certainty, since our knowledge of the requirements in nourishment of the algæ is still so fragmentary. If, now, it is some deficiency or other in the nourishment that has caused them, this type of variation must, according to present day opinion, be classed under fluctuating variability among the different kinds of branchlets, and deserves then to be distinguished at the most as local forms. If, on the contrary, these dwarf forms occur not simply isolated among the normally developed ones, but show a certain constancy within a given district, it is more probable that we have to do with special races. For it is evident that, since we do not know what influence the different external conditions and especially those of nourishment exert, and since we have no opportunity of conducting cultural experiments, it is absolutely impossible to determine objectively whether we have to do with individual variations or with races with constant character. In such cases it must often be a matter of taste for the taxomonist if the plant in question is to be classed as a race or only as a local form.

The dwarf forms that I observed in Ceylon were: *C. taxifolia, f. interrupta* (fig. 6), *C. plumaris, f. umbellata* (fig. 9), *C. lætevirens f. depauperata* (fig. 20) and *C. parvula* (figs. 43, 44). Of these it seems to me that some doubt arises only in the case of *C. parvula* (fig. 44), *i.e.*, whether it is not rather to be regarded as a distinct species, since, at Beruwala, where I collected it, it occurred in several places and seemed to be a more or less constant species. I have, therefore, classed it as a separate species. As for the others, they showed all the signs of being mere accidental varieties, which diverge so much, however, that I think we are justified in distinguishing them as special forms.

4. *Summary.*

In the preceding we have thus got to know different kinds of shoot variations which can occur in one and the same *Caulerpa*. And we have seen that these are of the following kinds :—

1. Variations which depend on the locality, and which are to be considered as adaptations or ecologisms.
2. Variations which cannot be considered as ecologisms, but which are the result of fluctuating variability amongst the different branchlets (= pinnules).
3. Variations which can be considered as phylogenetic stages of evolution (for instance, that the basal branchlets or pinnules are of more primitive form than the upper branchlets).
4. Bud variations of atavistic origin (*C. crassicaulis f. mixta ?*).
5. Dwarf forms.
6. The variations which do not fall under any of the above categories may, lastly, be bud variations without atavistic origin (= mutations).

As Reinke has pointed out, it is to be noted especially about *Caulerpa* that no sharp line can be drawn between individual variations and bud variations owing to their characteristic mode of propagation, since all the *Caulerpa* individuals originate as buds on a common horizontal axis, and thus all variations are bud variations in the widest sense of the term. (Cf. the relation between ontogeny and phylogeny in *Caulerpa*, p. 16.)

All these factors again work together and cause the multifarious diversity of *Caulerpa*. And here it is to be noted—as several writers have already pointed out—that all this diversity and all these variations depend exclusively on changes in the purely vegetative sphere, for no organs of fructification nor spores of any kind are to be found in these plants, and REINKE has, therefore, hit the mark when he says *that the somatic plasma is the medium in and through which the variations of the Caulerpas originate.*

IV.—TAXONOMY OF THE CAULERPAS.—DEFINITION OF THE SPECIES.

It is clear that, as long as we have no firm basis for determining the factors which cause the formation of a species, we can have no real objective principles by which we can determine its limitations. It is for this reason that the conception of the specific character of a species varies more than anything else in the different works on Caulerpas. While some authors prefer small but often less sharply distinguishable species, others prefer wider species, under which are classified a huge number of sub-species, varieties, and forms, often without it being possible for the reader to explain why a certain form should be called there "variety," now only "form."

In this respect also the Caulerpas have been subjected to various fates. LAMOUROUX, the founder of the genus *Caulerpa*, knew 10 species in 1809. Since then new species have been described, one by one, and KUTZING could enumerate 41 species in 1849, divided by him into several genera. The first really valuable monograph on the genus *Caulerpa* was published by J. G. AGARDH in 1872, and he could then distinguish no less than 64 species divided into 13 groups. In 1898 Madame WEBER v. BOSSE, in her monograph, reduced the number of the species to 54, but these species have numerous sub-species and varieties of different rank. It is undoubtedly a great merit in her work that thereby the unity, the great affinity between the various forms, is so strongly accentuated. But, as REINKE so felicitously points out, it is not necessary to group together different species even if transition forms can be found between them. For besides the practical difficulties that accompany such a taxonomy—for one is forced to use as many as four different names (species, sub-species, variety, form) to make quite clear what one is refering to—so too from a purely theoretical point of view one must note that one might just as well reduce the whole genus to one, or a few species, dependent on whether one assumes a monophyletic or polyphyletic origin. But systematic botany ought to lay stress not only upon unity but also upon diversity, and from this point of view it seems more satisfactory to me to employ a more limited species definition, as the older authors did. The genetic relationship of the different species is then not confused, at any rate.

If we apply this to the Ceylon species of *Caulerpa* it is really only the group *clavifera-uvifera-lætevirens-Chemnitzia-peltata* that makes difficulties; for in this group the diversity is greatest. While some *Caulerpa*-species, as *verticillata, crassifolia, sertularioides*, are less variable, the *racemosa* group (WEBER v. BOSSE) on the other hand, as observed above, is especially rich in forms. It is evident that the genus *Caulerpa*, as so many other genera of plants, shows types of different constancy. While some species vary but little, in other groups the variety is very great and probably new forms are now originating. It is thus probable that in Ceylon this is the case with forms belonging to *clavifera, uvifera, Chemnitzia, peltata, nummularia*, and others. In this connection it must be observed that geographical distribution in some cases quite clearly shows that the different groups of forms have in part a tendency to have a distribution which excludes other groups; so, for instance, *C. Chemnitzia, uvifera*, and their forms occur especially in the north of Ceylon, whereas *C. clavifera* and *nummularia*, have more predominantly southern distribution. This may possibly be bound up with the conditions of life being so different in different parts of the Island, coral-reefs and rocks in the south, sand in the north.

But with respect to the geographical distribution of these algæ in Ceylon and its causes, this problem, until I have had an opportunity of studying all the algæ of the island, can only be dealt with by me cursorily

V.—ON THE GEOGRAPHICAL DISTRIBUTION OF THE CAULERPAS.

1. The Distribution of the Caulerpas in Ceylon.

Different Species in the North and in the South.

The Relationship between the different External Conditions in the North and in the South.

In this chapter, finally, we shall deal with the occurrence and geographical distribution of the Ceylon species of *Caulerpa.*

The first question we have to answer is, How are the Ceylon Caulerpas distributed in Ceylon? Here, of course, it is to be noted that of the twenty odd *Caulerpa* species in Ceylon, only relatively few, about a third, occur so abundantly that they leave their stamp on the vegetation as a whole. The others occur only sparsely and scattered about, and cannot be classed as plants characteristic of the marine flora of Ceylon, even if they sometimes may occur quite locally in such numbers that they form real associations of their own (*C. verticillata, C. lætevirens.*)

Species which occur more or less abundantly and which—in large districts, at least—are very characteristic elements in the Ceylon algal flora, are *C. clavifera; uvifera, Chemnitzia, peltata, nummularia, imbricata,* and possibly even *sertularioides.* Of these *C. sertularioides* occurs scattered along the whole coast, never in great masses, but always rather isolated, hemmed in between other algæ. The others, on the contrary, occur in great quantities, and contribute in many places to give the algal vegetation as a whole its stamp. Here it should be observed that *C. clavifera, nummularia,* and *imbricata* occur especially in the south-west and in the south (Colombo–Tangalla), while *C. uvifera, peltata, Chemnitzia,* have a more pronounced northern distribution (Gulf of Mannar, Jaffna, Trincomalee). These groups, it seems to me, confine themselves to provinces of their own to a certain extent. Here, again, it is to be observed that the species that have a main distribution in common are also characterized by a certain resemblance in organization. So for instance, *C. clavifera, nummularia,* and even *imbricata* are characterized by relatively short vertical axes, which gives rise to a more mat-like mode of growth so that the whole assimilation system is on the same level. On the other hand, both *uvifera* and *peltata,* as also *Chemnitzia,* have lengthy vertical axes that wave in the swell, and thus they form quite a different type of organization.

These differences in organization and distribution of the different species are concurrent with the external conditions of algal life being so different in north and south. In southern Ceylon the coast is partly rocky and the rocks there are often fringed by splendid coral-reefs; whereas, in the north around the islands at Jaffna and at Adam's Bridge, the shores are shallow sand beaches with loose bottom where fringing coral reefs rising to about the level of the sea are lacking.

I have already dealt above with the differences in organization that usually accompany these different external conditions, and it is very remarkable that the short-axed *clavifera,* the most common *Caulerpa* on the coral reefs of south-west Ceylon, is replaced in the north by the closely related long-axed *uvifera,* in the same way as *C. nummularia* and *imbricata* in the south are replaced by the allied *peltata* and *Chemnitzia* in the north. All these species, as is known, are very closely related, and have also been classed by Weber v. Bosse as one single broad species, *C. racemosa, sens. ampl.* ("Monographie des Caulerpas," p. 356) with a great number of sub-species, varieties, and forms. For practical as well as scientific reasons I have deemed it advisable to prefer a more narrow definition of the species, but this does not affect the fact that all these species and forms are genetically very closely related. With respect to the form of the pinnules, *C. clavifera* is allied to *uvifera* just as *nummularia* is allied to *peltata;* but from the point of view of organization in general we must group them differently, since then *clavifera* and *nummularia* show themselves to be representatives for one type, *uvifera-peltata* for another. I have already in the preceding given these plants as examples of the fact that also in the genus *Caulerpa* there is—as against what Reinke tries to prove—a difference between morphological and adaptational characters. And now we see that this difference in adaptational character most closely corresponds with the distribution of the species, so that similarly organized species have a common centre of distribution. This clearly follows from what has been stated above, *i.e.*, that especially *clavifera* and *nummularia* have quite another distribution than *uvifera-peltata*. And since the characters which separate these two groups are to be regarded as adaptations to the external conditions within the respective distribution districts, these closely related species, their organization and distribution, may be given as examples of the principle (WETTSTEIN, "Grundzuge d. geogr.-morphol. Methode d. Pflanzensystematik," p. 30) that forms or species which are adaptations to external conditions with a limited distribution also themselves have a distribution which coincides with that of the conditions in question.

To the less common forms of *Caulerpa* that occur in Ceylon belong the following species :—

C. verticillata	*C. corynephora*
C. scalpelliformis	*C. lætevirens*
C. crassifolia	*C. dichotoma*
C. taxifolia	*C. parvula*
C. Freycinetii	*C. longistipitata*
C. cupressoides	*C. sedoides*
C. Lessonii	*C. Fergusonii*

Of these *C. verticillata* has only been observed at Galle, Colombo, and at Tuticorin in South India ; at the first-named place locally but abundantly and forming a special association. The species is not noted from the east coast, nor from the islands and banks which form Adam's Bridge. It is thus predominantly of a western distribution in Ceylon.

C. scalpelliformis, which is probably a deep water form, is only known from the Gulf of Mannar (Pearl banks, Paumben, Tuticorin).

C. crassifolia and *taxifolia* have similar distribution ; the former is the rarer and has been observed from Weligama in the south to as far as the north end of the Gulf of Mannar (Pearl banks and Paumben) ; the latter at several places within the same district.

Several species have only been observed in solitary specimens, as rarities. Of these—

C. Freycinettii (Jaffna)	*C. corynephora* (Tuticorin)
C. cupressoides (Paumben)	*C. longistipitata* (Paumben)
C. Lessonii (Pearlbanks, Tuticorin)	*C. Fergusonii* (Paumben)

have only been observed in the north from the Pearl banks, Paumben, Tuticorin, Jaffna, but are absent from the south-west coast, which has, nevertheless, been the most closely investigated.

On the other hand there are some species with very singular and isolated occurrence, which are only known from the south coast, viz :—*C. lætevirens* (Galle, Weligama); *C. dichotoma* (Weligama); *C. sedoides* (Dondra Head, Matara, Weligama);* also *C. parvula* is only known from some isolated places (Beruwala in the south-west and Paumben in the north).

If we examine these different species from the point of view of their organization and mode of life, it is remarkable that several of the northern forms prove to be pronounced sand Caulerpas with coarse, horizontal axes, and richly and finely branched roots, *e.g.*, *C. Freycinetii*, *cupressoides*, *Lessonii Fergusonii*, besides which *crassifolia*, *taxifolia*, and also *scalpelliformis* join them.

On the other hand it is to be noted that such species as *C. lætevirens*, *sedoides*, and possibly *dichotoma*, which have only been observed in the south, are pronounced rock Caulerpas. The species that have been observed especially in the north are, moreover, often deep water Caulerpas—for instance, *C. scalpelliformis*, *C. crassifolia*, *C. cupressoides*, *C. Lessonii*, *C. Fergusonii*—whereas those that have been found only in the south are surface Caulerpas.

* Note that *f. mixta* has also been observed at Paumben !

From what has been said above it follows that the difference in organization that prevails among the predominating *Caulerpa* species in the north and in the south, and which depends on the difference in the external conditions of life, can also be traced in such *Caulerpa* species as are rather to be considered as being more accidental ingredients in the flora. Here, too, thinning, owing to external influences, makes itself felt, so that, for instance, the rocks and reefs in the south harbour species that in their organization show themselves more fitted for these.

It is remarkable that the north-east coast of Ceylon, as far as we know, has no *Caulerpa* that is not known in other parts of the Island. It is striking, for instance, how at Trincomalee, where the rocks seem to be excellent localities for algae, the marine flora is apparently scanty and, in richness of species and luxuriance in general, very inferior to that on the rocks in the south-west. This fact seems already to have made itself clear to HARVEY, to judge by his disappointment at Trincomalee. (See "Memoir of W. H. HARVEY," London, 1869, p. 251).

2.—THE DISTRIBUTION OF THE CEYLON CAULERPAS IN OTHER PLACES.

Having dealt with the distribution of the Ceylon Caulerpas in Ceylon, we will investigate their geographical distribution elsewhere. But, first, we must remark that the following species are hitherto only known from Ceylon :—

C. imbricata	*C. parvula*
C. dichotoma	*C. Fergusonii*

These, then, must, for the present at least, be regarded as endemic species.

Among the remainder we find that, of the species which make up the main mass of the Ceylon Caulerpa vegetation, the majority are species with very wide distribution—from the Red Sea in the west to the eastern islands in the Pacific, and also in the West Indies. Such species are—

C. clavifera	*C. Chemnitzia*
C. uvifera	*C. peltata*
C. sertularioides	

C. nummularia is not reported from a more western point than Ceylon, and seems to have its main distribution in the Indian Archipelago and tropical Australia. In this connection it must, of course, be borne in mind that such statements about distribution must be taken with some reserve as far as the definition of the species is concerned, as different authors have different interpretations for the various species. Dealing with the distribution of the species, one has therefore always to reckon with the wider sense of the name in question. The restricted species and forms are, of course, much more limited in their distribution.

Of the *Caulerpa*-species that are comparatively rare in Ceylon, the two following have also the same extended distribution (Red Sea, Pacific, West Indies) : *C. crassifolia* and *C. Freycinetii.*

On the other hand, there are several of the rarer species for which Ceylon and the peninsula of India form the western limit of their distribution, as far as we know. Such are :—

C. verticillata	*C. Lessonii*
C. taxifolia	*C. corynephora*
C. cupressoides	*C. sedoides*

and possibly *C. longistipitata.*

The last-named is, be it noted, only found beyond Ceylon in the Gulf of Siam, and has thus its west limit in Ceylon ; but, on the other hand, the closely related *lentillifera* has a still more pronounced west distribution, since it occurs in the western parts of the Indian Ocean (Madagascar).

While, comparatively speaking, so many species have their western limit in Ceylon, *i.e.*, they themselves have a more easterly centre of distribution, it is very striking that Ceylon is not the east limit for hardly more than one species, viz., *C. scalpelliformis*, which together with closely allied forms occurs from the Red Sea to Ceylon in the north and has also a wide distribution on especially the west and south-west coast of Australia and Tasmania. It is very remarkable that this species is not known from the Pacific, but, on the other hand, it has been collected on the west coast of Africa (Angola), that is, in the Atlantic.

Lastly, Ceylon is the north, or perhaps better the north-west limit for two species, the central distribution of which seems to be Australia, even if they also occur in the West Indies—*i.e.*, *C. laetevirens* and *C. sedoides*. For the former, the central distribution of which seems to be North and West Australia, southern Ceylon is certainly the north limit. *C. sedoides* has similarly its central distribution in Australia, but occurs also in the Gulf of Siam; it is also found in the West Indies. In any case, Ceylon forms its north-west limit, and it occurs there only on the south coast, not in the north at all.

We find, therefore, that the main mass of the Ceylon Caulerpa vegetation consists of many species with extensive distribution (from the Red Sea in the west across the Indian Ocean to the Pacific Islands in the east, together with the West Indies), but also of several species with a more easterly main distribution for which Ceylon and India form the western limit.

Finally, the Ceylon Caulerpa flora harbours some Australian elements and one species with a pronounced western distribution and, of course, the endemic species mentioned above.

(3) The Geographical Distribution of Caulerpa in General.

In this last chapter we will deal with the question of the geographical distribution of the *Caulerpa*-species in general. They belong almost exclusively to the true tropical flora, and have their main distribution in the tropical and sub-tropical coasts of the Red Sea, the Indian Ocean, and the Pacific, and also in the tropical Atlantic (to which must be added the Mediterranean), especially the West Indies.

But it must be noted in this connection that the Indian Ocean and the Pacific harbour far more species than the Atlantic. Of the 50 to 60 *Caulerpa*-species known, the majority belong to the ocean area of the Indian and Pacific Oceans, which too is considerably more extensive than the tropical Atlantic (including the Mediterranean), which does not harbour as many *Caulerpa*-species. Many of the species belonging to the former area have a wide distribution, from the Red Sea and the east coast of Africa in the West to the easterly Pacific Islands in the East. Others, however, have a considerably more limited distribution.

Thus, especially southern Australia, including Tasmania, is the home of several characteristic and closely related species forming some very natural groups within the genus, namely, J. G. Agardh's groups, *Hippuroideæ*, *Lycopodioideæ*, *Sedoideæ pedicellatæ*, and *Opuntioideæ*, of which only an occasional species occurs exceptionally beyond the Australian coasts.

Of the species that occur in the tropical Atlantic (and Mediterranean) the majority are common also to the Pacific and Indian Oceans, and there are but half a dozen *Caulerpa*-species at the most that occur exclusively in the Atlantic, whereas the Indian-Pacific Ocean has many (30 to 40) species that do not occur in the tropical Atlantic.

It seems from this that it may be asserted that the genus *Caulerpa*, at least at the present time, has its main distribution within the Indian-Pacific Ocean area.

Very remarkable is the distribution of the species, reaching a number of about 12, which the tropical Atlantic has in common with the Indian-Pacific Ocean. Of the *Caulerpa*-species occurring in Ceylon the following also occur in the West Indies :—

C. verticillata	*C. clavifera*
C. crassifolia	*C. uvifera*
C. taxifolia	*C. lætevirens*
C. sertularioides	*C. Chemnitzia*
C. Freycinetii	*C. sedoides*
C. cupressoides	

i.e., about half the number of the sum total of the Ceylon *Caulerpa*-species. These are entirely lacking along the southern coasts of South America, which, of course, fall in part outside the tropical zone, and in general do not harbour any *Caulerpa* at all. The flora of the Cape is also very poor in Caulerpas; only five are known, and among the species common to the Atlantic and Pacific only two, *clavifera* and *Chemnitzia*, are included in this number and they are, moreover, *exclusively* found in Natal and on the east side of South Africa, which is washed by the warm Mozambique stream, but not on the west side, which has a much less tropical character owing to cold antarctic currents. It is, therefore, a remarkable fact that the centres of distribution which the species have in common, the Atlantic Ocean on the one hand, and the Indian-Pacific Ocean on the other, are at the present time separated from each other, so that there is no communication between the two different districts for the different species. MURRAY, who has closely studied the problem of the distribution of the tropical algae, has pointed this out with reference to all the marine flora that the Atlantic and the Indian Oceans have much in common. To explain this fact MURRAY has suggested that the two rather similar tropical floràs in the Atlantic and the Indian Oceans, which now communicate only *viâ* the Cape, must probably "have been periodically mingled at the epochs of warmer climate at the Cape."

This is perhaps not beyond the bounds of possibility, but it seems to me not improbable that the resemblance between the flora districts of the tropical Atlantic and of the Pacific-Indian Ocean may be explained naturally in another way, namely, that it (the resemblance) must be regarded in combination with the geological data which argue in favour of a pre-historic direct communication between the Pacific and the Atlantic, either across the Isthmus of Panama or further south. That such a communication existed even as late as in the Tertiary Age is beyond all doubt (Compare P. M. DUNCAN "On the Fossil Corals of the West Indian Islands"; R.T. HILL, "The Geological History of the Isthmus of Panama and portions of Costa Rica"; A.E. ORTMANN, "Tertiary Invertebrates"), though opinions differ when the question arises *where* the communication took place, some geologists assuming a more southerly connection than across the Isthmus of Panama.

It is very remarkable that the tropical algal district in the Atlantic is almost confined to the West Indies. This probably depends on the eastern coast of South America, just as the western coast of Africa—as MURRAY points out, not offering suitable habitats for algal growth. But then one can scarcely assume that, even if warmer water washed the south coasts of South America and especially of Africa, a more luxuriant algal vegetation should have been harboured then than is the case to-day, seeing how little suited they are said to be for algal growths of any kind. I therefore think that the communication and the relationship between the floral districts of the Indian-Pacific Ocean and the West Indies can be more naturally explained in another way, *i. e.*, that these districts once had direct communication over the districts where now the Central or South American continent separates the two great oceans.

If we examine the geographical distribution of other marine organisms, we cannot fail often to notice a greater resemblance between the West Indies and the Indian-Pacific Ocean than between the West Indies and the rest of the Atlantic. Let us, for instance, examine the marine phanerogamic plants, to the geographical distribution of which ASCHERSON ("Die geographische Verbreitung der Seegräser") has devoted careful study.

Of the genus *Thalassia* belonging to the family of the *Hydrocharitaceæ* there are only two most closely allied species, viz., *Th. Hemprichii* with uniform distribution from the Red Sea, the Northern Indian Ocean (but not the east coast of Africa, nor the Cape!) to the eastern islands of the Pacific, and *Th. testudinum*, confined to the West Indies alone.

A quite analogous distribution is true of the two closely allied *Cymodocea* species, *C. isoetifolia* and *C. manatorum*, which together form the group *Phycoschœnus*, ASCHERS., which is sharply distinct from the other *Cymodocea*-species. The distribution of *C. isoetifolia* almost perfectly coincides with that of *Th. Hemprichii*, that is to say, the Red Sea, the North Indian Ocean, to the eastern islands of the

Pacific, and the distribution of *C. manatorum* coincides with that of *Th. testudinum*, *i.e.* is exclusively confined to the West Indies.

Similar is the distribution of the two *Halodule* species, viz., *H. uninervis* (FORSK.) ASCHERS., in the Indian Pacific Ocean and *H. Wrightii* ASCHERS., in the West Indies. The latter seems to occur also on the west coast of Africa, but not in the south at the Cape These species are so similar to each other that OSTENFELD ("Flora of Koh Chang," Part V., Hydrocharitaceæ, Lemnaceæ, &c., page 262), who has devoted a comparative study to them, says : " On the whole it is not possible to distinguish the two species when sterile, except using their quite different geographical distribution as criterion."

Also within the genus *Halophila* analogous distribution can be traced. The majority of the *Halophila* species are at home in the Red Sea, Indian Ocean (they do not reach the Cape, however), and the Pacific, and, besides, there occur very closely allied forms in the West Indies, but not from other parts of the Atlantic coasts of South America, nor from the west coast of Africa. OSTENFELD has lately described from the Gulf of Siam (Koh Kahdat) a *H. decipiens* which is so strikingly like the West Indian *H. Baillonis* that he says (*loc. cit.*, p. 261) : "If the geographical distribution was not so quite different I should prefer to regard it as a variety of *H. Baillonis*, but it is not probable to suppose such a connection, as the sea phanerogams generally have very natural and limited areas and *H. Baillonis* is confined to the shores of the West Indian Archipelago."

Ergo : numerous marine species with wide distribution in the Indian and Pacific Oceans, and which are lacking on the east coast of Africa and at the Cape, find their parallel within the West Indies in often closely allied species which are exclusively confined to the West Indies. The marine flora of the West Indies, at least the marine phanerogams and *Caulerpa*, thus show much greater resemblance and affinities to the Pacific and Indian Oceans than to the rest of the Atlantic. That this is the case also with regard to other groups of algae is certain, and I hope to return to this point again.

That the same is the case also within certain groups of the fauna, where relationship is traceable between West Indian and Pacific species, has been pointed out by several investigators (WALLACE).

One is therefore forced to the opinion that the marine flora and fauna of the West Indies, in part at least, is an off-shoot of the Pacific. In the earlier epochs of the Tertiary Age, and at least up to the beginning of the Miocene period, North and South America, as just mentioned, were separated from each other so that the Carribean Sea was only a bay of the Pacific, or a kind of straits between the Pacific and the Atlantic, and not before the transition of the Tertiary Age into the Quaternary Age did the volcanic formations arise which make up the present Isthmus of Panama and which ever since have separated the Atlantic from the Pacific. But since the Carribean Sea was at relatively so late a period no more than a bay of the great unbroken ocean which is formed by the Indian Ocean and the Pacific, what is then more natural than that this part of the Atlantic should still often show resemblances to the Pacific more than to the rest of the Atlantic. And that such a primitive and old group of plants as *Caulerpa* already then had species that still survive, is highly probable ; since other tertiary organisms are, as far as their species go, very closely allied to or the same as still existing species. And that also such a primitive group as the sea phanegorams in the West Indies and in the Pacific and Indian Oceans should be represented by species that are very closely allied, if not quite identical, follows then as a matter of course. That the species are not quite identical, perhaps only shows that they, after being isolated, have undergone somewhat different evolution, which however has not led them very far apart. This is best shown by this, that among the species in common there are no less than two genera (*Thalassia, Halodule*) and one very characteristic sub-genus (*Phycoschœnus* of *Cymodocea*), all of which consist of only two species, of which one is exclusively confined to the West Indies, the other to the Indian-Pacific Ocean.

By assuming that the similarities between the algal floræ of the West Indies and Pacific and Indian Oceans depend on a former direct connection across the present American belt of land, a number of peculiarities in the distribution of some algæ can be explained which cannot be explained by the hypothesis of a connection by way of the Cape. Thus there are several *Caulerpa* species which the West Indies and the Pacific-Indian Ocean have in common that do not occur farther west than Ceylon and the peninsula of India. Such are *C. verticillata*, *taxifolia*, and *cupressoides*, and to these could also be added one species which is only known from the West Indies and the Pacific, but not from the Indian Ocean, viz., *C. fastigiata.* These species have, therefore, a distribution which in the West does not reach the east coast of Africa, but have, on the other hand, a more eastern centre of distribution in the Pacific. To suppose that these species too, could possibly have come by way of the Cape to reach the West Indies, or *vice versa*, seems unreasonable, for in that case they could scarcely have failed to leave traces in Africa, whereas their distribution is very naturally explained by the supposition of a connection between the Atlantic and Pacific across Central America.

I therefore consider it much more probable that the explanation of the resemblances pointed out by MURRAY between the algæ of the West Indies and those of the Indian Pacific Oceans, must be looked for rather in the historical development of the connection of land between North and South America, which shows that the whole Carribean Sea was once only a bay of the Pacific, than in the assumption that it depends on a connection *viâ* the Cape in a time when the external conditions for tropical algae were more favourable there than to-day.

For a definitive proof of the above a more detailed comparative investigation of the whole algal vegetation must, of course, be undertaken, and I hope to be able to return to this matter before long.

For the present I will content myself with pointing out that the geographical distribution of *Caulerpa* as well as that of the marine phanerogams, clearly indicates that the relation of the marine flora of the West Indies to that of the Pacific-Indian Ocean must not be determined without taking into consideration the geological history of the connecting link of land between the two Americas.

VI.—LIST OF THE SPECIES.

1.—CAULERPA VERTICILLATA, J. G. AGARDH.

J. G. AGARDH, Till Algernes Systematik, I., p. 6.

A. WEBER v. BOSSE, Monographie des Caulerpes, p. 267.

SYN. *Stephanocoelium verticillatum*, KÜTZ.

MURRAY, Catalogue of Ceylon Algæ in the Herbarium of the British Museum, p. 38.

EXSICC.: WITTROCK et NORDSTEDT, Algæ exsiccatae, No. 347!

FERGUSON, Ceylon Algæ, No. 233 and 425!

This plant occurs at Galle in a small but clearly defined district where it constitutes almost the whole of the vegetation. It grows at Galle exclusively around the mouth of the stream or canal that enters the sea at Victoria Park to the north of the town proper. The low rocks, which are here quite covered by sand and mud formed by the stream are entirely coated with *C. verticillata* together with a little *Ceramiaceæ*, and these form the bulk of the vegetation. However, *C. verticillata* did not grow higher than up to the low-water mark, so that it was never exposed at low-water.

Structure of the shoots.—As Professor REINKE in his work on Caulerpa (page 7), in describing this species, confesses that he has been unable to confirm the statement to be found in the literature of the subject, viz., that it has a horizontal rhizome, we may here briefly describe the structure of its shoots and its manner of growth (fig. 1).

It always grows in thick tufts, surrounded by sand, out of which the green tufts stick up so high that they are fully exposed and wave to and fro in the swell. If we examine such a vertical assimilating branch, we shall find that it is rather richly ramified below the sand, and consists of up growing axes which all grow out of a more or less pronounced horizontal stem (fig. 1 *a*). Horizontal axes occasionally start higher up the vertical branch (fig. 1 *b*). Both the horizontal and the vertical axes bear roots, round which grains of sand are very firmly fastened, so that they do not come away even if violently shaken in water. With careful manipulation we can observe down in the sand remains of "assimilators" (in REINKE's terminology), that have evidently been sanded over. As, moreover, the older horizontal axes often grow quite deep, this characteristic reminds us to some extent of many dune grasses, which when covered with sand form their regenerating shoots from axes higher up the stem, by which means the plant continues to keep on the surface of the sand. The danger of over-sanding may be very great sometimes for *C. verticillata* in its home at Galle, since after heavy showers masses of sand and earth are carried out to sea from the stream, so that the water becomes quite muddy. The subterranean system seems to resemble the rhizomes of the higher plants in that it functions as a store for reserve-material, for its basal branches and axes are quite filled up with starch. The grains of starch, which are comparatively few in the assimilating branches, increase in the lower axes and in the horizontal rhizomes, and are so numerous there that the rhizomes are stained quite dark blue by iodine. They probably function as stores during the plant's resting-time, for in *C. verticillata* there are clear indications of periodicity.

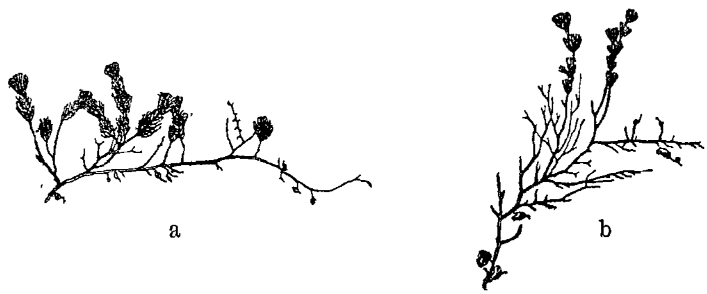


Fig. 1.—*C. verticillata*, J. G. AG. (1 × 1).

Periodicity.—From notes taken by me it seems that *C. verticillata* at Galle reaches its highest development during the months from November to March, when it occurs in masses at the mouth of the river. On visiting the identical spot in August of the same year (1903) it was scantier, but *Ceramia* and other Florideae were more abundant. The specimens of this plant collected by Prof. KJELLMAN (WITTROCK & NORDSTEDT, Algæ exsicc. No. 347) at Galle during the expedition of the "Vega" also date from December.

Geographical Distribution.—CEYLON: Galle ! Colombo (FERGUSON No. 233, 22-1-1871); THE EAST INDIES: (Tuticorin, FERGUSON No. 425) to the Friendly Islands (HARVEY); THE WEST INDIES, in several places.

2.—**CAULERPA SCALPELLIFORMIS** (R. BROWN) WEBER v. BOSSE.

WEBER v. BOSSE, Monographie des Caulerpes, p. 286.

MURRAY, Catalogue, p. 38

f. intermedia, WEBER v. BOSSE.

f. denticulata (DECAISNE) WEBER v. BOSSE.

EXSICC.: FERGUSON, Ceylon Algæ No. 411 !

Only observed once locally in shallow water on the projecting spit of land on the west side of Paumben Pass (3-4-03) together with quantities of *Codium* and *Chrysymenia*. I have not seen it anywhere else in Ceylon.

It is, in general, an extremely large *Caulerpa* with leaves attaining as much as 36 cm. in length, but with an average of about 20 cm. The lobes vary considerably in shape, being now quite narrow and scarcely dentated and curving upwards, now short and broad, clearly dentated, but not curved. Such different forms of lobes occur both on different leaves from the same rhizome and also on *the same leaf*. Of forms that have already been described the main mass of my material resembles most closely the *v. intermedia*, WEBER v. BOSSE, especially the specimens from the Mauritius (according to specimens in AGARDH's Herbarium in Lund, No. 16,431) sketched by WEBER v. BOSSE ("Monographie des Caulerpes," Pl. XXIII, Fig. 7). In Ceylon there are, therefore, transition-forms between *f. intermedia* and *f. denticulata*, but on the other hand I have never seen *f. typica*, WEBER v. BOSSE (*C. scalpelliformis*, J. G. AGARDH), a characteristic type that seems to be confined exclusively to Australia.

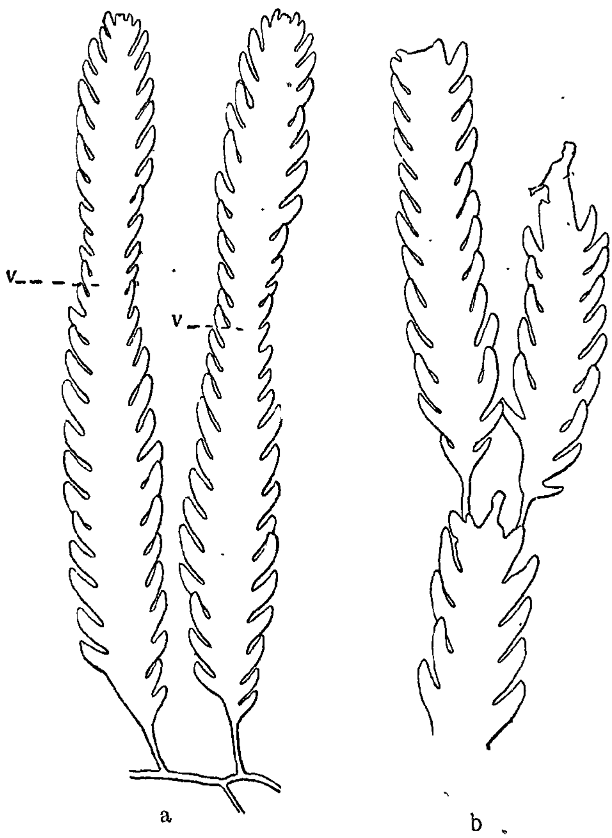


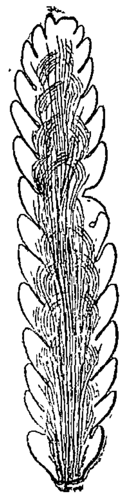
Fig. 2.—*C. scalpelliformis* (R. BR.) W. V. B. (1 × 1).

Structure of the shoots.—Especially characteristic of this species is the rich formation of regenerating shoots, precisely as J. G. AGARDH (Till Algernes Systematik I., p. 13) has asserted of it. These arise either from the points of the lobes, or from the median part of the lamina. Fig. 2 *b* shows an example of this kind of regeneration. But the leaves could increase in another way too without there being any sharp difference in the shape of a petiole. It seems to be such kind of regeneration to which J. G. AGARDH refers when in the description of his *C. scalpelliformis* (*loc. cit.* p. 13) he says: "Frondes saepe quasi innovatione prolongatae, lobis in una parte innovationis brevioribus, dein iterum longioribus," and a very fine example of this can be seen in a *C. scalpelliformis* (Herb. J. G. AGARDH, No. 16,425) collected by HARVEY in Australia. Another case can be seen in fig. 2 *a*. The terminal point of growth of the leaf (once situated at *v*) has after a short period of inactivity, resumed its activity, whereby the leaf has grown longer. This shows itself most clearly in the fact that the leaf has increased in breadth, so that the newly formed basal part has become broader than the upper part of the older portion of the leaf. (An example of the same kind is afforded by HARVEY's Plate XVII. in "Phyc. Australia" I.)

A proliferation has consequently taken place without the previous formation of a petiole. The leaves of Caulerpa show, therefore, examples of a continued and repeated apical-growth which is unknown in leaves of higher plants, but on the other hand is known in leaves of ferns and lower plants. This goes to prove the predominant shoot-nature of the assimilators, even if they have a shape analogous with leaves. This apical growth, although rhythmical, seems to be rather undefined. From this it is easily explained why the leaves in this species can attain such a great length, greater than in any other *Caulerpa ;* and it is such long growing forms that make up the *f. intermedia.*

If we examine such a leaf more exactly, we shall always find that it shows regularly alternating narrower and thicker parts, due to its development having gone on rhythmically, while the growing point has not worked uniformly, but periods of relative rest have followed periods of more active increase :

consequently a kind of pronounced periodicity in development. The same seems to me to be clear from WEBER v. BOSSE's drawings, (*loc. cit.*, Pl. XXIII., fig. 2, 5, 7).



Fg. 3.
C. scalpelliformis (R. BR.) W. V. B. (1 × 1).

This unlimited increase in length appears to be more characteristic of *f. intermedia* than of *f. denticulata* (WEBER v. BOSSE, *loc. cit.* Pl. XXIII.), which, even if not always, has yet frequently shorter leaves which are not so strongly proliferate.

Although in general the internal construction of the Caulerpas is not dealt with in this paper, I cannot refrain from touching on the arrangement of the protoplasm strings and of the chloroplasts, so characteristic of this species, as shown in fig. 3. The same has already been pointed out by JANSE ("Die Beweg. d. Protopl. v. C. prol." p. 190) in connection with the description of the same phenomenon in *Caulerpa prolifera.* Numerous main veins run through the centre of the leaf, and from them fan-shaped veinlets run into the lobes, but curve back again toward the main veins, and hence arises the characteristic structure which is shown in fig. 3. It is specially chacteristic of *C. scalpelliformis.*

Geographical distribution.—INDIA : Paumben ! (*f. intermedia* and *f. denticulata*); Tuticorin (FERGUSON, No. 411) ; the Pearl banks in the Gulf of Mannar (Dr. HERDMAN in E. S. BARTON's, "List of Marine Algæ collected at Ceylon in 1902.") From the RED SEA to the INDIAN OCEAN (Mauritius—Australia—Tasmania) ; ATLANTIC (Angola on the West coast of Africa according to several specimens in J. G. AGARDH's Herbarium in Lund ! Brazil, according to MURRAY's "Catalogue of Ceylon Algæ," p. 38).

3.—**CAULERPA CRASSIFOLIA** (AGARDH) J. G. AGARDH.

J. G. AGARDH, Till Algernes Systematik I., p. 13.

M. A. HOWE, Phycological Studies II., p. 574.

SYN. *Caulerpa pinnata*, WEBER v. BOSSE, Monographie des Caulerpes, p. 289.

Caulerpa Harveyana KUTZING, Tab. Phyc. VII. : 5, III.

Caulerpa mexicana SOND. in MURRAY, Catalogue p. 38.

EXSICC : FERGUSON, Ceylon Algæ Nos. 154, 337, 412 !

By examining the original type specimen of the younger LINNAEUS' *Fucus pinnatus* in the herbarium of the Linnaean Society in London, HOWE has shown that this plant belongs to the group Sedoideae and consequently has nothing to do with the *C. taxifolia* (VAHL) *v. crassifolia* AGARDH, which is the type for J. G. AGARDH's *C. crassifolia* created by him as a distinct species in "Till Alg. Syst." 1, p. 13. I have had an opportunity of examining the specimens HOWE mentions in his paper (*loc. cit.* p. 575), and which are to be considered as the type specimens for *crassifolia.* They are Nos. 16,445 and 16,446 in J. G. AGARDH's herbarium in Lund, and the specimens of this species that I have collected in Ceylon are quite identical with these, the original specimens from the West Indies. The same is the case with the specimens collected by FERGUSON (Ceylon Algæ, Nos. 337, 154, 412), which are kept in the Peradeniya herbarium under several different names, such as *C. taxifolia* AG. (C. A. 412), *C. mexicana* SOND. (C. A. 154), and *C. crassifolia v. Harveyana* (KG.) GRUNOW (C. A. 337).

There is no doubt left that this plant occurs both in the Indian and the Atlantic Oceans as WEBER v. BOSSE (*loc. cit.* 291) mentions, even if C. AGARDH's note "In mari Indico & rubro," as HOWE has shown, depends on faulty identification of the younger LINNAEUS' *Fucus pinnatus.* It is worthy of remark that in the AGARDH herbarium itself there are, of *C. crassifolia,* only specimens from the Atlantic but none from the Red Sea, nor from the Indian or the Pacific Oceans.

C. crassifolia occurs in Ceylon rarely in the littoral zone. Thus I have only found it at Weligama (9-3-03) inside the little reef at a depth of 1½m., where the water was very thick with sand. On the other hand, it seems much more common on the Pearl Banks in the Gulf of Mannar. Thence come fine large specimens from North Moderagam Paar (Gulf of Mannar, leg. JAS. HORNELL, 3-4-03) from a depth of about 10m. (sandy bottom with *Halophila*).

C. crassifolia from Ceylon is, in respect to the increase of the leaf, defined (even if sometimes, though rather exceptionally, a repeated point growth may be observed) as is typically the case in *C. scalpelliformis*.

That such a pronounced growth can occur in *C. crassifolia*, however, is shown by specimens of the species collected by LENORMAND in Venezuela (Herbarium in the Royal Riks-Museum of Stockholm as well as by several specimens in the AGARDH herbarium in Lund. *e.g.* Nos. 16,457–16,460) : from the creeping horizontal axis rise several assimilators and these have very clear proliferations ; the growing point is, as it were, continued in a petiole which supports a new leaf, or, again, the formation of a petiole is wanting, and only the size of the lobes is diminished, to increase again later on. By this means different stories are built up of longer and shorter branches above one another. In passing, mention may be made of the fact that LENORMAND's specimen also very clearly shows that the point of an assimilator can change its character and grow into a rhizome.

It is impossible for me to distinguish any different forms of *C. crassifolia* in Ceylon. A few specimens have, it is true, somewhat more vertically erected lobes, but they do not seem to have the character even of local forms.

Geographical distribution.—CEYLON · Weligama, at a depth of about 1½m. ! The Pearl Banks in the Gulf of Mannar (at a depth of about 10m.), collected by JAS. HORNELL ! FERGUSON, Ceylon Algæ No. 337! ; Tuticorin, collected by FERGUSON (Ceylon Algæ No. 412)!

RED SEA, INDIAN OCEAN, PACIFIC, ATLANTIC (from the West-Indies to the Canaries).

4.—CAULERPA TAXIFOLIA (VAHL) WEBER v. BOSSE.

WEBER v. BOSSE, Monographie des Caulerpes, p. 292.
MURRAY, Catalogue, p. 38.
EXSICC. : FERGUSON, Ceylon Algæ, No. 80 !

f. typica. Pinnules pronouncedly sickle-shaped, curved upwards, 4-5 times as long as the breadth of the main axis.

SYN. *Caulerpa falcata*, KUTZING, Tab. Phyc. VII., 5, v.

f. tristichophylla. Like to the foregoing form, but some of the assimilators have the pinnules at the base clearly arranged in three rows (fig. 5).

f. asplenioides (GREVILLE), WEBER v. BOSSE, *loc. cit.* p. 292 (fig. 4).

f. interrupta. Like the foregoing, but smaller and between the pinnules almost naked parts of the main axis. This variety is formed by repeated rhythmical point-growth of the assimilator (fig. 6).

C. taxifolia occurs on the shores of Ceylon in several forms, which, however, are not sharply distinct, but in places occur mixed together. Most common in the littoral zone is the form described as *f. typica*, illustrated by Kutzing under the name of *C. falcata* (" Tab. phyc." VII., 5, v).

But I have also observed *f. asplenoides* GREV. growing together with the main form, especially at Matara in pools filled at low-water. The form *asplenioides* is, in its more pronounced forms (fig. 4), fairly characteristic, with its short, straight, not sickle-shaped pinnules, but transitions into the *f. typica*, are rather common. *F. asplenioides* seems to occur especially in deep water, and this is also the form that occurs on the pearl-banks on the shells of the pearl-oyster (*Margaritifera valgaris*), where it has been collected by HORNELL (Nov., 1902).

Besides these there occur also some other forms, which, however, are rare, and which do not play any characteristic part in the vegetation. One, which I have called *f. tristichophylla* (fig. 5), I have also observed together with specimens of the *f. typica* at Paumben (3-4-03).

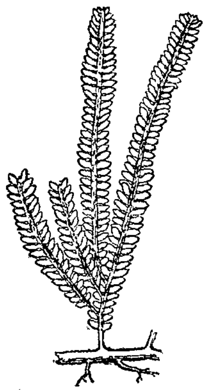


Fig. 4.—*C. taxifolia* (VAHL) W. v. B. *f. asplenioides* (GREV.) W. v. B. (1 × 1).

Fig 5.—*C. taxifolia* (VAHL) W. v. B. *f. tristichophylla, n. f.* (1 × 1).

From a horizontal axis with a predominant number of assimilators of the main type, shoots forth a branch here and there with a few pinnules in three rows (fig. 5). It is, therefore, closely allied to *C. falcifolia*, and constitutes one of the links between *C. taxifolia* and *C. falcifolia*, as predicted by WEBER v. BOSSE. As *f. tristichophylla* has only a few assimilators with pinnules in three rows and, moreover, only at the base, and as in all other respects it corresponds with *C. taxifolia*, I have come to the opinion that it must be classed under this species, the more as I agree with REINKE in considering that to point out a link of this kind between two otherwise well distinct forms does not necessarily prove that these extreme forms belong to the same species. I am therefore of opinion that in spite of this form one is quite justified in maintaining both *C. taxifolia* and *falcifolia* as different species. Probably they have a common origin. In reality one can observe also in, for instance, HARVEY's specimen (Friendly Islands Algæ No. 70. Herb. J. G. AGARDH No. 16,522), a few branches with pinnules in only two rows, *i.e.* typical *taxifolia* branches, but for the rest all the others are provided with pinnules in three rows. *C. taxifolia* stands in exactly the same relation to *C. falcifolia* as *C. sertularioides* to *C. selago*. *C. taxifolia f. tristichophylla* is consequently analogous with *C. plumaris f. Farlowii*. WEBER v. BOSSE ("Monographie" p. 295).

Fig 6. *C. taxifolia* (VAHL) W. v. B. *f. interrupta, n. f.* (1 × 1).

As for the *f. interrupta* (fig. 6) it is a little deep-sea form from the pearl banks in the Gulf of Mannar growing together with *f. asplenioides* on the shells of the pearl-oyster. It is a reduced *f. asplenioides* with small, weak branches and small assimilators, with the pinnules in groups on the main axis and branchless parts in between. It is clear that it has originated in a manner analogous with *C. scalpelliformis f. intermedia*: that is to say, that the point growth of the assimilators has gone on rhythmically and hence similar formations have arisen, which can be best compared with proliferations. The form seems to be more occasional, but is, however, of theoretic interest as being a form analogous with similar forms of other species, as for example *C. plumaris f. umbellata*, WEBER v. BOSSE (*loc. cit.*, p. 295).

Geographical distribution.—CEYLON: local and occasional as at Matara! (*f. typica!* and *f. asplenioides!*) in rock-pools; Weligama! (at a depth of about 2 m. inside the reef together with *Halimeda gracilis*); Colombo (*f. typica*, FERGUSON Ceylon Algæ, No. 80!); Pearl Banks in the Gulf of Mannar! (*f. asplenioides*.

and *f. interrupta* at a depth of about 10 m.), also at Paumben ! (South-India) at a depth of about 6 m. (*f. typica*). INDIAN OCEAN. PACIFIC (*f. asplenioides* at Sandwich-Islands). ATLANTIC (the West Indies).

Note that the closely allied *C. falcifolia* has its distribution in the Pacific and on the coasts of Australia.

5.—**CAULERPA SERTULARIOIDES** (GMELIN) HOWE.

HOWE, Phycological Studies II., p. 576.

SYN. *Caulerpa plumaris* (FORSKAL) WEBER V. BOSSE. Monographie des Caulerpes, p. 294.

Caulerpa plumaris, AG. MURRAY, Catalogue p. 38.

EXSICC.: HARVEY, Ceylon Algæ No. 61!; FERGUSON, Ceylon Algæ Nos. 3, 40 !; WITTROCK *et* NORDSTEDT, Algæ exsiccatae No. 344!

f. brevipes (J. G. AGARDH).

WEBER V. BOSSE, loc. cit. p. 294.

f. longiseta (J. G. AGARDH).

WEBER V BOSSE, loc. cit. 295.

f. umbellata (WEBER V BOSSE)

WEBER V. BOSSE, loc. cit. 295.

Caulerpa sertularioides f. brevipes (fig. 7) is a common littoral form at the surface of the water and seems to prefer spots somewhat exposed, where it grows in company with other green algæ, often in thick tufts (fig. 8). So it occurs on the western, more exposed side of the Galle reef, especially on the flat coral rocks below the Star bastion. On the surface it is often very short and the vertical axes often do not attain more than 1 cm. in height.

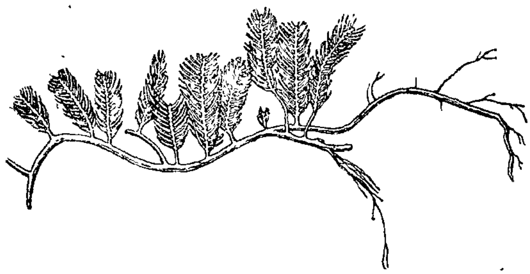


Fig. 7.—*C sertularioides* (GM.) HOWE *f brevipes*, (J. G. AG.). (1 × 1).

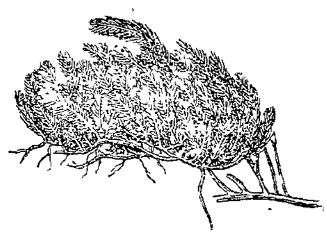


Fig 8.—*C. sertularioides* (GM.) HOWE *f. brevipes* (J. G. AG.). (1 × 1).

The leaves in C. *sertularioides* are often characterized by the same rhythm as I have already described before in several other Caulerpas, *e.g.*, *C. scalpelliformis*, *crassifolia*, and *taxifolia*. The growing point after a period of rest begins a new activity, whereby the first formed pinnules are very short and afterwards increase in size. As now the activity of the growing-point lasts only a very short time and consequently only a small increase in the leaf takes place each time, we thus get the characteristic *f. umbellata* (fig. 9), which is characterized at a hasty glance by its external likeness to *C. verticillata*, in that the branches are arranged in tufts around the main axis. Of course a sharp difference is constituted by the fact that *f. umbellata* has the pinnules predominantly in two directions, in contrast to *C. verticillata*. That *f. umbellata*, however, can also have them in several directions follows from WEBER V. BOSSE's note (*loc. cit.* p. 295).

Fig 9.—*C. sertularioides* (GM.) HOWE *f. umbellata* (W. V. B.) (1 × 1).

The two forms *f. brevipes* and *f. umbellata* are thus rather closely allied to one another ; they grow promiscuously, and from the same *rhizome* there arise also both the one and the other form.

Also *f. longiseta* (fig. 10) characterized by its long, narrow pinnules in close rows, is not uncommon on the shores of Ceylon. But it occurs scarcely ever, if at all, in the upper part of the littoral zone, but usually in somewhat deeper water. It commonly grows, not together with *f. brevipes*, but, as far as I have observed it, in deeper water, *e.g.*, at Trincomalee at a depth of from 10 to 15 m. It often grows together with *C. taxifolia* as at Weligama, where these two species occurred at a depth of about 1·5–2 m It also occurs at the same place inside cavities in coral stones at a depth of about 3 m.

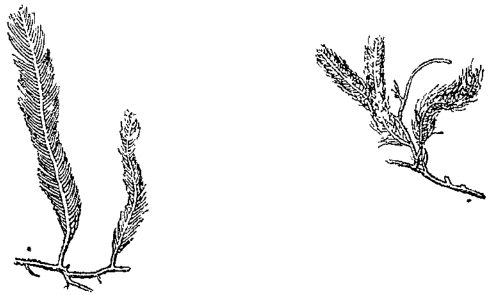


Fig. 10.—*C. sertularioides* (GM.) HOWE *f. longiseta* J. G. AG. (1 × 1).

Geographical distribution.—CEYLON; in many places; in the upper part of the littoral zone (*f. brevipes* and *f. umbellata*) and also in deeper water (*f. longiseta*) : Tangalla (*f. brevipes*) ! Weligama (*f. longiseta*) ! Galle (*f. brevipes*, *f. umbellata* and f. *longiseta* [KJELLMAN in WITTR. et NORDST. Alg. exsicc. No. 344])! Colombo (FERGUSON, Ceylon Algæ Nos. 3, 40! in *Herb.* J. G. AGARDH No. 16,474 (*f. umbellata* and Nos. 16472, 16473, *f. longiseta*); Jaffna (*f. brevipes* and *f. umbellata*)! Trincomalee (*f. longiseta*)!

RED SEA, INDIAN OCEAN, PACIFIC (to the Friendly Islands), ATLANTIC (from the West Indies to Cape Verde).

6.—CAULERPA FREYCINETII, C. AGARDH.

f. lata, WEBER v. BOSSE, Monographie des Caulerpes, p. 313.

I have observed this *Caulerpa* only once, namely, on the south beach of the island of Mandaitivu outside Jaffna in the north of Ceylon, at a depth of about half a metre at low water. It is a pronounced sand form, which has a strongly and well-developed rhizome creeping in the sand with short coarse assimilators. These are spirally bent with branches entangled, forming as it were small matted balls that stick up out of the sand. *C. Freycinetii* is very rich in forms and has an extensive distribution. *f. lata* occurs in the Red Sea; in the Gulf of Siam, and the Indian Archipelago as far as the Marian Islands and the Friendly Islands. REINKE mentions that *C. Freycinetii* occurs in East India, but does not specify any definite locality. In any case it has not been noted before from Ceylon* where, however, it seems to be a rare and accidental constituent, at least in the littoral flora.

Geographical distribution.—CEYLON : Jaffna (the island Mandaitivu)! RED SEA, INDIAN OCEAN PACIFIC, ATLANTIC (the West-Indies).

7.—CAULERPA CUPRESSOIDES (VAHL) WEBER v. BOSSE.

var. typica, WEBER v. BOSSE, Monographie des Caulerpes, p. 327.

I have found this *Caulerpa* only once in the district investigated, namely in the upper littoral zone at Paumben Pass, where it grew together with *C. longistipitata*, *Chrysymenia sp.* and others. The plant is thus very rare within the Ceylon marine-flora district, in any case in the littoral region at least WEBER v. BOSSE (*loc. cit.* p. 330) points out that the characteristic for this form (= *var. typica* WEBER v. BOSSE) is the great regularity with which the sub-navicular pinnules are arranged in three rows along the main axis, while at the same time an occasional branch with the pinnules only in two rows is not rare. This *C. cupressoides* from Paumben Pass corresponds exactly with this description and with WEBER v. BOSSE drawings (*loc. cit.* Pl. XXVII, 7 b, 2a, 3, and XXVIII.; 1). In general the main branches are three-sided, but of the side branches of the last order an occasional one is two-sided. Moreover it corresponds exactly with the specimens collected by BORGESEN from the West Indies.

Geographical distribution.—SOUTH INDIA : Paumben Pass! : INDIAN OCEAN, PACIFIC, ATLANTIC (the West-Indies).

* It is however reported from the Laccadive Islands, Minikoi (GARDINER)

8.—**CAULERPA LESSONII,** Bory.

Bory, Voyage de la "Coquille," Crypt. p. 193. 1828 Atlas, Pl. 22, Fig. 3.

Kützing, Tab. Phyc. vol. 7, tab. 6.

Syn. *Caulerpa fissidentoides*, Greville, Remarks on some Algæ bel. to the Genus Caulerpa. Ann. and Magazine of Nat. Hist., vol. XII, sec. ser. (1853), p. 3, Pl. II.

Caulerpa Lessonii, J. G. Agardh, Till Alg. Syst. I., p. 24 (1872).

Caulerpa pennata, J. G. Agardh, loc. cit. p. 26 (1872). Type-specimen in Herb. J. G. in Lund. No. 16,624 (= Harvey, Friendly Isl. Alg. No. 68, note ! some specimens largely intermixed with *C. sertularioides* (Gmelin) Howe !).

Caulerpa Lessonii Weber v. Bosse, Monographie des Caulerpes, p. 339 (1898).

Caulerpa plumulifera, Weber v. Bosse, loc. cit.

Syn. ? *Caulerpa amicorum*, Harvey. Friendly Island Alg. Nos. 62, 63 (Herbarium J. G. Agardh in Lund. Nos. 16,630, 16,631).

Exsicc. Ferguson, Ceylon Algæ No. 413 (Tuticorin, South India)!

f. typica. The vertical axes more or less branched. The assimilators about 5 mm. in breadth with predominantly two-sided (but sometimes at the base also three-sided) pinnules, often larger than the main axis, which goes up to 2 mm. in breadth (fig. 11).

f. tuticorinensis. The vertical axes repeatedly furcated with the basal parts cylindrical for a good way up and without pinnules. The assimilators of three kinds: the majority not above 2 mm. in breadth, flat, with two-sided pinnules of about the length of half the main axis, others flat, as before, of a breadth of up to 5 mm. with two-sided pinnules somewhat bent upward, rather longer than the main axis, which is 2 mm. in breadth (that is, of the same kind as the *f. typica*), and finally too, though rare, assimilators with cylindrical main axis and only three-sided pinnules (fig. 12).

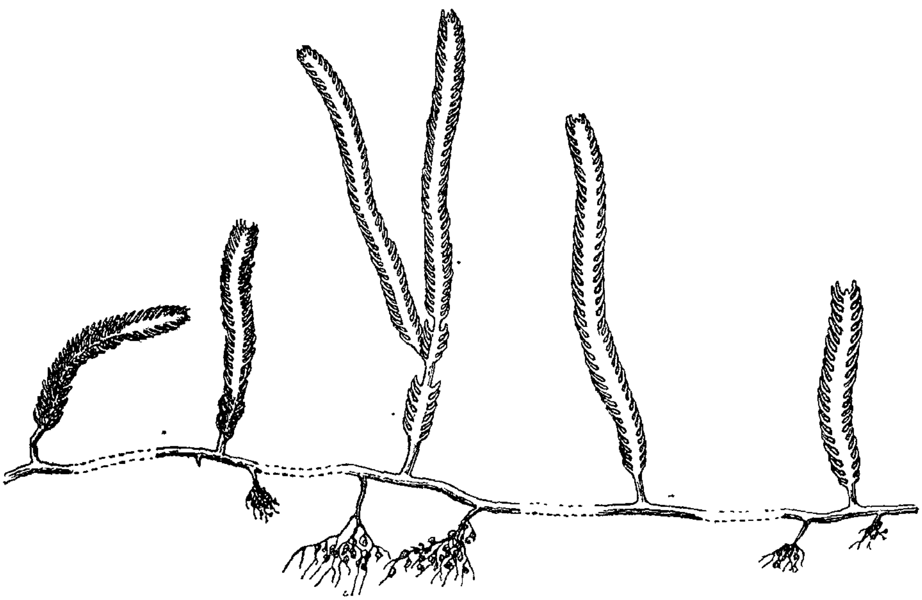


Fig. 11.—*C. Lessonii* Bory *f. typica.* (1 × 1).

The plant designated by me as the main form (fig. 11), was collected in the district by J. Hornell, east of the East Cheval Paar in the Gulf of Mannar, at a depth of about 10 m. It is a sand *Caulerpa* with the same mode of growth as *C. Freycinetii* with a very coarse horizontal stem, which often grows very deep in the sand.

The horizontal stem has very big root-branches which spread themselves in tufts of very fine branchlets, on which particles of sand are affixed very firmly. The basal parts of the assimilators are cylindrical and often without branchlets or pinnules for shorter or longer spaces.

The form *tuticorinensis* (fig. 12) has not been observed by me otherwise than in preserved specimens, and I can say nothing about its mode of growth.

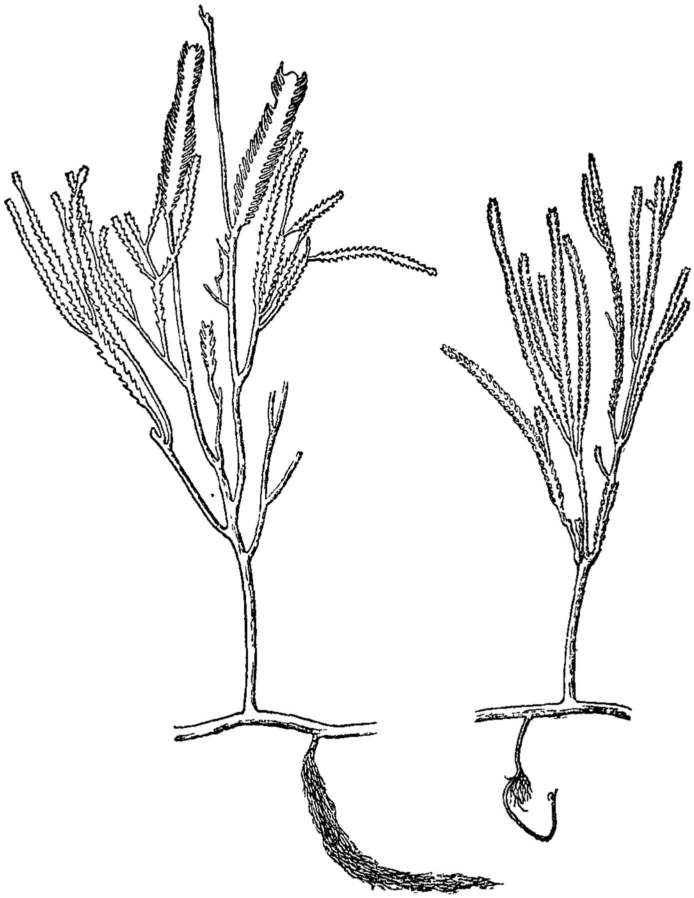


FIG 12.—*C Lessonii*, BORY, *f tuticorinensis n. f.* (1 × 1).

Remarks on the species.—Few Caulerpas, one may say, are so variable as those belonging to the group Thuyoideae. Hence, too, the nomenclature of these species is very confused and hard to disentangle. With respect to the species in question it seems to me that the following remark should be made to make clear my opinion about *C. Lessonii* and its synonymy.

The alga that BORY ("Voyage de la Coquille") described under the name of *Caulerpa Lessonii* is characterized by its flat main axis, distinguished by relatively great breadth, with usually two-sided branchlets. Even if, as WEBER v. BOSSE mentions (*loc. cit.* p. 339) BORY's fig. (or, at least, the copy in Kutzing, "Tab. Phyc." V. T, Tab. 6) has been drawn somewhat too broad, in any case Bory's *Lessonii* must have been characterized by relatively great breadth in comparison with related forms. These latter are to be looked for, on the one side, especially among the *C. cupressoides* series and particularly among var. *lycopodium*, WEBER v. BOSSE, and var. *disticha*, WEBER v. BOSSE; and on the other, also among the *C. Freycinetii* series var *pectinata.* But the main axis in these forms never, in general, approximately reaches the breadth which has been figured in *C. Lessonii*, BORY Clearly, then, this character must be laid stress on when diagnosing *C. Lessonii*. The fact is that the main axis in this species reaches as much as 2 mm. in breadth (exclusive of pinnules, of course) and is evidently flat, with two-sided pinnules.

That the plant I have reproduced here from Ceylon (fig. 11), collected by HORNELL on the pearl-banks in the Gulf of Mannar, is identical with GREVILLE's *fissidentoides* (see GREVILLE, Pl. II., *loc. cit.*) seems to me to be beyond any shadow of doubt. GREVILLE's figure has the main axis in certain parts almost 2 mm. in breadth, and in my figure (drawn natural size from formalin material) the main axis in many places is fully 2 mm. Also the circumstance that *C. fissidentoides*, GREV., has been collected on "the shores of the Peninsula of India" supports to some extent the assumption that these plants are quite identical. But, on the other hand, this species is, according to WEBER v. BOSSE—who had an opportunity of examining the type specimens—synonymous with *C. Lessonii.* Curiously enough J. G. AGARDH does not mention—as far as I have been able to find—anything about GREVILLE's *C. fissidentoides.*

If, now, it is quite evident that the alga from the pearl banks is identical with GREVILLE's *C. fissidentoides* and therefore also with BORY's *C. Lessonii*, on the other hand the matter is by no means equally evident as far as another alga hereunto belonging is concerned, which has been collected by FERGUSON at Tuticorin in S. India and numbered 413 in his "Ceylon Algæ." It has been determined by GRUNOW as *C. Lessonii*—on the label in the Peradeniya Herbarium one reads "C. pectinata, Kutz"—and it is presumably the very same alga as MURRAY calls *C. fissidentoides* in his "Catalogue of Ceylon Algæ," p. 37. WEBER v. BOSSE, on the other hand, will not accept this determination (cf. "Monographie," pp. 339, 340) but is of the opinion that FERGUSON's Ceylon Algæ No. 413 is to be referred rather to *C. plumulifera*, ZANARDINI (= *C. pennata*, J. G. AGARDH), at the same time as the author questions whether *C. plumulifera* is not possibly to be coupled with *C. Lessonii*, a matter which can only be settled when fresh specimens have been examined. In the Algal Herbarium in Peradeniya, which was kindly placed at my disposal, there are several specimens of this FERGUSON's Ceylon Alga 413, but also another one too (FERGUSON, C. A. 161) labelled "*C. fissidentoides.*" though of the last-named there is only one very poor specimen, only a few indeterminable fragments.

Where do these forms belong? The first named (C. A. 413) fairly corresponds in the main with WEBER v. BOSSE's description and figure of *Caulerpa plumulifera*, ZANARDINI (*loc. cit.* p. 340, Pl. XXXI., fig. 3). It is, then, distinguished by assimilators with fairly long cylindrical petioles and with many branches (fig. 12). For the rest, the greater part of the branches also look as in WEBER v. BOSSE's figure (*loc. cit.* Pl. XXI. fig. 3), which seems to justify this form being referred to *C. plumulifera.* But on a closer examination of the Peradeniya specimens it is soon clear that some are characterized by branches of a quite different kind, viz., partly broad, coarse ones, which by their size and breadth are sharply distinct from the others (the transitions to which are also very abrupt), and partly weak cylindrical ones with three-sided pinnules.

Fig. 12 shows specimens of FERGUSON's C.A. 413. It is remarkable how the great broad branches absolutely correspond with the character which has been pointed out as characteristic for *Lessonii. i.e.* the relative breadth of the axis (up to and above 2 m.m.) and the length of the pinnules. A comparison between these branches and *C. Lessonii* in fig. 11 shows, therefore, a perfect correspondence. But from this it is also the more explicable how GRUNOW has been able to call this Alga *C. Lessonii*, and how MURRAY has included *C. fissidentoides* in his Catalogue of Ceylon Algae. On the other hand, these broad branches are not found in all specimens—*e.g.* not in FERGUSON's specimens in AGARDH's Herbarium (Nos. 16614, 16615)—and probably were not in the material that WEBER v. BOSSE had an opportunity of examining—they are not figured in her monograph Pl. XXXI., fig. 3—and from this it is quite natural that she should not have combined this species with *Lessonii*, but rather with *C. plumulifera*, ZANARDINI. But the appearance of the broad branches in the Peradeniya specimens shows, on the other hand, that one is justified in combining it with *Lessonii*, granting it to be a special form, characterized—as so many other *Caulerpa* forms—by some branches showing an appearance that corresponds with one species, other branches with another. As far as the third kind of branches is concerned, they have an appearance that can be seen from fig. 12. They are narrow, weak, and covered in all their length with small three-sided branchlets or pinnules. By their weakness, and by the fact that they are covered in all their length with three-sided pinnules, these branches differ from those with three three-sided pinnules only at the base in the plant from the pearl-banks. The peculiar transition form which FERGUSON collected at Tuticorin, and which is of great interest owing to the construction of its shoots, I call *f. tuticorinensis*. The nature of this kind of shoots, etc., I have already discussed before in the general part of this work, and I will only emphasize in this place that I am not of opinion that the classification of this form under *Lessonii* as the main species must necessarily be so explained that *f. tuticorinensis* is subordinate to *Lessonii f. typica*. I have only wished in this manner to point out their close genetic relationship.

I think, therefore, that I have shown that BORY's *C. Lessonii*, described and figured as early as 1828, must be retained as at least relatively a well-characterized form. The name *fissidentoides* (GREV.) from the year 1853 must therefore be placed in the list of synonyms. And in my opinion we should also refer *C. pennata* (J. G. AGARDH) from 1872 to the same list The type-specimens (Herb. J. G. AGARDH No. 16,624) which served AGARDH as the material for his description, are evidently smaller forms of the same species I have figured in fig. 11. Such weaker branches are also to be found among the material of *C. Lessonii* collected by HORNELL. But then AGARDH's *C pennata* is of the very same coarse structure as *C. Lessonii* and with rather broad main axes. AGARDH, also, in the diagnosis speaks about "rachis atiuscula," just as he says about the plant that is it "robustior." To avoid confusion one must remember that AGARDH's specimens are, as he himself expressly pointed out (Till. Alg Syst. I., p. 26) mixed with *C. sertularioides* (= *C. plumaris* (FORSK.). It follows as a matter of course that *C. plumulifera*, according to WEBER V. BOSSE's definition, must also be ranged among the synonyms. If ZANARDINI's specimens should also be included is an open question, as I have not had an opportunity of examining ZANARDINI's type-specimens.

That *C. Lessonii* is closely related to *C. cupressoides* is beyond a doubt. Especially the broader forms among the *lycopodium* series are very similar to *C. Lessonii*, and I have been very doubtful about *f. amicorum* in particular, as it offers great resemblance to *Lessonii*. It seems to me not improbable that perhaps several of these forms classed by WEBER V. BOSSE among the comprehensive *C. cupressoides* might with equal reason be transferred to the *Lessonii* group. This may also apply to some *C. Freycinetii v. pectinata* forms. For as WEBER V. BOSSE writes (*loc. cit.* p. 316) about this plant: "Souvent une partie de la fronde, ou des frondes entières, portent de petits ramules opposés, pectinés, *presque aussi grand que ceux du Lessonii.* * Ces échantillons portent dans les livres et la collection de MAZÉ et SCHRAMM les noms erronés de *C. pectinata*, KUTZ ou de *C. Lessonii*, BORY."

But it is precisely the occurrence of large broad shoot branches with opposite pinnules that seems to refer these forms rather to *Lessonii* than to *Freycinetii*. As for these forms belonging to the Thuyoideae series, it is of more importance that a critical study of them be made in their natural habitat, combined with experimental cultures, and of their geographical distribution, than of perhaps any other Caulerpas, in order to get an insight into the principles governing the variation of these plants, which is necessary as a basis for their taxonomy.

In this connection we may point out that this FERGUSON's C. A. 413, according to notes in the Peradeniya Herbarium, was collected by him at Tuticorin in S. India, and consequently does not really belong to the Ceylon flora. But as all the algæ collected by FERGUSON at Tuticorin have been distributed in the collection "FERGUSON, Ceylon Algae," it is explicable that several forms have been mentioned in literature as being from Ceylon, although, strictly speaking, they have not been found there. For reasons mentioned in my introduction, they are more conveniently dealt with in connection with the Ceylon marine vegetation in general, though not belonging to the flora of Ceylon in a strict politico-geographical sense.

* Italicised by the present author

Finally, with regard to the plant named *C. fissidentoides* (FERGUSON, Ceylon Algæ No. 161) in the Peradeniya Herbarium its determination is quite impossible, owing to its insignificance and poor condition. It seems to be closely related to such a form as *C. plumulifera* on Pl. XXXI, fig. 2 (but not fig. 3) in WEBER v. BOSSE's Monograph. On the other hand, it also seems to be very like *C. Freycinetii* var. *pectinata* (Pl. XXVI., fig. 3) and especially the specimens of this form from Koh Kahdat (Gulf of Siam) collected by JOHS. SCHMIDT (No. 108) determined by WEBER v. BOSSE and now in the collections of the Botanical Museum at Copenhagen.

Geographical distribution.—CEYLON : Pearl Banks in the Gulf of Mannar (*f. typica*) collected by J. HORNELL ! SOUTH INDIA ; Tuticorin (*f. tuticorinensis*) collected by FERGUSON (Ceylon Algæ No. 413) ! INDIAN OCEAN ; PACIFIC OCEAN.

9.—**CAULERPA CLAVIFERA** (TURNER) C. AGARDH.

C AGARDH, Species Algarum, p. 437.
J. G. AGARDH, Till. Alg. Syst. I., p. 36.
SYN. *C. racemosa v. clavifera*, WEBER v. BOSSE, Monographie des Caulerpes, p. 361.
EXSICC. WITTROCK ET NORDSTEDT, Algæ exsiccatae No.345. FERGUSON, Ceylon Algæ No.17.

f. macrophysa (KÜTZING), WEBER *v.* BOSSE, *loc. cit.*

f. remota. The vertical axes and also the stalks of the branchlets more or less elongated ; the branchlets separated by rather long intervals (fig. 14). This form grows in deeper water.

Caulerpa clavifera is the most common *Caulerpa* in Ceylon. It occurs in somewhat different localities both on rocks and amongst corals, but especially amongst the latter, on both sheltered and more exposed places Amongst corals, on spots with rich supplies of changing water it seems to reach its highest development, and it seems to be one of the very few algæ which can grow together with living corals and Actinians. It grows in rather large tufts (fig. 13) with the horizontal branches creeping amongst the Actinians, and with only the always short vertical axes with their large sparsely scattered spherical branchlets sticking up above them. When it grows directly on stones the roots are rather more numerously arranged as adhesive organs and it becomes a form with a relatively fewer number of coarser branches. Also the vertical axis can attain somewhat different development in different localities. But what is so characteristic of this form is, that the whole assimilation system, *i.e* , the spherical branches in general, is horizontally spread out in one level. This can be seen best if we look at fig. 13. From the coarse horizontal axis issue these vertical axes, but they are often exceedingly short, so that the spherical branchlets seem almost to be situated directly on them. If, on the other hand, the vertical axes are longer, they frequently come to lie recumbent with the spherical leaves directed only in one direction. A *Caulerpa clavifera* tuft seen from above consequently shows only a mass of small green spheres without any clear arrangement of axis system (fig 13). It seems to me as if J. G AGARDH has best drawn attention to this in his description of this plant ("Till. Alg. Syst."I., p. 36) when he says : "Surculi breviores, magis ramosi et intricati quam in plurimis. Frondes erectiusculæ quoque saepe breviores. Hinc ramificatio multo magis irregularis saepius adparet, surculis repentibus, frondibus erectis radicibusque non prope distinguendis, sed in speciminibus exsiccatis quasi sine ordine invicem mixtis." It follows from this

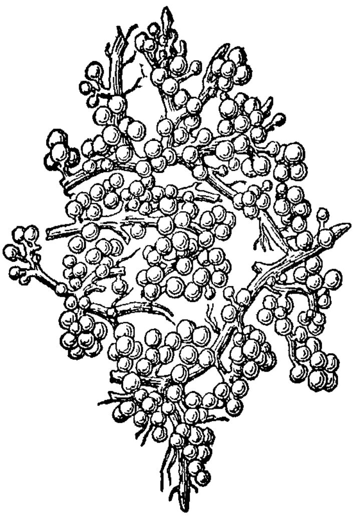


FIG. 13.—*C. clavifera* (TURN.) C. AG (1 × 1)

manner of growth that this *Caulerpa* in a natural state assumes a very characteristic appearance, which can be gathered from Mrs. PEASE's description of the mode of growth of this plant in Jamaica when she says: (F. S. COLLINS, "The Algæ of Jamaica," p. 237): "*Caulerpa clavifera* grew like little clusters of green grapes in big raggy masses." TURNER has also succeeded in describing the same characteristic appearance in his "Historia Fucorum" I., p. 126: "The name of *F. clavifer* has been taken from the appearance of the plant when recent, in which state the branches look as if merely a cluster of small clavate bodies." But the idea of this mode of growth cannot be clearly gathered from even carefully prepared herbarium specimens (cf. for instance WITTR. et NORDST. Alg. Exsicc. No. 345 as 1,204), and this fact has not been sufficiently pointed out in the descriptions.

This *C. clavifera* is a pronounced littoral alga, which is only met with exceptionally in deeper water, and then often under a changed appearance. I have frequently seen it so near high-water mark that at low-water it is only washed by the swell and is thus always fully exposed to almost the whole strength of the tropical sun. And, pressed against the substratum as it is, it might not unappropriately be compared with that type of heath-plants which has been called "espalier plants" (WARMING)—it then receives that strength of light from practically one direction only.

With respect to the size of the spherical branchlets, this varies a little. In general the majority of the forms seem as if they ought to be referred to the *f. macrophysa*, at least according to WEBER v. BOSSE's definition of this form in her Monograph (p. 361).

Fig. 14.—*C. clavifera* (TURN.) C. AG. f. *remota n. f.* (1 × 1).

As has been mentioned above, *C. clavifera* forms are, as a rule, never met with in other places than in the uppermost part of the littoral region. Sometimes, however, one can find in deeper water a *Caulerpa* form which apparently is closely related to *clavifera*. Fig. 14 shows such a one, which I found at Galle in a dark deep pool growing on another alga. It differs in that the vertical axis system has been elongated and the branchlets or pinnules have been separated, and especially in that the stalks of the branchlets are often considerably longer than the spherical vesicles, while the main axis itself has been also considerably elongated. The whole plant gets through this, a habit which reminds one of *C. Lamourouxii*, at least its forms which have always cylindrical main axis. The original *f. Lamourouxii*, as it was described by TURNER—and according to him by C. A. and J. G. AGARDH—had only cylindrical axis. But, owing to the occurrence of transition forms to such forms as have flat axis, WEBER v. BOSSE has brought together all these forms under var. *Lamourouxii*, which thereby has received a very extended sense.

Whether such a form as this should be classed under the *Lamourouxii* series, however, seems to me to be very doubtful. There are no transition forms at all from *clavifera* to such ones with flat main axis to be found in Ceylon. This form should, on the contrary, most certainly be derived from *clavifera*, the only closely related form that grows in the district and of which it must be considered as a deeper water or shade form. Naturally it could imaginably be derived from *C. uvifera*, but this *Caulerpa* does not occur at all within the south-west region of Ceylon, but only in the north. Whether it is identical with J. G. AGARDH's *C. racemosa laxa* (Till. Alg. Syst. I p. 35) can only be determined by examining the type-specimens, but there are none in AGARDH's Herbarium. I propose to call this form *f. remota*.

I have not found any periodicity at all in the development of this species; it seems to have the same appearance all the year round.

Geographical distribution.—CEYLON: very common along the coast, but especially on the south-west, more rocky part with coral reefs. Tangalla! Dondra Head! Matara! Weligama! Galle (with *f. remota*)! Ambalangoda! Beruwala! Kosgoda! Jaffna! Kangesanturai! Trincomalee!

RED SEA; INDIAN OCEAN; PACIFIC; ATLANTIC (West-Indies).

10.—CAULERPA UVIFERA (TURNER).

SYN. *C. racemosa β. uvifera*, J. G. AGARDH. Till. Algernes Syst. I., p. 35.

C. racemosa var. *uvifera*, WEBER v. BOSSE, Monographie des Caulerpes, p. 362.

F. COMPRESSA, WEBER v. BOSSE, loc. cit. p. 363. EXSICC.: HARVEY, Ceylon Algæ No. 63.

f. intermedia, WEBER v. BOSSE, loc. cit. p. 363.

f. planiuscula. Some branchlets flattened out from above, but between these and the spherical ones regular transition forms are to be found (fig. 16, 17).

SYN. *C. racemosa* var. *uvifera f. intermedia* WEBER v. BOSSE. loc. cit. (pro parte) Fig. 24 a, b, Pl. XXXIII.

What constitutes the main difference between the *clavifera* and the *uvifera* series is that in the latter (fig. 15) the vertical axes (= assimilators, REINKE) reach a higher degree of development, while at the same time they are not so close. They are, as a rule, somewhat longer and have more numerous extremely close branchlets, which are situated around the vertical main axis. The assimilation system does not, therefore, lie on the same level, but each assimilator forms a more limited whole. This probably depends to some extent on the mode of growth.

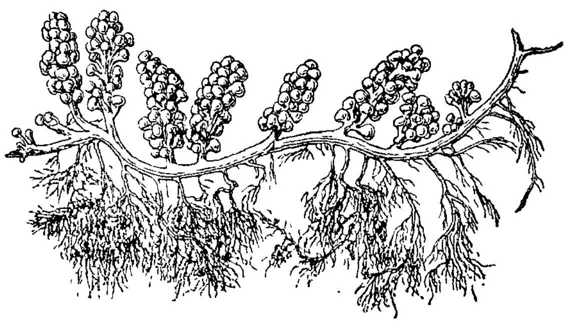


Fig. 15.—*C. uvifera* (TURNER). (1 × 1).

For, in Ceylon, *C. uvifera* is not to be found in the same places as *C. clavifera, i.e.*, in the strictly littoral regions. On the contrary, I have never seen this *C. uvifera* on the coral reefs or rocks in the south-west of Ceylon, where rocks predominate; I have only found it at Jaffna and Kangesanturai in the north of Ceylon from rather deep water and where the shores have quite a different character, with a loose bottom consisting of sand and coral-mud. At Kangesanturai it occurred abundantly, lying free on the beach, washed ashore probably from somewhat deeper regions. It is also remarkable that in regard to the root-system quite a remarkable difference prevails between *C. racemosa* and *C. uvifera*. The latter has, as can easily be seen by comparing figs. 13, 14, and 15 a much more richly developed root-system.

The root branches are longer and more branched, parting into innumerable fine root-branchlets. These adhere so firmly to sand and shell particles that on uprooting these plants masses of sand and the like will loosen and accompany the roots sooner than these latter break. The *clavifera*, preferably growing on corals and stones, on the other hand, has not by a long way so finely branched a root-system, but is fixed by few and coarser root-branchlets.

The difference that exists between *C. racemosa* and *C. uvifera* in respect to their organization corresponds therefore with different localities. The majority of Ceylon forms of *uvifera* observed by me seem to belong to *f. intermedia* (WEBER v. BOSSE), at least when chief importance is laid on the character which is laid stress on in the diagnosis, viz., that " les ramules " are evidently stalked.

The *f. compressa* WEBER v. BOSSE (HARVEY, Ceylon Algæ 63) I have been unable to find again. On the other hand, in the Peradeniya Herbarium there is a little form from Bentota labelled " *C. sedoides* AG. " which seems indentical with Harvey's C.A. 63. Probably it is a mere accidental form, which does not play any very important part in the vegetation.

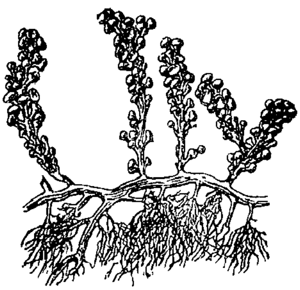


Fig. 16.—*C. uvifera* (TURNER *f. planiuscula n. f.* (1 × 1).

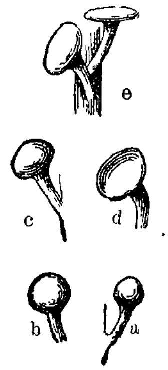


Fig. 17.—*C. uvifera* (TURNER) *f. planiuscula n. f.* Different kinds of branchlets—a, b, c from the base, d, e from the top. (3 × 1).

The *f. planiuscula* is of a great theoretical interest. Fig. 16 shows a picture of it. WEBER v. BOSSE has, in her monograph figured such a form (*loc. cit.* Pl. XXXIII. fig. 24 *a* and *b.*) and also described its origination, though only in the explanatory text accompanying the figure (p. 401, &c), without, however, giving it a special name and only arranging it under *f. intermedia*. She does not mention it in dealing with the different forms of *C. uvifera*. As to the mode of growth and habit, it corresponds with other *uvifera* forms. On a closer examination of the axis, however, we shall find that, especially at the point, flattened out vesicles occur together with transition-stages to the spherical ones (fig. 17). Such branches remind one somewhat of *C. peltata* and *C. Chemnitzia*, but from these the *f. planiuscula* differs partly by the lack of cylindrical branchlets at the base, partly too by the flattened branchlets being more sharply distinguished—the vesicle being more distinctly set of from the stalk and not with the shape characteristic of *Chemnitzia*. The organisation of *f. planiuscula* means, as we can see, a certain increase of the assimilating surface, in analogy with *C. peltata* and *C. Chemnitzia*. But whereas, as for instance in *Chemnitzia*, the flattened branchlets are derived from strictly cylindrical branchlets, in *f. planiuscula* they are formed by transformation of spherical branchlets (cf. fig. 17). These different forms consequently show a fine example of how forms externally similar may be developed in different ways.

Geographical distribution.—CEYLON : *f. intermedia* on the north coast of Ceylon in the deeper parts of the littoral zone ; the islands around Jaffna ! Kangesanturai ! *f. compressa*, Bentota (FERGUSON) and HARVEY (without any more clearly defined locality) ; *f. planiuscula*, Jaffna !

RED SEA ; INDIAN OCEAN ; PACIFIC ; ATLANTIC (West Indies).

11.—**CAULERPA CORYNEPHORA**, MONTAGNE.

SYN. *C. racemosa* var. *corynephora*, WEBER v. BOSSE, Monographie des Caulerpes, p. 364.

f. complanata (J. G. AGARDH) WEBER v. BOSSE, loc. cit.

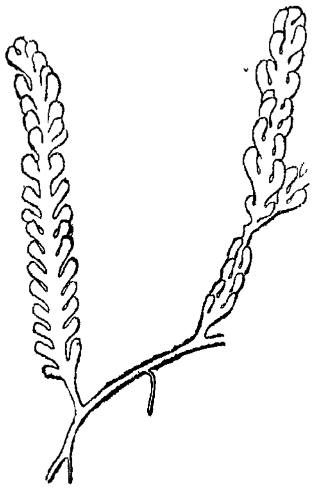


Fig. 18.—*C. corynephora* MONT. *f. complanata* (J.G. AG.) W. V. B. (1 × 1).

In the Herbarium in Peradeniya there is, under the name of "*Caulerpa clavifera* var. ? DICKIE," a *Caulerpa* collected by FERGUSON at Tuticorin (Ceylon Algæ No. 414) on the Indian Coast. As these algæ are in his collection of Ceylon Algæ and as Tuticorin is situated close to the flora district of Ceylon, a mention of this *Caulerpa* form may not be without interest. Fig. 18 shows the appearance of this *Caulerpa*. It has a strongish horizontal rhizome with a vertical axis clearly flat and the branchlets arranged in two opposite rows. It is evident that it belongs to the *corynephora* series in WEBER v. BOSSE's opinion, and corresponds well with J. G. AGARDH's description of *C. complanata* ("Till. Alg. Syst." I., p. 33), as also with type-specimens in AGARDH's Herbarium in Lund. We may call special attention to the correspondence with AGARDH's description of the branchlets (ramenta) as can be seen from the picture. That is to say, they are partly more regular in breadth, partly also constricted at the base, and consequently more clavate at the point. When branches of the latter kind predominate this form has a resemblance to the *Lamourouxii* series, with which the *corynephora* series has evidently some relationship.

Geographical distribution.—SOUTH INDIA : Tuticorin (FERGUSON, Ceylon Algæ, No. 414) ! CELEBES ; Tropical Coasts of AUSTRALIA.

12.—**CAULERPA LÆTEVIRENS**, MONTAGNE.

SYN. *Caulerpa racemosa* var. *lætevirens*, WEBER v. BOSSE, Monographie des Caulerpes, p. 366.

f. laxa (GREVILLE). WEBER v. BOSSE, loc. cit. p. 367.

GREVILLE, Remarks on some Algæ bel. to the Gen. Caulerpa, Pl. II., figs. 1, 2. Ann. and Magazine of Nat. Hist., vol. XII, sec. ser. (1853).

Caulerpa laxa, GREV. MURRAY, Catalogue p. 38.

EXSICC. HARVEY, Ceylon Algæ No. 64.

f. depauperata. In all respects very slender and weak, smaller than any other forms; it is most nearly allied to *f. laxa*, of which it is probably to be considered a *dwarf* form (fig. 20).

f. cæpitosa. Branchlets swollen up, rigid, cylindrical, or somewhat clavate, the vertical axis short, not above 15 mm. in height and the whole plant firmly and closely tufted with very rigid branchlets rather closely pressed together (figs. 21, 22).

C. laetevirens is perhaps one of the rarest *Caulerpa* forms in Ceylon. I have only observed it at Galle (*f. laxa*, *caespitosa*, and *depauperata*) and Weligama (*f. laxa*) on the south coast, and only at the first-mentioned place in any great quantity, forming a distinct association. At Galle it grows on the ledges north of Victoria Park ; there it constitutes by itself almost the whole vegetation in localities strongly exposed to swells, where the slender assimilators swing to and fro in the waves.

In its organization it also shows adaptations to such a mode of life. The rhizome (fig. 19 *a*) or the creeping horizontal axis is relatively strongly developed, and very long, with numerous closely set root-branches fixed to the scarred rocks ; on the other hand, the vertical axes are few and with rather large intervals between them. The result is that the plant becomes firmly fixed, because the rhizome and the system of roots are so strongly developed in comparison with the relatively few and short assimilation branches which they have to keep attached. The vertical axes are slender with close pinnules. These, in regard to their form, may vary a little, in that they are sometimes quite cylindrical—which is the most common, sometimes more clavate and somewhat flattened laterally. The former kind of branches is the commoner, and if both kinds occur on the same vertical axis the cylindrical ones are to be found at the base, the clavate ones at the top. This form is precisely GREVILLE's *C. laxa* (HARVEY, Ceylon Algæ No. 64) according to specimens in J. G. AGARDH's Herbarium in Lund (No. 6,744).

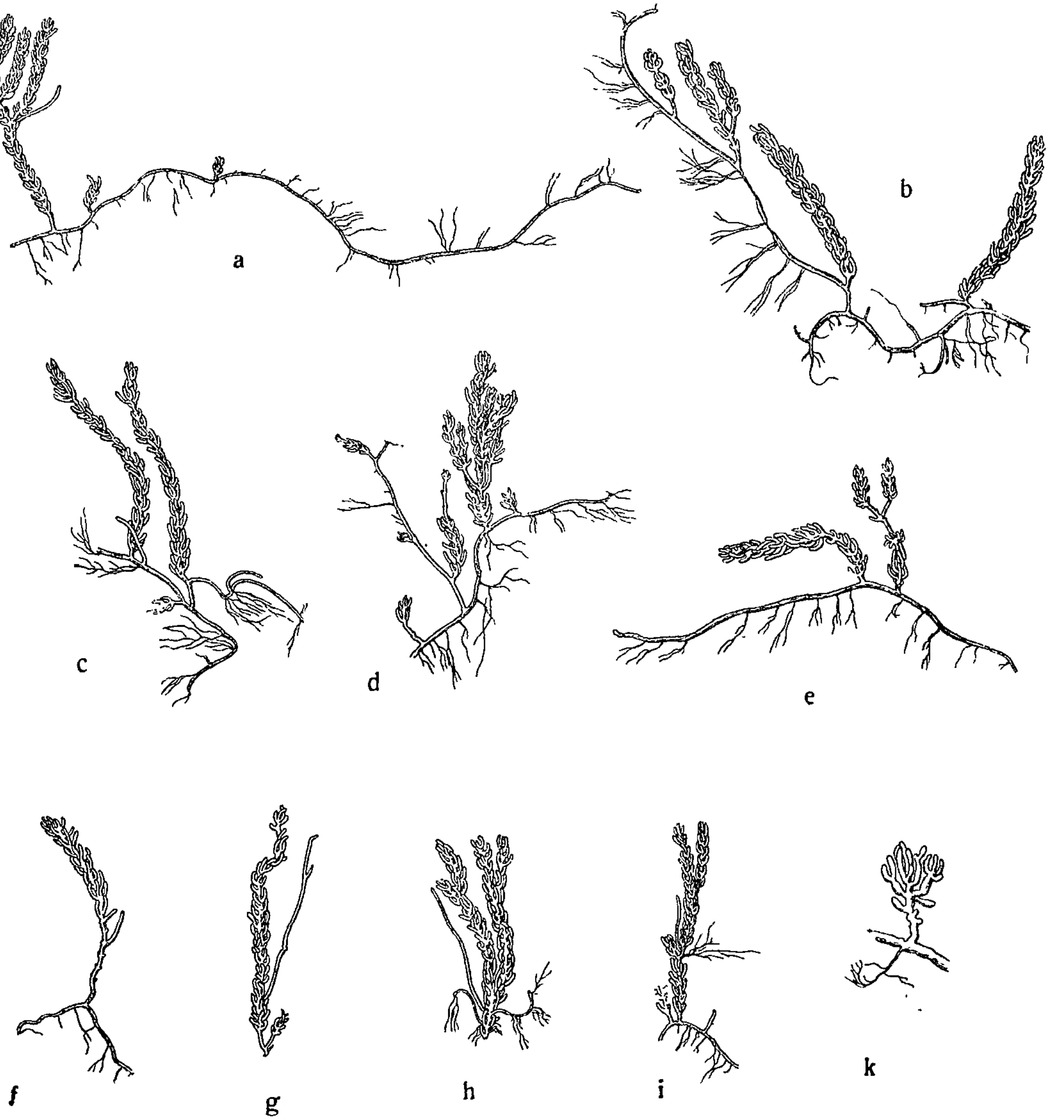


Fig. 19.—*C. lætevirens* (MONT.) *f. laxa* (GREV.); (a—i 1 × 1 ; k 2 × 1).

As specially characteristic of *forma laxa* and what may also be regarded as a kind of adaptation to its manner of growth in strongly exposed places, is its very strongly developed formation of rhizomes : see fig. 19. In this connection it may be especially pointed out that this form shows great inclination to let the branchlets grow out to horizontal axes which take root and contribute to attach the plant ;

they are consequently a kind of haptera (fig. 19 *a*, *c*, *f*, *g*, *h*, *i*) ; but these branchlets again form vertical axes and behave exactly as the other horizontal axes. The figures show several examples of this : so in fig. 19 *f*. we see a vertical axis where most of the pinnules at the base are gone, and only a few remain, which are just in the stage of growing out. They have not, however, as yet reached any length. Different is the case, on the other hand, with those which are given in fig. 19 *a*, *g*, *h*. In fig. 19 *a*, for instance, may be seen a fully grown branch beginning to branch; in fig. 19 *h*, where, moreover, several branchlets have grown out it has formed roots too; and the same is the case in fig. 19 *i*, &c. In all these cases it has been assimilation branches that have changed character and turned into attaching organs. These changed branchlets might possibly be looked upon as of little value, since they do not develop in the same level as the rest of the rhizome system ; but here we must observe that the rocks are, of course, very uneven, with crevices and cavities, so that the haptera easily grip, even if they are developed higher up. This form with its creeping and climbing rhizomes entangled in each other forms almost mat-like associations, from which here and there rich shoot systems radiate. Of all the Caulerpas I have studied in Ceylon there is none which shows itself in its system of shoots so well adapted for the conditions of life in which it grows as this. That the same seems to be the case with this species in other places, for instance Western Austra'ia, can be gathered from HARVEY's notes ("Phyc. Austr." I., Pl. 30). HARVEY says that the rhizomes form mats of the length of an inch or more with numerous and long roots, an apperance which is also to be seen in his figures of this plant. HARVEY also mentions that it grows "in exposed tide-pools" even if it is not absent in sheltered places.

But the branchlets not only grow out into new rhizomes, but may also directly branch and form new assimilation branches. This is also a rather common case and several examples of it are to be seen in fig. 19 *a*, *d*, *e*, *h*, *i*, *k*. In fig. 19 *d* appears an assimilator where three to four closely set branchlets have grown out in this manner into new assimilators, which are placed as a whorl around the main axis. In fig. 19 *k* is shown, doubly magnified, a young assimilator of which the branchlets have begun to part themselves in several branchlets. In few Caulerpas can the branchlets change so easily both into rhizomes and into new assimilators as in *lætevirens f. laxa*. The branchlets thereby very evidently betray their shoot-nature.

Fig. 20.—*C. lætevirens* (MONT.) *f. depauperata n. f.* (1 × 1).

I have never seem any forms so big that they could be classed under *f. typica*, WEBBER v. BOSSE (*loc. cit.* p. 366), nor have I seen any that could be classed under *f. cylindrica* with any certainty ; practically all are identical with *f. laxa*, GREV. But, on the other hand, one can sometimes find forms as exceedingly stunted as those figured in fig. 20 and which I have called *f. depauperata*. Such dwarf forms may also be seen in other Ceylon Caulerpas.

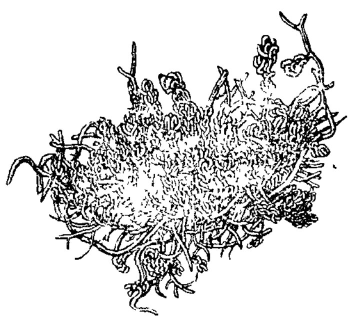


Fig. 21 —*C lætevirens* (MONT) *f cæspitosa n. f* (1 × 1).

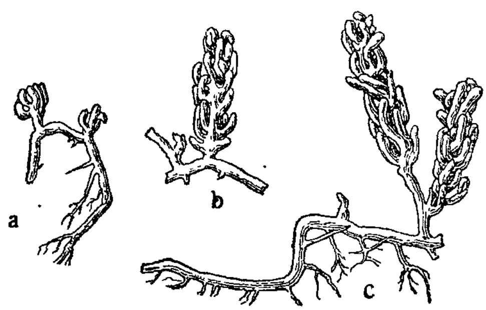


Fig 22 —*C. lætevirens* (MONT) *f. cæspitosa n. f.* (2 × 1).

As an ecological form of great interest *f. cæspitosa* (figs. 21, 22) is worth considering. It differs partly by being somewhat smaller and in the form and rigidity of its branches, and partly and especially in its mode of growth. The vertical axes are very short and closely set. The often flattened branchlets are rather rigid, and turned either up or down, and mostly directed so that as much of the surface as possible is exposed (fig. 22). This is often produced by a torsion of the branch, so that the flat side gets turned upwards. Moreover, the branches sometimes become somewhat enlarged at the point · in any case the result is that a close compact tuft-formation is produced with, at the same time, the exposure of as much of the assimilation-surface as possible. To the rigidity of the tuft-formation contributes, too, the fact that the branchlets are very rigid and not, as in the other forms, easily waved to and fro. This form, so biologically different, was found by me on stones together with several other tuft-forming seaweeds in somewhat deeper water, so that they were not laid bare at low-water and not so strongly exposed to the swell as *f. laxa*.

Finally, it seems to me to be by no means unimportant to point out that the *laxa* forms in Ceylon showed themselves very constant and well defined from other *Caulerpa* forms. In every case transition forms to the *clavifera* and the *uvifera* series were entirely absent.

Geographical ditribution.—CEYLON : Galle (*f. laxa* and *f. depauperata* in exposed places ; *f. caespitosa* in somewhat deeper water or not so exposed places)! Weligama! INDIAN OCEAN (Western Australia) ; ATLANTIC (West Indies).

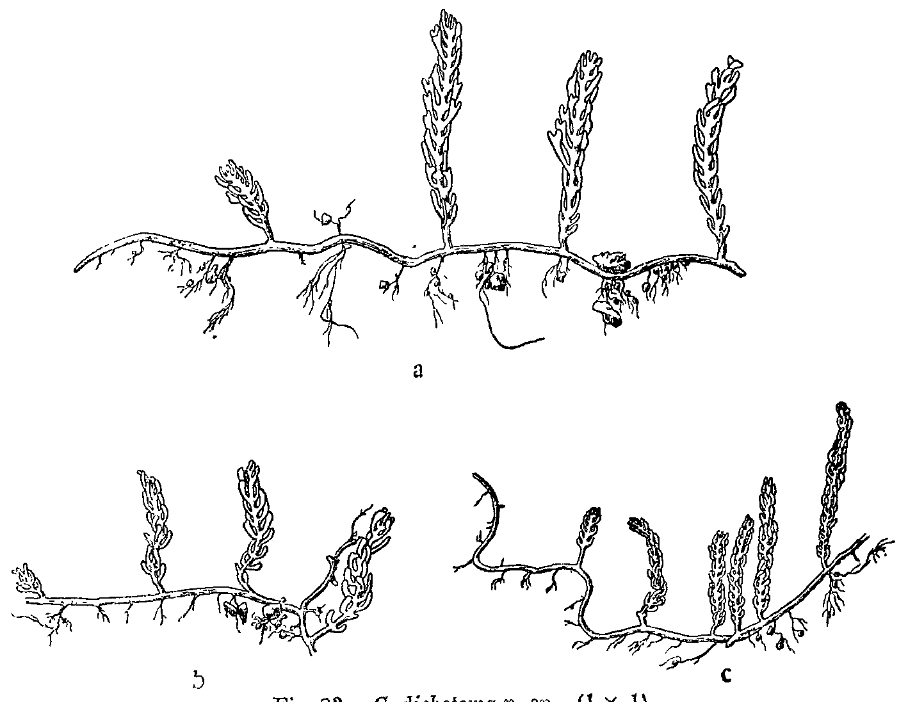


Fig. 23 —*C. dichotoma n sp* (1 × 1).

13.—**CAULERPA DICHOTOMA,** n. sp.

The horizontal axis enlarged, creeping, with the upward flattened vertical axis up to 4 cm in height with generally opposite, always flattened branchlets with generally furcate dichotomous points (figs. 23, 24).

C. dichotoma comes near to *C. lætevirens* and *C. Lamourouxii*, but differs from both in having the greater part of its branchlets dichotomous.

I found this *Caulerpa* at Weligama at a depth of from 1 to 2 m. on sandy bottom.

What justifies its creation as a special elementary species is its characteristic quality of the branchlets being dichotomous (fig. 23). A typically developed axis with such branchlets is to be seen in fig.

24 *a*. In general, the branchlets at the base seem to be undivided (fig. 24), and the dichotomous branchlets only begin higher up. On the other hand, assimilators from the same horizontal axis occur, with both prevalently simple and prevalently dichotomous branchlets

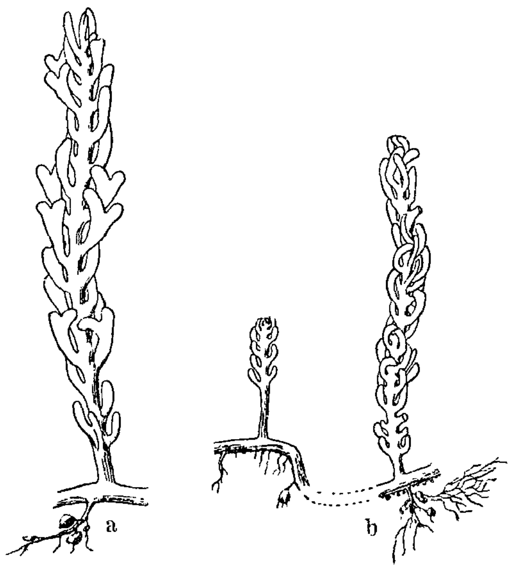


Fig. 24.—*C. dichotoma n. sp* (2 × 1).

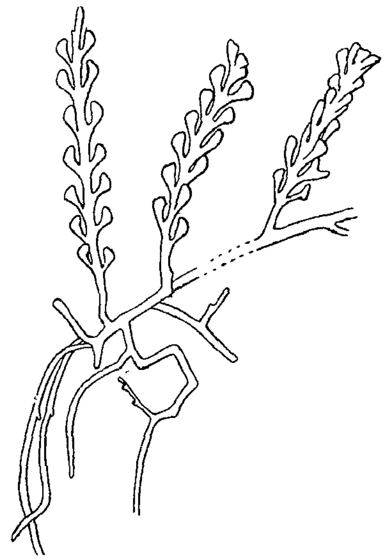


Fig. 25.—*C Lamourouxii* (TURN.) from Yemen coll. by MONTAGNE. Specimen in the Herb. in the R. Riksmuseum in Stockholm. (1 × 1).

This *Caulerpa* is without any doubt nearly related to both *C. lætevirens* and such types as *corynephora* or *Zeyheri*. The correspondence with *C. lætevirens*, especially the *f. laxa*, shows itself in the simple pinnules, especially at the base, which also in *f. laxa* are somewhat flattened together from the sides. Moreover, the vertical axes are often cylindrical in *C dichotoma*, in which case also the pinnules radiate from all sides, and this is especially the case at the base. The plant, too, at a first glance gives the impression of a *C. lætevirens*, though the mode of growth is rather different. On the other hand, the flattened axes with their opposite pinnules indicates a close resemblance to *corynephora*. But a new fact is added to this, viz., the tendency of the pinnules to branch dichotomously, and it is this character that justifies the creation of this plant as a special elementary species. A certain resemblance seems to be present to the little weak *f. Zeyheri*, too, which has also the pinnules opposite and laterally flattened; but it is always very slender, and at the same time it has always simple pinnules of somewhat different shape, so that a confusion with *C. dichotoma* is not likely to occur. However, *C. dichotoma* is very similar, or at least analogous in its development to both *lætevirens* and *Lamourouxii* (in WEBER v. BOSSE's definition). In the Herbarium in the R. Riksmuseum in Stockholm there is a *Caulerpa* labelled *C. clavifera* AG. (Yemen) from MONTAGNE's Herbarium. On the same shelf are mounted two distinct forms, not only typical *clavifera*, but also some specimens of another with flat axes and opposite sparse pinnules with the appearance of *C. Lamourouxii* (Pl. XXXII. 1 WEBER v. BOSSE, *loc. cit.*). On one of these (fig. 25) there are a few axes in which some branches show a trace of this very dichotomy which occurs typically in *C. dichotoma*. And on a closer examination of other Caulerpas I also found in the Herbarium in the Copenhagen Museum a Caulerpa on the label of which was only noted that it had been collected in "India orientalis." with similar dichotomous branchlets. It is a rather low, flat *Caulerpa* with sparse single branchlets. One of these is dichotomous. But in none of these latter specimens were the dichotomous branchlets so plentiful as in *dichotoma*. Probably *C. dichotoma* is a form which is closely allied to *lætevirens* and *Lamourouxii*, which two latter are themselves closely allied. But this does not prevent *dichotoma* being distinguished as a special elementary species, and REINKE is undoubtedly right in pointing out that the discovery of some transition forms between two *Caulerpa* types need not necessarily result in the union of these species.

C. dichotoma has a different mode of growth to *C. lætevirens f. laxa*. for the former does not occur on rocks in very exposed localities, and the latter does. *C. dichotoma* is only to be found on sandy bottoms in somewhat deeper parts of the littoral zone.

Geographical distribution.—CEYLON : Weligama (at a depth of about 1 to 2 m) !

14.—**CAULERPA CHEMNITZIA** (ESPER) LAMOUROUX.

J. G. AGARDH, Till. Algernes Systematik, I., p. 36.

SYN. *C. racemosa* var. *Chemnitzia*. WEBER V. BOSSE, Monographie des Caulerpes, p. 370.

Few Caulerpas, as far as their definition goes, may be said to be more difficult to diagnose than *C. Chemnitzia*.

It is really indisputable that the opinion—in the main—of the position of this form, as expressed by WEBER V. BOSSE, is right · it is to be considered as a transition form between *C. racemosa* (WEBER V. BOSSE *sens. lat.*) and *C. peltata*. Its distinguishing character is that, as a rule it has branchlets of different kinds, viz., partly cylindrical ones at the base of the vertical axis, and partly, higher up, such as slowly increase in breadth and are nearly trumpet-shaped. Figs. 26 and 27 show pictures of some which I consider to belong to typical *C. Chemnitzia*.

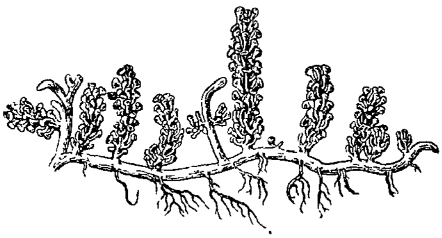


Fig. 26.—*C. Chemnitzia* (ESP.) LAM. (1 × 1).

Fig. 27.—*C Chemnitzia* (ESP.) LAM. (3 × 1).

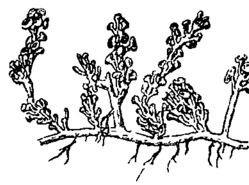


Fig. 28.—*C. Chemnitzia* (ESP.) LAM. f. *ad peltatam* (1 × 1).

A closer examination of this species shows, however, that it has not always these types of branchlets but that it varies very considerably, and these variations may point in different directions. One type of variation is to be seen in fig. 28 and fig 29 . the cylindrical basal axes are rather few, but on the other hand the trumpet-shaped axes begin very early, and they constitute the majority of the branchlets, ultimately to change—and it is this that is most noteworthy—into typical *peltata* branches with large discs and a sharp limit between disc and stalk (fig. 28.) Herein we can see a good example of the fact that *C. Chemnitzia* can go over to *C. peltata* and that the supposed relationship between *C. Chemnitzia* and *C. peltata*, as supposed by former authors, *e.g.*, DECAISNE, ZANARDINI, is fully justified.

But, on the other hand, there are also forms which point in quite a different direction. In Ceylon too, there are *C Chemnitzia* forms which have their upper branchlets developed more in a spherical than a disciform way. Fig. 30 shows such a form growing together with other *C. Chemnitzia* forms. Such are more rare on the Ceylon coast, but occur more frequently on other coasts. Thus ASKENASY (" Forschungreise, S. M. S. Gazelle," IV., Algen) mentions such a form from New Guinea, and BORGESEN has collected a similar one in the West Indies at St. John (WITTR., NORDST. ET LAGERH. Alg. exsicc. No. 1,586) which is very characteristic in that the upper part of the vertical axis to nearly half the length of the axis is provided with spherically swollen branchlets. It is also a typical form of this kind that REINKE gives in fig. 57 of his work on Caulerpa. Such forms seem to be more common in the West Indies and it is apparently such a form that J. G. AGARDH has grouped as *β. occidentalis* in his Caulerpa Monograph,

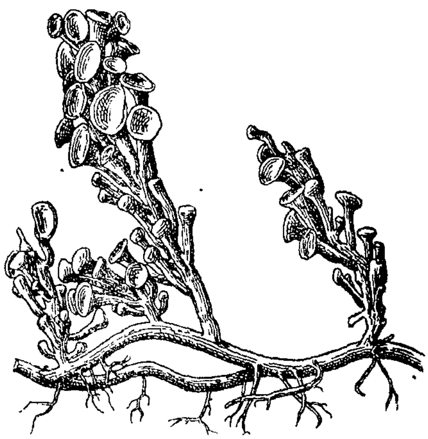


Fig 29.—*C. Chemnitzia* (ESP,) LAM. f. *ad peltatam*. (3 × 1).

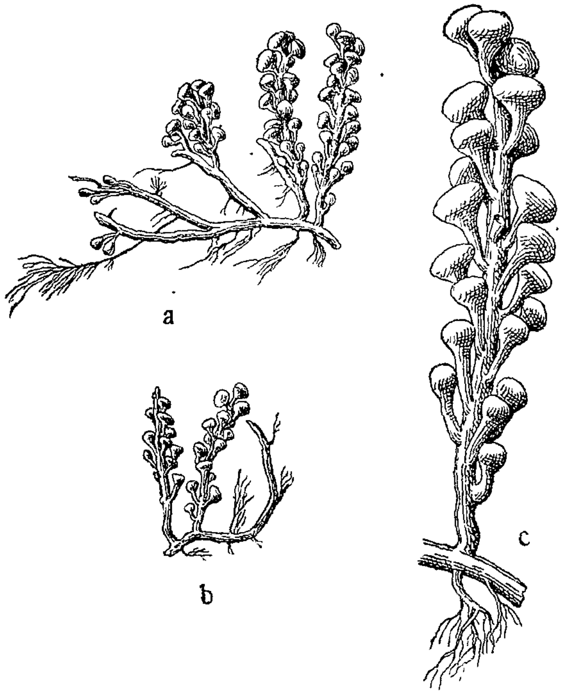


Fig. 30.—*C. Chemnitzia* (ESP.) LAM. f. *ad uviferam*. (a, b 1 × 1; c 3 × 1).

p. 37. And it is naturally the existence of such forms as has induced WEBER v. BOSSE in her monograph to class *C. Chemnitzia* as a variety of *C. racemosa* (*sens. lat.*) thereby following up an idea suggested first by ASKENASY *loc. cit.* p. 16) even if she lays stress on its transitionary position between "*racemosa*" (*sens. strict.* = *uvifera*) and *peltata*.

But if now *Chemnitzia*, as I have already shown, can develop to the same extent in the *peltata* direction as in the *uvifera* direction, it seems evident to me that it could with equal justification be classed under *peltata* as under *racemosa-uvifera* (*sec.* WEBER v. BOSSE). And judging from the variations of this species in Ceylon, one would be inclined to prefer the latter. But in my opinion both would be equally unhappy. For it is clear that *C. Chemnitzia* should be considered as a more original form than either *uvifera* or *peltata*. In reality it can develop into either. That in both variations the *basal* branchlets, *i.e.*, the first formed and earliest developed, are cylindrical seems to prove that this is an original character. If all the branchlets continue to be of this kind we get *C. lætevirens*, while if some begin to show trumpet-shaped swellings, but with flattened points, we have the typical *Chemnitzia*, which—according as the variation assumes the disciform or the spherical shape—gives rise to *peltata* or *uvifera*, respectively. But it follows from this also that *C. Chemnitzia* is to be placed under neither the one nor the other, but should be classed as independent, as a special elementary species, and that the others should consequently be subordinated to it as varying in different directions.

Also such a form as *C. imbricata* might be directly attached to *C. Chemnitzia*, *i.e.*, by means of the little *f. mixta* with the cylindrical basal pinnules. But since this lacks the slowly tapering trumpet-shaped branchlets, this is a reason that opposes such a suggestion.

Geographical distribution.—CEYLON : only the North parts : Jaffna! Kangesanturai (from somewhat deeper water) ! SOUTH INDIA : Paumben Pass ! RED SEA ; INDIAN OCEAN ; ATLANTIC (West Indies) ?

15.—CAULERPA PELTATA, LAMOUROUX.

J. G. AGARDH, Till. Algernes Systematik, I., p. 37.

SYN. *C. peltata* v. *typica* (pro parte) WEBER V. BOSSE, Monographie des Caulerpes, p. 375.

This species has a characteristic mode of branching and growth (fig. 31). From the rather coarse horizontal axes spring long vertical axes with plenty of peltate branchlets. As the illustrations of this

Fig. 31.—*C. peltata* (LAM.). (1 × 1).

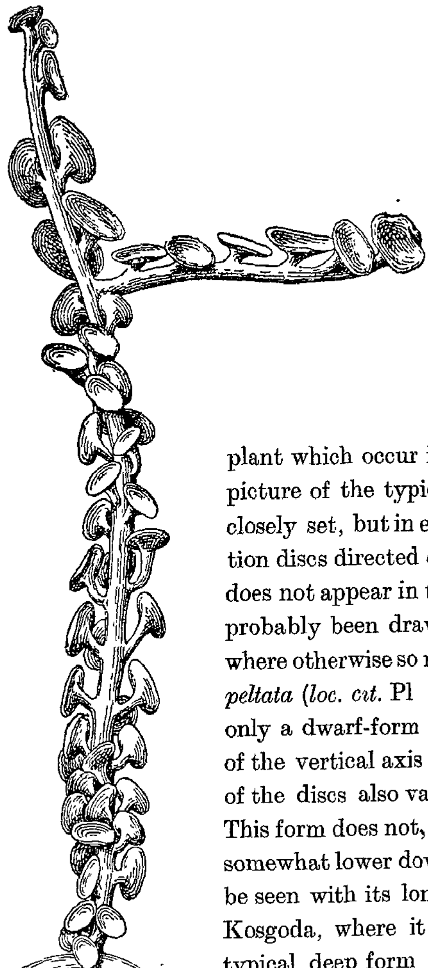


Fig. 32.—*C. peltata* (LAM.) f. *ad nummulariam* (3 × 1).

plant which occur in literature are rather unsatisfactory, I have in fig. 31 given a picture of the typical *peltata* form. The disc-shaped branchlets are more or less closely set, but in every case they radiate in all directions with the peltate assimilation discs directed obliquely upwards. It is precisely this direction of theirs which does not appear in the figures of this form which occur in literature, and which have probably been drawn from dried material. So in WEBER V. BOSSE's monograph, where otherwise so many Caulerpas have been excellently reproduced, the figure of *C. peltata* (*loc. cit.* Pl XXXI. 9) is scarcely happy, and in REINKE's work on Caulerpa only a dwarf-form with discs pointing in one direction is drawn. The length of the vertical axis naturally varies very much from 1 up to 10 cm. The diameter of the discs also varies, but the average diameter may be said to be about 3 mm. This form does not, as a rule, occur in the uppermost part of the littoral region, but somewhat lower down. It is consequently never exposed at low water, but can then be seen with its long axes swaying to and fro in the swell. This was the case at Kosgoda, where it grew on stones in densely shaded pools together with such a typical deep form as *Dictyurus purpurascens*. In very similar circumstances it grew also at Kangesanturai on the island of Jaffna. At the last-named place I observed a rather remarkable form ; fig. 32 is a picture of it. It is a largely branched, elongated form of which the majority of the branchlets are typical *peltata* branchlets Some of the assimilators, however, are clothed only at the base and a little way up with such branchlets : at the top, on the other hand, branchlets of a different kind are developed, especially on the side axes : the joints become longer between the different branchlets, at the same time as their discs increase in size. Moreover the side axes have a pronounced tendency to develop their disciform branchlets on one side only, *i.e.*, on the upper side; which apparently depends on their position in relation to the horizontal level. For, horizontal axes form their assimilation system only on the upper side, vertical ones all round, which is natural from the point of view of their exposure to the light of most advantage to them; this is especially the case if these horizontal axes take root. A transition to *C. nummularia* is thus effected, since, as I will show later on, it is just this form that is characterized by its assimilation discs being one-sidedly developed on the horizontal procumbent main axis.

Also in another respect this form is remarkable in that, as fig. 33 shows, some of the disciform assimilation branchlets are somewhat swollen and thus would very closely remind one of *clavifera* branches, if a rather evident border did not give evidence of the branchlets having originally been flat (fig. 34). WEBER v. BOSSE mentions about *C. macrodisca* (AGARDH), that its great branchlets are "distinctement bombés dans l'eau pour devenir bientôt plates quand ils en ont été retirés." While then in the case of *C. macrodisca* it seems to be the rule, in *peltata* it is rather the exception, the majority of the branchlets having qiute flat assimilation discs. It is to be noted that *C. nummularia*, too, seems to have the same tendency. So HARVEY's Friendly Island No. 76 (Herb. J. G. AGARDH, 16814), very evidently shows a mixture of *nummularia* and *clavifera* branches. This form HARVEY has called *C. clavifera v. platydisca.*

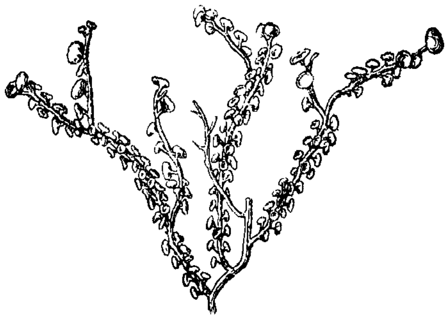


Fig. 33.—*C. peltata* (LAM.) f. *ad claviferam* (1 × 1).

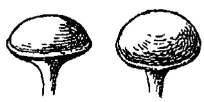


Fig. 34.—*C. peltata* (LAM.) f. *ad claviferam*, swollen branchlets from the upper part of an axis. (3 × 1).

Geographical distribution.—CEYLON: in the somewhat deeper parts of the littoral zone: Galle Kosgoda! Kangesanturai! Jaffna!: distribution for the rest uncertain, because of the incompleteness of the notes previously made about it.

I have seen unmistakable specimens of this form from the RED SEA and from the JAVA SEA (Batavia).

16.—CAULERPA NUMMULARIA (HARVEY) REINKE.

REINKE, Ueber Calerpa, p. 39.

J. G. AGARDH, Till. Algernes Syst. I., p. 38.

EXSICC.: HARVEY, Friendly Island Algæ, No. 77.

FERGUSON, Ceylon Algæ, No. 101

Under this name HARVEY distributed a Caulerpa from the Friendly Islands (No. 77) which was more exactly described by J. G. AGARDH ("Till. Alg. Syst." I., p. 38). As characteristic of this form he accentuated its great assimilation discs which are often crenulate at the border, and from these crenules new stalks and discs grow out. But AGARDH also points out that the species is closely allied to *peltata* and that the distinguishing character (*i.e.*, the crenulate discs) is far from being constant, for smooth-edged and crenulate assimilation discs occur together from the same horizontal axis. WEBER v. BOSSE also accentuates this character as the main character for her var. *nummularia*. REINKE, however, who in his treatment of the Caulerpas has a sharper eye for the morphopogical differences between the types, finds the boundary between *peltata* (main form) and *nummularia* to consist in the mode of branching. He says "Bei *nummularia* fehlen die Axen der Assimilatoren gewöhnlich ganz, so dass die kreisrunden, gestielten Blätter direkt dem Rhizom entspringen" ("Ueber Caulerpa," p. 39). With this REINKE seems, in my opinion, to have really hit upon the true character of this type. For, if we examine HARVEY'S type-specimen (Friendly Isl. Alg. No. 77, at least the examples which are preserved in the Herbarium in the R. Riksmuseum in Stockholm) we shall find that, in reality, there are very few discs which are crenulate, and not in a single case have I been able to verify that a new stalk grows out from the crenule of the disc. Every time I thought I had found such a case the stalk in reality shot out from the stalk of another disc; but owing to the pressing it had had, this was not evident, and it seemed to emanate from the crenule itself. On the other hand, it is very characteristic that the side-branches which support

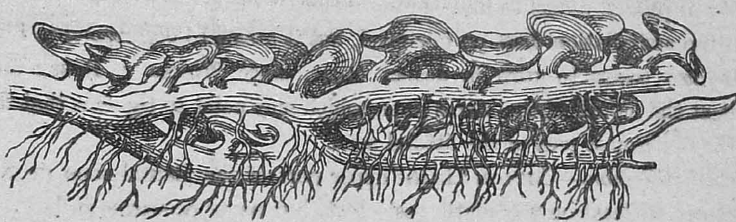


Fig. 35.—*C. nummularia* (HARV.) REINKE. (3 ×1).

the assimilation discs become procumbent and take root; and the result is naturally a mode of branching as REINKE described it, *i.e.*, the assimilation discs grow directly out from the rhizomes. Fig. 35 shows a picture of *C. nummularia* from the side. From the elongated creeping rhizome emanate numerous side branches and also single branchlets. The former become procumbent and form rows of horizontally placed assimilation discs. The branch formation may be so plentiful and the assimilation discs so numerous and close that such a tuft, seen from above, only shows the shape of a mass of assimilation discs without

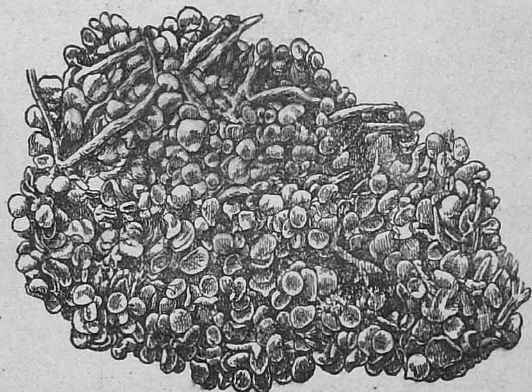


Fig. 36.—*C. nummularia* (HARV.) REINKE. (1 × 1).

apparent order, crowded about each other (fig. 36). This results from *nummularia*, in the same way as *C. clavifera*, being a pronounced light alga, and so belonging to the uppermost parts of the littoral zone just as in *clavifera* its whole assimilation system is horizontally broadened out in one level. Hence the tuft formation is distinctly carpet-like.

Undoubtedly this form is derived, as perhaps an ecological race, from *peltata* (main form), and the transition forms which I have already described show this very evidently; the horizontal axes in the form from Kangesanturai (fig. 32) have precisely the mode of branching characteristic of *nummularia*. To what extent light directly affects the formation of these forms, I do not venture to decide. But to judge from the difference between the intense light in the upper littoral zone, where *C. clavifera* and *C. nummularia* occur, and which, at low water especially, when they are nearly uncovered, is naturally of great strength compared with the shading that takes place in the deeper localities where *C. uvifera* and *C. peltata* occur, one is tempted to presume that this mode of growth depends to a certain extent on the light. Experiments alone can decide this point satisfactorily.

However it is evident that the most important difference between *C. peltata* and *C. nummularia* lies in the structure of the shoots. An examination of both HARVEY's original types and others shows that *nummularia* always has this mode of growth and the accompanying structure of the shoots. That also an occasional crenulate disc can be met with seldom is true, but this contributes much less to its character than the mode of growth itself. The diameter of the assimilation discs varies, but can be said not to exceed 5 mm.

It must be observed that the big and splendid *C. macrodisca*, which is included by WEBER v. BOSSE as a variety of *peltata*, seems to have quite a different mode of growth. It has not procumbent branches with all the assimilation discs on one level, but it seems to correspond in its mode of growth with *peltata*. It also seems to grow in deeper water, since WEBER v. BOSSE mentions that she had "dredged" it at the mouth of the Maros river, which may point to the fact that it does not belong in every case to the uppermost part of the littoral zone.

Geographical distribution.—CEYLON : in the upper part of the littoral zone on rocks and amongst corals, in many places, at least on the south-west coast, but never occurring in large quantities ; thus, around Galle (in many places on the reef and rocks north-west of Victoria Park, but also amongst the Madrepores below the Utrecht Bastion, and on stones at Watering Point) ! INDIAN OCEAN ; AUSTRALIA ; PACIFIC (Friendly Islands).

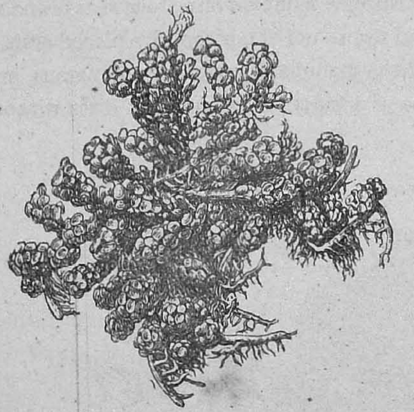


Fig. 37.—*C. imbricata* (KJELLM.). (1 × 1).

Fig. 38.—*C. imbricata* (KJELLM.) (1 × 1).

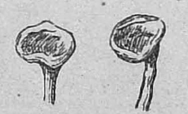


Fig. 39.—*C. imbricata* (KJELLM.) Flattened branchlets. (3×1.)

17.—**CAULERPA IMBRICATA** (KJELLMAN).

KJELLMAN in WITTROCK ET NORDSTEDT, Algæ Exsiccatæ No. 346 (sub nom. *Chauvinia imbricata*).

MURRAY, Catalogue p. 37.

SYN. *Caulerpa peltata* var. *typica f. imbricata* WEBER v. BOSSE, Monographie des Caulerpes; p. 375.

EXSICC. : WITTROCK ET NORDESTDT, Alg. Exsicc. No. 346.

f. minor. In all respects smaller and weaker. The size of the discs is upon an average 1 mm. in diameter (fig. 40).

f. mixta. The basal branchlets cylindrical ; the upper ones are typical imbricata—branchlets with the discs sharply defined from the stalk (fig. 42).

Under the name of *Chauvinia imbricaa*, Professor KJELLMAN described and distributed in WITTROCK ET NORDSTEDT, Algæ exsiccatæ, No. 346, a little *Caulerpa* from Galle in Ceylon, collected during the visit of the "Vega" expedition in the month of December, 1879. This *Chauvinia imbricata* was afterwards included by WEBER v. BOSSE as a form under *C. peltata v. typica*. As its character

Kjellman accentuated that the generally shortish vertical axes are thickly clothed or perfectly covered from base to apex with branchlets, which are disciformly flattened at the apex with a diameter of 3-4 mm (fig. 39). This character is quite sufficient for distinguishing this little *Caulerpa*, which in Ceylon is rather common in the littoral zone. Figs. 37 and 38 show pictures of it. It is generally tufted very thickly and seen from above one sees nothing of such a one but the close vertical axes nearly quite covered with branchlets.

The origin of this form can be imagined in various ways. One is that it is derived from a *parvula* form (see below) in which the branches have been erected and have afterwards radiated, at the same time as the branchlets have become somewhat larger. Some transition forms (*f. minor*) between these two species—which have the mode of branching of *C. imbricata* and the size of the discs of *C. parvula*—also point to the fact that such a development must not be considered as only a hypothesis and without any real foundation. As a matter of fact, these forms also occur in almost the same localities in the upper part of the littoral zone.

But *C. imbricata* can be imagined also to have originated in another way. If we study its organization we might give this as its characterization: *C. imbricata* is a somewhat dwarfed *C. uvifera* in which the branchlets have become somewhat disciformly flattened. In reality forms of this kind do occur which derive directly from *uvifera* by change of spherical branchlets to flattened ones. *C. uvifera f. planiuscula* is such a form. Moreover, there are some transition forms collected by KJELLMAN at Galle and by myself at Jaffna, which point to a relationship with *peltata* main form (fig. 41). If in such a one the vertical branches are shortened and get a more one-sided direction, at the same time as the discs grow smaller and closer, there then arises an *imbricata* form. Hence it seems probable that such a form could be derived from either the one or the other.

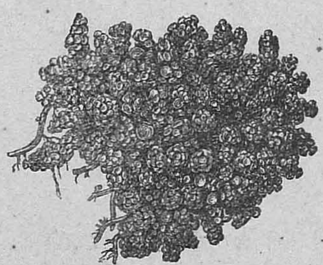


Fig. 40.—*C. imbricata* (KJELLM.) *f. minor* n. f. (1 × 1).

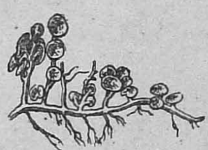


Fig. 41.—*C. imbricata*? (KJELLM.) f. *ad peltatam*. (1 × 1).

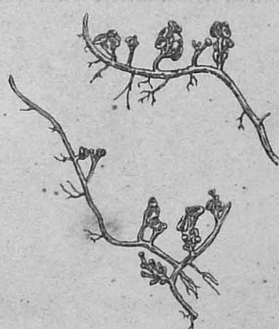


Fig. 42.—*C. imbricata*(KJELLM) f. *mixta* n. f. (1 × 1).

It is rather remarkable that variations of *C. imbricata* are to be found which are quite analogous with *C. Chemnitzia*. Fig. 42 shows such a form, for which I propose the name *mixta*. The basal branchlets are cylindical, about 3 mm. in length and only 1½ mm. in breadth, and at the apex abruptly cut off, as if truncated, just as in *Chemnitzia*. Somewhat below the middle of the vertical axis commence the typical *imbricata* branchlets—with the discs sharply defined from the stalk—and continue up towards the apex. This form, however, is not *C. Chemnitzia*, for the latter has not only basal branches which are cylindrical, but its upper branches increase only slowly in breadth and are almost trumpet-shaped. (*cf.* fig. 27), and often also the upper branchlets are spherically enlarged as in *racemosa*. WEBER V. BOSSE had also placed *Chemnitzia* under this species, but with the observation that it is an intermediary form between *racemosa* and *peltata*. In the form *mixta* the basal branchlets are cylindrical as in *Chemnitzia*, but the upper branchlets are typical *imbricata* branches. The mode of growth of this form in the upper littoral zone corresponds also in every respect with that of *C. imbricata*.

By reason of *C. imbricata* in Ceylon seeming to be a form or race equally distinguishable from the remaining *peltata* forms, as are *nummularia* and *typica* (WEBER V. BOSSE), I think there is little justification for placing it only as a form under *peltata* var. *typica*, as WEBER v. BOSSE has done. Var. *nummularia*, *exigua*, &c. should by equal right be included as forms, but WEBER v. BOSSE has given these a systematically higher rank in calling them "varieties," *i.e.*, equal with var. *typica*.

My contention is strengthened by the fact that *C. imbricata* itself shows some variations that could also be classed together. And if we are to place it under any other form it could as well be classed under the small *nummularia* forms, as for instance *f. parvula*, as under any of the others. The plausibility is equally great in either case.

Geographical distribution.—CEYLON: in the upper part of the littoral zone amongst rocks and corals, rather common; Matara! Galle (*f. minor*), in many places on the reef (as below the Sailors' Bastion, Star Bastion, Aeolus Bastion, Pigeon Island)! Ambalangoda! Jaffna! SOUTH INDIA: Paumben (*f. minor*, *f. mixta*)!

18.—CAULERPA PARVULA, n. sp.

The horizontal axes creeping with their side axes mostly procumbent. The whole plant thus forms mat-like tufts with the assimilation system on one level as in *C. nummularia*. The assimilation discs very small, about 1 mm., never exceeding 2 mm.

Under this name I will distinguish a very weak small form in the *peltata* group which I have observed in several places in the district investigated, and which is figured in figs. 43, 44. The mode of growth approaches that of *C. nummularia* in being richly tufted with the branches procumbent, and all the very small assimilation discs about on the same level, agglomerated together.

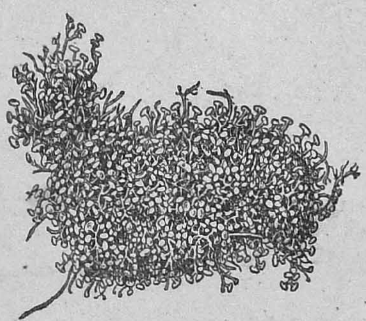


Fig. 43.—*C. parvala* n. sp. (1 × 1).

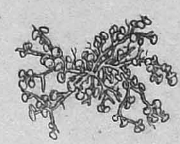


Fig. 44.—*C. parvula* n. sp. (1 × 1).

To judge from the very small dimensions of this plant—the diameter of the assimilation disc about 1 mm. and never exceeding 2 mm.—one might think it to be closely allied to *f. exigua*, WEBER v. BOSSE (*loc. cit.* p. 377, fig. 11, Pl. XXXI.); but the character distinguishing this latter—viz., its assimilation discs as if perfoliate, and situated as it were in one storey above the other—is entirely lacking. But as the assimilation discs are all in their dimensions rather constant, and the plant in other respects as far as its habitat is concerned, makes an impression quite different from *C. nummularia*, it seems to me to be distinguished as a special form. It forms, one may say, a transition species from the typical *nummularia* to the *imbricata* series. For if the side branches, instead of being procumbent were to grow upwards, and if, together with this, the branching were to become radiate, we should have *C. imbricata*.

At Paumben, in the Island of Rameswaram, I have also collected some transition forms (*C. imbricata*, *f. minor*, fig. 40) between this form and *C. imbricata*.

Geographical distribution.—CEYLON: Rather locally in rock-pools at Beruwala, and at Paumben in the Island of Rameswaram (SOUTH INDIA)!

19.—CAULERPA LONGISTIPITATA (WEBER v. BOSSE).

SYN. *C. lentillifera* (J. G. AGARDH) WEBER v. BOSSE, var. *longistipitata* WEBER v. BOSSE in TH. REINBOLD's Marine Algæ in Flora of Koh Chang by JOHS. SCHMIDT, Part IV., p. 105.

The horizontal axis extended, with rather few vertical axes (=assimilators); these are simple, only exceptionally branched, with the branchlets or pinnules generally opposite in two rows, but sometimes also projecting in all directions. The branchlets at the top provided with a little ball-shaped vesicle of about 1-2 mm. in diameter, bounded by a remarkable constriction. The basal part of the same length or shorter than the vesicle. The diameter of the vertical axis commonly not exceeding twice that of the branchlets.

I have observed this *Caulerpa* in the more sheltered places of the littoral zone at the islands at Paumben Pass, especially on stones, with its long creeping rhizomes adhering thereto or entangled in other algæ; sometimes it also occurred drifting and entangled in algæ which had broken loose.

Fig. 45.—*C. longistipitata* (W. v B.). *b* shows an assimilator with the branchlets in many rows. (1 × 1).

This *Caulerpa*, which I have placed as a species of its own, was first described by WEBER v. BOSSE as a variety of *C. lentillifera* in Major TH. REINBOLD's paper on the algæ from Koh Chang in the Gulf of Siam collected by Dr. JOHS. SCHMIDT. I have had an opportunity of examining these type specimens and I can assert their conformity to the Ceylon specimens. That WEBER v. BOSSE, with such limited material, was presumably unwilling to create a new species among the Caulerpas is comprehensible when one thinks of the great multiformity of these organisms, and the more so as this author is inclined to form wide-embracing species (so wide-embracing as far as *lentillifera* is concerned, that even a form so different as *C. Kilneri* is included). But my study of this plant from a somewhat richer material from Paumben showed that it is in the main constant, and it seems to me to be rather well characterized and distinct from *C. lentillifera*, with which it is most closely allied.

C. longistipitata differs from *C. lentillifera*, as WEBER v. BOSSE points out, in the small number of the rows of pinnules (fig. 45). This may vary a little, however, but the predominant number of vertical axes have the pinnules in opposite order (fig. 46 *b.*), and this gives the plant a rather characteristic habit. Its next important character is the relatively considerable length of the pinnule in comparison with the ball-shaped vesicle, which last is also greater than in *C. lentillifera* in general. In *C. longistipitata* its diameter is rather above than below $1\frac{1}{2}$ mm., and often reaches as much as 2 mm. The length of the pinnules often reaches the same measure, *i. e.*, they are also as long as the vesicles, but in every case always longer than half their diameter. Finally, we must point out that the vertical axes are very weak in comparison with the pinnules, and only about twice as broad, and often not even that, but less. This seems to me to be worthy of accentuating, because it has not been pointed out by WEBER V. BOSSE, who, on the contrary (*loc. cit.* p. 382), is of opinion that this is a very subordinate character depending only on the age of the plant.

An examination of fig. 1 *a*, PL. XXXIV. in WEBER V. BOSSE's Monograph shows just as the study of the original specimen itself (No. 16,851) in AGARDH's Herbarium, that *C. lentillifera*, J. G. AGARDH, has relatively thicker vertical axes and smaller vesicles, whereas in *C. longistipitata* the axis in its breadth is most often below or at least never above the diameter of the vesicles (figs. 45, 46). In this respect I have never seen any variation in *C. longistipitata*.

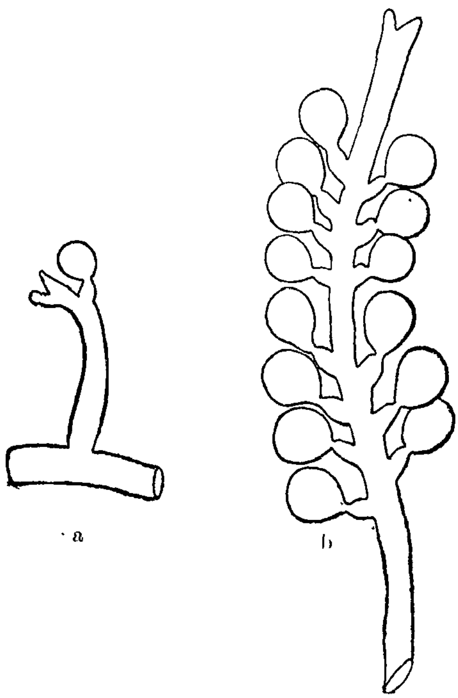


Fig 46 —*C. longistipitata* (W. V B.). (*a* 5 × 1, *b* 4 × 1)

For this reason it seems to me to be fully justified if we consider *C. longistipitata* as a distinct elementary species. My opinion here is supported by the fact that in the district where this species occurs, in the islands in the north between India and Ceylon, it showed itself very uniform, nor are any real *lentillifera* forms known from Ceylon. Its geographical distribution also seems to strengthen this view. *C. lentillifera*, J. G. AGARDH, is only known from the Red Sea and the western parts of the Indian Ocean (Madagascar), that is, it has *Western* distribution; *C. longistipitata*, on the other hand, is known from the Gulf of Mannar and the Gulf of Siam in the north, to New Guinea in the south, consequently it has a more *Eastern* distribution; *C. Kilneri*, finally, only from the Timor Sea.

Geographical Distribution.—SOUTH INDIA: Paumben Pass! PACIFIC (Gulf of Siam).

20.—**CAULERPA SEDOIDES** (R. BROWN) C. AGARDH.

C. AGARDH, Spec. Algarum, p. 438.

J. G. AGARDH, Till. Algernes. Systematik 1., p. 39.

WEBER V. BOSSE, Monographie des Caulerpes, p. 387.

f. crassicaulis, J. G. AGARDH, loc. cit. p. 40.

f. mixta. In all respects smaller and weaker. The horizontal axis about 1 mm. in diameter. The vesicles (branchlets), ·5 to 2 mm., commonly 1 mm. in diameter, of different kinds, viz., (1) sessile or pedunculate with spherical tops and evident constrictions; (2) sessile with somewhat pear-formed tops; (3) long, extended, cylindrical.

I have found *C. sedoides f. crassicaulis* in Ceylon in several specimens from Matara, Dondra Head, and Weligama on the south coast (fig. 47). Almost all correspond well with AGARDHS's *f. crassicaulis*. Thus the vesicles are, as a rule, always spherical, there are no joints on the main axis, and the closely set branchlets stick out in all directions around the main axis. But, on the other hand, the

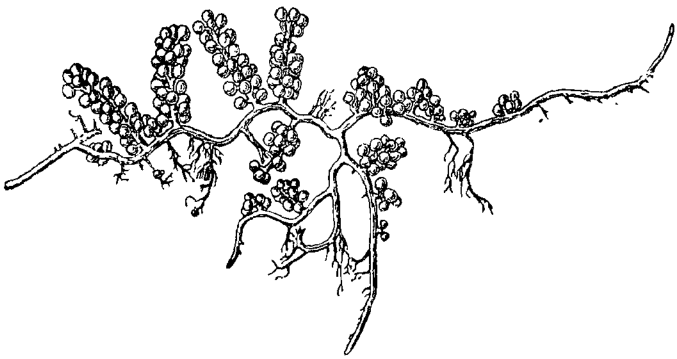


Fig. 47.—*C. sedoides* (R. BR.) C. AG. *f. crassicaulis* J. G. AG. (1 × 1).

vesicles are sometimes provided with a very short but distinct stalk (fig. 48), and this seems also to be the case with AGARDH's own type-specimens, a character again shown in some high-grown *crassicaulis* forms (in the Herbarium of the R. Riksmuseum in Stockholm) from Torres Strait (Aug. 1846). Also WEBER V. BOSSE speaks about (*loc. cit.* p. 388) a *Caulerpa* from Upola, in which some branchlets are

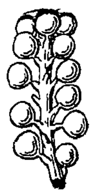


Fig. 48.—*C. sedoides* (R. BR.) C. AG. *f. crassicaulis* J. G. AG. (2 × 1).

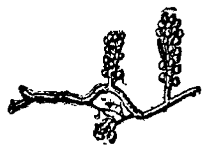


Fig. 49.—*C. sedoides* (R. BR.) C. AG. *f. mixta n. f.* (1 × 1).

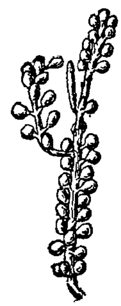


Fig. 50.—*C. sedoides* (R. BR.) C. AG. *f. mixta n. f.* (2 × 1).

pedunculate, reminding one almost of *C. racemosa v. clavifera*, from which it is however distinct by its constriction. Both in Matara and Weligama the *f. crassicaulis* showed itself very uniform and scarcely variable and gave the impression of being a distinct race.

In the island of Jaffna in the north of Ceylon I found some peculiar specimens of a very exceptional appearance. It is these that I have described as *f. mixta* (figs. 49, 50). In all respects it is more slender and weaker than the preceding form. In addition to small pedunculated vesicles with constrictions below the top, it has pear-shaped branchlets, clearly indicating opposite arrangement just as in *f. geminata*, HARV.; finally, and this is the most characteristic feature, some few branchlets grow out cylindrically to a breadth of 3 mm., and show themselves to be of the same shape as *C. ambigua* OKAMURA (*cf.* OKAMURA, "Algæ from Ogasawara-jima." Pl. 1, figs. 4, 6, 7).

Geographical distribution.—CEYLON: Dondra Head! Matara! Weligama (*f. crassicaulis*)! in the last named place at a depth of about 1½ to 2 metres (at low-water) inside the reef together with *C. sertularioides* and *C. taxifolia*; in the other places in the upper littoral zone; Jaffna (*f. mixta*)! INDIAN OCEAN; PACIFIC OCEAN.

C. sedoides in a wide sense is known from Australia, New Zealand, and Tasmania in the south. From Ceylon, the Gulf of Siam (SCHMIDT) in the north, and to the Friendly Islands in the east The different forms seem to have their different limited districts: thus, *f. tasmanica* and *geminata* have exclusively southern distribution (Australia and Tasmania), whereas *f. crassicaulis* has exclusively northern, true tropic distribution (the tropical coast of Australia, Ceylon to Friendly Is.). This possibly points to the fact that these forms have rather the character of different races or elementary species, an inference that is furthermore strengthened by the fact that, as I have mentioned above, *f. crassicaulis* in Ceylon is constant and uniform. Against this, *f. mixta* seems more local, and, as I have above tried to show, its peculiar branching may probably be explained as a kind of atavistic bud-variation.

21.—**CAULERPA FERGUSONII** (MURRAY).

MURRAY. On some new species of Caulerpa, p. 212, pl. 53, fig. 1.

WEBER v. BOSSE, Monographie des Caulerpes, p. 389 (*sub nom. C. Fergusoni*).

EXSICC.: FERGUSON, Ceylon Algæ, No. 415.

This *Caulerpa*, only known from Ceylon, I have observed once at Paumben Pass, and there very scantily, growing on mud or slime together with *C. longistipitata* and *Enalus acoroides*. To the description of this plant, which we owe to MURRAY, the following may be added:—

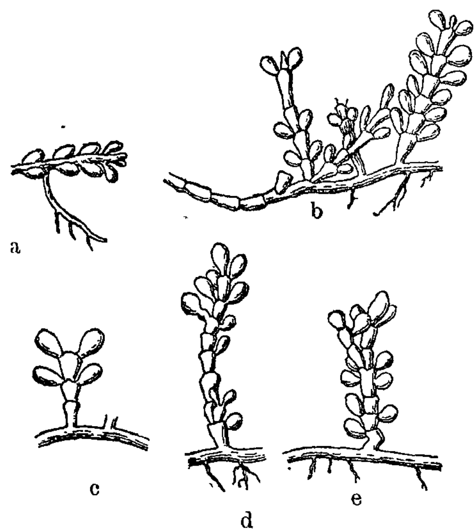


Fig. 51.—*C. Fergusonii*, MURR. (1 × 1).

It does not seem to be uncommon for the branched stem, when situated horizontally, to form coarse roots downwards and jointed side branches upwards. Fig. 51 *a* and fig. 51 *b* show this case, which is far from being rare among *Caulerpas*, and which seems to occur also in the related *C. cactoides*. (*cf.* MURRAY, *loc. cit.* pl. 52, fig. 8, and WEBER V. BOSSE, *loc. cit.* p. 391). Moreover it seems to happen, though more rarely, that the vertical axes are jointed right up from the base without any branchlets being formed from the joints at the base (fig. 51 *c*). It has been pointed out that the difference between *Fergusonii* and *cactoides* may consist in the former plant being only jointed at the place where the side branchlets are formed, as against *cactoides*, which is jointed the whole way up, though the base seems to lack side branchlets for a part of the way up. This character, though right in the main, does not always hold good, and sometimes one can observe at the base (fig. 51 *c*) some evident joints without any side branchlets at all.

Just as in *C. cactoides*, *C. Fergusonii* can also have regeneration branches, *i.e.*, may repeat the branching of the mother axis. A branchlet in fig. 51 *d* seems to branch ; it looks as if the branchlet itself were jointed. In other cases the branch-formation takes place as follows . between two branchlets the growth of a side axis takes place. Hereby the branches become verticile (fig. 51 *e*), a case which WEBER V. BOSSE has also observed in *C. cactoides*, loc. cit. p. 391. When such a side branch is formed between two branchlets it is, to begin with, quite similar to these, and all three form a whorl of branchlets. By this a formation arises which resembles the verticile branches in the fossil *C. Carruthersii*. It is therefore remarkable that also in living Caulerpas verticile branches may be formed, though it must be considered to be a rare occurrence. From a phylogenetic point of view it is interesting in any case.

From what has been stated above it seems that this form of *C. Fergusonii* is much more closely related to *C. cactoides* than to *C. sedoides*.

Geographical distribution.—CEYLON (FERGUSON) SOUTH INDIA : Paumben Pass, in the littoral zone, in shallow water on mud, together with *Enalus acoroides* !

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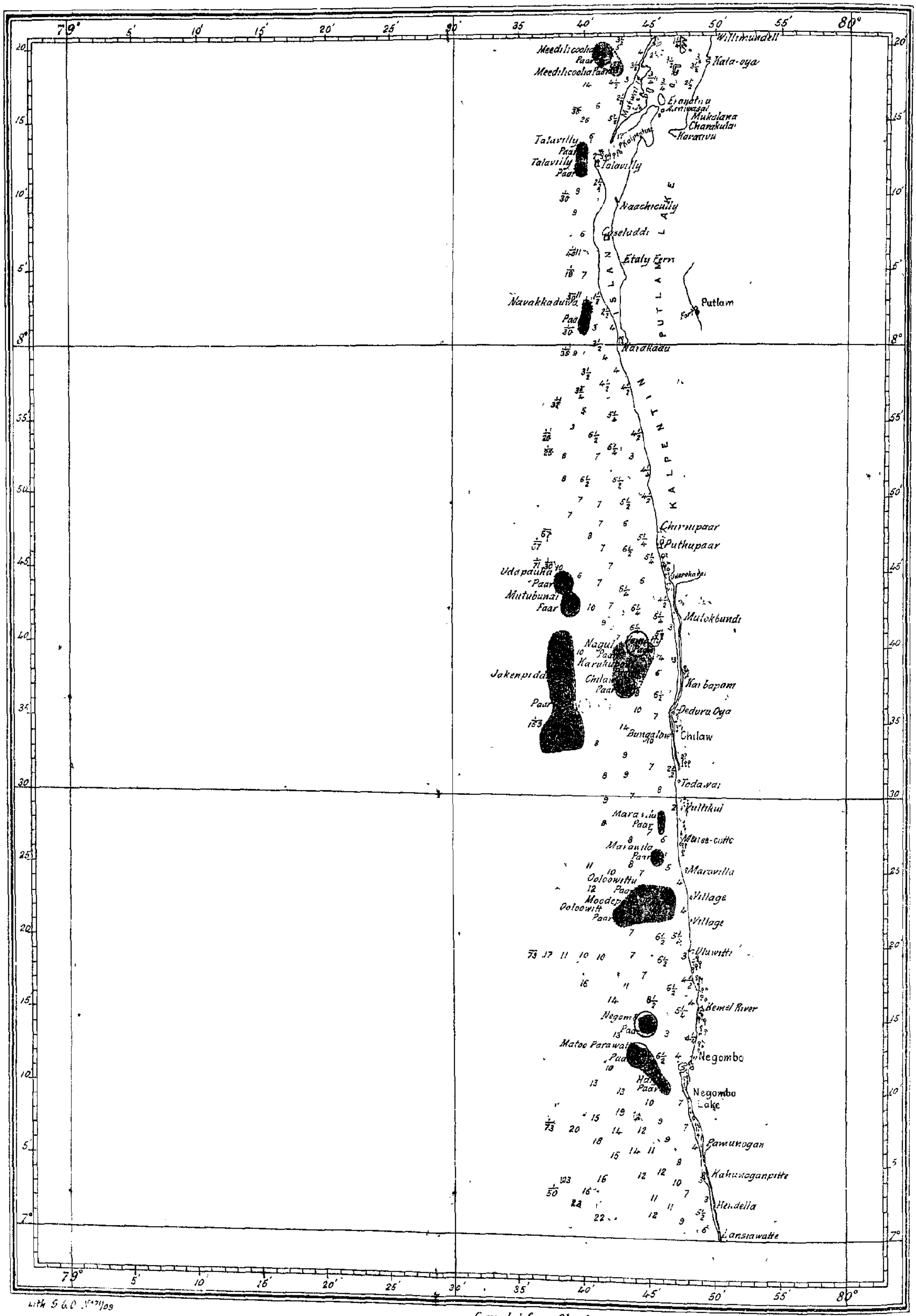
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Udapauha Paar
Mutubunai Paar
Mulokbundi
Jakenpidd Paar
Kaibapam
Deduru Oya
Chilaw
Bungalow
Toda.vai
Pullikul
Maravilla
Village
Village
Kemel River
Negombo
Negombo Lake
Pamunogan
Kahunoganpitte
Hendella
Lansiawatte
Compiled from Charts supplied by the Master Attendant, Colombo

Reports from the Ceylon Marine Biological Laboratory.

PART III.] No. 5. [VOL. I.

REPORT ON AN INSPECTION OF THOSE PEARL BANKS UNDER GOVERNMENT CONTROL SITUATED BETWEEN DUTCH BAY AND NEGOMBO.

With one Chart.

By T. SOUTHWELL, A.R.C.Sc. (LOND.), F.L.S., and J. C. KERKHAM, R.N.R.

INTRODUCTION.

THOSE pearl banks not included in the lease to the Ceylon Company of Pearl Fishers, Limited, and therefore still under Government control, lie scattered about on that shallow-water plateau, bound on the north by a line drawn east and west from Dutch Bay Point, on the west by the overfalls, and extending on the south to a point near Negombo.

This plateau is simply the southern prolongation of a much larger plateau extending as far north as Talaimannar Point. Its general shape is that of a triangle, having its broad base to the north, and includes those pearl banks under the control of the Company so renowned for their general productiveness The narrow apical end of the plateau south of Dutch Bay Point is under Government control, and is an area which has of recent years yielded but few and not very productive fisheries.

Both in the case of the area under the control of the Company as well of that under Government control the western limit of the pearl bank plateau is sharply defined, shelving out suddenly on the west from 9 to 13 fathoms into 100 fathoms, but whilst this fact is known, it is unfortunate that the correct position of this sudden overfall is not fully indicated on the charts, and even where indicated is not wholly correct. This applies more particularly to the area still under control, since the regular and systematic surveys on the Company's ground has resulted in the position of the line of overfall being more correctly known. The determination of this line on the Government area, though interesting in itself, would however be of little practical importance

It is well to note here certain facts connected with Dutch Bay Point. The line drawn east and west from this point separates the pearl banks under lease from those still under control. A private survey of Dutch Bay conducted by the Company during October of last year resulted in the discovery that Dutch Bay Point is not a fixed position. The sandy spit forming this point appears and disappears with the successive monsoons.

The topography of the whole of Dutch Bay is incessantly changing. Subsidence of the land, and possibly elevation, at closely contiguous points are proceeding rapidly. On the east side the islands of Karativu and Ipantivu were continuous with each other within quite recent times. At present subsidence of the land has resulted in the two islands becoming separated. The low-lying ground originally connecting them together now forms a sandy shoal. Further evidence of the subsidence of the land (not the mainland, but Karativu) is furnished by the fact that mangrove trees are to be found quite a cable's length west from the shore, and the trees along the coast line of the island are already partly submerged.

On the west side of the bay, and not more than one and a half mile away, "Dutch Bay Land" has become separated from the mainland—according to the natives—within the last year. At first we were inclined to believe that this part of the land was in process of elevation, but on further investigating the matter we were convinced that elevation was not taking place, but that the separation of "Dutch Bay Land" from the mainland was incidental on the subsidence of Karativu, which had forced the sea over the low-lying sandy area nominally joining "Dutch Bay Land" to the mainland.

A depression on the spit, just near the beacon, seems to mark the real northern extremity of the land (or Dutch Bay Point) We correlate the formation of this sandy spit north of the beacon with the force of the south-west monsoon. During strong monsoon weather the sea striking the coast further south catches the sand and drifts it north, where it segregates on the spit in question, extending it in a northerly direction for about one-fifth of a mile. During the north-east monsoon erosion of the spit takes place as rapidly as its formation during the south-west.

We detail these facts because the position of this uncertain point determines the line of demarcation between the banks under lease and those still under Government control, and since the beacon marks the most northern staple structure in the vicinity, and was probably erected for that purpose, we take it that the beacon marks Dutch Bay Point. The difference, however, between the two positions in question is so slight as to be unimportant.

The last inspection of the Government pearl banks was conducted by Professor Herdman, F.R.S., in 1902, when oysters were found on four out of the eight paars examined, and good oyster ground—potential paar—was found in many other places. The last fishery on these banks was conducted on the Chilaw Paar in 1884, when the sum of Rs. 17,153 was realized

It is a well-known historical fact that these southern paars are not nearly so productive as those on the northern area The factors at work, biological and physical, which have resulted in certain areas on the whole plateau being more suitable and productive than other paars, are not clearly or fully understood, although we believe that the present inspection has furnished further light on the question.

In view of the fact, however, that fisheries *have* been held on these southern paars, and that a considerable quantity of young oysters were actually found on some of them by Professor Herdman in 1902, it seemed reasonable to suppose that adult and fishable oysters might at any time be found thereon, and this fact, together with the desirability of obtaining further information relating to their general unproductiveness, led the Company to suggest to Government the desirability of having the paars inspected, and the suggestion was later on accepted.

The inspection of the banks under the Company's control was completed on February 28. The Inspection Barque Rangasamee and staff were left in Dutch Bay, and the ss Violet proceeded to Colombo in order to embark Dr. Willey, F.R.S., who was appointed to accompany the expedition as guest. We would here express our indebtedness to Dr. Willey for much assistance and advice during the trip, and in particular for the naming of much of the fauna.

The ss. Violet left Colombo on the evening of March 2, arriving in Dutch Bay the following morning. The inspection was commenced on the afternoon of March 3 from the north, working south, and occupied fifteen consecutive days. We arrived in Colombo on the evening of March 17.

Narrative.

The ss. Violet left Colombo on the evening of March 2, arriving in Dutch Bay the following morning at daybreak (March 3), where the Inspection Barque Rangasamee, the motor, and water boats, together with three inspection boats and their respective crews, awaited our arrival. Having completed necessary arrangements by noon we moved at once to the Madalaikulai Paar, arriving there in time to lay out the buoys, &c., ready for inspection work thereon the following day.

March 4.—Inspected the North Madalaikulai Paar by divers. The ss. Violet took twenty-two hauls of the dredge on the South Madalaikulai Paar during the morning. Lifted up buoys and moved during the afternoon to Talaivillu Paar.

March 5.—The two Talaivillu Paars (north and south) inspected by divers, the ground being buoyed out in rectangular form to include both paars. The ss. Violet conducted dredging operations to the south during the morning, whilst Dr. Willey and one of us examined the Talaivillu coral reef. Moved in the afternoon to Navakaddu Paar.

March 6.—Buoyed out the Navakaddu Paar in rectangular form and inspected same by divers. The ss. Violet conducted dredging operations on the southern extension. Moved in the afternoon to Karkopani Paar. Strong northerly current experienced during the evening.

March 7.—Inspected Karkopani Paar by divers. The ss. Violet dredged over the Wanatty Paar during the morning and trawled over the Nagal Paar during the afternoon. Moved in the evening to the south end of Karkopani Paar.

March 8.—South end, Karkopani Paar, inspected by divers. During the afternoon we moved to the Chilaw Paar. The ss. Violet then dredged west, in order to locate the Jokkenpiddi Paar, but finding that within 1¼ mile from the ship the water rapidly deepened to ten and fourteen fathoms, a buoy was placed there, believing that the overfall was close by. It was found later on, however, that this deep water was the eastern edge of a remarkable depression situated between the Chilaw and Jokkenpiddi Paars. During the evening, whilst on the Chilaw Paar, finding a strong northerly current running, we liberated ten drift bottles.

March 9.—Chilaw Paar inspected by divers. The ss. Violet away watering in Dutch Bay.

March 10.—Moved at daybreak to Nagal Paar and inspected same by divers. During the morning the ss. Violet proceeded west, took a line of dredgings, and located a position on the north end of Jokkenpiddi Paar, and, having buoyed the position, we moved there in the afternoon. After we had cast anchor the ss. Violet again took lines of dredgings, finding 14½ fathoms on the west, 2½ miles distant, then south, where a position on the Mid-Jokkenpiddi Paar, in 7½ fathoms, was buoyed. Steaming east towards Chilaw Paar the western extremity of the depression found on the 8th instant was located, and it was thereby clearly proved that this depression is of limited area and lies between the Chilaw and Jokkenpiddi Paars. Moved in the afternoon to the northern extremity of Jokkenpiddi Paar.

March 11.—North end, Jokkenpiddi Paar, inspected by divers. During the morning the ss. Violet dredged over the Mutubunda Paar. Moved in the afternoon to a position intermediate between the Adaupuka and Mutubunda Paars, over which, later, the ss. Violet dredged. Weighed and moved in the evening to Mid-Jokkenpiddi Paar.

March 12.—Mid-Jokkenpiddi Paar inspected by divers. The ss. Violet dredging to the south and west during the morning, buoying a position on the south end of Jokkenpiddi Paar, and locating the overfalls. Weighed and moved in the afternoon to the south end of Jokkenpiddi Paar, and later on the ss. Violet located the east, west, and southern extremities of Jokkenpiddi Paar.

March 13.—South end, Jokkenpiddi Paar, inspected by divers. During the morning the ss. Violet, taking a departure from Chilaw and dredging south, located and dredged over the Maravilla Paar, finding the northern end to consist of shells, &c., and buoying a position on the south end, to which we moved in the afternoon. Experienced a strong northerly current during the night. Liberated ten drift bottles.

March 14.—South Maravilla Paar inspected by divers. During the morning the ss. Violet located and dredged over the North Oolawitti Paar, and also over the South Oolawitti Paar, finding sand only on the latter. Weighed and moved in the afternoon to the North Oolawitti Paar, the ss. Violet again dredging, later on, over the South Oolawitti Paar.

March 15.—Both Oolawitti Paars inspected by divers, the ground being buoyed out in rectangular form. During the morning the ss Violet dredged over the Moodipani Paar. Weighed and moved in the evening to the Negombo Paar. The ss. Violet proceeded at midnight to Colombo for water.

March 16.—Negombo Paar inspected by divers. The ss. Violet returned at 2 P.M. from Colombo, and we moved to the Muttu Parawatti Paar.

March 17.—Muttu Parawatti Paar inspected by divers. During the morning the ss. Violet dredged over the Holy Paar and the immediate vicinity. Weighed anchor at 1.30 P.M., proceeding to Colombo, where we arrived at 5.30 P.M. the same day.

We append to this report charts supplied us of the whole of the pearl bank area under control, together with a linen tracing of all areas inspected either by means of the trawl, dredge, divers, or by lines of dives.*

* Not reproduced.

With reference to dredging operations carried out so extensively by the ss. Violet during the trip, and with such congratulatory results, we would point out that for prospecting work only this agency is vastly superior both in point of thoroughness and extensiveness to ordinary diving, and serves to prove how clearly Professor Herdman, who initiated the method, understood the practical requirements on the banks.

The average area covered by a diver during one dive—which cannot be repeated more than every five minutes—is, in say six fathoms of water, approximately three square yards. The ss. Violet, with both dredges out, each dredge three feet broad, steams at three knots per hour, and thus in the same time (five minutes) covers 300 square yards. allowing that one dredge is being examined whilst the other is out. It thus becomes clear that for prospecting purposes dredging is much superior to diving. This superiority, however, breaks down when oysters occur in fishable quantities, since the divers discriminate between oysters and rubbish, and the dredge does not.

Two dredges were employed concurrently. As a rule, a haul was made every five minutes. It is important to note that the true position of the vessel was determined by sextent angles and bearings *at each haul of the dredge,* and each haul will be found duly charted and numbered on the chartlets accompanying the "Faunistic Results" as an appendix to this report.*

We also forward herewith an account of the exact nature of the fauna obtained at each haul of the dredge numbered, together with a subsidiary account of the fauna obtained by native divers. The numbers on the chartlets showing each haul of the dredge, for each and any day, corresponds with the number on the appended list of "Faunistic Results."

From these data the exact and particular fauna found at each particular point on any paar dredged over can be accurately noted. These facts, however, only apply to dredging results, since in the case of ordinary inspection by divers the fauna of any particular paar had of necessity to be quoted in general terms.

We are aware that the determination of the fauna in general has previously been given by Professor Herdman in his report for 1902. We merely append the fauna results obtained during our inspection as an addition to knowledge, of which the local general fauna of any paar in particular can be correlated by any one who cares to undertake the work. In any case the results quoted may be of use in further investigations, since it often happens—and particularly so on the northern paars—that certain areas can be identified irrespective of bearings from the fauna found thereon.

The number and position of each haul of the dredge would have been charted on the linen tracing had not the comparatively small scale, together with the variety of other, and perhaps more important details, rendered this work impossible.

With reference to the rectangular method of inspection, we wish to say that this is a new innovation tried by us for the first time, and with complete success, during the Government inspection. Up to the present inspection by divers has been carried on in circles. The latter method will be found fully described by Professor Herdman in his reports, and works well when the areas in question are circular, or approximately so. When "paars," however, are known to be elongated, the rectangular method results in a considerable saving of time, whilst the actual *modus operandi* and results are as equally satisfactory as in circular inspections. The difference is merely the way in which the ground to be inspected is buoyed out. Besides this, the rectangular method is easier to work, since the wind, being about due north during inspection time, allows the boats, starting from windward (north), to work leeward, east and west across the area in question

Charts and Navigation.

We were furnished with three charts by the Survey Department for inspection purposes, covering the area to be inspected. The one of the northern part was compiled by Capt. Donnan, and had the paars charted. On the charts of the mid and southern portions, however, the paars were not charted. None of the charts showed a parallel of latitude, and although they each indicated a meridian of longitude, this stationary line was differently placed on each of the charts.

We had in our possession a small chart, 10 miles to the inch, also drawn up by the Survey Department, on which the paars were indicated by red ink, and this, with other information in our possession,

* Not reproduced.

was enlarged and transferred to the larger chart supplied (1 mile to the inch) for a working basis. Since accuracy is never to be looked for in so casual a chart, compiled on so small a scale, and for general purposes only, the navigation was a matter of some little difficulty. The coast line, too, from Talaivillu Point, south, is utterly featureless, save for St. Anna's Church, Chilaw, and Negombo, with their river points too far apart to render the location of banks, which often do not cover more than a quarter mile square, an easy matter In some instances the position of a paar had to be determined by prospecting with the dredge, whilst the normal inspection of the preceding day was in progress.

We have already called attention to the fact that the position of Dutch Bay Point, as indicated by the spit, is uncertain, and also to the fact that the position of the overfalls is not satisfactorily determined. Both these points are connected with the actual extent of the potential paar ground under control.

As we have said, some difficulty was experienced in locating "paars" and accurately fixing their positions, especially those north of Chilaw, owing to the considerable difference in the contour line of the coast, particularly Talaivillu Point, which appears to be charted 1½ mile east of its true position, as indicated by bearings taken of Dutch Bay tope and beacon with Arunakalu tower. The positions of Dutch Bay tope and beacon had previously been determined by bearings of Kutrimalle tower and Arunakalu tower. The positions of these latter trigonometrical stations were furnished by the Government Survey Department on a chart subsequent to that used by Capt. Donnan In the tracings furnished with charts, appended herewith, we have indicated the coast line in red as shown by the chart used by Capt. Donnan, and the subsequent survey in black as being presumably more correct.

It will be noticed that on Capt. Donnan's chart Arunakalu tower is charted eight cables N. 22½° E. of the position shown on the subsequent one The latter charted position of Arunakalu tower was that used to determine the positions of Dutch Bay tope and beacon.

The first indication of any appreciable difference in the contour line of the coast was when surveying Dutch Bay with a view to establishing a nursery there in October last. It was then found that the whole of "Dutch Bay Land" had apparently altered very considerably in contour, and the soundings in the bay were entirely different from those previously given. The sand spit originally connecting Karativu with Ipantivu island had disappeared, and the southern and western part of Karativu had subsided very considerably, as full-grown trees now stand in nine feet of water.

Another very important change is that a channel has formed, cutting off a portion of Dutch Bay Land, and the new waterway will doubtless affect the velocity and volume of water flowing in and out of the entrance to Dutch Bay, probably causing a fall of sand in a fresh locality and affecting the soundings considerably. Such causes doubtless account for the very different soundings in the Bay, varying many feet, as shown by the two charts supplied by the Government Survey Department.

We mention these facts merely because, had these southern areas under the Government control been so productive as those north, a thorough and accurate survey of the paars, overfalls, and coast line, together with more landmarks—say one in every eight miles—would have been essential for an efficient and extensive inspection.

Considering it advisable to state the ways and means adopted in the location of "paars" in general under the difficulties just stated, we here give particulars regarding each paar examined.

The Madalaikulai Paars as charted by Capt. Donnan were located with ease, the landmarks being good Arunakalu tower was conspicuous for a considerable distance south, as this tower, together with Kutrimalle tower, had been previously cleared of forest growth, whitewashed, and obscuring trees removed from their immediate vicinity. This work occupied the Company's staff of boatmen for three whole days during February last. These two trigonometrical stations were used to accurately locate Dutch Bay tope, which latter position formed an important landmark for the paars further south.

The new channel formed during last year across Dutch Bay Land was clearly visible when dredging over the inner Madalaikulai Paar. The breadth of the channel was determined whilst in Dutch Bay, and is six cables from north to south, having a small sandy islet in the middle, so that there are, strictly speaking, two channels. The south one has only a few feet of water, whilst the northern channel is twelve feet deep. We were told by the local inhabitants that the channel was slowly extending on the north side, where a small tope of coconuts is threatened. The soundings immediately outside this channel have apparently recently altered too, for we located a sandy shoal south of the one charted and carrying $2\frac{1}{2}$ fathoms, the bottom being hard, fine, white sand.

Talaivillu Paars.—The Talaivillu Paars were located by a single bearing of Arunakalu tower, as bearings of Dutch Bay tope and beacon put the ship's position outside the overfalls.

The bearing of Arunakalu tower was here sufficient to locate the paar, as the distance from the coral reef off Talaivillu Point and the overfalls is not more than one mile, so that the bearing of Arunakalu tower fixed our position north and south, the coral reef east, and the overfalls west. We have reason to believe that Talaivillu Point is charted $1\frac{1}{2}$ mile east of its true position, as indicated by bearings of Dutch Bay tope and beacons, which landmarks had previously been determined by accurate bearings of Kutrimalle and Arunakalu trigonometrical stations. When on the Madalaikulai Paars we were unable to make the bearing of Talaivillu Paar agree with those of Dutch Bay tope and beacon. We would mention that Dutch Bay tope has furnished us with a useful bearing as far north as the north end of Karativu island.

Talaivillu Paar covers a narrow area of about a mile from east to west, bounded on the east by a coral reef and on the west by the overfalls.

Navakaddu Paar.—This paar was located by a single bearing of St. Anna's Church with the distance from same. The soundings here, as at Talaivillu, limiting the area east and west. Shoal water found on the east, and the overfalls on the west, necessitated a rectangular inspection, which was extended south by lines of dredgings to cover the whole area charted as paar ground.

St. Anna's Church forms a useful and conspicuous object, the only one between Dutch Bay and Oodoopekeret near Chilaw. Arunakalu tower is lost sight of south of Talaivillu Point. A remarkable but very small deposit of black mud composed of magnetite was found on this paar, which probably merely represents disintegration of material in the immediate vicinity. The same kind of deposit is regularly found on the beach at many places north and has a commercial value. This kind of mud is quite different from " river mud."

Karkopani Paar.—Whilst on this paar some slight errors were apparent having reference to the charted positions of the landmarks in the vicinity, as we could not make the bearings of Karkopani village come in with those of Chilaw bungalow and Oodoopekeret house. We were also unable to make the Deduru-oya river entrance come in satisfactorily. We had therefore to rely on the bearings of Chilaw bungalow and Oodoopekeret house, which were very conspicuous here, and were therefore used to fix all our positions off the Chilaw, Karkopani, Wanatty, and the Nagal Paars.

One paar—the Chilaw Paar—was found to be all sand, except a little calcrete on the extreme W.S.W. The soundings increase west of this paar to $9\frac{1}{2}$ and 14 fathoms, again decreasing to 8 fathoms as Jokkenpiddi Paar is reached, which latter is distant eight miles from the shore. This depression is a continuation of that noted elsewhere.

The Deduru-oya river appears to have no effect whatever on the inshore paars off Chilaw, where the ground is free from muddy deposit. The river entrance, we were told, is practically closed by a bar of sand during the south-west monsoon

Jokkenpiddi Paar.—Jokkenpiddi Paar appears to be a distinct coral reef, extending five miles north and south and tapering at each extremity. In the centre it is about $2\frac{1}{2}$ miles broad. The reef is composed largely of living coral, which made dredging almost impossible. On three occasions lines of dives had to be resorted to, as the dredges fouled living coral immediately on being shot.

The soundings increase rapidly both on the east and west. On the east side the water deepens to 14 fathoms, which represents the remarkable depression previously noted. Still further east the water shoals abruptly to 9 fathoms, just before reaching the charted position of Chilaw Paar. The bottom of this depression is sand only.

On the west, the overfalls to the south of the paar were found to be as charted, viz., $10\frac{1}{2}$ miles from the shore. From the north end of this paar a line of dredgings and soundings were taken due west, in the hope of being able to locate the overfalls at about $1\frac{1}{2}$ mile from the ship's position. We obtained 14 fathoms $2\frac{1}{2}$ miles west from our anchorage and distant $11\frac{1}{2}$ miles from the coast.

Time did not admit of our fixing the line of overfall on the north, as we had to locate the centre of Jokkenpiddi Paar in order to be ready for the following day's inspection work.

The depression noted does not reach the parallel of Nagal Paar on the north, and although the direction and extent south was not determined, we are of opinion that it merely represents an arm-like inshore continuation of the overfalls, insinuated between the Chilaw and Jokkenpiddi Paars. It is interesting to note that the sandstone and rock dredged up from the centre of Jokkenpiddi is identical in nature with the sandstone found on the foreshore of Chilaw.

Maravilla Paars.—The position of North Maravilla Paar was dredged over and found to be all sand, with many living shells. A patch of coral *débris* was located to the south, which from bearings obtained was evidently the South Maravilla Paar. This position was buoyed, but on being inspected by divers the following day proved to be of limited extent and of no importance.

Oolawitti and Moodipani Paars.—The positions of these paars were determined by bearings of Chilaw and Negombo. The North Oolawitti and Moodipani Paars are obviously one, and continuous. The South Oolawitti was twice dredged over and found to be all sand.

Negombo Paars include the Negombo, Holy, and the Muttu Parawatti Paars, and they are evidently one, and continuous. No obvious reason for their separation into distinct areas was apparent. Their positions were fixed by bearings of Negombo fort and the Kammal-oya estuary. A feature of these paars was the presence of a flat, coarse-grained sandstone impregnated with iron, probably the true "paar." This kind of rock is seldom or never found on the northern banks. These paar grounds alternate with sandy patches, and have a look of general unproductiveness.

Physical and Biological Features.

It became apparent early during the inspection that in a general way the "paars" on the ground under the Government control are at present not well defined, a fact serving to prove *a priori* the truth of the statement made by Professor Herdman that the whole of the area is potentially paar ground.

During our trip the weather was so fine and the sea so calm that in most cases we were able accurately to determine the nature of the bottom up to 8 fathoms, even before the hauls of the dredge had been made or before the divers had been down The southern part of the plateau up to the overfalls is not nearly so well surveyed as that under the Company's control, a fact to be correlated in the first place with their comparative unproductiveness as well as to private enterprise.

The present known and *charted* paars on the southern plateau seem in the main to be independent of the nature of the ground. Some areas are charted as "paars," where the bottom is all sand, whilst other parts are not recognized as paar ground, in spite of the fact that the sea bottom is obviously more suited for oyster cultivation than other places charted as paars.

On the whole, it would appear that no efficient survey of this southern potential area has been made. The present known paars probably simply represent areas casually inspected by Capt. Donnan, which areas later on came to have an importance and significance not at all in accordance with the possible productivity of the ground concerned.

It would seem quite likely that, although the area under the control of Government is recognized as being not nearly so productive as that at present under the Company's control, this fact is not wholly due to the intrinsic differences in the degrees of productiveness on the areas in question. The southern paars have seldom been inspected. If paars are only examined, say once in seven years, and often longer, it is quite possible that a bed of oysters may mature and die in the interval.

We are not arguing that the southern paars actually are, or possibly could be, as productive as those on the northern area. We are merely pointing out that they are not so frequently examined, a fact which to some degree accounts for their obvious but not necessarily real unproductiveness.

It is quite true that certain paars, such as the Chilaw and Karkopani, have a historical importance which cannot be ignored, since fisheries—though but rarely—are known to have been conducted on them. On the other hand, we would point out that many other areas on the Government banks are equally potentially productive, and although not recognized as such, this is merely due to the fact that they have not been as regularly—probably never—examined.

We would also note that the present charting of the paars is not in accordance with the nature and possibilities of the ground concerned, and we regard it as advisable that a thorough charting of probable productive areas, or paars, should be definitely made, in contradistinction to areas obviously and necessarily unproductive on account of their permanent sandy bottom.

As illustrating the point in question, we would observe that there is no apparent reason why the Moodicooli Paar should be separated into two distinct parts, since the ground in the vicinity is similar and perfectly continuous. We are also of opinion that this potential paar ground extends as far south as Talaivillu Paar, and probably much further, since we were unable to determine the southern limit in the time at our disposal. Similarly, there appears to be no reason why the Karkopani, Wanatty, Chilaw, Udapauka, and Nagal Paars should be separated and made distinct, since the nature of the ground in the vicinity connecting these paars together is quite uniform. As we have already said, we regard these distinctions into paars as artificial, and as representing areas casually examined by Capt. Donnan irrespective of the paar ground proper.

In order to prove that oysters have a habit of occurring on ground not artificially and formally circumscribed on charts as paar ground, we would point out that within recent years the Kutrimalle and Karativu Paars have become "new paars."

The bed of oysters found on the "Kondatchi Paar" by Professor Herdman in 1908 were in reality situated between the Challai and the Kondatchi Paars, and even as recently as November of last year (1908) large deposits of spat were found on the Company's area, 2½ miles distant from the nearest charted "paar." These facts fully amplify, within narrow limits, the term "potential paar ground" as used by Professor Herdman.

Many of the so-called paars of the south were dredged over, or inspected, and found to be all sand. Instances in point are the Maravilla, South Oolawitti, and the Chilaw Paars. The North Oolawitti Paar was found to be merely the north-western extremity of the Moodipani Paar. There can be *no* doubt but that the North Oolawitti and Moodipani Paars form one continuous whole, and the same applies to paars in the vicinity of Negombo, where the Negombo, Muttu Parawatti, and Holy Paars are obviously one extensive paar.

The "paars" at Talaivillu, Chilaw, and Negombo are separated by very great interspaces, in one instance up to 24 miles, which areas up to the present have not been inspected. We have no proof that good paar ground does not exist between these widely separated areas, and in fact it would appear likely that the paar ground is more or less continuous. Oysters may mature and be present in such quantities as to be fishable on these areas. We have no proof otherwise, and the nature of the bottom on the parts in question, as actually seen from the ship, seems to indicate that such is the case. The historical productiveness of a paar or otherwise appears therefore to be, in the instances quoted, and on the ground examined, not necessarily dependent on the nature of the ground in particular, but on the fact that certain areas have never been examined.

Under such conditions it is obviously uncertain whether such areas are *really* productive or not. At least it is uncertain to *what degree* they are productive. In order to give some tangible idea of the ground, regarding which at present nothing is known, we here append the distances separating the charted paars .—Madalaikulai to Talaivillu, 7 miles ; Talaivillu to Navakaddu, 10½ miles ; Navakaddu to Karkopani, 24 miles ; Jokkenpiddi to Maravilla, 9½ miles. As we have already said, we believe from what observations we were able to make in the short space of time at our disposal that much of this ground *is* paar ground, and ought to be examined occasionally.

It was found whilst inspecting the Jokkenpiddi Paar that about the centre of this paar a shallow ridge arises and runs to its southern extremity. This ground is covered by only 7½ fathoms of water, whilst immediately to the west it rapidly deepens to 14 fathoms, and is apparently close to the overfalls. On the east side also the water suddenly deepens to 13 fathoms, forming the depression between the Chilaw and Jokkenpiddi Paars already noted.

There are, however, many reasons for believing that the unproductiveness of these southern paars is by no means wholly due to insufficient inspection, and we now wish to deal with certain phenomena observed by us, which we believe to be connected therewith.

On much of the ground examined we found handfuls of living spat or oysters, varying in age from a few weeks to four years, of which we forward samples, but being in general about six months old. A notable exception, however, was the Karkopani Paar, where large numbers of oyster shells about four years old were found, indicating that a considerable number of oysters had matured there and been lost.

The outstanding feature, however, which occurred to us was that although the paars in general had ceased to be—or at least were not at present—productive, they were still able to support a few oysters, but that these oysters did not occur in quantity, and, as a rule, died at about two years of age. Probably a few young oysters are always to be found on the paars in question, and since these particular oysters usually spat once before they die, a perennial though small supply are always to be found thereon.

Although the banks under the Company's control are often quite as barren as those at present under Government control, the latter banks are almost yearly replenished by deposits of spat which appear to be brought down from the Indian coast, and to be independent of the exceedingly few and scattered adult oysters often found at the time on the banks in question. It is a secondary point that these spat almost invariably disappear, and does not concern us here and now. The point we wish to emphasize is that deposits of spat of this kind are probably derived, not from oysters actually on the banks at the time, but from external sources, and do not appear to reach the southern paars at all. So that the supply of young oysters on the south is strictly in accordance with the reproductive possibilities, &c., of the local oysters present. That currents account in some measure for the differences observed in the degrees of productiveness between the paars under Government control and those under lease there can be no shadow of doubt.

As illustrating the question, we would point out that on the northern area under lease there are practically no currents during the north-east monsoon, a fact largely due to their being situated under the lee of the land. We have proof that this is so over long periods of time. During our examination of the banks *not* under lease, however, we encountered fairly strong and persistent northerly currents, a phenomenon as unique as it was surprising. These northerly currents were experienced in particular on the Karkopani, Maravilla, and Negombo Paars, and a set of ten drift bottles were liberated on the Chilaw Paar, and a further set of ten on the Maravilla Paar, concerning which we hope to furnish details to Government later.

So far as we are aware no explanation has hitherto been furnished as to the reason why, during the north-east monsoon, such strong currents should be experienced on the banks not under lease, whilst those under lease present one vast expanse of dead calm. In the latter case the overfalls are situated far out at sea, often as far as eighteen miles. From this broad shallow-water plateau evaporation on a large scale takes place. To the south, however, the overfalls are much nearer the coast, sometimes not more than a mile away. The shallow-water plateau to the south is therefore of comparatively small area, and surface evaporation is consequently of small account. This results in the fact that evaporation on a large scale takes place on the areas not under control, whilst on the ground under control the area is so small that comparatively little evaporation takes place. The ultimate result is that currents are set up from the south to equalize the effect. This we believe was the cause of the currents we encountered whilst on the Government banks as previously detailed. The resultant current, however, does not actually reach the banks under lease, and is never experienced north of Talaivillu Point. This *induced* current appears to enter the straits of Anewasel and also the new channel recently formed across "Dutch Bay Land," and in large measure accounts for the incessant synchronic and local piling up (and subsequent erosion) of Dutch Bay Point as already noted. Such an explanation finds a parallel in similar and well-known phenomena exhibited in the Bay of Bengal, in the Red Sea, and in the Mediterranean. It will be obvious that such currents in all probability only affect the shallow-water plateau, which, of course, is the potential pearl bank area.

We believe that the foregoing facts fully and amply explain the phenomenon of differences in currents during the north-east monsoon on the two areas concerned, and have to do in large measure with the differences in productivities observed on the banks in question.

A similar difference in currents exists during the south-west monsoon. It is well known that currents during this monsoon run due south (and against the monsoon weather) on the ground not un r lease, whilst on the northern plateau the current is not nearly so strong, and, save for local and transient phenomena, may be said to be absent.

From information obtained by the drift bottle experiment carried out by the Company, and also from private information, we have reason to believe that the full force of the south-west monsoon (and consequent current) on striking the Indian coast north of Cape Comorin is deflected on to the Ceylon coast from about Talaivillu, south to Colombo. That a strong southerly set *is* actually experienced on the part in question is well vouched for by masters of vessels travelling in the immediate vicinity during the south-west monsoon.

On the area *not* under control, however, we have ample proof that the water becomes piled up as a cushion, in which, save for purely local and temporary effects, a marked current is decidedly absent. According to the observations of native fishermen and other and more reliable authorities, the mean sea level in the Gulf of Mannar rises several inches during the south-west monsoon. There is thus some tangible reason for believing that the northern pearl bank area forms a *cul-de-sac*, outside the range and run of the full force of the current.

It was the opinion of Professor Herdman that the frequent deposits of spat found on the Company's banks were brought down from the Indian coast. We fully concur in this opinion, believing that the oyster larvæ, being pelagic during the first nine days of their existence, *are* brought across from the Indian coast by currents, and that, instead of being carried as far south as Talaivillu, the action of a strong and continued south-west wind, having effect only on the most superficial layer of water, results in the larvæ being drifted and settling more north of Talaivillu—in short, on the Company's pearl banks—which, as we have seen, forms a more or less sheltered *cul-de-sac* of water, besides being the position of a mechanical resultant between a superficial southerly current and a south-west wind. Not only does such a theory account for the frequent deposits of spat obviously derived from external sources and found from time to time on the Company's banks, but it also accounts for the absence of large deposits of spat on the southern area. Besides this, the theory—for such it really is—fully falls in line with what actually observed facts are to hand. It is a point of secondary importance that the sea bottom on the area under lease is more adapted for oysters reaching maturity than that not under lease, besides being—as we have seen—more protected.

We are not arguing that all spat deposits on the northern area are derived from external sources, since the immense numbers of adult oysters found thereon at certain times must result in a local replenishing of the banks irrespective of other sources. Moreover, we are of opinion that when large deposits of spat are found on the southern banks, that such spat is in all probability either derived from the oysters on the Company's area or otherwise from the Indian side, and that the fact of such deposits reaching the banks not under lease is to be correlated with certain temporary irregularities of the currents during the spatting season, which in the light of the foregoing explanation of current phenomena are easy to understand. It would be interesting to obtain information regarding the deposits of oysters on the Indian side, but since inspection work is not carried out extensively there such data is difficult to obtain.

We lay this emphasis on superficial currents, particularly during the south-west monsoon, because it is during this monsoon that oyster spat is liberated as a general rule. We do not believe this rule to be absolute, but we have ample proof that it is very general, and that the normal and usual spatting period is during July and August. During the November inspections conducted by the Company on their own grounds, it is invariably found that when spat deposits *are* discovered during this month they are from three to four months old.

In short, then, we believe that during the south-west monsoon the Indian coast north of Cape Comorin has the effect of deflecting currents, which, escaping the pearl banks not under control, strikes the Ceylon coast from about Talaivillu to the south, and that owing to their position as a *cul-de-sac*, together with the fact that the interaction between a southerly current and a south-west wind has the tendency to cause pelagic oyster larvæ to drift thereon, as well as to the natural protection arising thereby, that spat, having its origin on the Indian coast, eventually drifts on to the northern banks not under control, where, save for the ravages of fishes and the like, it finds a safe and secure shelter. Conversely we believe, for reasons just stated, that such drift spat seldom reach the pearl banks under control, which fact, together with the close proximity of these banks to the overfalls, and the comparative unsuitability of the sea bottom, has resulted in their being more or less unproductive.

As corroborating these ideas relative to the currents prevalent on the pearl bank plateau, it is important to note that along the south-east Indian coast—as, for example, at Tuticorin—the flood tide runs north—entirely opposite in direction to that of the west coast of Ceylon. It therefore happens that on the Indian side the flood tide and south-west monsoon flow together, whilst on the west coast of Ceylon—at least on the southern area—they run in opposition.

Again, at Paumben, it is found that during the south-west monsoon the current through the Pass is persistently north both at flood and ebb tide, although the flood tide is always and everywhere stronger than the ebb tide. This current through the Pass represents the overflow from that body of water on the northern pearl bank area, whose mean sea level is raised above normal, caused, as we have seen, by the deflection of the current on the Indian side. It is further evident that if the spat found on the northern pearl bank area from time to time is in part brought across from the Indian side, it must be derived from parts south and west of the Paumben Pass, since the current in the Pass during the normal spatting season is running *north* and not south.

Of the deep sea currents we have little information, for data under this heading is necessarily difficult to obtain. Although observations have been made on the 6-fathom currents prevalent on the pearl banks under lease during the north-east monsoon for the last three seasons (1906–1909), the results are not to be co-ordinated, showing how indefinite, uncertain, and of no consequence these currents are.

With reference to the deeper currents on the southern areas we have no information, save that when on Negombo Paar the divers reported that the sandy bottom there was thrown into long undulating ridges. These bottom currents are not at present understood, and the few known facts are not to be correlated. Whereas the surface currents on the whole pearl bank area are due to evaporation, wind, and deflection, bottom currents, on the other hand, are in all probability purely tidal. From such little information as we have we are inclined to think that over the whole pearl bank area the flood tide in, say, six or seven fathoms runs due south and the ebb tide north, and that a purely local but complex current runs along the whole line of overfalls

A further point of some importance is that the nature of the sea bottom on the southern paars is fundamentally different—particularly near Chilaw and Negombo—from that on the Company's banks. The change is transitional and not sudden, taking place between Dutch Bay and Navakaddu. South of the latter point the ground—except on areas of sand and living coral—is for the most part a flattish coarse sandstone, with large quartz grains, brightly coloured and strongly impregnated with iron salts. This particular kind of paar is foreign to the northern banks, where a dead coral or a shelly calcrete is predominant. We are unable to say whether this sandstone paar is as satisfactory or as useful for oyster culture as the more calcareous coral and calcrete, but it was clearly apparent that the fauna on ground having such a "paar" bottom was not nearly so extensive, varied, or abundant as it is customary to find on the northern paars.

On a few paars, such as the Wanatty, North Maravilla, and Mid-Jokkenpiddi, much dead shell was found, whilst on the Moodipani Paar, in particular, the dredge continually brought up immense numbers of shells, all long dead, with no other fauna of any kind. It was obvious that whatever factor or factors had resulted in the death of the pearl oysters in the vicinity had equally affected other molluscs. This condition of things is common not only on the north, but *everywhere*, and it is only because cockles, mussels, pinnas, false oysters, and the like have no commercial value that the mortality amongst such molluscs, together with their general ecology, is not noticed or understood.

The last point we would call attention to is the close proximity of the southern paars to the overfalls. We know from facts collected over long periods of time that on the northern area in particular spat occurring on paars in proximity to the overfalls invariably disappear, a phenomenon repeatedly witnessed on the Periya Paar. It is believed that this disappearance is due to the local complexity of currents in the immediate vicinity of the overfalls, but surprisingly, and also unfortunately, up to the present no definite observations have been made in this connection.

We propose collecting, in the near future, information (by experiment and observation) on these local currents. Whatever the cause is, it appears to follow that similar causes are likely to be at work elsewhere, and particularly on the southern paars, where, since the plateau is so small and narrow, the effects would be of comparatively greater consequence.

To summarize then we are of opinion that—

(1) The southern paars are exposed to continuous adverse surface currents not prevalent on the northern paars, which probably results in no external deposit of spat reaching them or settling thereon, and which also probably carries away any local deposit occurring on them.

(2) The nature of the sea bottom does not appear to be so admirably adapted for oyster culture in general as that on the grounds under lease.

(3) The close proximity of these banks to the overfalls, as judged by parallel examples furnished from the northern paars, renders them unsafe as oyster beds, although the actual *modus operandi* by which this is brought about is not at present understood.

(4) Of the bottom currents we know little, but from what few facts are known we are of opinion that they are of no consequence, and are not sufficient to account for the disappearance of spat, save perhaps in the vicinity of the overfalls, in which case the effects would be greater and of more consequence on the southern than on the northern banks.

Remarks.

Professor Herdman, in Vol. II., page 33, of the " Ceylon Reports," states that " From the early Sinhalese records it seems probable that the banks off Chilaw were much more productive in ancient times than they have been during the last century. Chilaw seems, in fact, to have been formerly as important a fishery centre as Silavaturai. The Sinhalese poem 'Kovul Sandesaya,' written about the middle of the fifteenth century, refers to the pearl-lined shores of Chilaw in such a manner as to suggest that this locality was the centre of southern, or Sinhalese, pearl fisheries. In Portuguese and Dutch times its fame seems to have been eclipsed by that of the more northerly banks worked from the settlement at Mannar; but as the Chilaw region is still productive, and yielded at least three fisheries in the nineteenth century, it is possible that beds of oysters may have remained undiscovered and unfished. The report shows great gaps—from 1820 to 1871 and again from 1888 to 1899—so that probably the history looks less favourable than the reality may have been.

" The fishery in 1803 was on the Jokkenpiddi Paar, and that in 1815 was on the Karkopani, so that the fishery in 1884 was the only one on the Chilaw Paar proper—all were small fisheries. On the whole, the record is uneventful, and there have been no great successes and no marked catastrophes; there are no new conclusions to draw, but the banks may still be of value. There seems no reason why a bed of oysters should not mature on occasions, and part of the Chilaw region will at least serve from time to time to supply a stock of young oysters to the Chilaw or other paars that require replenishing."

We concur fully in this opinion. The observations made by the Professor left us but little room for obtaining any further information or any new light, save on the subject of currents.

As we left Dutch Bay, however, the sea bottom seemed to us to become less and less adapted for oyster cultivation, besides being less protected, and we accordingly believe that the history of these pearl banks falls in line with Professor Herdman's and our opinion of this ground to the south. We believe, however, that since such large areas have never yet been examined, and since those paars known to be more or less productive are so infrequently inspected, it would be wise to have the whole area casually examined about once in three years We say " casually " because a thorough survey would occupy a year at least, and would possibly not be worth the necessary trouble.

The charts and chartlets which we forward herewith* are not necessarily charts of the actual paar ground, but merely charts of the areas examined. We make this distinction because it was obvious to us that similar inspection circles obtained years ago had later on come to have an undue significance.

Work on the fauna prevalent on the southern paars was carried out extensively, although the results do not figure largely in this report. A new Anomuran Crustacean was discovered, and interesting observations were made regarding the habitat of another species in this group, and it is hoped to shortly publish an account of the work as Part IV., Reports from the Ceylon Marine Biological Laboratory.

In conclusion, and on behalf of the Company, we wish to express our thanks to Government for allowing us to inspect their banks, and for thus providing a further opportunity for re-investigating

* Not reproduced.

certain obscure phenomena connected with the welfare of the pearl oyster. We trust our observations will materially assist in elucidating many problems connected with these world-famous pearl banks. Our only regret is that no adult and fishable oysters were discovered.

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JAS. C. KERKHAM, R.N.R.,
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April 11, 1909.

APPENDIX B.

March 4, 1909.

Madalaikulai Paar ($4\frac{1}{2}$ miles from Spit-end).

Five fms. Half Mile W.S.W. of centre of paar.

Preliminary position.—Two dives yielded: Halimeda (basket full), Galaxia heterocyathus, Sarcophytum rugosum, Pagurus setifer, Mundia spinulifera, and small white pipe fish. Bottom described as peaky rock.

Paar proper.—5 fms. Inspection by divers. Faunistic results.

Bearings :—Dutch Bay Beacon, N. 61° E.; Dutch Bay Tope, N. 76° E.; Arunakalu Tower, S. 62° E.; R. C. Church (Silaway kovil), S. $66\frac{1}{2}$° E.

Halimeda abundant. A little red weed. A little flat sandy paar. Calcrete and Nullipore scanty.

Living coral include :—

(1) Madrepores 9 spp., including M. scandens.
(2) Porites 4 spp., including P. arenosa.
 1 sp. knobbed.
 1 sp. cake-like.
 1 sp. massive.
(3) 1 Coelaria arabica.
(4) 1 Goniastrea halicora.
(5) 1 Galaxia heterocyathus.

Dead coral abundant.

Five spat ages varying from 2 to 4 months, mostly on dead coral. Fine encrusting Nullipore. Living Spongodes, slate coloured. 3 spp. Sarcophyton:—1 slate coloured and encrusting; 1 yellow gray, erect with broad base; 1 yellowish green.

Scarcity of sponges, ~~but scarlet~~ indiarubber sponge found. Zoanthus shackletoni common. Pentaceros lincki scanty. Cyprea ocellata. Portunids. Blue social Ascidians.

Predominating features —Living Madrepores, Porites, Halimeda, and dead coral.

Madalaikulai Paar (Inner or Southern Paar).

Shot at E. buoy on the northern part inspected by divers in $3\frac{3}{4}$ fms.

1st haul.—Dead coral with one spat. Nullipore balls. Calcrete. Conus sp. Dead Turbo. Alpheus sp. and two Rhodosona sp.

2nd haul.—Dead and living coral. Calcrete. Holothuria nigra Pecten sp. and Portunids.

3rd haul, 4 fms.—Living Turbinaria with galls round barnacles. Dead coral.

4th haul, $4\frac{1}{4}$ fms.—Similar to last, with Hydroids, Stomatopods (Genus Scula), and white Leptoclinids.

5th haul.—More varied Calcareous reddish branched Algæ. Goniastrea sp Nullipore balls. Living Favia sp. False spat on Campanularia sp. Axinella donnani. Aulospongus tubulatus. Brown encrusting sponge sp. Scarlet Filograna with white tubes. One spat on dead Malleus vulgaris.

6th haul, 4 fms.—Halimeda. Red calcareous branched Algæ. One adult oyster on dead coral. Dead coral abundant Living Favia affinis, large Goniastrea sp., and Turbinaria crater. Fleshy Alcyonarians 2 spp. Indiarubber sponge Axinella donnani. Holothuria nigra and a pink sp. Culcita sp. (cushion star-fish). Dorippe spp. Rhinolambus sp and white Leptoclinid sp.

7th haul, $4\frac{1}{2}$ fms.—Dredge full. Living Favia sp. A little calcrete with one spat. Nullipore balls. Cycloseres sinensis. One spat on dead coral. Small crimson papilliform Zoanthid Indiarubber sponge. Aulospongus tubulatus. Axinella donnani. Scarlet Filograna with white tubes. Lepralia culcullata and Fasciolaria trapezium.

8th haul, $5\frac{1}{2}$ fms.—Scanty. Goniastera sp. living. Dead Turbinaria crater. Zoanthids as in 7th haul. Red tubular sponge. Lepralia culcullata. Holothuria nigra. Stomatopods, one green, one reddish. Portunids. Pecten sp. and an Ecteinascidian.

9th haul.—Little Halimeda. Porites arenosa. Coral *débris* and calcrete. Nullipore balls. One 7-weeks spat on crimson Zoanthids. 2 spp. sponge, one black and smooth, another yellowish. Colochirus quadrangulatus. Gastropod egg capsules, square in cross section. Galathea elegans, and Ecteinascidians, blue with yellow band round peristone.

10th haul.—Dredge nearly empty. Dead coral. Dark maroon Polyzoa sp. Flat white Nudibranch. Mauve encrusted Ascidian. Ecteinascidians 2 spp., one colourless, one blue with yellow band round peristone. Scarlet Filograna in white tubes.

11th haul.—Coral débris. Scarlet Filograna with white tubes. Sarcophyton sp. Aulospongus tubulatus. Pentaceros lincki. Clypeaster humilis. Echinodiscus auritus. Calappa sp. Conus sp. Galathea elegans. Encrusting Diplosoma sp. One small eel. One very young spat on dead coral.

12th haul, $4\frac{1}{2}$ fms.—Halimeda. Living Turbinaria crater. Coral débris. Clypeaster humilis. Gastropod egg capsules. Axinella donnani. Portunids. Pagurus setifer. Fasciolaria trapezium. Sand encrusted Ascidians in quantity.

13th haul, $4\frac{3}{4}$ fms.—Coral débris. Living Turbinaria crater. Clycloseris sinensis. Clypeaster humilis. Pentaceros lincki. One dark red and one yellow Polyzoa spp. Axinella donnani. Red tubular sponge. Gastropod egg capsules. Sand encrusted Ascidians and an heliotrope Leptoclinid.

14th haul, $4\frac{1}{2}$ fms.—Somewhat scanty. Turbinaria crater. Slate coloured sponge sp. Slate coloured Sarcophyton sp. Red encrusting sponge. Pentaceros lincki. Black and white Crinoids. Culcita sp. (cushion star). Avicula vexellum, with one oyster spat attached to it (3 to 4 months old). White Amaroucium and one Dab.

15th haul, 5 fms. (N. and S. line of paar).—Haul scanty. Calcrete. Shell débris. Cycloseres cyclolites. Sarcophyton 2 spp. Clypeaster humilis. Echinodiscus auritus. Linckia miliaris. Lepralia culcullata. Small white Cyprea. White encrusting Leptoclinid; and a zebroid (brown and white) Didemnul, encrusting.

16th haul, $4\frac{1}{2}$, then 4, $3\frac{1}{2}$, and 3 fms.—Bottom fine hard sand and a little mud (dredge empty).

17th haul, 3 fms.—Fine sand and a little mud (dredge empty).

Two dives were here taken in $2\frac{3}{4}$ fms. on fine sand. A third dive taken near by in 4 fms., also on fine hard sand.

18th haul.—Dredge lined with canvas to catch bottom. $4\frac{3}{4}$ fms. One spat 2 months old. A little calcrete and coral débris. Holothuria nigra. Sea-urchin with purple spines. Stomatopods. Ecteinascidian sp., blue with circumoral yellow ring.

19th haul.—Dredge lined with canvas. Calcrete and living Favia 2 spp. Coral débris. Colochirus quadrangulatus. Red sponge balls. Pagurus setifer and a scarlet Heteropsammia sp.

20th haul, $4\frac{1}{4}$ fms.—Living coral, mostly Turbinaria crater, also Porites arenosa and Nullipore. Sarcophyton sp. Axinella donnani. Aulospongus tubulatus. Pentaceros lincki. Pecten sp. Fasciolaria trapezium. Black Cyprea. Sandy Ascidians. Three spat $2\frac{1}{4}$ months old on dead coral and one spat on Nullipore. Dredge badly torn.

21st haul.—Dredge badly torn. Halimeda. Coral débris. Living coral, including Turbinaria crater and Favia affinis. Nullipore. Sarcophyton 2 spp. Axinella donnani. Aulospongus tubulatus. Holothuria nigra. Large Calappa sp. One spat associated with sandy Ascidians and one spat on Ostrea sp.

22nd haul.—Halimeda. Jointed calcareous Algæ. Living coral in quantity, mostly Turbinaria crater. Coral débris. Spongodes sp. (slate coloured). Palythoe sp. forming dense sandy colonies. Zoanthus shackletoni and 3 spat associated with Ascidians.

Dredging discontinued as dredges were all torn.

Characteristic features:—Absence of Madrepore corals. Quantity of Turbinaria crater. Ascidians abundant.

March 5, 1901.

Talaivillu Paar.

Rectangular inspection by Divers.

Faunistic results:—Reddish branched calcareous Algæ. A little Halimeda. Coral débris in preponderance. Living coral included Turbinaria crater, Turbinaria sp. with one spat in cup, and a Meandrine coral

Spongodes sp. (slate coloured). Sarcophyton 2 spp., and a greenish Palythoe colony.

Predominating features:—Preponderance of dead coral.

Talaivillu Paar (South part, about 6 fms.).

Faunistic results:—Reddish branched calcareous Algæ.

Living coral included:—Madrepore 2 spp. Labrynthine coral. Favia affinis and Galaxia heterocyathus.

Sarcophyton 2 spp. Yellow tubular sponge. A few crabs (one smooth and red). Pteroceras lambis and a big Cassis sp.

Predominating feature:—Living coral passing into dead coral on the north.

The Talaivillu coral reef was examined during the morning.

March 6, 1909.

Navakaddu Paar.

Rectangular inspection by Divers.

Bearings :—St. Anna's Church, N. 15° E.; Talaivillu Point, N. $8\frac{1}{2}$° E.; Navakaddu Village, S. 41° E.

Faunistic results :—Green and brown parti-coloured strap weed. Sargassum. Halimeda. Reddish branched calcareous Algæ. Red weed. Red jointed succulent seaweed. The strap-weed covered with "false spat" of 2 spp., aged 6 weeks (?), viz., Avicula vexellum and A zebra. A little sand, black mud, and clay mud. Dead coral abundant. One true spat on calcrete. Two Fungoid corals. Living Sarcophyton sp., and a red digitate sponge.

Outstanding features :—Abundance of brown weed (Laminaria) with attached "false spat" and dead coral. Good ground on the east, but note the presence of mud.

Dredging and diving lines on the southern extension of Navakaddu Paar.

Faunistic results :—*1st haul*—Dredge hitched immediately, bringing up *small* quantities of red weed. Coelaria sp. Favia affinis. Coral débris and black sponge.

2nd haul.—Dredge nearly empty. Weed 3 spp. and a little calcrete. Dredge torn and dredging temporarily discontinued.

Diving :—*1st dive.*—Nothing. Reported peaky rock $1\frac{1}{2}$ to 2 feet high.

2nd dive—Halimeda, weed 3 spp., and a little calcrete.

Dives now taken every $\frac{1}{4}$ mile; courses given on chart.

3rd dive, $3\frac{1}{2}$ fms.—A little weed and calcrete. Rock reported too massive to move. Solitary Zoanthids.

4th dive.—Rock too large to bring up sample.

5th dive.—As last dive. Rock reported to be 4 feet high, with sandy interspace.

6th dive.—Brown strap weed (Laminaria). Dichotomous reddish weed. Solitary coral and calcrete. Small shells, including "Suran," the spat borer. Strombus sp. Avicula vexellum and A. zebra in small quantities.

7th dive, 4 fms.—Laminaria and weed of two other species. A little sand. Diver reported "massive rock."

8th dive.—Laminaria and other weed of many species and a little calcrete, all in small quantities.

9th dive, 6 fms.—Fine sand only.

Dredge shot again.

1st haul.—Empty Bottom sand.

2nd haul, $7\frac{1}{2}$ fms—Dredge full. Laminaria, on which were large deposits of Avicula vexellum and A zebra, not more than 6 weeks old. A little calcrete and sand. Dead Favia sp. and living Favia affinis.

3rd haul, $8\frac{1}{2}$ fms.—Empty Sand.

4th haul, $9\frac{3}{4}$ fms—Laminaria. Red Caulerpa. Two pieces calcrete. Pinky salmon-coloured sponge. Pentaceros lincki. No false spat.

5th haul.—Laminaria and red Caulerpa only. No false spat.

6th haul, $7\frac{1}{2}$ fms.—Black slimy mud (Magnetite) and a little calcrete, sand and sandstone ("paar").

Predominating features :—Laminaria with young "false spat" 2 spp. Avicula vexellum and A. zebra. Note presence of mud.

March 7, 1909.

Karkopani Paar.

Inspected by Divers.

Bearings :—Chilaw Bungalow, S. 25° E., Oodoopekeret House, N. 25° E.; Chilaw River entrance, S. $36\frac{1}{2}$° E.

Faunistic results :—Quantities of strap and brown seaweed generally. A little sand with Amphioxus. Few Nullipore balls. Dead oyster shells. Four spat (2 to 6 months). Large quantities of calcrete.

Living Turbinaria crater, Goniastrea sp., &c., in small quantities. Axinella donnani, and a few specimens of Pentaceros lincki. Dead chank with capsules.

Outstanding features :—Immense quantities of calcrete in large blocks, with large quartz grains, forming ideal ground; also seaweed.

Wanatty Paar.

Dredging Results.

1st haul, $6\frac{3}{4}$ fms.—Laminaria. Halimeda and other weed. Calcrete and heaps of Nullipore with dead shells. A little living coral and Pentaceros lincki.

2nd haul, $6\frac{1}{2}$ fms.—Laminaria and Sargassum plentiful. Red calcareous Algæ. Calcrete and Nullipore Few dead shells and shell débris. Two spat. Living coral scanty. Clypeaster humilis.

3rd haul, 6 fms.—Bottom sand. Dredge empty, save one Sepia sp.

4th haul, $5\frac{1}{2}$ fms.—Laminaria and Sargassum plentiful. Shell débris. Calcrete and Nullipore. Living Turbinaria crater and Favia cavernosa. Fungia dentata. Cycloseris sinensis. Tubular sponge. Lemon-yellow sponge. Zoanthus sp. Pinna sp. Pentaceros lincki, and a small Lithodes sp.

5th haul, 5½ fms.—Full. Dead coral and débris abundant. A few adult Avicula vexellum. No weed. Favia affinis. Juncella juncea. One large oyster, and also one small and one large recently dead shell.

6th haul, 5½ fms.—Principally Sargassum and coral débris. Nullipore balls. Favia affinis. Petrosia testudinaria and 3 other spp. Sarcophyton sp. Dab, and a Leptoclinid.

7th haul, 5½ fms.—Sargassum. Laminaria and other weed. Petrosia testudinaria and another sponge. Nullipore. Pentaceros lincki and one spat.

8th haul, 5½ fms.—Nearly empty. Laminaria. Astropecten sp., and Laganum depressum.

9th haul, 6 fms.—Empty. Bottom sand.

10th haul, 6 fms.—Nearly empty. Laminaria and Sargassum. Solitary coral with commensal Aspidosiphon sp. Tubular sponge. Echinodiscus auritus. Ophuroids 3 spp. Astropecten sp. Calappa gallus and Pinna sp.

11th haul, 6 fms.—Nearly empty. A little Sargassum. Pentaceros lincki and another sp. Ophuroids 3 spp. and white, massive, sandy Leptoclinids.

12th haul, 6 fms.—Nearly empty. Sargassum and Laminaria. Solitary coral with Aspidosiphon sp. Echinodiscus auritus. Turbinella pyrum. Black Cyprea. Massive Leptoclinid (white), and one salmon coloured.

13th haul, 5½ fms.—Laminaria and Sargassum. Axinella donnani and Aulospongus tubulatus. Lepralia cucullata, Murex haustellum.

14th haul, 5½ fms.—Little weed. Much calcrete and Nullipore. Living Favia cavernosa. One oyster and 2 spat. Holothuria nigra. Echinodiscus auritus and Pegasus draconis.

15th haul, 6¼ fms.—Full. Calcrete, and dead coral much bored by Clione. A little living Favia affinis. Nullipore plentiful. Adult Avicula vexellum on calcrete. Three adult oysters and one dead. Petrosia testudinaria, sponge sp., and Pennatula sp.

16th haul, 6¼ fms.—Dredge full. Calcrete. Coral débris much bored by Clione. Living Favia cavernosa. Three spat on calcrete and one recently dead adult. Petrosia testudinaria and sponge sp. Little sand and Nullipore.

17th haul, 6¼ fms.—Nearly empty. Living Turbinaria crater. Pinna sp. Petrosia testudinaria and Cycloseres sinensis.

18th haul, 6 fms.—Dredge full. Twelve spat Assorted ages on Nullipore, and associated with Pecten sp. Sargassum, Laminaria, and other weed in quantity. Coral débris and two large sea-urchins.

19th haul, 6 fms.—Twenty spat on Nullipore and associated with Pecten sp. Ages from 6 months to 4 years. Laminaria and leafy weed. Large Porites arenosa. Red calcareous Algæ. Green Stomatopods and Pentaceros lincki.

20th haul, 6½ fms.—Half full. Three spat. Ages mixed to one year. Laminaria, Sargassum, and other weed. Turbinaria crater. Porites arenosa and Favia affinis. Nullipore balls, much calcrete and coral débris. Petrosia testudinaria. Axenilla donnani, Aulospongus tubulatus, and Pentaceros lincki.

21st haul, 7½ fms.—Full. Sargassum and other weed scarce. Much coral débris and Nullipore. Turbinaria crater, Favia affinis, Porites arenosa. Petrosia testudinaria, Axenilla donnani and 2 other spp., one black and digitate. Cancellus investigateris in Porites arenosa and six oysters. Ages mixed from 6 months to 2 years.

22nd haul, 7½ fms.—Strap weed. Nullipore with one spat. Red sponge balls and Murex haustellum only.

Predominating features :—Coral débris much bored by Clione plentiful. Dead shells and weed also abundant.

March 8, 1909.

South End Karkopani Paar.

Inspected by Divers.

Bearings :—Chilaw Bungalow, S. 30° E. ; Oodoopekeret House, N. 10° E.

Faunistic results :—A little Laminaria and brown weed generally. Some sand, much calcrete, and a little Nullipore.

Living Porites arenosa. Favia affinis and Turbinaria crater. Juncella juncea. Indiarubber sponge. Pentaceros lincki, and adult Avicula vexellum.

Predominating features :—Calcrete and living coral.

March 9, 1909.

Chilaw Paar.

Inspected by Divers.

Bearings :—Chilaw Bungalow, S. 42½° E. ; Oodoopekeret House, N. 25° E.

Faunistic results :—Much strap weed. Sargassum. Calcrete and sand. Little living coral (Turbinaria crater and Goniastrea sp.). Some Diapatro tubes. Thirty-seven solitary corals, with commensal Aspidosiphon sp. One spat. Indiarubber sponge. Sarcophyton sp. and a massive sandy Leptoclinid.

Predominating features :—Weed, calcrete, and sand.

March 10, 1909.

Small inspection of Nagal Paar.

Bearings :—Chilaw Bungalow, S. 37° E. ; Oodoopekeret House, N. 38° E.

Faunistic results :—Sargassum. Laminaria. Some sand with Amphioxus. A little living coral Favia sp.). Much calcrete. Axinella donnani and a few dead shells.

Predominating feature :—Calcrete.

West of Nagal Paar.

Dredging and diving results.

Faunistic results :—*1st haul,* 7¼ fms.—Sargassum. Laminaria. Much calcrete. Nullipore. Favia 3 spp. and Clypeaster humilis.

2nd haul, 7½ fms.—Sargassum. Laminaria and a little sand. Much calcrete and dead shells. Aulospongus tubulatus and Clypeaster humilis.

3rd haul, 8 fms.—Empty, save a little weed and calcrete.

4th haul.—Sargassum. Laminaria. Calcrete. A few dead oysters and Nullipore. Aulospongus tubulatus and Axinella donnani.

5th haul, 8¾ fms.—Empty.

6th haul, 8¾ fms.—Nearly empty. A little Sargassum. Sponge sp. and adult Avicula vexellum.

7th haul, 9½ fms.—Nearly empty. A little Sargassum. Two spat on an Avicula attached to Echinogorgia psuedosasappo.

8th haul, 9¼ fms.—Empty.

9th haul, 9¼ fms.—Empty.

10th haul, 9¾ fms.—A little Sargassum and 3 spat.

11th haul, 8¾ fms.—Paar ground (Jokkenpiddi). Dredge full of Nullipore and calcrete, with some weed.

12th haul, 7¾ to 8¼ fms.—Just like last haul, with living Turbinaria crater.

13th haul, 8¼ fms.—Sargassum and Laminaria. Favia sp. and Madrepore sp.

The paar ground (Jokkenpiddi) well defined. East of the paar the ground is clean sand and rock

North Jokkenpiddi Paar.

Bearings :—Chilaw Bungalow, S. 52½° E. ; Oodoopekeret House, N. 59° E.

Dredging results west of west buoy :—

1st haul, 9¼ fms.—Much weed. Dead and living coral. Blue and brown sponge spp. and one spat.

2nd haul, 9¼ fms.—Much weed. Pentaceros lincki. One spat and Filograna sp

3rd haul, 9¼ fms.—Much weed. Holothuria nigra and Synascidians.

4th haul, 9¼ fms.—Much weed. Little living and dead coral. Nullipore balls exceedingly numerous.

5th haul, 10¼ fms.—Little weed. Dredge contained little else, except immense numbers of Nullipore balls. No spat.

6th haul, 13¼ fms.—Same bottom. One spat on strap weed. Calcrete and a large Holothuria nigra.

7th haul, 13 to 14 fms.—Some weed. Nullipore abundant. Calcrete and one Culcita sp.

Dredging south of south buoy :—

1st haul, 8¾ fms.—Nearly empty.

2nd haul, 9 fms.—Empty.

3rd haul, 8¾ fms.—Dredge caught. Clypeaster humilis and Conus sp.

4th haul, 8¾ fms.—Empty.

5th haul, 9 fms.—Little weed only.

6th haul, 9¾ fms.—Empty.

7th haul, 7½ fms.—Few shell fragments and a little strap weed.

8th haul, 8½ fms.—Dredge caught. Living and dead coral. Avicula vexellum on Gorgonid sp. Tubular sponge. Creeping Madrepore sp. and old, broken, dead valves of pearl oyster.

Dredging east of station buoy :—

1st haul, 7½ fms.—Dredge caught. A little paar with Mactra sp.

2nd haul, 7½ fms.—Weed. Indiarubber sponge. Calcrete and abundant tubular sponge.

3rd and 4th haul, 8½ fms.—Both dredges caught on creeping Madrepore sp. Port dredge badly damaged. Now steamed about a mile over 7½ to 8 fms.

5th haul, 7¾ fms.—Diopatra tubes. Ribbon weed.

6th haul, 7¾ to 8½ fms.—Same bottom. Echinodiscus, dead bivalves, and plenty of Diopatra tubes. Sandy bottom.

Then 11¾, 13¾, 14½, and 14 fms. Then full speed ahead to station buoy.

March 11, 1909.

North End Jokkenpiddi Paar.

Inspection by Divers.

Bearings :—Chilaw Bungalow, S. 58½° E.; Oodoopekeret House N. 59° E.

Faunistic results :—Much strap weed and Sargassum. A little Halimeda, much coral débris, and calcrete. Living coral, included Madrepore 2 spp. and Turbinaria crater. Some sand. Gorgonids 2 spp. (maroon and yellow). Axinella donnani, Aulospongus tubulatus, and 2 other spp. Aniculus strigatus in Conus sp Sarcophyton sp. Holothuria nigra and Clypeaster humilis. Five spat.

Outstanding feature :—Coral débris.

Dredging results,* &c., between north end of Jokkenpiddi Paar and the Muttubunda Paar.

Faunistic results :—

1st haul, 10 fms.—Empty, save a little Sargassum and Laminaria.

2nd haul, 9½ fms.—Nearly empty. A little weed. Also Clypeaster humilis and Astropecten sp.

3rd haul, 9½ fms.—Nearly empty. A little weed only.

4th haul, 9½ fms.—Little weed, few Aulospongus tubulatus, and Gorgonids 2 spp. (maroon and yellow).

5th haul, 9¾ fms.—Nearly empty. A little weed, Aulospongus tubulatus, and a "mealy sponge." One spat.

6th haul, 9½ fms.—Empty.

7th haul, 9¼ fms.—Empty.

8th haul, 9½ fms.—Nearly empty. A little weed. One spat and a tiny Rhinobatis columnæ.

9th haul, 9¼ fms.—Empty.

Divers went down twice, each time reporting flat rock just covered with sand.

10th haul, 9¼ fms.—Dredge full. (Approach to Muttubunda Paar.) Much strap weed, Sargassum, and calcrete. Axinella donnani and Aulospongus tubulatus. Gorgonids 3 sp. (maroon, yellow, and purplish) and Clypeaster humilis.

11th haul, 9¼ fms.—Dredge half full. Much weed, calcrete, and Nullipore. Pentaceros lincki. Adult Avicula vexellum. Dead oyster shells and Gorgonid spp.

12th haul, 9¼ fms.—Full. Much weed, calcrete, Nullipore, and some oyster shells. Aulospongus tubulatus and Gorgonids 3 spp.

13th haul, 9¼ fms.—Dredge torn. Empty, save a little weed and one oyster shell.

14th haul, 9¼ fms.—Full. Much weed. Calcrete, some sand, and dead shells. Aulospongus tubulatus.

Diver made two descents and reported *flat* rock with a superficial covering of sand.

Shot trawl at 9.30 A.M. and hauled at 9.45 A.M. Trawl all torn to shreds.

Remarks.—Ground between Jokkenpiddi and Muttubunda flat and barren. Very weedy. Muttubunda consists of peaky rock.

Udapauka Paar.

Dredging and Diving.

Faunistic results :—

1st haul, 8¾ fms.—Empty.

2nd haul, 8½ fms.—Weed abundant. A little sand and calcrete. Few dead shells and Axinella donnani.

3rd haul, 8 fms.—Full of weed. Some sand and calcrete. One Nermertine with proboscis quite a foot long. Dorrippe sp. colour of Sargassum.

4th haul.—Hitched. Empty.

5th haul, 7½ fms.—Weed principally. Some sand and black sponge. Pentaceros lincki. Conus sp. Sea-urchins (white). Clypeaster humilis. Dorippe sp. and a pipe fish.

6th and 7th haul.—Both hitched, bringing up one spat, Clypeaster humilis, a little sand, and sponge.

Diver made two descents in 7½ fms., both on soft sand, tested with a marling spike.

8th and 9th haul.—Both hitched, bringing up a little living coral and weed.

10th haul, 7 fms.—Full of Sargassum and Laminaria. Some Turbinaria crater, calcrete, and Filograna. One oyster. Portunids and small fish on Madrepore sp.

11th haul, 8 fms.—Full of weed. Some living Madrepore sp. and Turbinaria crater. Filograna. One oyster and 7 spat. Little calcrete. Phyllospongia holdsworthi common.

12th haul, 8 fms.—Similar to last, but no spat. A little Nullipore and black Commatulids with commensal Alpheus. Also Vermetus.

13th haul, 7½ fms.—Weed. Nullipore, Pentaceros lincki. Dromia unidentata. One dead oyster shell. One spat and Vermetus.

14th haul, 8 fms.—Full of Sargassum and Laminaria. A little dead shell and Nullipore.

15th haul, 7½ fms.—Full of weed. A little calcrete and Nullipore. Aulospongus tubulatus. Clypeaster humilis. Axinella donnani and Vermetus.

16th haul, 7½ fms.—Weed. Dead coral. Filograna abundant. Some calcrete and Pentaceros lincki.

Predominating features :—Enormous quantities of Sargassum and Laminaria. Vermetus also typical.

March 12, 1909.

Mid-Jokkenpiddi Paar.

Bearings :—Chilaw Bungalow, S. 73° E. ; Oodoopekeret House, N. 51° E.

Faunistic results :—Much Sargassum and a little Laminaria and sand. Calcrete abundant, and some quantity of shell débris, including oyster shells, and 4 young oysters. Some Nullipore.

Living coral included Madrepore studeri (?), conulose coral, a slender spreading Madrepore. Porites arenosa. Turbinaria crater and Favia affinis.

Indiarubber sponge (Spongelia elastica ?), tubular sponge, and another. Pentaceros lincki and white Leptoclinid.

Predominating features :—Living coral. Calcrete. Weed and shell débris noticeable.

Dredging South End of Jokkenpiddi Paar.

Faunistic results :—

1st haul, $9\frac{3}{4}$ fms.—Empty.

2nd haul, $9\frac{1}{2}$ fms.—A little Sargassum and living coral.

3rd haul, $8\frac{1}{2}$ fms.—Some weed. Living Turbinaria crater and a black Didemni

4th haul.—Hitched at once. A little weed, black sponge, red sponge, and dead oyster shells.

. Diver went down, reported peaky living coral, steamed $\frac{1}{4}$ mile, then shot in 8 fms.

5th haul, 8 fms.—Nearly empty. Small quantities of green Goniaster sp. Dead Turbinaria crater and Coscinaria donnani. Little calcrete and Nullipore. A smooth scarlet sponge. Some adult Avicula vexellum and white encrusting Leptoclinids.

6th haul, $8\frac{1}{2}$ fms.—Much weed. Little calcrete and living Goniaster sp.

7th haul, $8\frac{3}{4}$ fms.—Nearly empty. Little calcrete, dead coral shells, and Nullipore. Yellow-brown Gorgonids. Echinodiscus auritus and Clypeaster humilis.

8th haul, $8\frac{3}{4}$ fms —Nearly empty. Little weed and one spat. Astropecten sp. Echinodiscus auritus Clypeaster humilis. A little sponge. Diapatro tubes and Rhabdocynthia sp.

9th haul, $8\frac{3}{4}$ fms.—Empty, save a fragment of Nullipore. Axinella donnani. Astropecten sp. Fungia dentata and Avicula vexellum.

10th haul, $8\frac{3}{4}$ fms.—Sand, dead shells, and a little Nullipore. Aulospongus tubulatus, Clypeaster humilis. Astropecten sp. and fish eggs.

11th haul, $9\frac{1}{4}$ fms.—Shell débris only.

12th haul, $9\frac{1}{4}$ fms.—Empty, save three specimens of a green Sycon sp.

Diver sent down, brought up basket full of shell débris and Nullipore.

Predominating feature negative. Utterly barren ground.

March 13, 1909.

South Karkopani Paar.

Inspection by Divers.

Bearings :—Chilaw Bungalow, N. $87\frac{1}{2}$° E. ; Karkopani, N. 48° E. ; Deduru-oya estuary, N. 78° E.

Faunistic results :—A little weed, some sand with Amphioxus, a little calcrete, and Nullipore. Sponge 2 spp. and one spat.

Predominating feature negative. Remarkably barren.

March 14, 1909

North Oolawitti Paar.

Faunistic results :—

1st haul, $6\frac{3}{4}$ fms.—Nearly empty. A few Mectra sp. and dead oyster shells.

2nd haul, $6\frac{3}{4}$ fms.—Same, plus Holothuria nigra.

3rd haul, $6\frac{3}{4}$ fms.—Same, with a little weed, Octopus eggs.

4th haul, 7 fms.—Empty, save for a few large Astropecten sp. and empty shells.

5th haul, 7 fms.—Exactly similar.

6th haul, 7 fms.—Empty One oyster shell.

7th haul, 7 fms.—A little weed, few shells, and calcrete. Tubular sponge sp. and Aulospongust ubulatus, Holothuria nigra and Astropecten sp.

8th haul, $7\frac{1}{4}$ fms.—Weed. Living Turbinaria crater. Few dead oyster shells. Tubular sponge and egg capsules of Murex sp. (?).

This position was bouyed.

9th haul, $7\frac{1}{2}$ fms.—Empty.

10th haul, 8 fms.—Empty.

11th haul, $7\frac{1}{4}$ fms.—Empty.

Steamed back to buoy. Took two dives there, divers bringing up large quantities of shelly calcrete and a little flat sandstone.

Steamed $1\frac{1}{2}$ mile S.W. $\frac{1}{4}$ W. Then shot in a position near the South Oolawitti.

1st haul, $9\frac{1}{4}$ fms.—Empty.

2nd haul, $9\frac{1}{2}$ fms.—Empty, save for a trace of weed and a few sea-urchins.

3rd haul, $9\frac{1}{2}$ fms.—Exactly similar.

4th haul, $9\frac{1}{4}$ fms.—Exactly similar.

5th haul, $9\frac{1}{4}$ fms.—Empty. Two or three dead oyster shells.

6th haul, $8\frac{1}{2}$ fms.—Empty.

7th haul, $8\frac{1}{4}$ fms.—Empty. Two or three oyster shells.

Predominating feature negative. The most barren ground I have seen. See later inspection results on this paar

Maravilla Paar.

Inspection by Divers.

Bearings :—Chilaw Bungalow, N. $12\frac{1}{2}°$ E., distant 7·6 miles ; Moolecottah Village, N. 71° E.

Faunistic results :—Ground utterly barren. Sand (with Amphioxus) only, plus one Axinella donnani and a few Mactra sp.

Oolawitti Paars.

Dredging results :—First nine dredgings were upon sandy bottom ; then at 9 fathoms came upon abundant Nullipore balls. Fasciolaria trapezium. Diopatra and the usual Echinoderms with little weed. About this point laid down station buoy. Dredged from here back to ship and found continuous Nullipore ground with little weed and shell débris, including dead pearl oyster valves estimated at $1\frac{1}{2}$ to $3\frac{1}{2}$ years old.

March 15, 1909.

North and South Oolawitti Paars.

Rectangular inspection by Divers.

Bearings :—Negombo, S. 17° E. ; Chilaw, N. $12\frac{1}{2}°$ E.

Faunistic reesults :—Sand with Amphioxus, Nullipore, calcrete, and a few dead oyster shells in small quantities.

Outstanding feature negative. Apparently very barren ground.

The North Oolawitti and the Moodipani Paars are continuous.

Moodipani Paar.

Dredging results :—

1st haul, 6 fms.—A little weed, many dead oyster shells of varying ages, some calcrete, and Nullipore. Clypeaster humilis, Echinodiscus auritus, and "Leopard-star."

2nd haul, $6\frac{1}{4}$ fms.—Sargassum and Laminaria. Much calcrete. A few dead oysters shells (one year old). Pentaceros lincki. Coscinaria donnai. Small crabs. Tubifex tubes. Aulospongus tubulatus and a dab.

3rd haul, $6\frac{1}{4}$ fms.—Empty, save a few oyster shells.

4th haul, $5\frac{1}{4}$ fms.—Half full. Small shell débris exceedingly plentiful, mostly oyster shells of varying ages. The rest Mactra and other Llamellibranch débris. A little calcrete and two small oysters.

5th haul, $5\frac{3}{4}$ fms.—One oyster. Similar in character to last, plus one sponge sp. and 2 spp. of Petrolisthes, symbiotic therein.

6th haul, $5\frac{1}{2}$ fms.—Empty, save a few living Mactra sp. and some oyster shells.

7th haul, 5 fms.—Nearly empty. A little calcrete and shell débris. One oyster, Mactra sp., and Clypeaster humilis.

8th haul, $5\frac{1}{4}$ fms.—Living Turbinaria crater. Shell débris. Nullipore. One spat. Maroon sponge sp. Greenish sea-urchins. Holothuria nigra and another pink sp.

9th haul, $6\frac{1}{4}$ fms.—Nearly empty. Sargassum. Turbinaria crater and one oyster. Diogenes (?) sp. in quantity in Pectenaria tubes.

10th haul, $5\frac{1}{2}$ fms.—Nearly empty. Two adult Avicula vexellum. Three oysters. Petrolithes armatus, Holothuria nigra, and Turbinaria crater.

11th haul, $9\frac{3}{4}$ fms.—Empty, save a little calcrete and weed.

12th haul, $6\frac{1}{2}$ fms.—Empty. save Pentaceros lincki. A little calcrete and oyster shells. Some Porites arenosa and 1 spat (3 months old).

13th haul, $6\frac{3}{4}$ fms.—Empty, save Favia affinis and a brownish black brittle-star.

14th haul, 8 fms.—Empty, save a little weed, dead assorted shells, and Clypeaster humilis.

15th haul, 8 fms.—Nearly empty. Laminaria, Astropecten 2 spp., and a little calcrete.

16th haul, $6\frac{1}{2}$ fms.—Weed. Nullipore. Calcrete, and living Porites arenosa, Pentaceros lincki. Clypeaster humilis and a few dead oyster shells.

17th haul, $6\frac{1}{2}$ fms.—A little weed. Some calcrete and dead coral. One spat. Holothuria nigra, sponge sp., and Fasciolaria trapezium

18th haul.—A little weed. Much Nullipore and shell débris (coarse stuff including oyster shells). Nine spat. Goniaster sp. Filograna and a sponge sp.

19th haul, 6 fms.—Calcrete. Turbinaria crater. Living Porites arenosa. Nullipore and twenty spat.

20th haul, 6 fms.—Nearly empty. A few Mactra sp. and oyster shells. Clypeaster humilis. Greenish sea-urchins. "Leopard-stars" and some calcrete.

21st haul, 6 fms.—Weed. Calcrete and Aulospongus tubulatus. Three Holothuria nigra and Clypeaster humilis

22nd haul, 6 fms.—Similar.

Predominating features :—Abundance of assorted shell débris with calcrete. This "paar" is continuous with the North Oolawitti.

March 16, 1909.

Negombo Paar.

Inspected by Divers.

Bearings :—Negombo Fort, S. 52° E. ; Keymelle river mouth, N. 74° E. ; R. C. Church tower, S. 56° E.

Faunistic results :—A little weed. Coarse sand with many Amphioxus. Large, long Cirripathes sp. Large masses of calcrete and paar rock (sandstone), fine and coarse grained. Living Favia 3 spp. Axinella donnani. Pentaceros lincki and Coscinaria donnani.

Predominating feature :– Quantity of calcrete and paar rock. Excellent ground.

March 17, 1909.

Muttu Parawatti Paar

Ordinary inspection by Divers.

Bearings :—Keymelle river mouth, N. 55° E. ; Negombo Fort, S. 81° E.

Faunistic results :—Some Sargassum. Plenty of coarse sand (with Amphioxus) and dead coral, calcrete, and paar. Porites arenosa. Turbinaria crater and Favia affinis. Indiarubber sponge, Holothuria nigra, and Pentaceros lincki.

Predominating features :—Dead coral, calcrete, paar, and sand.

Holy Paar, Negombo.

Dredging results :—

1st haul, 8¼ fms.—Empty, save a few pearl oyster shells.

2nd haul, 8 fms.—Scanty. A little ribbon weed and Nullipore. Pentaceros lincki and Clypeaster humilis.

3rd haul, 8 fms.—Empty, save 1 pearl oyster shell and 8 Mactra spp.

4th haul, 8 fms —Ribbon weed and shell débris, including a few dead pearl oyster shells. Also Clypeaster humilis.

5th haul, 7½ fms.—Culcita sp. and a flat, sandy, hard, loose "paar," strongly impregnated with iron, and having coarse quartz grains.

6th haul, 7¾ fms.—Two pearl oysters and a few dead shells. Filograna sp. Pagurus setifer. Astropecten sp. Clypeaster humilis, Echinodiscus auritus, and a little "paar."

7th haul, 7½ fms.—A large piece of paar Living Turbinaria crater and aulospongus tubulatus.

8th haul, 7½ fms.—Much paar, calcrete, and a few dead pearl oysters. Colochirus quadrangulatus and Pentaceros lincki.

Nearing "paar" proper.

9th haul, 7½ fms.—Hitched. Quantity of calcrete, coloured tubular sponge, and two dead oyster shells.

10th haul, 7½ fms.—Hitched Coscinaria donnani. Numbers of sea-urchins and Clypeaster humilis.

11th and 12th haul, 7½ fms.—Both hitched. A little calcrete and paar Aulospongus tubulatus. Petrosia testudinaria. Gorgonid sp. and Avicula vexellum.

Diver here made two descents in 7½ fms. and reported (*a*) sand, (*b*) hard peaky "paar" with sandy interspaces. Steamed a little then. Two more dives (see chart) :—(*a*) 7¾ fms. Hard peaky paar with sandy interspaces ; (*b*) 7¾ fms. Sand

13th haul, 8 fms.—A little calcrete Few dead oyster shells and indiarubber sponge.

14th haul, 7¾ fms —Fouled. Empty.

15th haul, 7¾ fms.—Empty. Sandy bottom.

16th haul, 7½ fms.—Empty. Sandy bottom.

17th haul, 7½ fms.—Spatangoids, sea-urchins, and sponge sp. ; all scanty.

18th haul, 7½ fms.—Empty.

19th haul, 7 fms.—Hitched. Some paar. Living Favia affinis. Two spat. Astropecten sp.

20th haul, 7 fms.—Paar, calcrete, and a few oyster shells. Living Symphyllia sp. and Favia affinis.

21st haul, 7½ fms.—Empty.

22nd haul, 7½ fms —Living coral and a few dead oyster shells.

23rd haul, 7½ fms.—Calcrete and paar. Dead oyster shells and coral.

Predominating features :—Abundance of paar and Echinoderus. Life in general scanty. Good ground. Apparently all the paars here are one. Dead shells one to two years old.

STATEMENT OF DRIFT BOTTLES LIBERATED ON THE GOVERNMENT BANKS.

No. of Bottle liberated	Date.	Hour.	Locality of Release.	Surface of Bottom Drifters.	Remarks.
821	March 10, 1909 ..	4.30 P.M.	Chilaw Paar. Bearings:—Chilaw bungalow, S. 48½° E.; Oodoopekeret, N. 25° E.	Sunk	Strong current running to the north and said by divers to extend to 9 fathoms.
822				do.	
823				do.	
824				do.	
825				do.	
826				do.	
827				Floated	
828				do.	
829				do.	
830				do.	
831	March 13, 1909 ..	7.30 P.M.	Maravilla Paar. Bearings:—Chilaw bungalow, N. 12½° E.; distant 7·6 miles; Moolecottah Village, N. 71° E.	Floated	Strong current running to the north and said by divers to extend to 6 fathoms.
832				do.	
834				do.	
835				do.	
836				do.	
837				do.	
838				Sunk	
839				Floated	
840				Sunk	

Sunk bottles form "bottom drifters."

DETAILS OF DRIFT BOTTLES RECOVERED.

No. of Bottle.	Date.	Place of Recovery.	No of Days afloat.
821	—	—	—
822	—	—	—
822	—	—	—
823	—	—	—
824	—	—	—
825	—	—	—
826	—	—	—
827	—	—	—
828	—	—	—
829	March 12, 1909	Maravilla (in a lagoon)	2 days
830	—	—	—
831	March 20, 1909	Udappu (on shore)	7 days
832	—	—	—
833	March 21, 1909	Udappu (on shore)	8 days
834	do.	do.	8 days
835	do.	do.	8 days
836	March 20, 1909	do.	7 days
837	—	—	—
838	—	—	—
839	March 22, 1909	Udappu (on shore)	—
840	—	—	—

Inspection Barque "Rangasamee,"
Silavaturai Reef, April 20, 1909.

Messrs. SOUTHWELL and KERKHAM to Mr. BOIS.

DEAR MR. BOIS,—IN our report to Government we laid great stress on the point that pelagic pearl oyster larvæ appear to be brought across from the Indian coast during the sou h-west monsoon. Lest this point may appear to be a purely theoretical idea on our part, having no basis in any concrete phenomena, we forward herewith details relating to a set of 80 drift bottles liberated near Tuticorin in July, 1908.

It will be observed that a very great majority of these bottles were finally picked up on *our banks*. This fact speaks for itself. When the final results of this drift bottle experiment carried out by the Company come to be tabulated, we are certain that other facts equally significant will be brought to light.

We ask you therefore to be good enough to forward this list to Government for their information as substantiating our statement.

A copy, in conjunction with our report, might also interest the Board.

We are, &c.,

T. SOUTHWELL.
JAS. C. KERKHAM.

REGISTER OF BOTTLE DRIFTERS RELEASED AND RECOVERED.

Released.

Date and hour of release	..	July 4, 5.45 A.M.
Locality of release	..	Lat. 8·25° N Long. 78·26° E., or 26½ miles S. 35° E. off Hare Island Lighthouse, Tuticorin.
Surface or bottom drifters	..	All bottles tried and floating.
Surface current { Direction	..	Southerly current.
Surface current { Force	..	3¼ knots.
Wind ..	..	S.W.

Recovered.

No. of Card.	Date recovered. 1908.		Place of Recovery.	No. of Days afloat.
600	July	21	Odyadi (on shore)	17
601	—		—	—
602	July	16	Ariputhurey (on shore)	12
603	—		—	—
604	—		—	—
605	July	17	Ariputhurey (on shore)	13
606	July	14	Karativu Point (on shore)	10
607	July	15	Aligahakelli, Karativu (on shore)	11
608	July	21	Thalerepadu (on shore)	17
609	—		—	—
610	July	16	Ariputhurey (on shore)	12
611	July	15	Karativu (on shore)	11
612	July	15	Aligahakelli, Karativu (on shore)	11
613	July	18	Vankali (on shore)	14
614	—		—	—
615	July	15	Karativu (on shore)	9
616	—		—	—
617	—		—	—
618	—		—	—
619	July	24	Thaalvapaadu, Mannar (on shore)	20
620	—		—	—
621	—		—	—
622	August	9	Udayady (on shore)	36
623	July	18	Vankalai (on shore)	14
624	July	13	Aligahakelli, Karativu (on shore)	9
625	—		—	—
626	July	14	Karativu Point (on shore)	10
627	—		—	—
628	—		—	—
629	July	31	Kadekully (on shore)	27
630	—		—	—
631	July	20	Odyadi (on shore)	16
632	—		—	—
633	—		—	—
634	July	15	Vankali (on shore)	11
635	July	14	Aligahakelli, Karativu (on shore)	10
636	July	22	Odyadi (on shore)	18
637	July	15	Karativu (on shore)	11
638	—		—	—
639	—		—	—
640	July	20	Udayady (on shore)	16
641	—		—	—
642	—		—	—
643	—		—	—
644	—		—	—
645	July	18	Vankali (on shore)	14
646	July	21	Thaloupatu (on shore)	17
647	July	25	Odyadi (on shore)	19

No. of Card.	Date recovered. 1908.		Place of Recovery.	No. of Days afloat.
648	July	5	Kannady (on shore)	1
649	July	13	Kalpentyn (on shore)	9
650	July	15	Vankali (on shore)	11
651	July	20	Udayady (on shore)	16
652	July	21	Odyadi (on shore)	17
653	July	17	Puttalam Roman Catholic Church (on shore)	13
654	July	5	Kannady (on shore)	1
655	—		—	—
656	July	31	Kadekulley (on shore)	27
657	July	27	Paruankarey (on shore)	23
658	October	1	Vellakarakudda (on shore)	88
659	July	1	—	—
660	July	13	Kalpentyn (on shore)	9
661	July	20	Thalvupadu (on shore)	16
662	July	13	Aligahakelli, Karativu (on shore)	9
663	July	14	do.	10
664	—		—	—
665	—		—	—
666	July	22	Vankali (on shore)	18
667	July	23	do.	19
668	July	27	Villay (on shore)	23
669	—		—	—
670	—		—	—
671	July	24	Odyadi (on shore)	20
672	July	5	Kannady (on shore)	1
673	July	21	Odyadi (on shore)	17
674	—		—	—
675	July	20	Odyadi (on shore)	16
676	July	16	Vankali (on shore)	12
677	—		—	—
678	July	21	Udayady (on shore)	17
679	—		—	—
680	—		—	—

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PART IV.] **Nos. 6 to 10.** [VOL. I.

SUMMARY OF CONTENTS.

With two Plates.

By T. SOUTHWELL, A.R.C.Sc. (LOND.), F.L.S., F.Z.S.

INTRODUCTION.

THIS report forms Part IV. of a series which were initiated by Mr. Hornell whilst holding the appointment of Government Biologist. The object of these publications was primarily to place on record a mass of information necessarily more or less not co-ordinated at that time. The object in continuing them is to add the results of later and fuller investigations for the use of future workers.

Part V. will be ready shortly. It has been deemed advisable to keep the publication in the same form, although, as will be noted from the context, the work is now being carried on by the Ceylon Company of Pearl Fishers, Limited.

There can be no doubt that the work is progressing, although it is impossible to realize the colossal nature of the undertaking.

In European oyster culture, which has been so successful on the Continent (Ierseke and Arcachon), the full knowledge of continued and extensive scientific investigation within narrow areas has resulted in its entire success as a commercial undertaking. A renter paternally guards an acre of ground over which he can wade at low water. The Ceylon oyster has naturally a different habitat, and different methods must therefore be applied.

The potential area in Ceylon covers over 700 square miles. Scientific investigation is in its infancy here. It is therefore easy to understand that the factors at work are at present out of hand. Even off the north-west coast of Australia, where experiments have been made over a much greater length of time, the results can hardly be said to have been successful.

The difficulties in reference to the Ceylon pearl oyster are of a special character, but we have no reason to believe that with the extensive programme of work, both scientific and nautical, which the Company are carrying out, the main difficulties should not eventually be thoroughly mastered, and successors be left to reap the benefit, just as the present workers have been left with some legacy of information.

Succeeding reports will deal with factors of direct oyster ecology.

The success of these commercial enterprises depends in large measure on the relation between the oyster and its environments being understood, and the acquisition of all forms of knowledge will therefore add to the elucidation. Hence the present report.

I am indebted to Dr. Willey for much assistance and advice, and for reading over the rough accounts ; to J. C. Kerkham, R.N.R., Superintendent of Fisheries, for his unfailing help, without which some of the experiments detailed would have been difficult or impossible of execution; to G. Henry, Esq., for drawing the figures which illustrate this paper; and, finally, I am indebted to the Ceylon Government for kindly publishing the results.

At Sea, Talaimannar (Ceylon),
January 21, 1910.

T. SOUTHWELL.

No. 6.

ON THE DETERMINATION OF THE ADULT OF THE PEARL-INDUCING WORM.

With nine Figures.

By T. SOUTHWELL, A.R.C.Sc. (Lond.), F.L.S., F.Z.S.

In a subsequent paper I shall have occasion to point out that the larvæ of the pearl-inducing worm multiply asexually in the tissues of the oyster, and this explains why the infection of the more or less adult oyster is usually extensive, although the primary infection may be inconsiderable. Not only so, but it becomes obvious to us why it is that the cestode larvæ in the pearl oyster are of very varying sizes, although in every case, to all appearances, the same species. It might be thought that since the initial stages of closely related animals are so nearly allied, the varying sizes of larvæ found in the oyster represent different species. I am now convinced that these different sizes merely represent the same species in different grades of development.

Figures of these larvæ are given in the reports made by Professor Herdman to the Ceylon Government, and it would certainly appear more probable, as well as simpler, for this larva to develop into a Tylocephalum (as is believed by Seurat) than into a Tetrarhynchus.

Nevertheless, young Tetrarhynchids are often to be found in the intestine of the oyster, and this no doubt led to the primary belief that the adult of the pearl-inducing larva was a Tetrarhynchus.

Of the exact reasons why it was stated that the adult worm occurred only in *Rhynoptera javanica* I am ignorant.

There are three outstanding points relating to this identification :—

(1) Only two stages in the life-history are definitely known : (*a*) the globular cyst in the oyster, and (*b*) the adult Tetrarhynchus in *Rhynoptera javanica*.

It was stated by Herdman and Hornell that a free swimming stage had been observed, but it has not since been seen.

(2) The initial method of infection of the oyster is not known.

(3) Under such conditions it appeared wise to determine (*a*) by experiment the nature of the adult, and (*b*) whether the adult worm occurred only in *Rhynoptera javanica* (*Walwadi tirrikai*), or whether there were multiple hosts.

Since many species of fish are known to feed on oysters, it appeared possible that the adult of the pearl-inducing worm might be looked for in many species of fish.

With a view to settling these points by experiment, I had an area of 64 square yards isolated, by expanded metal having a four-inch mesh, behind the Silavatarai coral reef. The depth was 2 fathoms, the bottom fine sand. This area was cultched with dead coral and calcrete obtained from the pearl banks. A few days later 35,000 young oysters were placed in this nursery, varying in age from about 8 months to 2½ years. Besides these, 1,000 oysters, 6 years old, from the Kondatchi Paar were also added. The object of these preparations was to place in this nursery a series of fish known to feed on oysters.

Fortunately we were in possession in our water boat of a lighter suitable for transporting purposes. It consisted of a midship tank section, 14 feet by 10 feet by 4 feet, which could be flooded with sea water, and which was supported fore and aft by air-tight chambers.

The following fish were trawled by the ss. Violet :—

Tetrodon immaculatus, length 13 inches.
Tetrodon stellatus, length 2 feet 3 inches.
Tæniura melanospilos, length 7 feet 6 inches.
Ginglymostoma concolor, length 6 feet 6 inches.

These were taken to the nursery in the water boat, a distance of about 14 miles, and before being placed in the nursery were treated with male-fern extract and castor oil (introduced into the stomach in *every* case) in order to clear, if possible, their gut from such parasites as might be already present.

These fishes were then immediately placed in the nursery along with the oysters, and fortunately survived both the transport and the dosing, so much so that in three days all the fishes were very much alive and active. Their movements could be seen clearly in the water from a stage erected over the nursery for the purpose.

It was curious to note that in every case the two species of Tetrodon moved about together always, and so did the ray and shark, although in the latter case the shark was notably the more active.

The food supply consisted entirely of oysters, save possibly such small fish* as were able to pass through the meshes of the expanded metal; but it is almost certain that these were never attacked. In support of this view I may mention that such small fish as were noted to be present occasionally, invariably swam about on the surface, whilst the fish placed in the nursery were typically bottom feeders.

The water was so clear and calm that the movements of the fish in captivity could be plainly seen daily, and they were never noted to attack the smaller fishes. Moreover, when the captive fish were eventually killed, no fish remains were found in their stomachs.

For reasons to be given later, it is very improbable that the presence of the small fish affected the ultimate result.

It was obvious from day to day that the oysters were being rapidly devoured, as broken fragments of shell could be clearly seen lying on the bottom, and this debris increased in quantity daily.

The operations were allowed to continue for 28 days, at the end of which time the captive fishes were caught separately and their gut and stomach contents carefully examined. The following table gives the results :—

Name of Fish.	Intestinal Contents.	Cestodes.	Other Parasites.	Remarks.
Tetrodon immaculatus ..	Few pearl oysters ..	Absent ..	Absent ..	Fish too small
Tetrodon stellatus ..	Large numbers of oyster spat	Absent ..	Chirocentrus sp, and Schistorchis carneus in numbers	Almost free from parasites
Ginglymostoma concolor ..	Empty ..	51 Tetrarhynchus unionifactor, 48 Tetrarhynchus herdmani	Anaporrhutum largum	Parasites in very healthy condition, both in stomach and gut
Tæniura melanospilos ..	Empty ..	150 specimens of Tetrarhynchus herdmani in the stomach only	Absent ..	Parasites in stomach only

Several points arise from the foregoing data worthy of consideration. *Tetrodon stellatus*, although known to feed extensively on oysters, is not a host for the adult worm, and thus, whilst being destructive, in nowise contributes to subsequent infection of the oyster, as the larvæ probably pass out uninjured

* Mostly Fistularia, sp.

and die in the sea water when liberated, or otherwise are digested in the gut of the fish. This being so, I regard this fish as being not only destructive to young oysters in particular, but useless for the purpose of oyster infection.

With reference to the shark and the ray introduced into the nursery, it was found from the very first that the shark was the more active, and able to withstand the emergencies of abnormal situations.

The absence of *Tetrarhynchus unionifactor* from the gut of the ray was as surprising as its presence in the shark. I am describing this extensive experiment in order that its value may be estimated by the somewhat conflicting evidence afforded. *The experiment was an initial one, and could be much improved upon at a second trial, although the management is by no means easy.*

Having the opportunity, the experiment appeared to be worth attempting, for I see no other means, save by feeding experiments, how the adult form may be definitely determined.

In summarizing the results, it is to be noted that no cestode was to be found in the gut of Tetrodon. This fact, together with observations which have been made for three years on parasites in fish in general, leads me to the conclusion that the adult of the pearl-inducing larva *does not occur in Teleosts.* Many of these fishes—such as *Lethrinus miniatus* and all species of Tetrodon found on the banks—whilst being very destructive to oysters, yield no return in the form of eggs to continue the reinfection of the oyster.

From observations made there seems to be little doubt that the adult of the pearl-inducing worm occurs solely in most of those species of Elasmobranchs which possess teeth sufficiently strong to feed on oysters.

I am unaware what reasons led to the initial belief that the adult worm occurred exclusively in *Rhynoptera javanica.* Many instances have been noted from time to time in which adult cestodes of a certain species occur in various species of Elasmobranchs.

The following casual list serves to give a few instances :—

Cestode.		Hosts.
Phyllobothrium minutum	.. ..	Carcharius melanopterus Trygon kuhli
Tylocephalum dierma	.. ..	Myliobatus maculata Trygon kuhli
Tetrarhynchus unionifactor	.. ..	Rhynoptera javanica Ginglymostoma concolor
Tylocephalum kuhli	.. ..	Trygon kuhli Trygon uarnack
Prosthecobothrium trygonis	.. ..	Trygon sephen Trygon kuhli

Many others might be given, but the above list illustrates the point. It would, therefore, appear natural to expect that the adult pearl-inducing worm occurs in most species of Elasmobranch fish which feed on oysters. The occurrence of *Tetrarhynchus unionifactor* in a shark is most significant. The prior discovery of this cestode in a ray—*Rhynoptera javanica*—shows at least that the adult may occur in both a species of ray and shark. Probably, further investigations will result in the discovery that the parasite has many hosts At the present moment the investigations are hampered by the fact that no oysters are to be found on the pearl banks.

Referring especially to the experiment in question, several features call for close attention.

The exclusive occurrence of Tetrarhynchus herdmani in *Tæniura melanospilos,* at once so surprising and interesting, means that this fish was —

(i.) Either in the first place exclusively infected with this particular cestode ; or
(ii.) That during the 28 days' isolation no oysters were eaten ; or
(iii.) That if oysters were eaten the parasites did not develop.

I do not suspect that this parasite was derived from the oyster. It appeared very strange that both fishes when killed were found to have their stomach empty. It is somewhat difficult to believe that no food was taken during the whole of these 28 days. The shark (*Ginglymostoma concolor*) remained active to the last, whilst the ray appeared somewhat emaciated.

It will be noted from the table given that 99 Tetrarhynchids were obtained from *Ginglymostoma concolor*. No other cestodes were found. Of these Tetrarhynchids, the majority were *Tetrarhynchus unionifactor*. I have no direct proof that these species of Tetrarhynchus were obtained from the larvæ in the pearl oyster, although I am inclined to think this was the case.

If such was the case, it proves that the life-history of this parasite is direct from the oyster to the fish, and that no intermediate stage is present.

In the light of past experience this seems more reasonable than the theory that the parasite passes through three hosts. Moreover, Balistes is not a very common fish on our banks.

In conclusion, I wish to say that I believe that a repetition of this experiment will conclusively prove that the pearl-inducing parasite has only two hosts, viz., the oyster and most Elasmobranch fish, and that the adult is *Tetrarhynchus unionifactor*, as previously determined by Herdman.

It will then only remain to determine how the infection of the oyster is previously brought about in order to complete the full life-history of this parasite. Figures of the jaws and teeth of Ginglymostoma concolor, Rhyncobatis djeddensis, Tetrodon immaculatus, and Lethrinus miniatus are shown on Plate I., figs, 3, 4, 5, and 6, and Plate II., figs. 7, 8, 9, 10, and 12.

No. 7.

A NOTE ON ENDOGENOUS REPRODUCTION DISCOVERED IN THE LARVÆ OF TETRARHYNCHUS UNIONIFACTOR INHABITING THE TISSUES OF THE PEARL OYSTER.

With two Figures.

By T. SOUTHWELL, A.R.C.Sc. (Lond.), F.L.S., F.Z.S.

It is well known that the tissues of the pearl oyster contain numbers of cestode larvæ. It is round such larvæ that pearls are found; but the larvæ seldom develop further in the tissues of the oyster. If, however, the oyster be eaten by the ray, *Rhynoptera javanica*, this larva is said by Professor Herdman and Mr. Hornell to develop into the adult worm named by them *Tetrarhynchus unionifactor.* This identification, though most probably correct, still requires further corroboration. Moreover, it would appear possible that since many species of fish feed on oysters, the adult of this pearl-inducing larva is likely to be found in many species of fish.

In making this suggestion I am aware of the fact that cestode larvæ usually acquire their adult stage *in a particular host*, as is shown in the following examples :—

	Medium.	Host.
Tænia solium ..	.. Pig ..	.. Man.
Bothriocephalus latus	.. Pike ..	.. Man.
Tænia cucumerina ..	.. Mouse ..	.. Cat.
Tænia elliptica ..	.. Dog louse (or tick)	.. Dog

and many others.

In view of the fact, however, that many other species of cestode (such as *Phyllobothrium pammicrum, Tylocephalum kuhli*, &c.) have their adult stage in at least two species of small ray (*Trygon kuhli* and *Trygon sephen*), the same might apply to *Tetrarhynchus unionifactor*, and this has been shown to be the case in a previous paper.

The pearl-inducing larva in *Placuna placenta*, the window-pane oyster of Lake Tampalakamam, Tuticorin, and elsewhere, is believed to be the same as the pearl-inducing larva in the Ceylon pearl oyster. This, however, is not proved, although it appears likely that such may be the case.

During an inspection of the Placuna beds in Lake Tampalakamam during 1905, Mr. Hornell found that the pearl-inducing larvæ in Placuna multiplied " endogenously " (Hornell, " Ceylon Marine Biological Reports," Part II., June, 1906).

This observation was confirmed and extended by Dr. Willey, F.R.S., at the same place nearly two years later (Willey, " Report on the Window-pane Oysters in the Backwaters of the Eastern Province," June, 1907). Similar observations, as pointed out by Willey, have been made on the endogenous multiplication of cestode larvæ elsewhere (Haswell and Hill, " On Polycerus, a proliferating Cystic Parasite of the Earthworm," Proc. Linn. Soc., N.S.W., (2) VIII., 1893; and Hill, " Contribution of a further knowledge of the Cystic Cestode," *op. cit.*, vol. IX., 1894).

The endogenous proliferation of cestode larvæ was also observed in parasites of an earthworm by Metschinhoff in 1868.

The same phenomenon was noted by me on two separate occasions (November, 1906, and January, 1909) in the larvæ inhabiting the tissues of the pearl oyster. This larva, as we have already noted, was identified by Professor Herdman as *Tetrarhynchus unionifactor*. The observations on the endogenous reproduction in *Tetrarhynchus unionifactor* are almost similar to those described by Hornell and Willey, and therefore need but little description.

The formation of endogenous larvæ within the parent cyst (or bladder worm) was only observed in two separate cysts of *T. unionifactor*. In each case the endogen produced was single (a monogen), and was formed about the centre of the parent cyst. In the cyst last observed the monogen was liberated from the parent cyst by the rupture of the parental wall whilst the cyst was actually under microscopic investigation. No pressure was applied to facilitate this result, the cyst lying free on the slide and enveloped in the blood of the host. The ruptured wall was rapidly repaired, apparently by the consolidation of the external protoplasm. No extravasation took place, and both the parent cyst and the monogen remained alive and active in this medium for two hours afterwards. The wall of the monogen was complete before rupture took place. (Plate I., figs. 1 and 2.)

The larvæ or cysts in the pearl oyster, as is well known, are of varying sizes, some being entirely microscopic, whilst others are quite visible to the naked eye. As Hornell says ("Ceylon Marine Biological Reports," Part II., June, 1906): "The *parthenogenetic** reproduction of this particular pearl-inducing parasite enables us to understand the hitherto puzzling fact that true cyst-pearls in Margaritifera vulgaris are quite frequently found in small clusters of two, three, and even four or more, for whilst this mode of increase in numbers has not yet been signalled in that oyster, such I have no doubt does there occur also, and furnishes a satisfactory explanation of the occurrence of clustered cyst pearls."

The discovery of endogenous monogenetic reproduction in Tetrarhynchus unionifactor therefore fulfils Mr. Hornell's prophecy, and, besides being a fact of considerable scientific interest, explains to us how increased infection in the pearl oyster is brought about, although the primary infection may be insignificant.

It is quite possible that further research may prove that this endogenous method of reproduction is not entirely monogenetic, in which case the results will fall in line with the observations made by Dr. Willey on similar occurrences in the larvæ inhabiting *Placuna placenta*.

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* The italics are mine. The phenomenon is not one of parthenogenesis.

No. 8.

ON THE RELATION OF CERTAIN PREDATORY FISH TO PEARL OYSTERS (MARGARITIFERA VULGARIS) ON THE CEYLON PEARL BANKS.

With ten Figures.

By T. SOUTHWELL, A.R.C.Sc. (Lond.), F.L.S., F.Z.S.

The sudden disappearance of beds of spat and adult oysters from the Ceylon pearl banks, besides being serious in itself, is usually also attended with some mystery, and, as a rule, there is little or no clue to hand at the time indicating the nature of the cause.

The phenomenon happens almost yearly, and is familiar to all who are in the least acquainted with the history of these world-famous banks.

The matter was investigated by Professor Herdman during his exhaustive inspection of the banks in 1902, since which time the collection of data on this subject has been carried out extensively and persistently.

The cause of this disappearance is attributed to the action of strong currents, over-crowding, ravages of predatory fish and star-fish, boring or piercing of the shell by Clione and certain molluscs, silting over by sand, as well as to natural death.

Evidence that many of the above factors are actually at work on the oyster beds from time to time is by no means lacking. It appears certain, however, from observed facts, that different destructive agencies assume very varying degrees of importance at different times and at different places, and probably the disappearance of a bed of spat or oysters is never wholly due to any single cause. It would naturally be expected that the devastation of a bed of spat or oysters would be attended by sure and certain evidences relating to the cause of the disaster, but it is usually found that such evidences are notably absent, or, if present, appear inadequate explanations of the devastation wrought.

This may be due to the fact that such evidences may not be sought for until long after the bed has disappeared, in which case the clue may have become lost during subsequent changes.

Beds of spat or oysters do not invariably disappear suddenly. Occasionally, beds—particularly of spat—*gradually* disappear, melting into nothingness before one's eyes, even though the sea presents one vast expanse of calm for weeks together, and where none of the aforesaid factors—save, perhaps, "natural death," which is no explanation at all—accounts for the phenomenon. Similarly, beds disappear during the south-west monsoon, when the sea is very rough indeed.

In the latter case, it is usual to believe that the heavy weather has swept the beds away without there being any proof that such is really the case. The difficulty, and almost impossibility, of obtaining such proof in the heavy weather experienced during this monsoon is, however, evident to all who are familiar with what the south-west conditions are on the west Ceylon coast, and the association of heavy weather with oyster disappearance is a natural explanation, though not the true one.

Since the facts connected with oyster disappearance are so difficult to obtain and so elusive, I thought it well to record certain observations made by me from time to time on the Ceylon banks—and particularly during November of 1908—on *one* of the causes of such disappearance, namely, the ravages of predatory fish.

It is well known amongst the local fishermen, who conduct fishing operations on the pearl bank plateau in general, that certain species of fish eat oysters.

During the extensive trawling operations carried out by me—and my predecessor—on the pearl banks for the last three years, it was frequently observed that spat in particular was found in the stomach or intestinal contents of many of the fish caught. This was particularly noticed in the fish casually caught with a line by the boatmen when the ship was at anchor on a bed of spat. Subsequently it was found by trawling that beds of spat form the feeding ground for many species of fish which congregate in numbers on the bank.

Fragments of oyster shell which had obviously been broken and smashed by some predatory fish have often been collected, and a figure of such a fragment will be found in Professor Herdman's report. The fact, then, that certain fish feed on oysters is well vouched for and has been known for many years. Up to the present, however, there are no details available which enable one to judge anything as to the *extent* to which such ravages are carried on, and the object of this paper is to furnish such details.

During November, 1908, two separate deposits of spat numbering approximately 400,000,000, and covering in all 964 acres, were found near the Periya Paar Karai. On re-examining the southern portion again in February it was found that the sea-bottom was covered with fragments of recently-broken oyster shell, and not a single oyster was found alive.

As a preliminary I had six dives taken at random over the bank, and thus obtained a small sample of the bottom. The divers reported that the bottom was covered with pearl oyster debris. The sample from these six preliminary dives consisted entirely of newly-broken shell. A casual examination of this debris showed that the cause of the disaster was largely, but not entirely, due to predatory fish. So far as I am aware, recently broken shell with the nacre still untarnished represents purely and simply the recent ravages of predatory fish. It is a well-known fact that nacre rapidly loses its lustre on exposure to sea water, as do many of the highly polished shells of Cyprea. So that it appears certain that the destruction had recently taken place.

A very few shells were undamaged, whilst some others were pierced by small holes, indicating the attacks of boring molluscs, such as *Systrum spectrum*, *Pinaxia coronata*, and others.

The total weight of the dried collection was 43 ounces, made up as follows :—

	Oz.	Per cent.
(1) Shell fragments	27	63
(2) "Nibbled" by fishes	9	21
(3) Bored by various molluscs	4	9
(4) Undamaged shell	3	7
Total	43	100

From these preliminary observations and statistics it was clearly evident that the ravages of fishes alone accounted for 84 per cent. of the dead oysters.

The following day 80 dives were taken over the area, the divers having particular instructions to bring up as much from the bottom as they could. They reported that the dead shell lay on the top of sand, thus proving that no silting over by sand had taken place. The sample brought in again consisted of oyster shell only, and this was dried, separated into the divisions previously noted, and weighed. The result was as follows :—

	Oz.	Per cent.
(1) Shell fragments	63	68·5
(2) "Nibbled" by fishes	14·5	15·5
(3) Bored by various molluscs	3·75	4
(4) Undamaged shell	11	12
Total	92·25	100

It will be noted from the statistics here given that the ravages of fish in each case account for 84 per cent. The figures appear to me to be sufficiently accurate to justify one in the belief that, although a certain small percentage of oysters had died from some cause or causes unknown, and others from the effects of boring molluscs, the disappearance of the bed was primarily due to predatory fish.

Expecting to obtain further information and statistics on the matter, the bed to the north was examined the following day. To my intense astonishment not a trace of the oysters was to be found. Eighty dives were taken over the area, occupying five hours, and dredging operations were carried out for hours without finding the slightest clue to indicate that oysters had ever been there.

The position of the ship was too well determined to allow of any possibility of my being off the position. At last the dredge, the meshes of which had become choked up with weed, came up full of sand containing the missing evidence. The sand contained large quantities of small shell debris, which had previously passed through the meshes and so escaped notice, and thus it became evident that this bed had shared the fate of its more southern companion. It is obvious that it was impossible to collect any statistics under these circumstances.

I mention this condition of things on the northern bank as illustrating the limited period during which the facts relating to the devastation or disappearance of a bed may be collected and the true relation of things understood.

During all the fish trawling operations which have been carried out so very extensively on the Ceylon pearl banks during the last three years, I have been able to gather fairly extensive information as to which species of fish feed on oysters. Almost every fish caught has been carefully examined in order to determine the nature of the stomach contents, and in this way thousands of fish, representing at least 120 species distributed over about 33 genera, have been repeatedly under observation.

It has hitherto been believed that the large rays present on the banks were the principal cause of the devastation. This may or may not be the case. Although I have trawled at least 16 specimens of ray, including large specimens of *Ætobatis narinari* (Euphrasen), *Rhynoptera javanica* (Mull and Henle), *Trygon uarnak* (Forsk), *Trygon bleekeri* (Blyth), some measuring 8 feet from the snout to the extremity of the tail, and none less than 2 feet, as yet I have never (save in one instance to be quoted later) found any molluscan shell in the gut. Besides this, thousands of smaller rays, such as *Trygon kuhli* and *Trygon sephen*, have been examined, and it has been invariably found that the stomach contents of the latter consisted entirely and in every case—save where empty—of worms or crabs, or both.

It is important to note, however, that 7,000 specimens of *Rhynoptera javanica* are said to have been caught in one haul of the net by the local fishermen in Dutch Bay in 1889, and if this species, or any other species possessed of such powerful jaw apparatus, move about in such large shoals, it is but natural to suppose and expect that they are quite capable of completely annihilating a very large bed of even old oysters.

Although I have seldom noticed any species of ray moving about in shoals, or found molluscan debris in the stomach contents, I am quite certain that the larger species of ray are capable of eating oysters, for I have isolated a ray weighing 5 cwt., placed a considerable number of living oysters on the enclosed ground, and found the shells in fragments within ten days. In this case the ray had no source of food supply save oysters.

Plate II., figs. 7, 8, and 11, may serve to give some idea of the powerful jaw apparatus possessed by some of these fish. Similarly, in relation to large species of fish of the shark tribe, and included in the group Carchariina, although many large species have been caught, it has seldom been found that oysters or other molluscan debris occurred in the stomach.

I am not arguing that the species included in these two great groups, and particularly those species attaining a large size, do not eat oysters; I am merely saying that, although oysters have been present on the banks during the greater part of the time during which the observations were made, and although some specimens of the larger species included in these two orders of fishes have been caught repeatedly, the result has hitherto been principally negative. It is quite likely, however, that although my results under this heading are of a negative character, this may be due to the observations not being sufficiently extensive, or to the fact that they were not made at the proper time. Again, it is very possible that the rays vomit out the shells from the stomach after absorbing the soft contents.

In thinking of sharks and rays, one naturally associates with them the power of tearing off the leg of an unfortunate bather, or the crushing of a hand or foot. It is therefore easy to think of them as crushing up an oyster shell.

When, however, one finds that a much smaller fish, called by the Tamils "velameen" (*Lethrinus miniatus*), and possessed of teeth not at all awe-inspiring (Plate I., figs. 3 and 4), is seldom or never found without oysters in its stomach, it indicates that, although many species of fish have teeth sufficiently strong to crush oysters, other kinds of "shell-fish" are more acceptable to these fish as food. *Lethrinus miniatus* is often found congregating on a bed of spat, and almost invariably contains oyster debris in its stomach. There can be no doubt but that this species of fish is most destructive to young oysters.

It is interesting to note that two other species of "velameen," viz., *Lutjanus gibbus* and *Lutjanus argentimaculatus*, although possessed of a masticatory apparatus as powerful as that of *Lethrinus miniatus*, prefer to live on a certain species of Mactra, whose shell is thicker than that of the pearl oyster, and up to the present oysters or oyster spat have never been found in the stomach of any species of Lutjanus. It is obvious that in this case the fish prefer other Lamellibranchiate food to oysters, and the condition of affairs is not merely a question of necessary teeth and jaws, but due to preference.

Amongst the fish I have found by observation to be *the most destructive* to oysters are those included in the family Gymnodontes. (Day, "Fauna of British India, including Ceylon and Burma, Fishes," vol. II.) This family includes the well-known globe-fish, whose jaws and teeth are somewhat similar in appearance to those of a parrot or a turtle (Plate I., figs. 5 and 6). The family includes five genera, viz., Triodon, Xenopterus, Tetrodon, Diodon, and Orthagoriscus. Only two specimens of this group were collected by Professor Herdman during his visit in 1902, viz., *Tetrodon margaritatus* (Ruppel) and *Tetrodon lunaris* (Bl. Schn.).

The most common genus on the banks, however, is Tetrodon, and of this genus three species are abundant, viz., *T. immaculatus*, *T. stellatus*, and *T. reticularis*. The two latter species often measure 18 inches long, and occasionally more than 2 feet.

The genus Diodon is represented by two rather small species, viz., *Diodon hystrix* and *Diodon maculatus*. The species of Tetrodon, however, are very common, and up to the present no specimen of any species of this genus has been found which did not contain oysters or oyster spat.

I therefore regard the species of this genus as being most destructive to oysters. Not only is their jaw apparatus of great power, but it would appear that they have a *preference* for oysters rather than other food, since no other food, save oysters, has been found in their stomachs, except a few portunids, *Avicula vexellum*, and the remains of small ophiuroids, and even these but rarely.

To summarize then, so far as observations go, the fishes most destructive to oysters or oyster spat are those included in the family Gymnodontes and commonly known as the globe-fishes; that *Lethrinus miniatus*, a member of the group Pagrina, is also very destructive to spat; and that as yet no spat or oysters have ever been found in the stomach of any ray or shark, although there is every reason to believe that many of the larger species included in these two latter orders commit great ravages. No other species or genera of fish, caught either by a line or by the trawl, have up to the present been found to have been feeding on oysters.

Apart from the ravages caused by fishes, it has also been found that turtle are likewise very destructive to oysters.

The two species of turtle occurring on the Ceylon pearl banks (viz., the leathery turtle and the green turtle) often attain a length of 3 feet, and sometimes more. They are most numerous from November to the early part of February, after which time they are in fact seldom seen even by the local fishermen.

In the season they are regularly to be found quite 18 miles from the shore. Thirteen specimens were caught in the trawl during December, 1907, on the Periya Paar, 16 miles from land. As a rule, these turtle appear to feed on seaweed. At times, however, their gut is found to be crowded with shell debris. Their jaws are so powerful that on one occasion I found the crushed remains of a chank shell (*Turbinella pyrum*) in the stomach of one specimen.

All the thirteen specimens caught in December, 1907, had been feeding entirely on spat, and several buckets-full of oyster shell debris were collected from their gut. Since turtle, however, apparently only visit the banks during certain seasons of the year, and since the number of individuals is comparatively few, I do not regard the ravages caused by turtle as comparable to that caused by predatory fish, which, besides being of many species, occur in such large numbers.

No. 9.

NOTES ON THE HABITACULUM OF TWO SPECIES OF PAGURIDS; A DESCRIPTION OF ONE NEW SPECIES; AND A LIST OF THE ANOMURA RECORDED TO DATE FROM CEYLON WATERS.

With six Figures.

By T. SOUTHWELL, A.R.C.Sc. (Lond.), F.L.S., F.Z.S.

Summary of Contents.

1.—Introduction.

The group of animals known as Anomura, or hermit-crabs, are, strictly speaking, of but little interest to any one save purely scientific men. They have no direct commercial importance, they are not enemies of the pearl oyster, but they serve as food to innumerable fishes of many species.

The members of this group are crabs, characterized by having usually a soft abdomen, which is protected by an adopted empty shell of a mollusc. This does not, however, apply to all the species of this tribe. Some species are quite free. Others, such as Galathea and Munida, live in the cavities of sponges, or dead coral, or on rock. Others, such as Cœnobita, are to be found by the hundred on the shore, feeding on coconut husks or dung. Other species, such as *Birgus latro*, or the robber-crab, are to be found solely on the shore, and are known to climb trees and eat coconuts. The females only enter the water to lay their eggs. So varied are the members of this group.

The present notes were made during a two weeks' inspection of the Ceylon pearl banks. Similar notes have been made continuously by the writer during the last three years, and the results will it is hoped be published later. The following notes form the first instalment.

2.—A Note on the Habitaculum of "Cancellus investigatoris," *Alcock.*

This species was first collected by the "Investigator" off the south-east coast of Ceylon in 32 fathoms, and was described by Alcock in his "Indian Decapod Crustacea, Part II., Anomura Fasciculus: 1, Pagurides," 1905. So far as I am aware it has since been obtained only by the present writer. (Southwell, "Ceylon Reports," vol. V., 1906.)

The striking peculiarity of this species is that certain parts of the legs and chelipeds are modified to form an operculum, which, when the animal is completely retracted, closes the mouth of the shell or shelter and affords complete protection. Not only so, but under such conditions the animals are apt not to be noticed.

Although the modification of certain appendages was duly noted by Alcock, no mention was made of the habitat of the species.

Similarly, also, in the report on the Anomura collected by Professor Herdman, no mention is made of the habitat. It appears likely that in each case the specimens had escaped from their "house" during preservation, and were subsequently found free amongst the general collection.

It is quite obvious that the highly perfected modified portions of the chelipeds and legs serve a very useful end, and a note on the habitat in which this species was found living is therefore of some importance.

During a survey of the Ceylon pearl banks this species was dredged up, occupying a small cavity on the ventral edge of a flattish lobulated piece of *Porites arenosa* four inches in diameter. When the animal was retracted, the modified portions of the chelipeds and legs formed a remarkably perfect operculum, and rendered the specimen difficult to detect. The terminal portion of the abdomen could be slightly protruded through a very small hole situated a little nearer the basal centre of the coral, and the specimen could turn completely round in its shelter. The tube appeared to be lined with reddish Nullipore (*Lithothamnion*).

Alcock gives the following description of the chelipeds and legs :—

"In the left cheliped the upper border of the merus is ill-defined, and the inner lower border is not spinose ; the palm of the hand is as high as long, and the fixed finger is not deflexed ; the whole outer surface of the palm and fingers is granulous ; the spines on the lower edge of the hand are not worn or obsolescent but are acute, and are continued on to the edge of the fixed finger ; there is no oblique crest in the lower part of the outer surface of the palm, but in the upper part there is a row of spines parallel with the upper border."

It was impossible to remove our specimen from its shelter without damaging it, so that the following notes refer to the animal *in situ*. (Plate I., figs. 14 and 15, and Plate II., fig. 13.)

Mouth of the shelter 18 mm. in diameter. Abdominal hole situated 10 mm. nearer the basal centre of the coral and 3 mm. across. Operculum formed entirely by the chelipeds and first pair of walking legs (supported by the second pair), their surfaces being covered with matted setæ and presenting a pavement-like appearance. Colour, variegated red.

Dorsal "elbow" (Plate II., fig. 13) of the operculum formed by the anterior extremity of the carpus in the chelipeds and by the merus in the first pair of walking legs. The opposing internal edges of those joints of the chelipeds forming the operculum are straight, their external edges convex. Both internal and external edges of those joints of the first pair of legs which form the operculum are curved. The perfection of modification in these parts will be obvious. In all other points the description given by Alcock is correct, so far as I was able to verify. It appears remarkable that this writer laid no emphasis on the opercular surface presented by this species, a point which, together with the fact that the habitat is not mentioned, seems to almost prove that its full significance was not appreciated. A figure of a crab (*Pylocheles miersii*) simulating this habitat is given in Alcock's "Naturalist in Indian Seas," where other cases of partnership are also described.

Alcock states that this species is nearly related to *Cancellus parfaiti* (Edw. and Bouv.). The points of difference are not quoted, but since Alcock's specimens were obtained from Ceylon waters, and agree so closely with this one, I assume mine to be *C. investigatoris*.

The interest and importance of this note is that at least one habitat of this species has been determined. Most probably there are other habitats.

Locality.—West coast of Ceylon, 7 fathoms.

Referring to the Paguridea, Alcock notes that "certain forms which hide in holes do not regain even an apparent symmetry, such as the species of Pagurides which hide in living sponge, and the Troglopagurus that lives in small holes in coral."

Of the latter genus, Thurston discovered and collected many specimens of the *T. manaarensis* from the Ceylon pearl banks, which were found inhabiting small cavities in coral. The genera Troglopagurus and Cancellus are nearly related.*

3.—A Note on "Diogenes rectimanus," *Miers.*

The species of Diogenes are always difficult to identify. This is partly on account of the fact that they are usually of small size, the carapace being from 5 to 15 mm. long on an average, and partly because the genus is very variable.

Certain species seem to merge into each other by insensible gradations, and often enough present slight erratic characters not previously recorded, and which may possibly be purely local variations.

Amongst the many well-defined *groups* of species distributed in this genus, the members of the following group are very closely related :—*Diogenes costatus*, Henderson ; *Diogenes rectimanus*, Miers ; *Diogenes investigatoris*, Alcock ; *Diogenes bicristimanus*, Alcock.

Of these, *Diogenes costatus* may be considered as a type, and the other species variations of a more or less permanent character.

The species *rectimanus* was recently obtained in 7 fathoms of water on the west coast of Ceylon (Moodipani Paar), and was found inhabiting Annelid sand tubes, which latter were attached to dead coral, calcrete, or rock (Plate I., fig. 16). In other instances the species was found inhabiting cavities of living coral (*Goneastrea*, sp.). The specimens were for the most part *adult*, though the carapace measured only 7 mm.

Specimens of this species obtained by Alcock, Henderson, and Lanchester measured respectively 12 mm., 25 mm., 9 mm. long, so that our specimens were rather small. They also differed from other described forms in the following particulars :—

(1) There is no row of spines parallel with those on the upper border of the palm.

(2) The internal faces of the merus, carpus, and dactylus of both chelipeds are mapped out into about eight white plate-like areas, separated from each other by shallow sulci, and set on a pinkish background. This feature was very characteristic.

Alcock speaks of this species as "inhabiting all sorts of broad-mouthed shells" often encrusted with sea-anemones ; and Lanchester's specimens were found in shells of Murex, Rissoa, Gibbula, and Neritina.

Most probably the fact that Alcock found his specimens inhabiting wide-mouthed shells is to be correlated with the large size of his specimens.

The variety of habitaculum assumed by this species is most interesting, and, together with a similar variety noted for the first time in *Cancellus investigatoris*, seems to indicate that the habitat of many other species of Paguridea may be much more varied than is at present known

I have seen species of the group Paguridea inhabiting the cavities of sponges (*Phyllospongia*, sp., and others), and in other cases found them without shell ; but in both instances the species, unfortunately, was not determined.

4.—A Description of "Clibanarius willeyi," n. sp. (Plate I., figs 17 and 18.)

Carapace smooth, minutely punctate, sharply truncated anteriorly, well calcified in front of the cervical groove, the cardiac region being clearly defined. Length 12 mm. Greatest breadth 7 mm., narrowing anteriorly to 4 mm.

Rostrum minute, scarcely extending beyond the edge of the carapace, and barely reaching the base of the ophthalmic scales.

* Since the foregoing was written twenty-seven other specimens have been dredged from the Kondatchi Paar in 3 fathoms (April, 1910), all inhabiting holes in *Porites arenosa*, and answering perfectly to the above description.

Eyestalks long and slender, longer than the anterior extremity of the carapace, and considerably longer than the antennal peduncle. Right eyestalk 5 mm. long, left eyestalk 6 mm. in the male, and *vice versâ* in the female.

Antennular peduncles 4 mm. long, stout, longer than the antennal peduncles, but shorter than the eyestalks. Flagellum short, 1 mm. long only.

Antennal peduncle two-thirds the length of the eyestalk. Proximal joint setose internally, and shorter, but stouter than the second joint, which latter is nude. Antennal flagellum 1 cm. long.

Antennal acicle spinose internally, glabrous, and but slightly overlapping the terminal joint of the peduncle.

Ophthalmic scales very broad at the base, tapering somewhat suddenly, and approximated throughout their whole length.

Left cheliped considerably stouter than the right one, 10 mm. long in a straight line, shorter than the carapace, smooth throughout, somewhat flattened internally, and minutely punctate externally.

Merus 5 mm. long and 2·5 mm. broad. Carpus 2·5 mm. long, and as broad.

Palm slightly longer than the merus, and twice as long as the fingers.

Fingers curved, with a hiatus between them when closed. A few bundles of minute yellowish setæ occur on the opposing surface of the fingers, which open and close in a plane almost vertical.

Right cheliped as long as the left cheliped, but not nearly so stout, considerably flattened, smooth internally; smooth, punctate, and less flattened externally. Merus smooth internally, minutely punctate externally, 4 mm. long, 2 mm. broad, slightly crested dorsally and ventrally, the crests bearing a few short silky hairs.

Carpus 2 mm. long, and as broad, slightly crested dorsally and ventrally, the dorsal crest bearing a few short scattered silky hairs and terminating anteriorly in a minute colourless spine.

Hand 5 mm. long, smooth internally, smooth and punctate externally, crested dorsally, the crest bearing four small teeth, near which occur a few scattered external tubercles. Movable finger small, 1½ mm. long, and tuberculated dorsally. There is a small hiatus between the fingers when closed, and they meet distally in two opposing circular horizontal discs.

Hand and fingers slightly setose, smooth internally, the fingers opening and closing in a plane barely horizontal.

The two pairs of walking legs permanently deflexed, smooth, and slightly flattened externally. Merus of second leg greatly flattened laterally, with a few hairs on its dorsal and ventral crests, 5 mm. long, 2 mm. broad. Merus of third leg exactly similar, save that the external surface is more convex.

Carpus of both legs 3 mm. long, 2 mm. broad, also with a few scattered setæ on their dorsal and ventral crests.

Propodite (of both legs) 5 mm. long, 1½ mm. broad, with a few scattered setæ on the dorsal surface, and tufts of yellow setæ on the ventral surface, increasing greatly in number anteriorly.

Dactylopodites 3 mm. long, tapering to an extremely sharp black corneous claw, with masses of short setæ arising in tufts on their ventral surfaces, and scattered setæ on their dorsal surfaces.

The merus of both walking legs is fixed almost at right angles to the carpus, and the dactylopodites are similarly fixed almost at opposite right angles to the propodites.

Third pair of legs small, sub-cheliform, with a pad of imbricating corneous granules at the base of the claw; less defined in the fourth pair, which are also small.

No paired appendages on the abdomen of either sex, except on the tail fin, where those of the left side are larger than those on the right side.

Natural Colours.—Carapace (both dorsal and ventral surfaces) black, chelipeds black, with yellow finger tips. Walking legs black, with a band of yellow round the dactylopodite, and yellow plates on the ventral surface of the ischium.

Antennæ and antennal acicle orange. Antennules blue, with an orange flagellum.

Eyestalks pale yellow when young, developing a dark dorsal surface in older specimens. Eyes deep rich blue.

In the mature male the abdomen is mottled green, and dirty white on the dorsal surface and right side. Left side salmon-coloured. In immature males dirty brown dorsally, gray ventrally. In females the abdomen is an even dirty brown. Eggs brilliant maroon.

Colours in Formalin.—Carapace dark maroon, both dorsally and ventrally. Chelipeds dark maroon, with yellowish finger tips.

Second and third pair of walking legs dark maroon, with intensely black tips. Antennæ yellow. Antennal acicle yellow. Antennular peduncle grayish yellow, with brilliant orange flagellum. Eyestalks yellow, with a dark dorsal longitudinal band. Eyes blue. Fourth and fifth pair of legs with brownish cross bands.

Abdomen various. Eggs yellow. In a few young specimens the maroon colours had faded to a brick red, and in some other specimens the colours were varied.

Locality.—Found living on the surface of the Tallaivillu coral reef, west coast of Ceylon, and covered by only six inches of water at ebb tide.

Sixty-four specimens, including males, females, and young forms. Found inhabiting Muricine shells, which in every case were strongly encrusted with Nullipore (*Lithothamnion*).

I have pleasure in naming this species in honour of Dr. Arthur Willey, F.R.S., who assisted in making the collection during a very pleasant trip we had together.

5.—A Complete List of Anomura recorded from Ceylon Waters.

The following is a complete list of the Anomuran Fauna of Ceylon recorded up to the present —

(1) Anomura collected by Thurston in the Gulf of Mannar and described by Henderson (Trans. Linn. Soc. (2), vol. V., Zoology, 1893).

Dromidia unidentata, Rupp.
Dromidia australiensis, Haswell.
Cryptodromia pentagonalis, Hilg.
Pseudodromia integrifrons, Hend.
Raninoides serratifrons, Hend.
Hippa asiatica, Milne-Edw.
Albunea symnista, Linn.
*Albunea thurstoni, Hend.
*Cœnobita rugosa, Milne-Edw.
*Diogenes diogenes, Herbst.
*Diogenes merguiensis, De Man.
*Diogenes miles, Herbst.
Diogenes custos, Fabr.
Diogenes planimanus, Hend.
Diogenes avarus, Heller.
*Diogenes costatus, Hend.
*Pagurus punctulatus, Oliv
Pagurus deformis, Milne-Edw.
Pagurus varipes, Neller.
*Pagurus setifer, Milne-Edw.
*Troglopagurus manaarensis, Hend.
*Aniculus aniculus, Fabr.
*Aniculus strigatus, Herbst.
*Clibanarius padavensis, De Man.
Clibanarius arethusa, De Man.
*Eupagurus zebra, Hend.
Petrolisthes dentatus, Milne-Edw.
Petrolisthes boscii, Aud.
*Petrolisthes militaris, Heller.
Procellanella triloba, White.
*Polyonyx obesulus, Miers.
Polyonyx tuberculosus, De Man.
*Galathea elegans, White.
Galathea spinosirostris, Dana.
Munida spinulifera, Miers.

Of the above 35 species, Professor Herdman found the 16 marked with the star, and also 32 additional species which were not obtained by Thurston, and which are described by Southwell in vol. V., "Ceylon Reports," 1906.

The following are the 32 species not obtained by Thurston, but collected by Professor Herdman:—

Remipes testudinarius, Laterille.
Mastigochirus gracilis, Stimpson.
Cœnobita clypeatus, Latreille.
Diogenes investigatoris, Alcock.
Diogenes rectimanus, Miers.
Pagurus asper, De Haan.
Clibanarius æquabilis, var. merguiensis, De Man.
Calcinus giamard, Milne-Edw.
Calcinus elegans, Milne-Edw.
Eupagurus carpoforaminatus, Alcock.
Spiropagurus spiriger, De Haan.
Catapagurus ensifer, Henderson.
Paguristes hians, Henderson.
Paguristes incomitatus, Alcock.
Paguristes pusillus, Henderson.
Cancellus investigatoris, Alcock.
Nematopagurus muricatus, Henderson.
Nematopagurus, sp.
Troglopagurus jousseaumii, Bouvier.
Petrolisthes armatus (?), Gibbes.
Petrolisthes serratus, Henderson.
Procellana quadrilobata, Miers.
Procellana serratifrons, Stimpson.
Procellana hornelli, Southwell.
Polyonyx biunguiculatas, Dana.
Pachycheles pulchellus, Haswell.
Galathea longirostris, Dana.
Galathea corallicola, Haswell.
Galathea australiensis, Stimpson.
Galathea grandirostris (?), Stimpson.
Munida japonica, Stimpson.
Munida alcocki, Southwell.

Since the "Report on the Anomura in the Ceylon Reports" was made, the following species have been collected and identified by the writer :—

Clibanarius willeyi, Southwell.
Clibanarius infraspinatus, Hilgendorf.
Clibanarius humulis, Dana.
Pagurus dearmatus, Henderson.
Pagurus euopsis, Dana.
Pagurus fabimanus, Dana.
Petrolisthes dentatus, Milne-Edwards.
Petrolisthes tuberculosa, Milne-Edwards.
Polyonyx hendersoni, Southwell.
Porcellana gækwari, Southwell.
Porcellana unilobotus, Henderson.
Albunea oxyophthalma

There are at present known about 650 species of Anomura, distributed amongst 73 genera.

This list is approximate, and includes the group Paguridea proper, the Galathidea, and other nearly related families whose systematic position is somewhat uncertain. Whilst some of the species of these two groups are cosmopolitan, most others have but a limited distribution. Others again only occur in very deep water.

Twenty-seven genera, including about 71 species, have already been recorded from the Ceylon pearl banks, and although in comparison this list appears very small, it compares most favourably with similar lists of other localities. It will, of course, be remembered that the pearl banks are very limited in area, and really only include a littoral fauna.

No. 10.

A DESCRIPTION OF A LARGE RAY, "TÆNIURA MELANOSPILES," BLEEKER, FROM THE CEYLON PEARL BANKS.

By T. SOUTHWELL, A.R.C.Sc. (Lond.), F.L.S., F.Z.S.

"Tæniura melanospiles," *Bleeker*, "Nat. Tyds. Ned. Ind., 1853," IV., p. 513; Day, "Fishes: India," p. 740.

This fish was caught in the trawl on the Periya Paar, Ceylon pearl banks, and was a female, weighing over 5 cwt.

The disk was broad and rounded. Length from snout to anus 4 feet. Greatest breadth of the disk 4 feet 10 inches (just a little posterior to the eyes). Snout broadly rounded and marked by a slight projection situated in a very shallow depression. Five inferior gill clefts, of which the third was the largest and the fifth noticeably less. First gill cleft 15 inches from the snout and 3 inches long. The gill clefts $2\frac{1}{2}$ inches apart. Last gill cleft 2 feet 1 inch from the snout. Distance between the first pair of gill clefts 19 inches. Distance between last pair 12 inches. Spiracle large, 4 inches across, and situated immediately behind the eye. Eyes 1 foot from the snout and 11 inches apart.

Mouth 6 inches wide and 10 inches from the snout. Lower lip strongly mammilated and split up into areas, each having a mucous pore. Upper lip a little frilled and partially enclosing the spiracles. Teeth with slightly rounded cusps and two roots.

Pelvic fins rounded, each 8 inches across and 1 foot long. Ventral surface of the pelvic fins slightly rugose.

Ventral surface of the body marked by numbers of mucous pores, each about the size of a pin head. Dorsal surface of body covered with small sharp black tubercles, having stellated bases, largest and white along the vertebral column. Two distinct patches of rather large tubercles also occur on each side of the body 15 inches behind the eye.

Tail 3 feet 6 inches long, and compressed dorso-ventrally into two lateral keels, which extend to the spine. Breadth at the root 5 inches. A single serrated spine 6 inches long and $\frac{5}{8}$ inch broad, situated 11 inches from the extremity of the tail. The serrations are on both sides of the spine. A cutaneous fold arises just ventral to the origin of the spine and is continued to the tip of the tail. This fold is split up into about four irregular lobes. Beyond the origin of the spine the tail is round and tapering. The whole tail is covered with numbers of tubercles similar to those on the body. They are largest and most numerous along the dorsal surface, and gradually increase in size towards the tip of the tail.

Two dorsal symmetrical depressions, each 1 foot long, are situated on each side of the backbone, and arise just posterior to the level of the last gill cleft.

Right ovary degenerate. After being caught this fish was placed in an isolated area in the open sea and fed exclusively on oysters (*Margaritifera vulgaris*) for 26 days, on which it appeared to thrive. When killed the entire gut was found to be empty, and since the fish was known to have been eating oysters, it seems likely that the shells were passed out through the mouth, after the soft parts had been absorbed.

Natural Colours.—Dorsal surface of the body varying shades of gray, with irregular splashes of deep black. White ventrally, with tints of red round the snout and lateral edges of the fins and blackish tints at the extreme posterior edge.

Tail dark gray with black patches as far as the origin of the serrated spine, then dense black, the tubercles also being black.

Habitat.—Periya Paar, Ceylon pearl banks, 9 fathoms, April, 1909.

The description of this species given by Day ("Fauna of British India: Fishes," vol. I.) is as follows:—

"Disk rather broader than long; its upper surface smooth. Tail very thick at its base, with two strong flattened elongated spines (upper $9\frac{1}{2}$, lower $5\frac{1}{2}$ inches long) serrated externally. From opposite these spines on the lower surface of the tail commences a broad cutaneous fold, which is continued to the extremity of the tail, and on its upper surface are numerous tubercles of the same character as on the tail. The colours have not been noted."

Two samples were captured in 1853, off the Coromandel coast, where they were said by the fishermen to be very rare. One had its disk 4 feet 11 inches long and 5 feet 11 inches broad. The other was 4 feet 1 inch long by 5 feet 11 inches wide. Inside the stomach of the latter were found the remains of some small crabs and a squilla.

It was, however, expressly stated that the body was smooth, but the tail covered with rough tubercles, all of which had a stellated base.

Habitat.—Red Sea and Coromandel coast of India to Batavia.

Day also considers this ray as identical with *Tœniura lymna*, Forskäl, of which the following brief description is quoted by Day.—"Disk rather longer than broad; a few spines along the middle of the back. Two long papillæ at the bottom of the mouth."

Colour.—Gray, with round blue dark-edged spots. A bluish band along either side of the tail.

Habitat.—Red Sea, coast of Africa to the Malay Archipelago; this ray consequently may probably be found off the coast of India.

If appears probable that Day never obtained this fish, and that his description is from hearsay. It will be noted that the descriptions do not agree with each other on even important points. The members of this species may be a little variable amongst themselves, as is known to be the case amongst the Trygons, in which case these anomalies of description are natural.

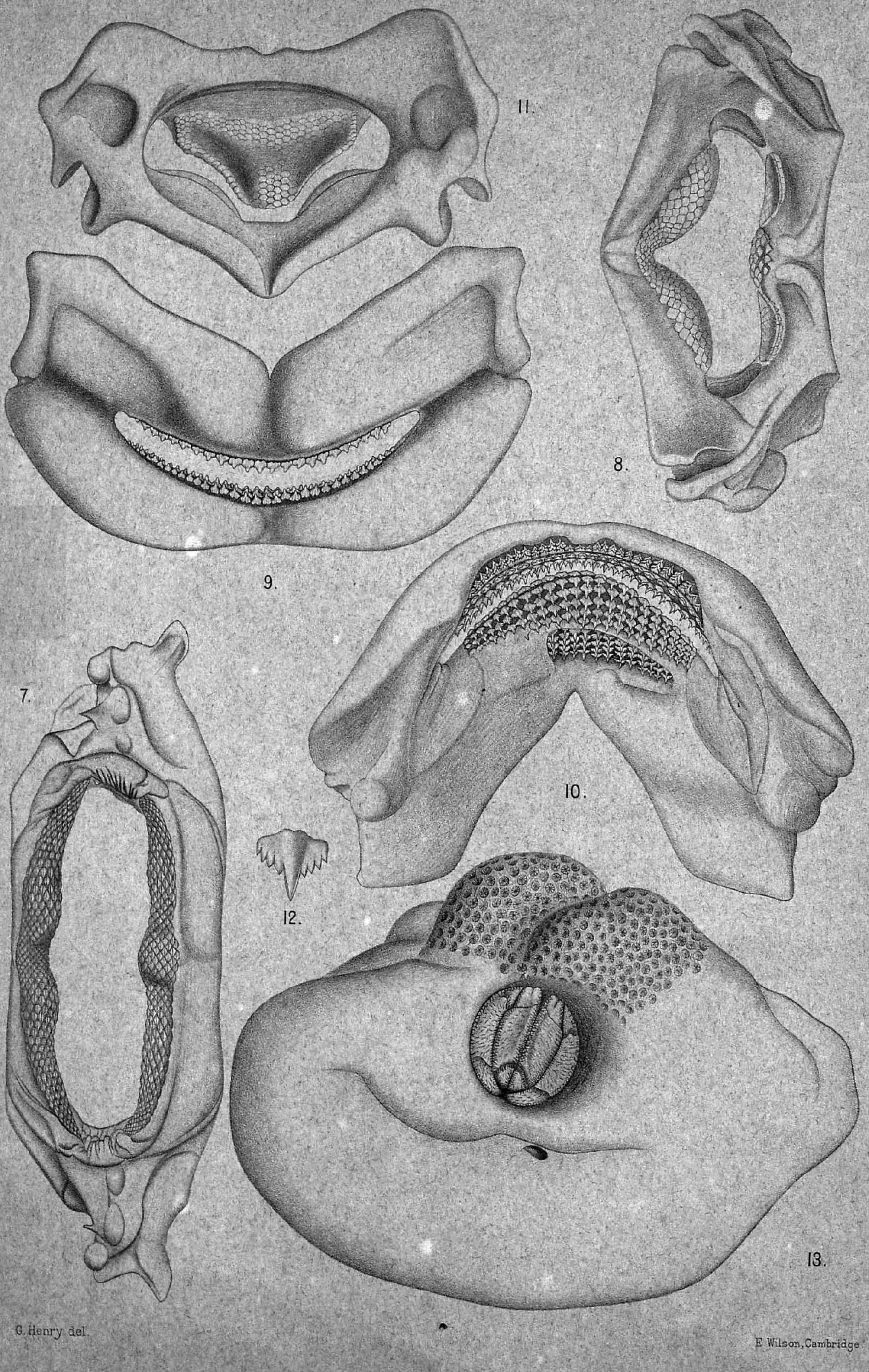
The points in which the descriptions vary may be summarized as follows:—

Day.	Ceylon Specimen.
(1) Surface of disk smooth.	(1) Surface of disk tuberculated.
(2) Two strong spines on tail.	(2) One strong spine on tail.
(3) Serrations on one side of the spine only.	(3) Serrations on both sides of the spine.

Since Day assumes that *Tœniura lymna*, Forskäl, is the same as our specimen, it is interesting to note that, although it is impossible to identify the fish from Forskäl's ridiculously short description, even the few points noted there do not agree either with the Coromandel or the Ceylon specimen, as shown by the accompanying tables.

Forskäl.	Day	Ceylon Specimen.
(1) Disk larger than broad.	(1) Disk broader than large.	(1) Disk broader than large.
(2) Two long papillæ at the bottom of mouth.	(2) Absent.	(2) Absent.
(3) Colour gray, with round blue dark-edged spots and blue bands on tail.	(3) Not noted.	(3) Varying shades of gray with splashes and white ventrally.

The Ceylon specimen was preserved, and has been presented to the Colombo Museum.



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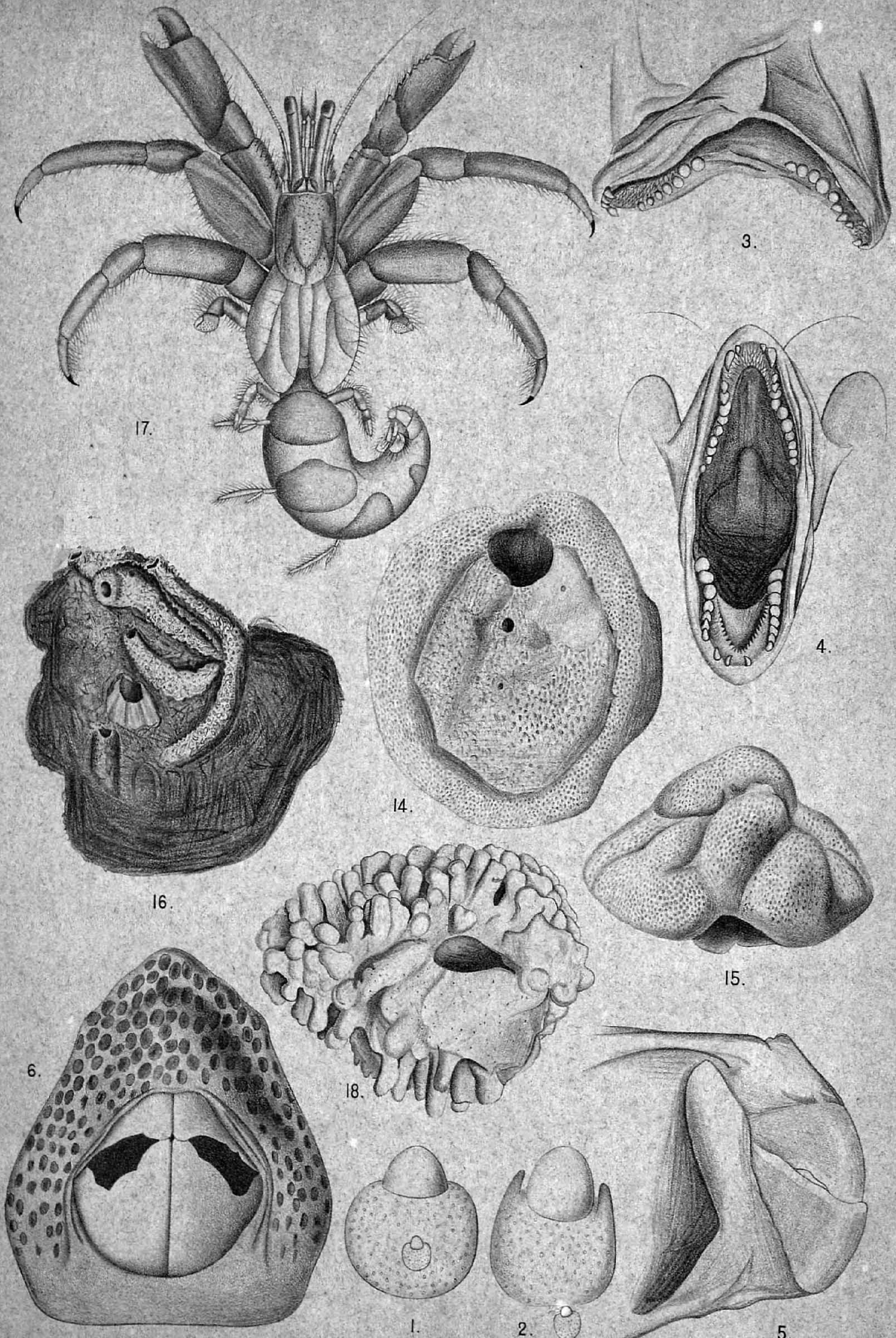


G. Henry del.

E. Wilson, Cambridge.

Examination of Plates.

Plate I.

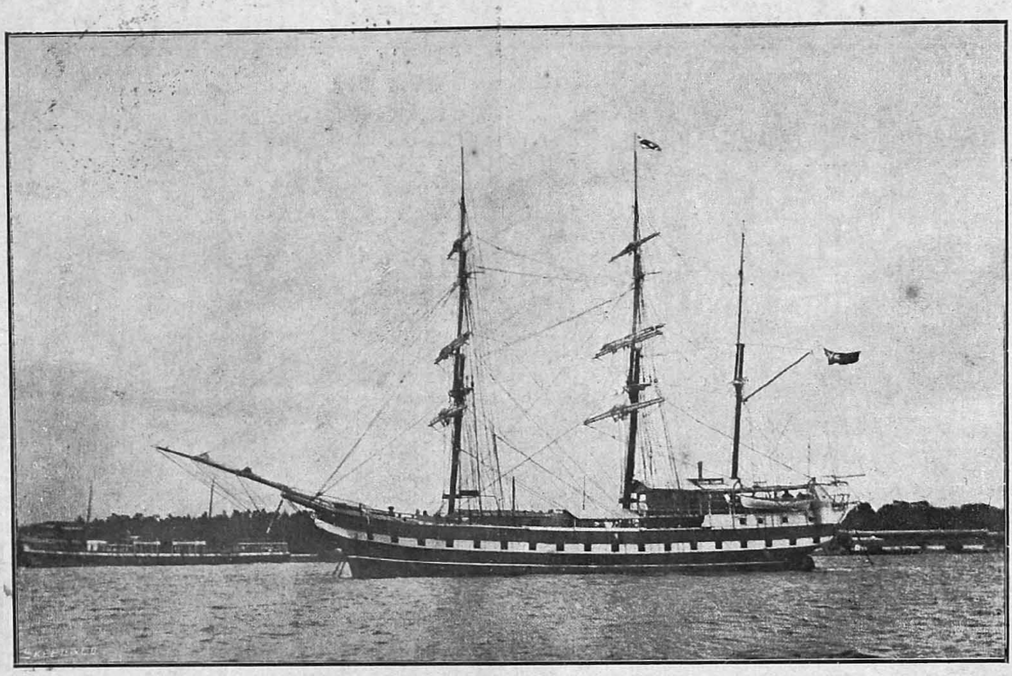
Figures 1 and 2 ..	Diagrams showing endogenous reproduction in *Tetrarhynchus unionifactor.* (× 100.)
Figure 3 ..	Jaw of *Lethrinus miniatus* in profile. Natural size.
Figure 4 ..	Jaw of *Lethrinus miniatus*, front view. Natural size.
Figure 5 ..	Jaw of *Tetrodon stellatus* in profile. Slightly reduced.
Figure 6 ..	Jaw of *Tetrodon stellatus*, front view. Slightly reduced.
Figure 14 ..	Habitaculum of *Cancellus investigatoris*, ventral view. Natural size.
Figure 15 .	Habitaculum of *Cancellus investigatoris* in profile. Natural size.
Figure 16 .	Habitat of *Diogenes rectimanus*, showing tubes. Natural size
Figure 17 .	*Clibanarius willeyi*, n. sp. (× about 5.)
Figure 18 ..	Muricine shell, containing *Clibanarius willeyi*, n. sp. Natural size.

Plate II.

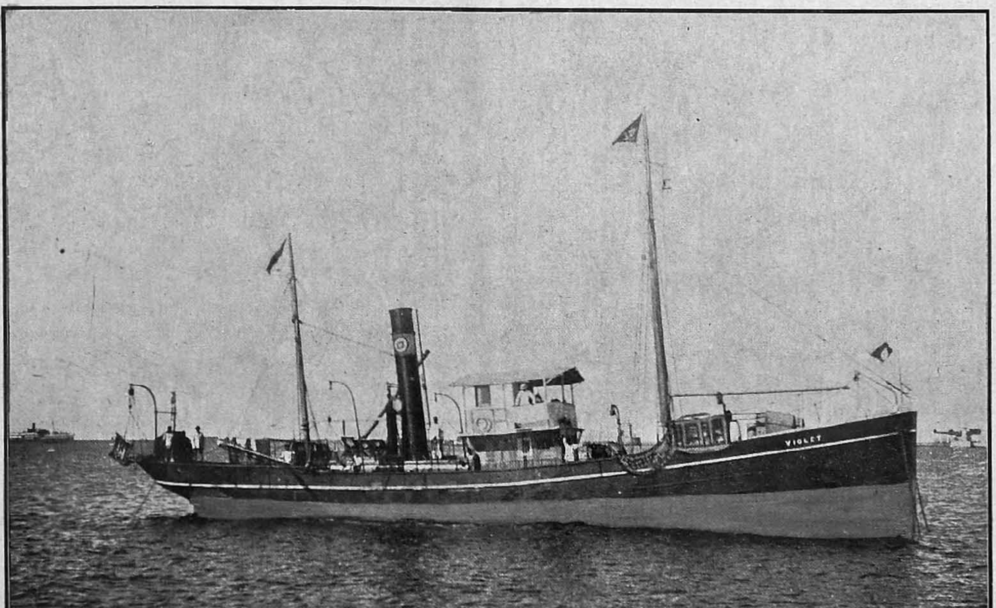
Figure 7	Jaw of a large *Rhyncobatis djeddensis*, showing plate-like arrangement of teeth for crushing. (× $\frac{1}{2}$.)
Figure 8 ..	Jaw of *Trygon sephen*, showing teeth. (× $\frac{1}{2}$.)
Figure 9 ..	Jaw of *Ginglymostoma concolor*, front view. (× $\frac{1}{2}$.)
Figure 10 .	Teeth of *Ginglymostoma concolor*, back view, membrane removed to show growth. (× $\frac{1}{2}$)
Figure 12 .	A single tooth removed and enlarged from *Ginglymostoma concolor.* (× 2.)
Figure 11 .	Jaw of *Trygon sephen*, showing bottom teeth. (× $\frac{1}{2}$.)
Figure 13 ..	*Cancellus investigatoris*, showing modification of the chelipeds to form an operculum. (× $1\frac{1}{2}$)

THE CEYLON COMPANY OF PEARL FISHERS, LIMITED.

INSPECTION VESSELS.



BARQUE "RANGASAMEE PORAWEE."



STEAM TRAWLER "VIOLET."

Reports from the Ceylon Marine Biological Laboratory.

PART V.] **Nos. 11 to 19.** [VOL. I.

SUMMARY OF CONTENTS.

By T. SOUTHWELL, A.R.C.Sc. (LOND.), F.L.S., F.Z.S.

With five Plates and one Chart.

INTRODUCTION.

THE aim and object of this series of publications from the Ceylon Marine Biological Laboratory is two-fold. Primarily they are intended to place on record such new facts and data as experience has shown and proved to be of intrinsic importance in the culture of the pearl oyster in Ceylon, and in this connection the present run of barren years has afforded unique opportunities for extensive scientific and nautical work, which would otherwise have been impossible. The elucidation of the factors at work which have collectively produced this barrenness, is receiving particular attention.

It is no longer believed that bottom currents annihilate whole beds of oysters. Undulatory movements in the lower layers of the water, consequent on the heavy weather during the south-west monsoon, undoubtedly exist, but the disappearance of oysters is due almost entirely to other causes.

The *rôle* played by surface currents in the re-stocking of the banks with exotic spat, during periods when oysters are absent from our own banks, is also receiving careful consideration, and the results are full of promise. These two great and fundamental factors, together with other points in oyster culture in general, will be more fully dealt with in Part VI., which it is hoped to publish in April, 1911.

The second object is to record, as far as time and opportunity allow, the rich harvest of purely scientific results which accrues to the worker who daily finds himself surrounded with a diversity of fauna and flora which, perhaps, only the Tropics can produce.

It is a privilege to again gratefully acknowledge my indebtedness to my co-worker, J. C. Kerkham, R.N.R., for his assistance in many ways, and also for his description of the inspection vessels.

To Mr. George M. Henry I am indebted for all the figures which illustrate this paper; whilst, finally, my grateful thanks are due to the Ceylon Government for again kindly publishing the results.

At Sea, Vankali Paar,
November 22, 1910.

T. SOUTHWELL.

No. 11.

DESCRIPTION OF THE COMPANY'S INSPECTION VESSELS, VIZ., THE SS. "VIOLET" AND THE BARQUE "RANGASAMEE PORAWEE."

With Photographs.

By J. C. KERKHAM, R.N.R.

THE "Violet" is an iron single-screw steam trawler of 149 tons gross and 57 tons registered, built in 1896 by Messrs. Cochrane & Cooper at Beverley, and fitted by Messrs. Holmes & Co. of Hull with triple expansion engines, the cylinder diameters being 11 inches, 17 inches, and 28 inches, and the stroke 21 inches. The present boiler, which was put in in 1907, is constructed for a working pressure of 180 lb. per square inch. The "Violet's" speed is 8 knots per hour, but for working purposes 7 is seldom exceeded.

The dimensions of the hull are: length 95 ft. 3/10, beam 20 ft. 6/10, depth of hold 11 ft. Draught when loaded and stored for sea 12 ft. aft, 9 ft. forward. Coal bunker capacity is 63 tons, and her fresh water tanks carry 21 tons. There are no ballast tanks. There is also ample space for stores, &c. The "Violet's" working radius is therefore (allowing 3 tons of coal consumption per 24 hours and a speed of 8 knots an hour) 4,000 miles, *i.e.*, twenty-one days' steaming.

The deck crew are accommodated forward in a roomy lower forecastle. The engine room crew have their quarters, which are also spacious, aft, abaft the engine room. A deck cabin under the bridge provides accommodation for the Master and the Engineer. There is also a small cabin on the bridge, which is reserved for the Company's executive. It has accommodation for one only, and is used as a chart room also.

The "Violet" has two masts, and is rigged as a ketch. She carries two otter trawls, and is also fitted with appliances for working six drag-dredges, booms being provided to give the necessary spread, and davits fitted for lifting the dredges on board, &c. The dredges are 4 ft. wide, and of 1, 2, and 3-in. mesh, as is required for dredging spat, young oysters, and old oysters respectively. The outrigger booms are also used for towing purposes. As many as twenty-four 20-ton boats (oyster fishing boats) have been towed at one time, six abreast, two from each boom and one from each quarter. This little vessel has therefore many uses: towing, trawling, and dredging, besides despatch work.

All the scientific instruments are kept on board the barque "Rangasamee Porawee," where the officers of the Company have their quarters.

The "Rangasamee Porawee" is a wooden vessel built of teakwood and barque rigged. She was built at Seetharamapuram, near Coconada, in 1876. Her burden is 289 tons. Dimensions: length between perpendiculars 109 ft. 6 in., beam 24 ft. 4 in., depth of hold at midship 12 ft. 6 in., and draws when loaded 14 ft., light loaded 9 ft. She is corvel built, and has a cutaway stem and square stern.

The barque was extensively overhauled in September, 1904, when she received a certificate of seaworthiness from the Registrar of Shipping after survey at Coconada, near where the repairs and overhaul were carried out.

The special fitting, &c., to adapt the "Rangasamee Porawee" for her present work are a large laboratory on the main deck, with an operating table and the necessary racks for specimen jars, &c. The poop is divided into a spacious mess room, two stern cabins, pantry, and bathroom, two outside cabins, and a latrine. On the poop deck a large airy cabin has been built, and also a chart room. The lower deck gives ample and spacious quarters for the crew, boatmen, and divers engaged on the work of inspecting the banks. The stores, &c., are kept in the lazarette at the after-part of the lower deck, and the lamp room and ship's stores at the forepart.

An aquarium is provided for use on board, and a dark room for photographic work. The ship's fresh water tanks hold 16 tons.

The barque provides comfortable, cool, and spacious quarters, and her lofty spars offer a conspicuous mark and a useful vertical angle for measuring distances when laying out buoys, &c.

No. 12.

PHYSICAL AND BIOLOGICAL CONDITIONS OF THE PEARL BANKS.

By T. SOUTHWELL, A.R.C.Sc. (Lond.), F.L.S., F.Z.S.

Much has been said and written from time to time about the pearl banks in general and the various problems relating thereto. The question of the intermittency of fisheries and the occurrence of oysters on the banks has been approached both from the nautical and the scientific side.

Records of observations are practically continuous over the last thirty years, and the experience of Capt. Donnan, extending as it did over thirty years, is of considerable importance. Since Donnan's time the question has been approached particularly from a scientific point of view. Facts recorded in the past have been duly noted, new data collected and co-ordinated, and a serious attempt made to solve the questions at issue.

The voluminous report made by Professor Herdman was indeed epoch-making, since it initiated new methods and placed the industry at once on a sounder basis. Probably there are no pearl banks in the whole world regarding which so much organized material has been collected, and there are certainly no pearl banks upon which so much scientific work has been done. As a result of all this, one would expect to find that periods of barrenness, which so often occur, have not that hall-mark of hopelessness they had years ago. The present situation, however, seems to indicate otherwise. There are two points to be considered in this connection. The first is that science and scientific methods are in their infancy here. There must needs be mistakes and misinterpretations along the way: there have been in the past, and probably there will be in the future. But just as applied chemistry has advanced the arts, and just as physics and mathematics have a commercial application, so surely the elucidation of biological phenomena on the Ceylon banks will eventually place pearl fishing on a satisfactory commercial basis. If scientific culture is not adopted, nothing remains save a yearly search for oysters, without any attempt being made to assist Nature, or understand the multitudinous factors at work which conduce, or otherwise, to the welfare of the oyster.

The second point is that the Ceylon pearl banks cover an area of over 700 square miles, and it must occur to any one that the attempt to understand—to say nothing of controlling—the factors at work on such an immense area is colossal in the extreme. On the Continent, as at Arcachon and Ierseke, a man paternally guards an acre of oyster ground which is exposed at low water. The continental beds owe their success largely to scientific culture.

But in Ceylon the oyster thrives best in the open sea, in about 6 fathoms. It therefore becomes obvious to us that culture must proceed on independent lines. In this connection it is well to note that the continental oyster is hermaphrodite, whilst in the Ceylon oyster the sexes are separate.

Since scientific methods were only really commenced six years ago, and since during this period oysters have been absent from the banks during half the time, and therefore no material available, it is quite reasonable to believe that scientific culture will be as successful here—if not more so—as at other places. There is a peculiar elusiveness in problems connected with the sea, primarily because the facts cannot be so easily ascertained, and also because there are so many interacting conditions dependent on each other and assuming different degrees of importance at different times and in different places. Incomplete facts lead to incomplete methods and result in failure.

As marking the point to which scientific culture has advanced at the present time, I shall deal in this paper with a variety of topics.

The experiments in oyster culture attempted on the Ceylon banks up to the present are similar to those in operation on the Continent, and, strictly speaking, they cannot be said to have been successful. Nor is this very surprising. The oysters in question are differently constituted and have different habits. In any case the experiments in Ceylon have been conducted on such an immense scale as to prove their utility or otherwise. There can be no doubt that the broad principles laid down by Professor Herdman form the framework on which successful culture must proceed, but it would appear that these processes must be modified in order to suit the requirements of the Ceylon oyster.

At present, apart from the enemies which are *known* to deplete beds of oysters, there is much that is not understood. Even when the banks are barren enormous beds of spat appear, and it is by no means certain from whence they originate. Work on currents—the liberation of drift bottles and the collection of various data—are intended to throw light on this question. Again, the depletion of a bed of oysters is not invariably due to circumstances which we understand perfectly, such as ravages of fishes, &c. Numbers of oysters seem to "die off" for reasons which up to the present have not been definitely determined. It is usual in the latter case to assume that the ground is unsuitable, &c., but the difficulty is that the ground suits other oysters, which thrive thereon. The problem is of deeper origin, and requires careful investigation.

There is still much to learn before the ecology of the Ceylon oyster is understood, and it is only *then* that a perfected system of culture can be adopted which will place the industry on a sound commercial basis. This has been done in other parts of the world, and I have no doubt that eventually it will be done in Ceylon.

Particular Problems connected with the Oysters.

It is well known that such extreme periods of barrenness occur on the banks that not a single adult oyster is to be found over the whole area. In spite of this fact, the banks may suddenly become replenished and covered with spat, which often occur over several square miles and exist in unthinkable numbers. From whence do these spat come ?

In a former paper ("Ceylon Marine Biological Reports," Part III.) it has been shown that during the normal spatting season (July to September) the surface current produced by the south-west monsoon on striking Cape Comorin is deflected in such a way that it reaches the Ceylon coast about the vicinity of Tallaivilli. Recent work with drift bottles during July, August, and September of this year (1910) has further proved this to be the case. It is almost certain that oyster larvæ are brought from the Indian side by this current, which eventually results in a spatfall on the Ceylon banks.

Since, however, potential oyster areas are but seldom inspected round the coast of Southern India, it is impossible to actually prove that our spat is often derived therefrom. There are, however, many reasons which lead me to this belief, and these will be dealt with very fully in Part VI. of this series.

Further, it will be remembered that the Ceylon banks lie scattered about on a shallow water plateau, bound on the east by the mainland and on the west by the overfalls (100–1,200 fathoms).

The larvæ of the pearl oyster are pelagic during the first few days (6–9 ?) of their existence. If oysters are present round the southern coast of India, the larvæ from these oysters, which spat during late July and August, would be liberated when the south-west monsoon was at its height. They would, therefore, become pelagic in that volume of water deflected by Cape Comorin, and thus drift towards the Ceylon banks.

The distance between a point midway between Tuticorin and Cape Comorin and the pearl banks is approximately 100 miles. It has been proved by the "drift bottle" experiments that during the height of the south-west monsoon the minimum average surface current is half a knot per hour. Consequently, in 200 hours it would be possible for larvæ to travel from a point midway between Cape Comorin and Tuticorin to the pearl banks. Assuming that the pelagic stage occupies 9 days, or 216 hours (the *exact* length of time is somewhat uncertain, but is said by Professor Herdman to be about 5 days, although it may be more), then the larvæ would just have time to drift on to the Ceylon plateau. It is, of course, absurd to attempt to reckon up fluctuating uncertainties in this way. Nevertheless, the broad general principle has a large basis of truth and fact.

If the current is sluggish during the height of the monsoon, the pelagic larvæ (when sufficiently developed) drop to the bottom in hundreds of fathoms and are lost. If, on the other hand, the surface current is a little quicker, then the larvæ arrive on the plateau ere they become sufficiently developed, and eventually, when the shell is formed, drop on the plateau, thus providing a "spatfall" on the Ceylon banks. The facts and theories quoted above are pregnant with very important possibilities, and will, as stated, be more fully dealt with in Part VI.

Even if it was eventually found that exotic spat was derived in the way indicated above, it is quite another matter controlling natural events of this kind to suit commercial requirements. Still, correct data forms the basis of all ultimate success, and the possibilities of the future are unlimited.

The second problem is connected with the disappearance of oysters, both young and old. It has been proved over and over again that the ravages of various fish and the "boring" of certain molluscs are real and very extensive.

There still remains, however, a fair percentage of oysters which die for some unexplained reason. Their perfect, undamaged, empty shells can be picked up wherever oysters occur in any quantity. This mortality is not due to overcrowding or to unfavourable ground, but seems rather due to some disease. As Professor Herdman remarks (Vol. V., "Ceylon Reports," pp. 125–126), one cause of mortality is "disease, due to the invasion of parasites, either (1) worm parasites, which are moderately large and not usually very numerous, and which, unless abnormally abundant, probably do little harm; or to the more minute and deadly protozoon parasite, such as Sporozoa, which may on occasions be present in enormous quantities, and probably cause epidemic disease. We have in various cases found Sporozoa in the tissues of the pearl oyster. We also know that a bed of adult oysters may get into bad condition, the individuals becoming thin, discoloured, and feeble; and under such circumstances rapid decimation takes place, and the bed, although not yet arrived at old age, may be practically wiped out by what is clearly a parasite disease. It is highly probable that such diseased conditions are, if not the result of, at least generally concomitant with, overcrowding."

During the last few years the same phenomenon has been repeatedly witnessed on a small scale, and has been found to commonly exist on beds of thinly scattered oysters, and is therefore not necessarily connected with overcrowding, although undoubtedly the latter condition facilitates infection and decimation. As a particular instance of this diseased condition may be mentioned the oysters now present on the Kondatchi area. The more adult forms are thin and emaciated. The shell is inclined to be large, but the weight or volume of the flesh is little more than half that of a normal oyster the same age. The infection quickly spreads to the younger oysters, and apparently results in an irregular and intermittent discharge of seminal products. The solution of the origin and nature of this disease is of considerable importance.

All the stages in the life-history of the pearl-inducing parasite are now known with some degree of certainty, and the only question relating thereto which remains unsolved at the present time has reference to the way in which the original infection of the oyster is brought about.

Once in the tissues of the oyster the larvæ multiply asexually, giving rise to younger and smaller forms. Thus, although the original infection of the oyster may be *insignificant*, the result of this multiplication is that the older oysters become considerably infected. (Southwell, "Ceylon Marine Biological Reports," Part IV., 1910.) Although at present endogenous reproduction appears to be monogenetic, it is highly probable that future work will prove it to be polygenetic.

This is the reason why in the tissues of the oyster very varying sizes of larvæ are found. These larvæ are capable of reaching the adult stage directly and without any intermediate host in the intestine of most species of Elasmobranch fish, and the host is not confined to one particular species or genus. It does not reach the adult stage in Teleosts, even though many species of fish belonging to this genera feed on oysters. No adult stage had been found in Balistes. The young stages recorded therefrom are not further developed than stages often found in the intestine of the oyster itself. There seems to be no reason for assuming that this species of fish is an intermediate host. The larvæ occasionally found in this fish are undoubtedly derived from the oyster—since it feeds extensively on them—but the worm certainly never becomes adult in Balistes. Should an infected Balistes be eaten by an Elasmobranch fish, there can be no doubt that the larvæ will develop into an adult worm, but the stage in Balistes is similar to one often found in the oyster. It is no further developed, and its presence in Balistes is purely accidental. Balistes in no sense forms an intermediate host. The same stage merely occurs both in the oyster and Balistes, and the development proceeds no further in either. But in both cases the larvæ may become adult in one or more species of Elasmobranch fish. Balistes, and some other species of Teleosts, merely act as "carriers."

Assuming an Elasmobranch to be infected with a Tetrarhynchus, the ripe proglottides crowded with millions of eggs pass into the sea water with the fæces. Most of these fish are bottom feeders, and one naturally imagines that the fæces fall over the bed of oysters on which the fish are feeding. Are the larvæ free swimming or are they passive, boring their way through the tissues of the oyster? On this question nothing authentic is known, and this is another question which remains unsolved. In any case the latter view is the more reasonable and more in line with our knowledge of the development of the Cestoda Herdman records the discovery of the free swimming larva, although it has not been seen since. It would appear difficult to satisfactorily identify an adult worm from a single free swimming larva. If the larva is passive and sedentary, then it means that the fish fæces containing the eggs must necessarily drop into position in order to ensure infection. If free swimming, which is unlikely, then the possibilities are present in the larva, and the facilities at hand which enable the parasite to find its host. Since the final worm probably occurs in several species of fish, it is by no means impossible for the larva to have more than one molluscan host.

It is but seldom that the infection of the oyster is not extensive. Such oysters sometimes occur on small isolated beds inshore and in the vicinity of fringing reefs. As an instance, I may mention that the infection of the very old oysters found on the Kondatchi Paar in 1908 was remarkably low, and, as bearing practical proof that infection and pearl yield are intimately connected, it is interesting to note that the pearl yield also was remarkably low, the valuation only working out at about Rs. 18 per 1,000 oysters.

There is a further question arising from the foregoing. Assume that oysters are absent from the banks for a considerable period of time, as is common. The advent of a new brood of young oysters means that infection must ensue before pearl formation can begin. From what source does the infection of the new brood originate? It is impossible to believe that the free swimming Cestode larvæ exist in a latent condition in the sea water through such long periods of time. The most probable solution is that the occurrence of young oysters attracts fish, many of which are already infected, and that the initial infection of the oysters is from this source. We have, however, seen that the adult of *Tetrarhynchus unionifactor* is rarely found in the fish caught on the banks.

Another question relating to the parasite is its mode of entry into the oyster. Is it taken in as food, does it enter the blood stream and thus get carried far and wide, or does it bore its way in, or do both processes co-exist?

There is no evidence to show. Even the gut contents and blood of oysters have repeatedly been examined microscopically, and, indeed, one would be fortunate to witness such a phenomenon. The occurrence of larvæ in the liver and other organs of the oyster seems to suggest that the parasites whilst in the food bore their way into the blood stream and are carried about until they encyst. On the other hand, the free surface of the mantle is the place where cyst pearls usually occur, and it seems natural to imagine that the parasite merely bores in and encysts. However, the question is merely of scientific importance, as rounding off our knowledge of the history of this interesting worm.

Muscle Pearls.—Muscle or seed pearls are invariably of small size and irregular in shape. They occur usually in numbers—when present at all—near the insertion of the levator, palpar pallial, adductor, and retractor muscles. Their origin is different from that of the true cyst or orient pearl, for they are not formed round a parasite, but round a minute limy opaque centre termed a calcospherule. The origin of these latter bodies is quite unknown, although it seems almost certain that they are depositions from the blood. Considerably more pearls are formed round calcospherules than round parasites, the ratio being about 13 to 1. They are therefore of considerable commercial importance.

No. 13.

CULTCHING, TRANSPLANTING, TRAWLING, AND DREDGING.

By T. SOUTHWELL, A.R.C.Sc. (Lond.), F.L.S., F.Z.S.

I.—Cultching.

Under the terms of lease (1905) the Company are required by Government "to deposit annually not less than 500 tons of cultch on the pearl bank area under lease." As is well known, oysters attach themselves by means of a byssus, or beard, to solid objects on the sea bottom. Since, however, the bottom of the ocean is not uniformly rocky, there remain extensive sandy patches. On areas of this kind oysters can find no means of attachment. The object of cultching is to deposit rock on such sandy areas, in order to render the sea bottom as uniformly rocky as possible.

The work was commenced vigorously in 1906 by the Company, and has been continued up to the present. Usually about 2,000 to 2,500 tons of material has been deposited annually on areas selected by the Scientific Adviser. The material consisted of broken bricks and tiles, and was brought up by dhonies from Colombo at a cost of about Rs. 10 per ton. Up to the present about 10,000 tons have therefore been laid down. The selected area on which the cultch was placed was one of those small sandy patches which alternate here and there with rock over the Cheval Paar. The first cultch was put down in 1906. This material is often brought up now (1910) by divers in a soft, putty-like state of decomposition. From this fact one can readily infer that the "life" of brick cultch is not extensive.

The total pearl bank area under lease is about 705 square miles, divisible as follows:—

	Square Miles.
(a) Paar.	
(1) Productive Paar	58
(2) Unproductive Paar..	31
(b) Sand.	
(1) Area inshore of, and including, the fringing reefs	176
(2) Sandy stretches	440
Total ..	705

The above figures have been carefully worked out, and will serve to indicate the general character of the ground. It will be noted that there is an aggregate of 616 square miles of sandy ground, which can roughly be divided into the following three divisions :—

(i.) The shelving beach up to the 3-fathom line, comprising 176 square miles, useless for oyster culture, and therefore not worth cultching. This estimate includes the inshore reefs and also the Bar reef.

(ii.) Small sandy patches alternating with rocky ground, as on the Cheval Paar, and including about 10 square miles. Such areas comprise the ground it was seriously intended to cultch.

(iii.) Besides the above, there still remain (*a*) extensive tracts of sandy ground, which have never been known to be productive; and (*b*) the submerged prolongation of Karativu island, which running approximately north for 10 miles terminates in the " Shoal Buoy" position. These combined areas comprise about 440 square miles.

These figures will assist in elucidating how really vast the sandy area is. Bearing in mind that it was only seriously intended to cultch areas indicated under (ii.), the following details further elucidate the colossal nature of even such a comparatively small undertaking.

Allowing that a minimum quantity of 1 cubic foot of cultch is sufficient to satisfactorily cultch 1 square yard of sandy ground at a rate of deposit of 500 tons per annum, the cultching of 1 square mile alone would occupy 155 years. On the Cheval Paar there are 5 square miles of sandy ground, as shown by the recent survey The cultching of the Cheval Paar itself would occupy 775 years, whilst the cultching of the entire sandy area would occupy 95,480 years. In these statistics I have allowed 40 cubic feet of cultch per ton.

Remembering that the cultch hitherto employed disintegrates in five or six years, it follows that although the idea is theoretically good, it is impossible to carry it out practically, even disregarding the enormous expense. Further, it is important to note that up to the present no life of any kind (save Polyzoa) has been found growing on the brick and tile cultch employed.

It would appear that for some reason or other artifacts, or manufactured materials, are totally unsuitable for cultching purposes. On the Continent, although similar materials are used for a similar purpose, the brick and tile are regularly covered with a tallow whitewash. There, however, the oysters are fundamentally different from those in Ceylon, and they have totally different habits. It is obvious that the treatment of brick and tile would, even if necessary, be impossible on the vast scale required on even a small area in Ceylon.

There is a further and more important consideration. On the pearl bank area a natural cultching is incessantly in progress, which enormously exceeds in extent all the attempts at artificial cultching which have been made up to the present by man. Shells, coral, Polyzoa, worm tubes, &c., become naturally cemented together into a calcrete or conglomerate, which experience shows us to be admirable cultch, and a material to which oysters cling. No form of cultch is permanent. But whereas bricks and tile disintegrate into mud and clay, the natural cultch is limy, and its disintegrated products are being unceasingly woven into new cultch. This fact has been repeatedly noted on the banks. Moreover, the disintegration is not nearly so rapid as in the case of bricks and tile. It is therefore clear that although the cultching of the banks is in theory admirable, in practice it is impossible.

II.—TRANSPLANTING.

Young oysters, or " spat," when present, are usually found early in November, and at this time they are about two or three months old. When abundant they occur in roundish clusters, about the size of a football, all the oysters being attached to each other's valves. In such a cluster there may be anything from 300 to 1,200 young oysters. Very commonly there is no central nucleus of cultch or rock to which they attach, and the clusters appear to occur in this form, whether the deposit is on sand or rock.

The spatfall on the Periya Paar in November, 1907, was very uniform in its distribution, and extended in a north and south direction for 6½ miles, and had an average breadth of 1¾ miles. On such an area as this one can safely reckon that the distribution of young oysters amounted to 1,000 per square foot. The number present over such an area as that indicated is unthinkable, but must have been about 396,000,000,000. Such a spatfall is quite normal at certain periods, and may even be much more extensive.

It is obvious that oysters occurring in such rich profusion are overcrowded, and that the food supply available must be inadequate. The mortality is invariably very high, and, in the case of those on the Periya Paar, their annihilation through a variety of causes was entire, well within a year.

As the oysters get older they not only require more food, but more room, and thus it happens that the clusters gradually fall to pieces, until eventually the oysters that have survived are practically individually separate. This natural scattering of the oysters, if taking place on rocky ground, allows the oysters to obtain a suitable and permanent attachment, whilst if occurring on sand no attachment is available and the oysters perish.

The object of transplanting is to thin out the beds as soon as discovered by transplanting a suitable number of oysters from the overcrowded place to a rocky and unoccupied area. The transplantation is necessitated almost purely by the fact that the food supply for such a vast number, all crowded closely together, is insufficient, and also in order to allow the oysters to continue their normal growth and assume their normal position on the floor of the ocean. Consequently it would be unwise to transplant oysters to an area already thickly populated with a variety of other animal life, for in this case the transplanted oysters would still run the risk of insufficient food.

During December, 1907, over 9,000,000 young oysters were transplanted from the Periya Paar to a selected area cultched with brick and tile on the Mid-west Cheval, a distance of only 4 miles, but they all died before May of the following year.

It is evident that transplanting if carried out properly is not only desirable, but necessary, if the majority of the oysters are to be saved, and given that opportunity to reach maturity which otherwise they would not have.

There are three methods of transplanting, and we will deal with each method separately:—

(*a*) *Trawling.*—On tolerably flat and sandy ground the form in which the spat occurs lends itself to trawling operations, and under these conditions the best results are obtained. The trawl is full in a short time, and the operations are carried on under ideal conditions and to the best advantage. As we have seen, 9,000,000 were transplanted from the Periya Paar to the Cheval in 1907 in about six weeks. This number, in my opinion, indicates the maximum result obtainable with the trawl, as the work was carried out by a skilled European, who was accustomed to trawling in the North Sea. The cost of transplanting is summarized in the working expenses of the "Violet" over this period, which amounted to about Rs. 9,500.

Should, however, the ground be uneven and rocky, extensive transplanting with the trawl is quite impossible. Only such oysters as lie in prominent positions are then picked up. The trawl becomes laden with rock débris, which during the "hauling in" operations breaks the tender growing edges of the oyster shell, and which may eventually tear the trawl. Even if the trawl is not torn, the utter hopelessness of picking out oysters from amongst tons of débris is only to be realized by those who have seen the results and noted the entire absurdity of the undertaking.

(*b*) *Dredging.*—Under most conditions dredging is less successful than trawling, for not only is the area covered much less than in the case of the trawl (therefore less economical), but on rocky areas the dredges, being made of steel, tear up the ground in such a way as cannot conduce to the welfare of the vast majority of oysters which occur in hollows and crevices where the dredge cannot reach, but into which dislodged débris falls. I cannot believe, after the experience I have had, that either trawling or dredging can ever be successful commercially, except where the sea bottom is perfectly flat (and this is seldom the case), or that the disturbance caused by these agencies on the sea bottom is not injurious to the oysters in general.

(*c*) *Skin Diving.*—This method has the double advantage of leaving the ground quite clean, and of oysters being more carefully dealt with, than is possible either in trawling or dredging. When normal spatfalls occur oysters are abundant, and a diver can quite easily bring up 500 oysters per dive. Suppose 100 divers were employed, and that each diver made 20 descents, the total would be 1,000,000 per day. I am aware that as the oysters began to thin out fewer would be brought up, but when such a condition was reached there would be no further need for transplanting. Allowing each diver Re. 1 per day and each manduck 50 cents, the total works out at Rs. 150 per day.

Besides our own inspection boats, only at most five dhonies would be required, and these could easily be obtained at Rs. 150 per mensem. The cost, therefore, over the same time is very much lower than the working expenses of the "Violet," the work is more effective, and the ground is left cleaner.

It by no means follows that the oysters transplanted live and thrive. In most cases the causes of death are obvious, and can be remedied. Among the foremost may be mentioned (*a*) too long exposure out of water, (*b*) exposure on a hot deck (particularly aboard a steamer) and to the sun, (*c*) the crowding together of large numbers of oysters, and (*d*) the breaking of the delicate edges of the shell.

Oysters out of water ought always to be scattered out on a cool wet deck, on the shady side if possible, and covered with gunny sacks which have been soaked in sea water. The sacks ought to be re-soaked about every half hour.

Under these conditions I have known oysters live for two days. When oysters are crowded together on deck the edges of their fragile valves are apt to get broken, and this allows sand to silt in when the oysters are replaced in the sea. I have seen many oysters with one side of the mantle in a state of degeneration owing to the presence of sand, a result brought about probably by fish having nibbled away the edges.

With the trawl and dredge, of course, the danger of such breakages is much greater, and is almost certainly fairly considerable. As I have already pointed out, accidents of this kind are almost sure to prove fatal to the oyster.

With regard to the oysters transplanted from the Periya Paar to the Cheval, the fact that the cultch there consisted of brick and tile, and the consequent possible lack of "foothold," may, along with other causes, have contributed to the death-rate.

The economic or commercial value of transplantation, however, is conditional. If whole beds of oysters, and particularly young forms, are devoured by voracious fish—and such has been shown to be the case ("Ceylon Marine Biological Reports," Part IV.)—then it follows that, although transplanting may ensure a sufficiency of food and allow ample room for growth, it does not protect the transplanted oysters from the ravages of predatory fish. In other words, certain fish eat oysters, irrespective of whether they occur on rock or sand. In view of this well-established fact, it has been deemed advisable to cover over transplanted oysters with horizontal wire netting (and also as many other beds as possible), and in this way, by the exercise of judicious care during transplanting operations, it is hoped to reap the fullest benefit therefrom when the opportunity occurs.

III.—Trawling and Dredging.

From the foregoing it will have become clear that the possibilities of work in general, on commercial lines, with the trawl and dredge, on the pearl banks is limited.

As substitutes for skin divers during a fishery they are quite unsuccessful, and even as accessories they are only useful on a small scale. Trawling and dredging operations can only be carried out successfully on a sandy or on a flat rocky bottom, and even then not on a sufficiently large scale to render such operations successful commercially. At least this is the case with the steamer now engaged in the work, viz., the ss. "Violet." It is to be remembered that adult oysters only occur on rocky ground.

The ground situated between Dutch Bay Point and Kodramallai Point, west to the overfalls, and comprising the Alanturai, Krusadai, and Muttuvaratu Paars, is for all practical purposes one entire carpet of coral. Much of this coral is dead, but there are considerable areas of living material. Over the *whole* of this area the trawl and dredge cannot be used at all, for immediately on being shot they hitch on the rock and are either lost or irreparably torn.

On the northern area, where coral and peaky rock is less abundant, the following example will illustrate the commercial possibilities of trawling and dredging:—During February, 1908, a bed of oysters was found on the Kondatchi Paar by Professor Herdman. The number present was estimated at 5,000,000. It was decided to fish this bed of oysters with the trawl and dredge, assisted by 40 divers and two dhonies, the season being too far advanced to allow of the usual camp being formed, and the expense of such a camp being in excess of the profits calculated to accrue from the oysters to be fished.

The Master of the "Violet," who had had an extensive experience in trawling, estimated that by these means he could lift one-third million oysters daily, and thus fish the entire bank in fifteen days.

Having had some experience of trawling and dredging, I was far from believing that the enterprise would be in any degree successful.

It was arranged that the divers should work only on the rocky parts, and that the "Violet" should fish on the flatter ground.

Operations commenced on March 21, and were discontinued on March 25, owing to the entire failure of the undertaking. The following table shows the results, which speak for themselves.—

Date.	Trawled by "Violet." Number.	Time. Hours.	Dredged by "Violet." Number.	Time. Hours.	Fished by Divers in 20 Hours.	Grand Total fished.	Company's Share.
March 21	1,055	5	—	—	—	1,055	1,055
March 22	6,750	14½	—	—	10,500	17,250	13,750
March 23	7,000	12	—	—	17,250	24,250	18,500
March 24	—	—	8,000	14	14,250	22,250	17,500
March 25	—	—	7,000	7	17,250	24,250	18,500
Total	14,805	31½	15,000	21	59,250	89,055	69,305

Total lifted by divers in 20 hours, 59,250. Total lifted by "Violet" in 52½ hours, 29,805.

It should be noted that the divers worked only 5 hours daily, whilst the "Violet," except on the first and the last day, worked thrice the time occupied by the divers—52½ hours—and only lifted half the number obtained by the divers.

These facts serve to show that commercially trawling and dredging are failures, for the experiment was carried out on a scale extensive enough to thoroughly test their capabilities.

The real utility of the trawl and dredge, so far as the pearl banks are concerned, lies in their usefulness as prospecting agents, and in this respect they form exceedingly valuable adjuncts to the inspection work.

Since only 2¼ square miles can be inspected by divers daily, it follows that the examination of the entire potential area would occupy some months. Whilst the normal inspection is proceeding, the "Violet" is engaged systematically trawling (and more particularly dredging) on other known areas. In this way no potential ground is left entirely unexamined. Should oysters occur at all the dredge is sure to reveal this fact, when a more thorough examination of the ground is then made by divers. The dredge is also useful in bringing up samples from the bottom, and the trawl for capturing fish for experimental work. These latter, however, are of subsidiary importance, and the best use that can be made of the trawl and dredge is for prolonged and extensive prospecting.

No. 14.

SPECIFIC FAUNA OF THE PAARS, WITH NOTES ON THE NATURE OF THE SEA BOTTOM.

By T. SOUTHWELL, A.R.C.Sc. (Lond.), F.L.S., F.Z.S.

The general characters of the pearl bank fauna and the nature of the sea bottom have already been carefully described by Professor Herdman, and I would here only summarize certain outstanding features which appear to be constant and characteristic, and therefore of some importance.

The fauna lends itself to classification under six heads :—

(1) The Fringing Reefs and Corally Areas in general.
(2) The Sandy Areas.
(3) The Periya Paar Area.
(4) The Kondatchi Area.
(5) The Cheval Area.
(6) The Rocky or true Paar Areas.

(1) The Fringing Reefs and Corally Areas.

On the ground under the control of the Company there are, strictly speaking, four discontinuous fringing reefs, named as follows :—

Bar reef, Dutch Bay.
Silavatarai reef.
Aripu reef.
Vankali reef.

The species of coral found on all these reefs are most varied, and consist of *Madrepore*, *Porites*, *Galaxia*, *Favia*, *Pocillopora*, *Turbinaria*, *Meandrina*, *Symphyllia*, *Montipora*, *Goniastrea*, *Cœloria*, &c. However, each reef presents distinct characters, which consist in the preponderance of one or more genera of coral.

Thus, the Bar reef consists principally of *Turbinaria crater*, the Silavatarai reef of *Madrepora* (*scandens* and *studeri*), the Aripu reef of *Madrepora* (*studeri ?*), and the Vankali reef of *Madrepora* (*studeri ?*) and a small species of *Turbinaria*, which grows in a particular way, leaving small isolated sandy holes or patches from 2 to 3 fathoms deep, the walls of which are almost vertical.

One peculiarity of the Bar reef is that, in contradistinction to the others, it runs out in an east and west direction, and the sea never breaks on it. It would appear that the sea breaks most over reefs where massive *Porites* occur on the seaboard. All these reefs are exposed at low water.

The whole of the southern paars, viz., Krusadai, Alanturai, Dutch Moderagam, Muttuvaratu, Hamilton's Muttuvaratu, Donnan's Muttuvaratu, with the intervening ground, which differ in no way from the areas dignified as "paars," are in *reality one continuous mass of coral*, consisting of almost all the species named growing together here and there in immense profusion. The southern paars, being one unity, thus differ from the northern ones, which are isolated and scattered. At places little sandy patches occur, but they are rare. On other parts the dead remains of the most massive species, such as *Symphyllia*, *Favia*, and *Porites*, become detached and form excellent cultch, whilst the more delicate *Madrepore* and *Turbinaria* become incorporated with shell, *Polyzoa*, worm tubes, and other fragments as calcrete. It is impossible to estimate the extent of this never-ending process of calcrete or conglomerate formation. Solid blocks of loose rock are often brought up, in which shell, coral, worm tubes, and the like are easily discernible, all united into an extremely compact and stable mass. This manufacture of natural cultch on the floor of the ocean is most important.

On the south the coral extends continuously in a westerly direction to the overfalls, and between Dutch Bay Point to the south and Kodramallai Point to the north. Between the reef and the beach, and parallel to the contour of Karativu island, the ground is sandy, shallowing gradually to the shore.

On those corally areas which constitute the Muttuvaratu, Krusadai, and in particular the Alanturai Paar, life in general other than coral is scanty, but *Halimeda* of two species is notably abundant, and their decomposing remains give the sea bottom a characteristic appearance, which simulates a coarse Foraminiferal sand.

On many parts of the southern paars huge masses of *Porites* occur, which growing on top of each other give rise to masses of solid "peaky rock." Portions of this reef are dead, notably on the Muttuvaratu Paar. Nullipore balls (*Lithothamnion*) are also common.

Coral growths are by no means limited to the areas just named. Isolated and living patches are to be found on the north and south ends of the Periya Paar, on the Cheval, Vankali, and Kondatchi Paars, and other places; but in these latter cases it is accidental, and by no means typical.

(2) The Sandy Areas.

These may be considered as useless ground. They include the areas between the reefs and the shore, and also a long strip of shoal, which from Karativu Point extends in a northerly direction for 8¾ miles and terminates suddenly in what is known as the "Shoal Buoy" position. At this point there is a sunken beacon, originally erected by Capt. Legge, whilst close by there are eight tanks sunk by Capt. Donnan and three trucks sunk by Mr. Hornell. Besides these two extensive sandy areas, other isolated sandy patches occur all over the pearl bank area without constituting a definite characteristic feature. It is here, where sandy and rocky patches alternate, that the enforced attempt at cultching is being slowly carried out.

Other entirely sandy areas include the following:—Karativu (in part), Kodramallai and the central part of the Periya, Old Dutch Moderagam, Old Dutch Jagerboom, Jagerboom, Challai, three Vankali's (inner), Dutch Anaivilundum, Dutch Nadukkuddi, and Koopay Paar, together with the ground between the Cheval and the Periya Paars.

The fauna of the sandy ground is remarkably scanty, and consists principally of starfish and *Holothuria nigra*, which occur in great abundance. Since these Echinoderms occur very largely on sand only, where oysters are usually absent, they cannot be of any importance as oyster-devouring enemies.

Here and there the sand is impregnated with Foraminifera, mostly *Heterostigina*, *Orbitolites*, and *Amphistegina*. A few chanks (*Turbinella pyrum*) may also be found, but these constitute the entire fauna.

Where the muddy and weedy basin of Portugal Bay opens to the sea, fishes such as *Rynchobatus djeddensis*, *Pristis cuspidatus*, *Pteroplatea micrura*, small specimens of *Carcharias*, and other mud-loving fish are remarkably abundant.

(3) The Periya Paar Area.

This area is about 11 miles long by 1½ mile broad, situated on the very edge of the overfalls, 18 miles from land, and lying in a N.N.W. direction. A fishery was held on the south end in 1879, and is the only one recorded on this paar. The south end is rocky. On the north end living coral is fairly plentiful, whilst the central portion is for the most part flat rock covered with several inches of sand. The rock is bare at places. Nullipore and starfish are abundant, and huge masses of the sponge *Petrosia testudinaria* form the outstanding feature. The fish fauna of this area is remarkably rich. Large specimens of the following species have often been trawled: *Tæniura melanospilos*, *Trygon uarnak*, *Serranus undulosus* (4 feet), *Lethrinus miniatus* (3 feet), besides many others.

(4) The Kondatchi Area.

There are really four old Kondatchi Paars, which closely abut on to each other. A fishery was held on one of these paars in 1801, and they again assumed some importance in 1908, when a bed of 5,000,000 adult oysters was found there. The spat from these oysters, consisting of various broods, has been deposited in the vicinity, but further inshore however, in $2\frac{3}{4}$–4 fathoms, and this fact seems to add additional proof that the spat from the oysters on the banks under lease are deposited and kept thereon.

The oustanding characteristic of the Kondatchi area is the presence of immense numbers of *Pinna bullata* and *Mytilus, sp.*, to which the area owes its entire importance. The bulk of the ground consists of coarse sand only, with occasional patches of living coral, calcrete, and nullipore.

Over some parts there is an immense growth of short, stunted, filamentous, dark green weed (*Cladophora, sp.?*) mixed with the sand. Nearer the shore the sand becomes mixed with mud, which gives it a dark appearance, and the quartz grains are not so coarse. It is here that *Pinna* and *Mytilus* are most abundant. The *Pinnas* lie with their pointed ends buried about 4 inches in the sand, and their byssus attached to large quartz grains. They often attain a length of 14 inches. The oysters growing on this paar, which is never covered by more than 4 fathoms, attain a large size, although they are narrow about the hinge.

Infection of the oyster is at a minimum, and globular parasites are comparatively rarely found. Hence their pearl yield has accordingly been found to be low. Moreover, from the numbers of undamaged shells which have been found here of late, it would appear that the oysters are not in a healthy condition. This may be due to the presence of some sporozoon parasite, but this, however, remains to be determined.

Along the western edge of the fringing reefs a few scattered oysters are invariably to be found. These oysters are small and dwarf, and seldom live more than two or three years. They spat at irregular intervals and give rise to a brood which, settling in the same locality, partakes of the same peculiarities. It may be that the irregular emission of spat conduces to a stunted, short-lived brood, but there can be no doubt that these reef forms appear unhealthy. Their occurrence in shallow water undoubtedly tends to the same result.

These conditions, together with the presence of an extensive fauna, which materially affects the food supply, are some of the adverse conditions which oysters occurring on this area have to contend with.

(5) The Cheval Area.

This paar is the central and largest member of the northern set of paars, which latter, in contradistinction to those of the south, are isolated and separate from each other.

The Cheval has hitherto been charted as a horseshoe-shaped paar, with the gap to the north. The recent survey of the pearl banks carried out by J. C. Kerkham, R.N.R., has shown that this orientation of the Cheval is incorrect. It is hoped that a full account of this survey will be published in Part VI. of this series. A recent chart is published with this number.

This configuration of the Cheval, as determined by Capt. Kerkham, is appended. It will be noted that the paar lends itself to a series of natural divisions :—

(1) West Cheval, comprising the whole of the western part, which as shown is merely joined to the rest of the paar by a narrow strip of rocky ground.

(2) An eastern part, which, to the south, is *not* joined to the western part as shown on Captain Donnan's chart, but which gives off three newly discovered extensions, viz. :—

(*a*) A northern extension ;
(*b*) A north-eastern extension, which includes the Kallatidal Paar ; and
(*c*) A south-eastern extension, including the true Kondatchi of Captain Donnan, although the Kondatchi area proper is quite distinct from this extension of the Cheval.

Between the eastern and the western parts there is sand only, rock being notably absent. This recent orientation of the Cheval we shall adopt in all future references to this paar.

The sea bottom on the Cheval Paar is as varied as its fauna, and perhaps the two are to be correlated. There is a distinctive fauna, marked by extensiveness and variety which is seldom found elsewhere. Fishes are fairly abundant, the most common being *Lethrinus miniatus* and *Serranus undulosus*, whilst *Balistes* occurs but rarely.

As we have seen, a strip of sand separates the West from the East Cheval. Here Echinoderms of many genera are common. The sand is shelly, with a few Foraminifera, and here and there nullipore balls are found.

The area constituting the paar proper consists of flat rock, living coral, calcrete, broken-down coral, and nullipore, with small intervening sandy patches. At places the rock is bare, whilst elsewhere it may be covered with a few inches of sand. Where it is bare it gives attachment and support to various animals, and at times to huge quantities of Sargassum and strap weed.

(*a*) *West Cheval.*—The northern part is very rocky, with scattered patches of living *Porites* and *Favia*. To the south sandy patches increase in extent and the paar ground proper ceases On the sand starfish and *Holothuria* are abundant. On the rock Sargassum and strap weed are enormously abundant, particularly near the centre. Amongst an extensive general fauna, the following occur commonly and in large quantities:—*Cavernularia obesa*, *Leptogorgia, sp.*, *Echinogorgia, sp.*, *Phyllospongia holdsworthi*, *Spongodes, spp.*, *Fasciolaria trapezium*, and *Pterocera, sp.*

(*b*) *East Cheval.*—Here the rock is often buried by a thin layer of sand. Calcrete, dead coral, and nullipore are common about the centre. To the north (including the Kallatidal Paar), east, and south it passes into sandy ground proper, where the usual Echinoderms occur abundantly. The fauna is not quite so extensive as on the west, but the same forms preponderate.

The outstanding faunistic feature of the Cheval in general consists in the abundance of fleshy *Alcyonarians*, *Gorgonids*, *Fasciolaria trapezium*, *Pterocera, sp.*, *Phyllospongia holdsworthi*, *Hircinia fusca*, and weed.

Amongst these varied conditions of life and sea bottom the Ceylon pearl oyster reaches its maximum of productivity.

The Moderagam "Paars" consist of a single narrow strip of rocky ground lying in a north and south direction to the south of the Cheval. Its characters are those of the southern parts of the general Cheval, where life is somewhat scanty. It is discontinuous with the Cheval, and does not consist of two parts, a north and south, as is charted by Donnan (see chart).

Herdman, in Vol. I., "Ceylon Reports," p. 105, states that the North Moderagam Paar of Captain Donnan is "all sandy, ridged, and furrowed ; no rock to be found," so that our Moderagam Paar is equivalent to Donnan's North Moderagam, and the South Moderagam does not exist.

(6) The Rocky or True Paar Areas.

A number of paars have no characteristic fauna. They include the following:—Dutch Moderagam Paar, one Vankali Paar, three Arippu Paars, Anaivilundum Paar, Nadakuddi Paar, and the Periya Paar Karai.

The bottom consists of flat rock covered with a few inches of sand, but bare in places. On the latter a few animals find attachment, and weed is abundant. Calcrete is common. The sand is shelly, and contains but small quantities of Foraminifera. Starfish and Echinoderms are numerous. The rock consists of a remarkably hard, medium-grained sandstone of a brown colour, and it is strongly impregnated with ferruginous salts. Outcrops of this rock are seen here and there along the west Ceylon coast, as at Chilaw, Kodramallai Point, and Moderagam (Devil's Point). It appears that exposed parts of this paar or rock may gradually become silted over in the course of many years, and new parts exposed. Such silting is, however, so infinitesimally small as to be negligible, so far as oysters are concerned.

I would here call attention to the fact that the Western Vankali Paar is enormously greater than is shown on present charts (see new chart), and appears to be very suitable rocky ground. A striking feature of this paar is the presence of numbers of small "pot holes," which conclusively prove that no silting takes place on this paar, as otherwise such cavities would become obliterated.

In conclusion, the most northern part of the area under lease, viz., that lying roughly between Adam's Bridge and Vankali Paar, consists of a dark muddy sand, on which the grass weed *Zostera* (?) grows in rich profusion. Here, too, chanks (*Turbinella pyrum*) are common. The fish found there are typical mud feeders, and include forms like *Drepane punctata*, *Ephippus orbis*, *Psettodes erumic*, *Polynemus zanthonemus*, *Plotosus canius*, &c. It is obvious that a bottom of this nature, besides being in shallow water, is absolutely hopeless as oyster ground.

No. 15.

NOTES ON THE GENERA MARGARITIFERA AND AVICULIDEA, AND ON POST-MORTEM COLOUR CHANGES IN ECHINOIDS.

By T. SOUTHWELL, A.R.C.Sc. (Lond.), F.L.S., F.Z.S.

(*a*) Margaritifera sugillata (Reeve) ?

Several times since I came to Ceylon I have seen oysters of a larger size than the average *M. vulgaris*, but with much more flattened valves than in this species. One of this larger species, viz., *M. sugillata*, was taken at Watering Point, Galle, by Professor Herdman in 1902. I have found the species difficult to identify, as I have no undoubted *M. sugillata* to compare with, but I think there is little doubt these individuals belong thereto.

The two specimens I have (one from Mid-East Cheval and the other from South Moderagam Paar, November, 1906) have a *very much flattened shell*, with *rostrum not marked off sharply* from the inner surface of the valve (as is so characteristic in *M. vulgaris*). Anterior tooth shows only as a very slight unevenness on the inner edge of the hinge. Lateral tooth also practically abortive—a very slight ridge in some, almost absent in others.

The posterior angle of the nacre, where it meets the hinge, is a right angle, or even may be an obtuse angle of, say, 95 degrees. The posterior sinus is practically absent, the only trace being a slight sinuosity. The length of *nacre exceeds* its height or depth as 69 : 40. In this it differs from *M. carchariarum*, where the depth exceeds the length as 75 to 70. Length of valve is decidedly greater than depth, as 83 : 76 and as 71 : 66. Length of hinge is very nearly *equal to depth of nacre*; 59 : 60 and 49 : 53.

Dimensions of the two specimens I have are :—

	Length of Valve.	Depth.	Length of Hinge.	Length of Nacre.	Depth of Nacre
A ..	83 ..	76 ..	59 ..	69 ..	60 mm.
B ..	71 ..	66 ..	49 ..	55 ..	53 mm.

Anal funnel is *palmate* in shape, extremely characteristic (see fig. 5, Pl. III., of Herdman's Anatomy of Pearl Oyster Report, Vol. II., where, however, it is possibly wrongly attributed to the "Black-lip" Margaritifera. The latter has an elongated tongue-shaped anal appendage). This shell cannot be *M. carchariarum*, as in the latter the depth of nacre exceeds the length of same (*vide* Jameson). Neither is it *M. natalensis*, as there the hinge is as long as the length of nacre, whereas in the Ceylon shell the length of nacre is considerably longer than the hinge. It cannot be *M. maxima*, as in the latter the nacre makes an *acute* angle with the hinge posteriorly in young shells, also in *M. maxima* the byssal cleft is less pronounced than in "Black-lip." In the present Ceylon form this cleft is quite as pronounced as in "Black-lip."

(*b*) Australian Black-lip Pearl Oyster (M. margaritifera).

During the inspection of the Karativu Paar, November, 1906, the Arab divers employed brought me a "Black-lip" of typical form and colour; the divers remarked that they got fine shells of this kind off Socotra and also Muscat.

The coloured margin of shell outside the limits of the nácre is *very narrow* in comparison with what it is in *M. vulgaris.*

The radial rows of white dots which are so characteristic of this species are well shown in the shell; they are due to the white bases of the digitate processes remaining after the processes themselves are broken off.

In this specimen the margin of each valve is characteristically armed with a row of long and rather broad processes, having the sides parallel. They remind one of the long nails of the Chinese literati! They are more or less coloured opaque white.

Ground colour of shell (outside surface) is *characteristically* a very *dark bottle-green.*

All digitate processes broken off, except those along margin of shell.

Soft parts.—Velum and pallial edge darkly coloured black, with some small amount of orange marking, chiefly through some of the broad marginal papillæ of the velum being so coloured. These papillæ are broad, short, and more or less spatulate.

Gills inclined to be darkly tinted. No orange there.

Adductor muscle narrow and not *massive*, as in *M. vulgaris;* indeed, in *M. sugillata* (?) and in another species (undetermined) *the adductor is narrow and comparatively weak when compared* with the same muscle of *M. vulgaris.*

Anterior edge of visceral mass short and less developed proportionately than in *M. vulgaris.*

Foot extremely small for size of shell.

Anal funnel *broad* and *not* funnel-shaped; really tongue-shaped, with a white wedge-shaped opaque region in the middle. Anal opening on a well-defined tubercle. Some orange pigment on the ventral aspect at base and extending forward a little way.

(*c*) M. margaritifera.

The anal funnel is speckled whitish, with two slight protuberances on each side near the anal aperture, and is orange-coloured at its base on the dorsal surface.

Pallial edge with small short fimbrial margin and broad spatulate orange-coloured fingers.

Margin of nacre golden bronze.

White spatulate processes occur on the velum, having a tinge of orange in the centre.

Anal ridge orange.

Spatulate velum processes black at bases, and the rest white with an orange tinge in centre. Anal ridge dark, nearly black. Funnel white, usually; edge entire.

(*d*) Linked Species (?) of the Genus Margaritifera.

M. margaritifera.	*M. capensis.*
Shell.—Massive, *regular.*	Massive, *contorted.*
Teeth.—None.	Feeble in young, absent in old.
Hinge.—Short, little more than half anterior part length of nacre.	Short, same proportion to nacre as others.
Nacre.—Lustrous, with margin of wet brassy orange or greenish iridescence; meets posterior end of hinges in obtuse angle in typical form.	Somewhat white and porcellaneous, margin of nacre not different coloured; meets posterior end of hinges in obtuse angle in typical form.

M. margaritifera.

Elastic hinge pad.—Elongated, length more than twice breadth.

Colour.—Typically with 10–18 radial rows of white spots, sometimes in bands, sometimes suppressed.

M. capensis.

"Squat," short, and deep; length less than twice breadth. Lower edge projects most prominently into cavity of shell.

In one specimen I have there are radial white bands.

Chief Differences.—Contortion of shell in *M. capensis;* difference in shape of elastic hinge pads and colour and appearance of nacre.

(*e*) Intimate Relationship between M. vulgaris of Ceylon and other "Lingah" forms, and M. radiata of the West Indies.

As touching this question, see Svedelius on Caulerpa in Part II. of "Ceylon Marine Biological Reports," also J. Arthur Thomson's quotation in Vol. III. of Herdman's Report, p. 301, of Ridley's note on the Alcyonarian genus "Acis," viz.:—

"The occurrence of this otherwise West Indian genus in the Indian Ocean, and in its western portion in particular, has a peculiar significance for the student of Geology, as showing that a communication probably existed between these two areas at a period later than that at which the genus was differentiated from the main stem of the family."

(*f*) Genus Avicula.

Avicula-Gorgonid Association.

On the west side of the Periya Paar Karai I dredged in from $7\frac{1}{4}$ fathoms quantities of yellow-brown *Leptogorgia lutkeni*, with branches thickly encrusted with a yellow-brown *Avicula.* (*Avicula radiata? vide* Herdman, Vol. I., p. 51.) On one specimen there were 160, and on others fully as many, if not more.

Colour of *Avicula* exactly that of the *Leptogorgia.* (Note.—The latter becomes very pale—dirty yellow—when dried, losing the rich brown tint of life. Colour of the *Avicula* does not change much when dry.)

The habit of growth of the *Leptogorgia* produces numerous short stout branches, frequently unilateral for considerable distances.

The *Avicula* fix themselves with the prolonged posterior ear directed upwards and outwards at almost precisely the same angle to the stem as the branchlets are given off, and thus they merge into the general habit and appearance of the Gorgonid, obtaining in all probability a considerable measure of immunity from enemies through this resemblance to a spicular indigestible organism.

Height of *Leptogorgia* colonies, 30 to 35 cm.

(*g*) Influence of Habitat on Aviculidæ.

Avicula (Margaritifera) zebra.

The colour of this species, as denoted by its specific name, is arranged in stripes; colour is dark brown upon a pale yellow ground.

Habitat is characteristically upon the plumose zoophyte *Halicornaria insignis* (for fig. of latter see Herdman's Report, Vol. II., and also a note on this noted association).

As the zoophyte has a pinnate arrangement of unbranched hyorocladia of brown colour, rising from a deep brown stem, the striped shell of *A. zebra* harmonizes perfectly with the surroundings amid which it lives.

The mollusc attaches usually to the stem of the zoophyte and lies at such an angle that the stripes or bands of brown on its shell coincide in direction (as they also do in width and distance apart) with the pinnæ of *Halicornaria*.

Herdman notes this protective colouration (Report I., p. 62) thus: "The beautiful large pinnate *Halicornaria insignis* is also found here, and usually bears the protectively-striped *Avicula zebra*, which is almost invisible on the zoophyte."

(*h*) Post-mortem Colour change in Echinoids.

The little *Laganum depressum* becomes an intense vivid green after death and exposure to the air. So also does the stout-shelled *Echinolampas oviformis* under the same condition.

Clypeaster humilis, on the other hand, becomes an intense yellow, but after a prolonged time, if kept moist, deep green patches begin to appear at the apertures of the body, especially at the centre of the rosette. If immersed in fresh water, a bright yellow tint is imparted almost immediately to the water. On breaking the tests the soft parts are found to be of an intense verdigris green colour.

Echinodiscus auritus becomes deeper brown-yellow after exposure in damp condition after death.

No. 16.

NOTES ON SOME CEYLON ACTINIARIA.

By T. SOUTHWELL, A.R.C.Sc. (Lond.), F.L.S., F.Z.S.

The nucleus of these notes on Ceylon Actiniaria was formed several years ago whilst examining Professor Herdman's collection, and they have been altered but little—or added to—for the present purpose. New material has been obtained, and the following remarks verified.

It is believed, however, that the notes will be of some use, and they are accordingly included here. Up to the present twelve species, representing eleven genera, have been identified. Practically nothing is known concerning the Actiniaria inhabiting the seas around Ceylon, so that it is not surprising to find that of these twelve species nine are new to this region. Of the remaining three species, two, viz., *Sphenopus marsupialis* and *Palythoa tuberculosa,* have previously been recorded from the Gulf of Mannar by Thurston, whilst the third, *Zoanthus shackletoni*, was recorded from Adam's Bridge as a new species by Haddon and Duerden.

In all cases the identification was from spirit specimens, and no attempt was made to examine them histologically. On the whole, the specimens were well preserved, but for any thorough work on this group it is absolutely essential that the animals should be narcotized before fixing in order to avoid undue contraction. This process is long and tedious, but the results justify the proceeding, particularly for histological work. In some cases the species have been determined quite satisfactorily, whilst in other cases, where doubt existed, I have preferred simply giving the generic name, rather than committing myself to a determination on which I was not definitely certain. It is very possible that some of these unidentified species may be new to Science. The collection is being added to yearly.

ACTINIARIA.

CERIANTHEÆ.

Family Cerianthidæ.

Cerianthus, sp.

Locality: Tamblegam.

One specimen. Length 2·9 cm. The animal was quite expanded, and tapered gradually towards the base. Aboral pore well defined. Tentacles numerous. Colour, brownish-yellow. No tube was present.

ZOANTHEÆ.

Family Zoanthidæ.

Zoanthus shackletoni, Haddon and Duerden (see 5*).

Localities: Reef, Galle; pearl banks.

* These numbers refer to the literature cited at page 212.

Several large colonies, one of which measured 30 cm. by 4 cm. Average height of polyps 1·5 cm diameter ·5 cm. These types agree with Haddon and Duerden's original description, save in the fact that the stolon appears to be better developed than in the original specimens.

Colour in spirit, yellow-brown.

This species has previously been recorded by the above authors from Adam's Bridge.

Zoanthus, sp.

Locality: Reef, Galle.

One small colony, measuring 7 cm. long and 5 cm. broad. Diameter of polyps 4 mm. Cœnochyme very thin and lamellar. Polyps closely set and scarcely projecting above it. Body wall not incrusted. The colony was strongly contracted, and rather badly preserved. On roughly sectioning, it was only here and there that something of the arrangement of the mesenteries could be observed. I am of the opinion that this species is new.

Colour in spirit, yellowish brown.

Isaurus duchassaigni, Andres, 3.

Locality: Gulf of Mannar, shallow water.

Several specimens. Length 2·7 cm., diameter 1·1 cm. Base firmly adherent, expanded, and irregular in outline. Polyps solitary, column not vertical, but slightly overhanging, and producing a marked asymmetry, in consequence of which the mouth comes to be situated partially on the concave surface. The convex surface bears irregular rows of rounded tubercles, giving the animal a knobbed appearance. The concave surface and the proximal quarter of the polyp is free from tubercles.

Colour in spirit, yellowish brown.

This species was recorded by Dr. Duerden from Jamaica, as well as by Andres, McMurrich, and others from other localities.

Gemmaria variabilis, Duerden, 3.

Locality: Reef, Galle.

One colony, measuring 10 cm. by 5 cm. Height of polyps 2·1 cm., diameter 1·1 cm. Colour in living condition. bright green. Polyps well separated, but connected by cœnosarc. Shape variable. Some are quite cylindrical, others somewhat club-shaped, and all of them are wrinkled towards the base.

Colour of spirit specimens, light yellow.

This species was recorded by the original describer from Jamaica.

Palythoa tuberculosa, Klunz.

Localities: Reef, Galle; pearl banks.

Six colonies, one measuring 19 cm. by 14 cm. Thickness 2·8 cm. Diameter of polyps 1·7 cm. The polyps were strongly contracted, and scarcely projected above the level of the cœnosarc. Colour in spirit, pinkish yellow; peristome a faint red colour.

This species was first recorded from Ceylon by Thurston.

Sphenopus marsupialis, Steenstrup, 4.

Localities: (1) Deep water outside pearl banks, Gulf of Mannar; (2) south-west of Col. Hamilton's Alanturai Paar, 9 to 26 fathoms.

Seventeen specimens; largest measured 6 cm. long and 4 cm. broad. Smallest measured 2 cm. long and 1 cm. broad. The species is solitary. The body wall is strongly incrusted, in consequence of which the whole animal is quite brittle.

Colour in spirit, brown.

Thurston first recorded this species from Ceylon. It is fairly common.

HEXACTINIÆ.

Family Ilyanthidæ.

Halcampa, sp.

Locality: Tamblegam.

Two specimens. Body vermiform. Length 7 cm. The diameter of the anterior half measured 6 mm., that of the posterior half measuring only 2 mm., the transition being rather sudden. Body wall longitudinally furrowed. Tentacles few and contracted. Posterior end distended into a vesicle.

Colour in spirit, dirty brown.

Family Sagartidæ.

Sub-Family Sagartinæ.

Sagartia, sp.

Locality: Reef, Galle.

Numerous specimens. Diameter 3·7 cm. Height 6 to 11 mm. Animals contracted into a flat cake-like mass. Base sinuous and slightly expanded. Tentacles very numerous, extremely short, tubular, and apparently open at their distal extremity.

Colour of spirit specimens, light yellow.

Sub-Family Phellinæ.

Phellia, sp.

Locality: Cheval Paar.

A series of ten specimens, covering shell of *Margaritifera vulgaris*, are referred here with some hesitation. Polyps apple-shaped. Largest specimen measured 3·2 cm. in diameter and 2·1 cm. in height. Basal margin very expanded and irregular in contour. Pedal disc flat and adherent. Basal part of polyps rugose, thick, and gradually thinning out into a very delicate capitulum. Tubercles, vesicles, and cynclides absent. Tentacles few and short. Acontia emitted through the mouth. Colour in spirit, light yellow. Owing to the limited time at my disposal the arrangement of the mesenteries was not determined, but the features cited above are so characteristic that I feel justified in relegating the specimens to this genus.

Sub-Family Metridinæ.

Calliactis, sp.

Localities: Pearl banks, Gulf of Mannar, shallow water.

Fourteen specimens. Diameter of largest 2 cm. Height 2·2 cm. Polyps slightly conical in shape. Pedal disc thin and broadly expanded. Cynclides prominent and arranged in one horizontal row near the base. Tentacles numerous. Acontia very strongly developed.

Colour in spirit, dirty brown.

This genus is abundantly represented in tropical seas.

Sub-Family Chrondactininæ.

Chrondactinia digitata, Müller, 8.

Locality Back Bay, Trincomalee, 11 to 13 fathoms.

Five specimens, attached to shell of *Tudicla*, sp. Base broad and rounded, measuring 2·8 cm. across. Polyps conical in shape, tapering sharply towards the summit. Height 7–11 mm. Body wall rigid and beset with a series of irregularly arranged tubercles, which are not very prominent. Scapus surrounded at the apex by a series of twelve larger tubercles. Mesoglea very thick. Circular muscle large and well defined. Colour in spirit, yellowish brown.

For some time I hesitated in the determination of this species, but it agrees so well with the description and figures given by Haddon of *C. digitata* (see 8) that I feel certain they are identical. The species had only been recorded from European seas, until this record from Ceylon by Herdman.

Genera unidentified.—I.—Locality: Gulf of Mannar, shallow water.

One specimen. Body flat as a sixpence. Length 2·9 cm. Breadth 2 cm. Colour in spirit dirty brown. Tissues delicate. Tubercles, acontia, and ridges absent. Mouth circular. Tentacles probably few and completely retracted. Specimen not anatomically examined.

II.—Locality: West of Periya Paar.

One specimen, growing on shell of *Margaritifera vulgaris.* Polyps conical in shape. Diameter of base 2·6 cm. Height 1·3 cm. Body wall rigid and tuberculated. Capitulum ridged. Tentacles completely retracted.

Colour in spirit, yellow.

The specimen bears some resemblance to *Chondractinia digitata*, but differs from it in the apparent absence of the twelve larger tubercles surrounding the apex of the scapus.

Although the specimen was not anatomically examined, I am of the opinion that it belongs to the genus *Actinauge.*

The *Actiniaria* are not numerous on the pearl banks, either in point of number or species. But, as noted, the collection of this group is increasing yearly, and it is hoped that the systematic account will be worked out fully, later.

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No. 17.

FURTHER NOTES ON THE DETERMINATION OF THE ADULT OF THE PEARL-INDUCING WORM.

By T. SOUTHWELL, A.R.C.Sc. (Lond.), F.L.S., F.Z.S.

The experiment described in No. 6 of Part IV., "Ceylon Marine Biological Reports," was attempted again this year, and unfortunately the results were not more definite in character than those obtained last year.

The object of this experiment was to obtain a series of fish known to feed on oysters, to enclose them in an area in the open sea by means of wire netting; to first clear their gut, if possible, from existing parasites, and finally to limit their food to oysters only, and thus eventually to obtain in their gut the adult worm of the pearl-inducing parasite.

The ss. "Violet" and "Rangasamee" arrived in Silavatarai on February 26, 1910, and succeeding days were occupied in dredging for oysters and trawling for suitable fish. The oysters placed in the enclosure numbered 12,000. They were of mixed ages, and, having been obtained from an inshore area (where alone oysters occurred), they were characterized by their lack of globular cysts in the tissues. Whereas ordinary oysters frequently contain a hundred pearl-inducing parasites, it was by no means common to find a single parasite in these oysters, which were eventually to form the food of the captive fish.

The following fish were trawled, dosed with male fern extract, and placed along with the oysters in the open sea enclosure behind the Silavatarai reef :—

(i.) One specimen, *Tæniura melanospilos*, 4 ft. 6 in. disc.
(ii.) Two specimens, *Serranus undulosus*, 4 ft. long.
(iii.) Three specimens, *Rhynchobatus djeddensis*, 5 ft. long.
(iv.) One specimen, *Ginglymostoma concolor*, 8 ft. 7 in. long.
(v.) Two specimens, *Trygon walga*, 6 ft. 6 in. by 3 ft. 7 in.

Of these, *Tæniura melanospilos* and one *Serranus undulosus* died from shock of transport. At the end of the third day all the specimens of *Rhynchobatus djeddensis* were dead, a result which I attribute entirely to starvation. For in spite of their powerful crushing jaws, it is certain they do not eat oysters. Their natural habitat also indicates the same fact, for they invariably occur on a muddy bottom in shallow water (2–4 fathoms). Several other specimens of this species were afterwards tried in the nursery, invariably with the same result.

As pointed out in Part IV. of this series, fish for the experiment were often trawled 14 miles from the enclosure, and the transport was effected by immediately depositing the fish caught by the trawl into our water boat (free from trawled débris), which latter consists of a midship tank section 14 by 10 by 4 feet. This tank section can be flooded with sea water, and the boat is supported fore and aft by air-tight chambers. Whilst steaming, sea water was continually pumped into the midship tank section, thus ensuring good aeration. This boat was brought alongside the enclosed nursery area; the fish were quickly dosed on deck and immediately placed in the enclosure.

It is to be noted here that the medicating of fish, besides being novel, is interesting, but there are no data to guide one as to the quantity suitable for administration. Besides this, different fish vary amongst themselves in their susceptibility.

The only check experiment I was able to make was with two rays, both trawled at the same place and at the same time. One was examined immediately, and found to contain numerous cestodes in its spiral valve. The other was treated with 30 minims of male fern extract and killed after three days. Only a very few cestodes were found, but the numerous reddish indentations in the spiral valve indicated clearly the positions of those cestodes which had been dislodged.

There thus remained in the nursery at the end of about a week the following fish :—

(a) One specimen, *Serranus undulosus.*
(b) One specimen, *Ginglymostoma concolor.*
(c) Two specimens, *Trygon walga.*

These fish kept well nourished and very active. One *Trygon* was killed on March 26, after having been in the enclosure since March 2; it was found that the parasites had not developed, and as there was no object in waiting in the vicinity of the experiment, I decided to proceed to Colombo for some time and to leave the experiment in progress. I returned again on April 18 and found all the fish in a thriving condition. I proceeded at once to kill them and to carefully examine their intestines.

The results are shown in the following table :—

Name of Fish	Intestinal. Contents.	Cestodes.	Other Parasites	Remarks	Days in Nursery.
Trygon walga ..	One small fish, adductor muscle of oyster, and slime	Minute undeterminable cysts	Absent ..	Well nourished	47 days
Serranus undulosus ..	Empty ..	*Tetrarhynchid* cysts on mesenteries only	A few Nematode cysts on mesenteries	Well nourished	47 days
Ginglymostoma concolor	Small fragments of adductor muscle of oyster	38 specimens of *Tetrarhynchus unionifactor* (adult of the pearl-inducing worm) 140 specimens of *Phyllobothroides hutsoni*, n. sp. 9 specimens of *Phyllobothroides kerkhami*, n. gen., n. sp.	Trematodes *Schistorchis carneus* in numbers on liver	Well nourished	31 days

It will be seen that *Tetrarhynchus unionifactor* was only found in *Ginglymostoma concolor*, and even there the number present was comparatively small. No cestodes of any kind occurred in *Trygon walga*, an unexpected result, which may be incident on the lack of cysts in the oysters eaten. The fact that no oyster shell has up to the present been found in the gut of any of these larger rays confirms my opinion that the shell is vomited after the softer parts are digested. That oysters were being devoured was evidenced by two facts: first, that it is impossible to believe that these fish could have lived so long practically without food, and second, that the floor of the enclosure was covered with crushed shell, without flesh. These latter I had the opportunity of examining carefully and repeatedly in a diving dress. It is interesting to note here the habit of the ray in question. When resting it lay on its ventral surface. By gently flapping its great pectoral fins the sand was disturbed to such an extent that the ray eventually became practically buried in sand and almost invisible, even when close by it in the diving dress and in the clear water of the Gulf of Mannar.

The specimen of *Serranus undulosus* exhibited remarkable tenacity to life. The chief interest attaching to the bony fish in the Gulf of Mannar lies in the fact that up to the present, although thousands of specimens belonging to many species have been repeatedly examined, no adult cestodes have as yet been found in them. Scores of cysts are to be found on the mesenteries, but these contain only the cysticercoid (the head), and no proglottides are present. This matter will be dealt with fully elsewhere.

The presence of two distinct genera of cestodes in *Ginglymostoma concolor* is by no means easy to understand or account for. However, there is one outstanding and important feature, viz., that I have as yet not found *Tetrarhynchus unionifactor* in any fish in the open sea, whereas 38 were found in the specimens of *Ginglymostoma concolor* which had been feeding on the oysters in the enclosure. And last year (March, 1909), under similar conditions, 51 specimens were found in the same species of fish in the same enclosure. It is to be particularly remembered that the oysters on which this fish had been feeding were remarkably deficient in the globular cysts, which eventually develop into the adult worms.

This was the case also last year, and it may account for the small number of *Tetrarhynchus unionifactor* found. The presence of 140 specimens of *Phyllobothroides hutsoni*, n. sp. (and 9 specimens of *Phyllobothroides kerkhami*, n. gen., n. sp.), are difficult to account for. It would seem probable that these cestodes were present when the fish were placed in the enclosure. I am aware that such may have been the case with *Tetrarhynchus unionifactor*. Nevertheless, comparing these results with those of last year, it will be found that in the latter 48 specimens of *Tetrarhynchus herdmani* occurred along with 51 specimens of *Tetrarhynchus unionifactor*, in the same species of fish and under exactly similar circumstances ("Ceylon Marine Biological Reports," Part IV., No 6) Had *Tetrarhynchus herdmani* recurred in this year's results, it might have led one to believe that this species, viz., *Tetrarhynchus herdmani*, was derived from the oyster. But since it did not recur. and *Tetrarhynchus unionifactor did*, I am inclined to believe that *Phyllobothroides hutsoni*, n. sp., was not derived from the oyster, but was present when the fish entered the nursery, and was not dislodged by the male fern extract. Another fact which appears to indicate that this is so is that whilst the specimens of *Phyllobothroides hutsoni*, n. sp., were large, those of *Tetrarhynchus unionifactor* were small.

Still, the results of these feeding experiments, though interesting, must up to date be regarded as somewhat unsettled, but the strong probability is that the adult of this interesting worm *is Tetrarhynchus unionifactor*, that its life-history is direct from the oyster to the fish, and that the adult may occur in all Elasmobranchs which feed on oysters.

No. 18.

DESCRIPTION OF NINE NEW SPECIES OF CESTODE PARASITES, INCLUDING TWO NEW GENERA FROM MARINE FISHES OF CEYLON.

By T. SOUTHWELL, A.R.C.Sc. (Lond.), F.L.S., F.Z.S.

THIS short report is intended to supplement the extensive investigations on the *Cestoda* carried out by Professor Herdman in 1902, and described in Vols. II. and V., "Ceylon Reports."

During the numerous trawling operations conducted by the Company's steam trawler "Violet," I have had unique opportunities, during the last four years, of repeated and extensive examinations of fresh material in a living condition. It is impossible in the present paper to give an adequate estimate of the approximate number of fish examined from time to time, but it must be many thousands, for it occasionally happens that from 500–700 fish are caught in a few hours. Since trawling is only carried on intermittently, I have had time to work out the species both of the fish caught and the contained cestodes, after notes had been made on the living material.

Particular attention has been paid to the Elasmobranchs in general, as many species of this group devour oysters. It is remarkable how rarely the adult of *Tetrarhynchus unionifactor* is found. Personally I have never found the adult form of this species during the whole of my observations, save the ones obtained from *Ginglymostoma concolor* during the feeding experiments described in Part IV. of this series, and again in the present part. It is most probable that this circumstance is incidental on the continued absence of oysters from the banks.

The largest forms of Elasmobranchs which commonly occur on the banks include—

Ginglymostoma concolor.	*Pristis cuspidatus.*
Tæniura melanospilos.	*Pteroplatea micrura.*
Trygon uarnak.	*Myliobatis nieuhofii.*
Rhynchobatus djeddensis.	*Ætobatis narinari.*
Mustelus manazo.	*Rhinoptera javanica* (occasionally).

Some of the above often attain a length of 8 feet, and, excepting the genera *Pristis*, *Mustelus*, and *Pteroplatea*, have enormously powerful plate-like teeth. There can be no doubt that they are capable of eating oysters, though they may have a preference for other articles of food. They have therefore been carefully examined, but up to the present have furnished no further information regarding *Tetrarhynchus unionifactor*, even though they are almost always infected with other cestodes.

The smaller rays, such as *Trygon kuhli* and *Trygon walga*, are about the commonest fish caught, and invariably contain large numbers of cestodes in their spiral valve. The food of these small rays consists almost entirely of worms and small crabs to the certain exclusion of oysters, save probably *very* young forms.

Teleosts, such as *Lethrinus miniatus* and *Lutjanus argentimaculatus*, fish which are known to feed on oysters, have also been repeatedly examined. Up to the present no adult cestodes have been found in them, which practically proves that this group contains only the initial or, at most, the intermediate stages. In this connection it is of great importance to note that in *Serranus undulosus*, as in many other genera, the mesenteries are crowded with club-shaped cysts, varying in size from 5 mm. to

25 mm., and they are rarely absent. They never occur in the gut. These cysts are of a silvery black colour with white bases, and contain young Tetrarhynchids, which measure up to 3 mm. in length Another kind of cyst also occurs extensively in this species, as well as in *Lutjanus argentimaculatus* These latter are milky white and egg-shaped, measuring 8 mm. in length. They also occur on the mesenteries, and contain attached Tetrarhynchids of a slightly smaller size. Similar cysts were collected by Professor Herdman, and are described in Vol. V., " Ceylon Reports." My species are, however, quite different. It is practically certain that the adult stage of these cystic Tetrarhynchids does not occur in the same species of fish, and therefore four questions naturally arise :—

(*a*) In what is the adult stage found ?

(*b*) Is the stage in these Teleosts an initial or a secondary one, and if the latter, what is the first host, and how do the cystic forms become adult ?

(*c*) In what manner does the larva reach the mesenteries ?

(*d*) What is the nature of the primary larva, and how is the infection of the first host brought about ?

The solution of these problems is by no means clear. Specimens of *Serranus undulosus* have repeatedly been caught measuring 4 feet in length, and it would therefore appear that if the adult of these cystic forms does not occur in *Serranus* itself, the final host must be of considerable size, in order to devour a fish of such proportions. I am aware, however, that specimens of *Serranus* caught in inshore waters are usually smaller.

It is a matter of some difficulty to determine theoretically whether the species of Teleosts named represent the primary or secondary host. The exceedingly voracious habits, and the large gape of *Serranus undulosus* in particular, would suggest that it is a secondary host in which the adult ought to be found, and that the globular cyst or first stage occurs in one of the molluscs which are eaten extensively.

Moreover, our present knowledge concerning the development of the group *Tetrarhynchidea* seems to indicate that there are only two hosts. If the cysticercoid stage occurs in the food stuffs eaten by these fish, then one would naturally expect to find the adult worm in the fish concerned. It is a most remarkable circumstance that up to the present I have been unable to discover any adult cestodes in any of the thousands of Teleosts examined.

In attempting to understand the position occupied by these cystic stages in the life-history of the parasite three considerations present themselves :—

(*a*) It is possible that minute encysted cestodes occur in the molluscan (or other) food eaten by these fish, and that these correspond to the globular cysts found in the oyster. When these molluscs are eaten, these larvæ develop further in the tissues of the second host into the encysted and more adult form found on the mesenteries of the fish in question. Unable to develop further there, they are dependent on the third host, before the adult stage can be reached. The difficulty here is in postulating a third host large enough to devour Teleosts, which often attain a length of 4 feet and a diameter of 10 inches.

(*b*) It is further possible, though very unlikely, that the larvæ found encysted in these Teleosts is not derived from any food, but is the result of direct infection from the final and second host. The difficulty in accepting this theory is the same as that given under (*a*).

(*c*) Lastly, it is possible and also most probable, that the encysted larvæ presumably occurring in molluscs develop directly into the adult in the spiral valve of some Elasmobranch, and that the larvæ found encysted on the mesenteries of certain Teleosts, whilst undoubtedly derived from similar molluscan cysts, represent culs-de-sac or blind terminations in the life-history of the parasite ?

This may appear to be an extravagant theory, but I can think of no better explanation. It is true that if such is the case there is an extensive " waste." Such a condition of affairs, however, is not uncommon in Nature, and is illustrated in the *Echinococcus* (*hydatid*) disease in man.

The percentage of cestode eggs or even larvæ, which ever reach maturity, must be very low indeed, and it may be that in the case under consideration the new conditions and the loss of the cyst wall due to digestion may stimulate the larvæ to further development, whilst the general conditions are at the same time unsuited to their full development.

The above are, however, at present but theories, and the working out of the entire life-history of the marine *Cestoda* in general presents a vast and interesting field for future workers. It is a common thing on the pearl banks, and elsewhere also, to find six or seven different genera of species of cestodes in the spiral valve of, say, *Trygon kuhli*. The food of this species of fish is well known, but our knowledge of the cysts from which the adult worm is derived and the life-history is a perfect blank. The same is the case with almost all cestodes. Although in most instances the interest attaching to the elucidation of such problems is purely scientific, it is not wholly so, and in this connection no better instance of the commercial value of such research work can be given than the pearl oyster. The whole interest attaching to pearl fishing in Ceylon centres round a cestode larva, its life-history, and its distribution.

I have examined many specimens of the same species of fish from which the cestodes were obtained, which are described in Vols. II. and V., "Ceylon Reports." Out of the 52 species of cestodes named and collected by Professor Herdman, I have obtained large numbers of 30 species, and found the descriptions given, not only sufficient for purposes of identification, but also very exact.

In this paper nine new species and two new genera are described, viz.:—

(1) *Calliobothrium farmeri*, n. sp.
(2) *Cephalobothrium abruptum*, n. sp.
(3) *Cephalobothrium variabile*, n. sp.
(4) *Phyllobothroides kerkhami*, n. gen., n. sp.
(5) *Phyllobothroides hutsoni*, n. sp.
(6) *Echinobothrium boisii*, n. sp.
(7) *Rhinebothrium insignia*, n. sp.
(8) *Cyclobothrium typicum*, n. gen., n. sp.
(9) *Tetrarhynchus spinulifera*, n. sp.

I also include a few further notes on the adult of *Tetrarhynchus unionifactor*, with a figure giving details, as the species is not figured in detail in Vol. V., "Ceylon Reports."

I have been unable to describe the internal anatomy of most of these new species, as the work has been done out at sea, but I am confident that the details given are sufficient to identify the species.

During the preparation of this paper I have laboured under an extreme disadvantage owing to the inaccessibility of literature. Throughout, however, I have endeavoured to be precise, and, above all accurate. The Trematode and Nematode parasites are not nearly so numerous as Cestodes. Amongst those collected by me, and not described by Herdman, are the following undetermined species:—

(*a*) Cysts containing Trematodes from *Pinna bullata*.
(*b*) Free nematodes 1 cm. long from the gut of the turtle (*Chelonia viridis*).
(*c*) Free nematodes 3·5 cm. long from the gut of *Tæniura melanospilos*.

The collection of 39 named species, including the new genera and species described herein, have been deposited in the Colombo Museum for reference.

All these cestodes were first killed in fresh water, and then preserved in 5 per cent. formalin.

Calliobothrium farmeri, n. sp.* (Plate V., Figs. 3*a*, 3*b*, and 3*c*.)

This large and graceful Cestode was found in the spiral valve of a small *Trygon walga*. Only two specimens were obtained,† but their size and tough nature allow of an accurate description of their external features. They attain a length of 7 cm. The head measures 5 mm. broad by about 2 mm. long. There are 4 sessile bothridia, borne at right angles to the long axis of the worm, or they may hang backwards a little. Not only are they sessile, but they are united together for some distance along their length in such a way that the anterior view of the head is almost that of a square. Each bothridium extends to the centre of the head, narrowing slightly and becoming produced or lumpy anteriorly, so that all four remain distinct. On the more central produced part of each bothridium two brown chitinous hooks are borne, which point backwards. They are visible to the naked eye. The distal part of

* Named in honour of Professor J. B. Farmer, F.R.S., D.Sc., Professor of Botany, Imperial College of Science, London.

† Several more specimens have since been obtained, from *Trygon kuhli*.

each bothridium bears 3 areolas or suckers on its anterior face, but is simple on its posterior face. The hooks overhang the proximal areola of each bothridium. Between the centre of the head and each pair of hooks there is a minute accessory papilliform sucker. All these, except the minute anterior suckers, can be well seen with the unaided eye. There is a swollen neck 2 mm. long and 1·5 mm. broad. Segmentation is first indicated by the cuticle being ringed, and in this part alone a pair of coiled lateral water vascular tubes can be seen. The proglottides are flat. There is no overlapping. The first proglottides are about 13 times broader than long, with slightly convex sides. These proglottides continue posteriorly with little or no alteration foı 3 cm., where the proglottides are then 3·2 mm. broad. The opaqueness of the worm makes these proglottides look more like a ringed cuticle ; but they are perfectly regular, and the division lines can be clearly seen. The proglottides from this point then increase in length and narrow slightly, becoming square, and finally cylindrical. The genital glands are lateral and situated close, and strictly parallel, to the edge. The genital pores are lateral, all on one side, and appear as deep narrow slit-like indentations.

The diagnosis of *Calliobothrium farmeri*, n. sp., is as follows :—

Stout opaque worms 7 cm. long. Head very large, with four sessile outspreading bothridia, which remain distinct, although united for some distance along their length. The anterior view of the head is that of a square divided into four, and indented along its lateral and dorso-ventral axes. The bothridia each bear 3 large areola-like suckers distally, which occupy the greater part of their anterior surface, and two brown backwardly directed hooks nearer the centre of the head, which overhang the proximal areola of each bothridium. There is a minute accessory papilliform sucker just immediately proximal to each pair of hooks. Posterior surfaces of bothridia simple. Neck short and swollen. About half the worm is made up of exceedingly shallow ring-like proglottides. The succeeding proglottides increase in length and narrow slightly, becoming square, then cylindrical. Greatest breadth 3 2 mm. There is no overlapping. Genital glands lateral, paired, and strictly parallel to the edges. Genital pores lateral, and all on one side. Water vascular tubes coiled.

Habitat.—The spiral valve of *Trygon walga*. Two specimens. Portugal Bay. March 9, 1910.

In various respects this cestode resembles the following species :—

Oncobothrium uncinatum, Rudolphi.
Calliobothrium ætiobatis, Shipley.
Calliobothrium eschrichtii, Van Beneden.
Calliobothrium verticillatum, Rudolphi.
Acanthobothrium coronatum, Rudolphi.

These genera are very closely related.

The following table summarizes some of the more important points in which the above species both agree and differ amongst themselves :—

	Bothridia.	Hooks.	Accessory Suckers.
Calliobothrium farmeri, n. sp. ..	Each bothridium with 3 loculi	One simple pair to each bothridium	One accessory sucker to each bothridium
Calliobothrium verticillatum ..	Each bothridium with 3 loculi	Four pairs to each bothridium	Three accessory suckers to each bothridium
Calliobothrium eschrichtii ..	Each bothridium with 3 loculi	Two pairs not bifurcated to each bothridium	One accessory sucker to each bothridium
Calliobothrium ætiobatis ..	Each bothridium with 3 loculi	One bifurcated pair to each bothridium	One accessory sucker to each bothridium
Oncobothrium uncinatum ..	Each bothridium with 3 loculi	One simple pair to each bothridium	No accessory suckers
Acanthobothrium coronatum ..	Each bothridium with 3 loculi	One bifurcated pair to each bothridium	Three accessory suckers to each bothridium

From the above it will be noted that *Calliobothrium farmeri*, n. sp., differs from the other species of the same genus in the possession of simple hooks.

The size of our species, the relative proportions of the head, and otheı variations in the strobilization are, however, sufficient to differentiate it from the rest.

CEPHALOBOTHRIUM ABRUPTUM, n. sp. (Plate V., Figs. 4*a* and 4*b*.)

Stout worms 11 or 12 cm. long from the spiral valve of *Pteroplatea micrura*. The head is 1·2 mm. broad, and is roughly egg-shaped, slightly longer than broad, and varying a little in shape with the state of contraction. It is really made up of two parts. Anteriorly there is a large protrusible sucker. This is succeeded by a basal part, shaped like a truncated cone having the broad base forward, and bearing 4 minute suckers with swollen lips, which are slightly raised above the surface, and are situated 2 on each side. There is a short neck, which is slightly longer than the head, and has the cuticle wrinkled.

The proglottides are oval in section, and are divided sharply into two sets. This division is a notable feature, which can be well seen with the naked eye. All the unripe segments are much broader than long, and the ripe segments are much longer than broad. This characteristic is most striking. The proglottides which succeed the neck are many times broader than long, with slightly convex sides and markedly wrinkled. As they become longer the wrinkling disappears and the edges become salient, and overlap more and more up to the last of the unripe proglottides, which latter are almost one-third as long as broad. Up to this point the worm measures from 6–8 cm. in length and 1·5 mm. broad. The ripe proglottides measure in all from 3–5 cm. in length. Only 1 or at most 2 proglottides separate the ripe from the unripe proglottides. As noted the ripe proglottides are half as broad as long, being about 1·2 mm. long and ·6 mm. broad. Their anterior extremities are considerably narrowed, and the two sides not quite symmetrical.

The reproductive organs are paired and are lateral. The genital pore is lateral and irregularly alternate. The penis is club-shaped, and is situated about one-third the length of the proglottis from the anterior end, and measures one-third the breadth of the proglottis. There is a clear patch—the uterus—situated anteriorly between the reproductive glands in each proglottis. The cuticle is not wrinkled.

The description of the genus *Cephalobothrium*, as described by Shipley and Hornell, is as under :—

A large median sucker takes up most of the head ; it is controlled by longitudinal muscles. Four small spherical suckers are placed equidistant from each other in the rim of the circular sucker. The proglottides are wider than broad, with the exception of the last six or seven. The reproductive pores are lateral and very irregularly alternate.

The diagnosis of *Cephalobothrium abruptum*, n. sp., is as follows :—

Worms 12 cm. long, stoutest about the centre. Head egg-shaped with a large terminal protrusible sucker and 4 subsidiary suckers having swollen lips. These latter are situated around the anterior end of the head, which latter gradually passes into the neck. The suckers are controlled by longitudinal muscles. Neck slightly longer than the head and wrinkled. Proglottides of two kinds, an anterior unripe set occupying about 7 cm., which are longer than broad, the transition being sudden. Neck and anterior parts of unripe segments wrinkled, the latter having convex sides, which gradually become salient. Ripe segments twice as long as broad. Reproductive glands paired and lateral. Genital pore lateral and irregularly alternate. Cuticle not wrinkled.

Habitat.—The spiral valve of *Pteroplatea micrura*. Eighty-seven specimens. Portugal Bay. March 5, 1910.

The species differs from *Cephalobothrium ætobatidis*, Shipley and Hornell, in the shape of the head and the terminal sucker, in having a short neck, and in being enormously larger.

It differs from *Cephalobothrium variabilis*, n. sp., in having 4 instead of 2 suckers, in having a protrusible sucker, and in the nature of the strobilization. It is to be noted that in *Cephalobothrium abruptum* the smaller and riper proglottides often drop off when the worm is exposed, and this circumstance might make the identification more difficult.

CEPHALOBOTHRIUM VARIABILE, n. sp. (Plate I., Figs. 5*a*, 5*b*, and 5*c*.)

This cestode is the longest one I have ever obtained from any fish. It was found in the intestine of a female specimen (containing 23 intra-uterine embryos, described in "Spolia Zeylanica") of *Pristis cuspidatus*, which measured 15½ feet, and was trawled in Portugal Bay (pearl banks) on December 15, 1909. Measurements of the living worm were not made, but the dead specimens measured 13 cm. In comparison to its length this worm is somewhat slender, never measuring more than ·5 mm. across the ripe posterior proglottides.

The 47 specimens found and examined were all fairly transparent under the microscope, and were only very slightly opaque.

No living specimens were examined, and it is interesting to note that no other species of cestode occurred along with it in the gut of the fish.

The outstanding features of this worm—which bears a close resemblance to *Cephalobothrium ætobatidis*, Shipley and Hornell—is its remarkable variability, hence the specific name. The head is somewhat triangular in shape, 1 mm. broad, the anterior base terminating in a huge circular sucker, bordered by thickened lips, which are slightly frilled, and which are controlled by very striking longitudinal bands of muscle. On each side of the head is a very minute U-shaped sucker. The thickened rim of the large anterior sucker, which is opaque, contrasts strongly with the thin tissue forming the central portion of the head, in which the longitudinal muscular bands can be clearly seen.

There is no myzorhynchus.

The "neck" appears to be pushed into the head, and its anterior extremity is somewhat opaque, so that the clear central part of the head shows up plainly between this and the opaque rim of the anterior sucker. The neck is very long, and clear transverse rings (which are not proglottides)—far apart—can be seen in it. The head and neck are minutely wrinkled.

The first proglottides are almost four times as broad as long, with insipient overlapping, which becomes very remarkably pronounced farther back. The posterior segments are squarish, with a remarkable bell-like rim, which strongly overlaps the succeeding proglottides.

Over 400 proglottides were counted.

The reproductive glands are situated laterally, and the genital pores are lateral and very irregularly alternate. The protruded penis is of moderate length, bent on itself at right angles, and points backward.

The water vascular system consists of four tubes running the whole length of the animal. They can be seen to spread out in the head round the terminal sucker. In the posterior ripe segments, and probably throughout, two of these tubes run centrally and one on each side.

The varieties met with are connected with the strobilization. Portions of the body may become attenuated or greatly enlarged. The normal short and broad proglottides may succeed a section with proglottides as broad as long, with convex sides, and *vice versâ*. A ringed puckering of the sides is common. Occasionally the last two or three proglottides may be much longer than broad, with the "bell rim" less pronounced. The head may appear elongated, or saucer-shaped, according to the state of contraction.

Some of the features just named are undoubtedly characteristic, whilst others (such as wrinkling of the cuticle) may be post-mortem effects.

The species differs from *Cephalobothrium ætobatidis* in—

(1) Being thirteen times longer.
(2) In the striking overlapping of the proglottides.
(3) In only having two subsidiary suckers.
(4) In its variability.

The diagnosis of *Cephalobothrium variabile*, n. sp., is as follows :—

Long worms of 13 cm. Head bell-shaped, with a very large terminal sucker, and two minute subsidiary ones. Neck very long. Anterior segments broader than long; posterior ones squarish, with a bell-shaped rim. Proglottides strongly overlapping. Reproductive glands lateral, and the pores are very irregular, alternate, and lateral. Proglottides variable.

Habitat.—The intestine of *Pristis cuspidatus*; 47 specimens. Portugal Bay. December 15, 1909.

PHYLLOBOTHROIDES, n. gen.

Head with four simple, undivided, leaf-like bothridia, which are slightly concave.

Overhanging the proximal part of each bothridium are a pair of simple or bifurcated hooks. Neck fairly long. Proglottides not salient. Cuticle ringed throughout.

PHYLLOBOTHROIDES KERKHAMI, n. sp. (Plate IV., Figs. 1*a*, 1*b*, 1*c*, and 1*d*.)

Two hundred and seventy specimens of this cestode were found along with a single specimen of another species—probably new—and seven specimens of *Rhinebothrium ceylonicum*, Shipley and Hornell, in the intestine of a large specimen of *Chiloscyllium indicum* (Gmel.) trawled on the Ceylon pearl banks during December, 1909.

The worm is small and delicate; the head is visible to the naked eye, and the posterior and ripe proglottides can be seen to be slightly curved upon themselves. These observations were made both on living and dead specimens. The former, after observations had been concluded, were first killed and cleaned in fresh water, then preserved in 5 per cent. formalin.

The adult worm measured 15 mm. Head squarish, and almost ·5 mm. across. There are 4 sessile bothridia, which are longer than broad, and which usually hang downwards like lappets, although they are capable of great movement. They are elliptical in shape and separated from each other. The outer surface of each is distinctly concave, and the outer edge very slightly thickened. When suitably pressed under a cover-slip the microscopic appearance of the bothridia, spread out, is roughly similar in appearance to a pressed wall-flower or a Maltese cross. On the anterior edge of each bothridium and on each side are a pair of long, slender, curved hooks, united at their base, and of stag-horn appearance. The hooks of each pair are of slightly unequal length, and the shorter one is expanded (humped) at its base. The bases of each of these pairs of hooks, which overhang each bothridium, arise close together near the anterior centre of each bothridium and curve out towards the free edge, where each bothridium adjoins the next. There are thus two pairs of hooks to each bothridium, making 16 hooks in all, arranged in pairs, which when viewed anteriorly appear as a regular rosette.

The spines are of a clear glassy consistency. There is no myzorhynchus, and suckers are absent. The neck, which is not attenuated, is as long as the head. The proglottides are at first much broader than long, but gradually elongate, until the last proglottides are 4·5 times as long as broad. There is no overlapping of the segments, and their lines of junction are perfectly straight. The last few segments are curved upon themselves, and narrow considerably towards their posterior ends. The segments were so opaque that the arrangement of the genital pores could not be made out. In all 28 proglottides were counted in the adult worm, besides a few anterior indistinct ones. The cuticle is minutely wrinkled.

The diagnosis of *Phyllobothroides kerkhami* is—

Small delicate worms 15 mm. long. Head squarish, with 4 concave bothridia or lappets, and a rosette of 16 anterior hooks. Neck as long as the head. The proglottides, which come after the head, broader than long, but increase in length posteriorly, until the last proglottides are 4·5 times as long as broad, and slightly curved on themselves. No overlapping of the segments, and their lines of junction perfectly straight. Cuticle minutely wrinkled.

Habitat.—Intestine of *Chiloscyllium indicum*; 270 specimens. Ceylon pearl banks. February 13, 1910.

I have pleasure in naming this species in honour of J. C. Kerkham, R.N.R., my fellow-worker, to whose assistance I owe much.

PHYLLOBOTHROIDES HUTSONI, n. sp. (Plate IV., Figs. 10*a*, 10*b*, and 10*c*.)

Over a hundred specimens of this worm were taken from a single specimen of *Ginglymostoma concolor*.

The worms measure up to 7 cm. in length. The head is square and conspicuous, being 1 mm. long and 1 mm. broad. It consists of 4 sessile, fleshy, sucker-like bothridia, which are slightly indented at the centre of their posterior edges. The margin of each bothridium is thickened. Surmounting each bothridium (*i.e.*, at the anterior extremity) are a pair of minute hooks.

There is a comparatively long neck, usually about 8 mm. long. Segmentation is at first indistinct, and the segments are broader than long; but they gradually elongate, first becoming square, then longer than broad. In the ripe proglottides the eggs are conspicuous. The genital pores are lateral and irregular. There is a median excretory tube which runs the length of the proglottides.

The proglottides succeeding the neck have straight edges, whilst the ripe ones become increasingly barrel-shaped. The posterior edges of the segments are not salient.

Habitat.—The spiral valve of *Ginglymostoma concolor*. One hundred and seventeen specimens. Silavatarai nursery. March, 1910.

ECHINOBOTHRIUM BOISII, n. sp. (Plate V., Figs. 6*a*, 6*b*, and 6*c*.)

A single specimen only was obtained from the spiral valve of *Ætobatis narinari*. The worm measured 10 mm. long, but all the ripe proglottides are missing. The head is 2 mm. long, and consists of an anterior umbrella-like structure 1·3 mm. broad, bearing numbers of long, pointed, curved, yellow spines or coronal hooks clustered principally at each side. This is succeeded by a somewhat bulbous neck devoid of spines and overhung, and somewhat hidden, by two lappets, which are united over the bulbous portion along the greater part of their length. It was not determined whether this neck was segmented or not. Succeeding the neck, and commencing immediately at the posterior end of the lappets, is an armed portion, or "Kopfstiel," 1·3 mm. long. This bears 8 longitudinal rows of minute teeth with 24 teeth in each row. These teeth are apparently triradiate, the paired shorter processes of each tooth being anterior, and their lateral terminations being either pointed or knobbed. The point of juncture of these parts of the teeth is somewhat thickened. Strobilization commences immediately. The segments are first much broader than long, becoming square, then cylindrical. The sides and division lines of the segments are perfectly straight. Our worm had no ripe proglottides, so that no observations were made on the reproductive anatomy. The diagnosis of *Echinobothrium boisii*, n. sp., is as follows :—

Head with spines and two lappets; umbrella-shaped anteriorly. Neck bulbous, unarmed, and covered by the two lappets, which are united along the greater part of their length. An armed region with 8 rows of teeth and 24 teeth in each row separates the neck from the segments. The latter are at first broader than long, then square, and finally cylindrical; their sides and lines of division perfectly straight.

Habitat.—The spiral valve of *Ætobatis narinari*. One specimen. Portugal Bay. December 18, 1910.

This species differs from *Echinobothrium rhinoptera*, Shipley and Hornell, in the size, in the shape of the head and neck, in the number of teeth on the "Kopfstiel," and in the presence of spines on the head. Although I have seen no other species of this genus, my specimen cannot be *Echinobothrium affine*, *E. typus*, *E. brachysoma*, or *E. musteli*, for these are said to have no neck. The neck in our specimen is well defined. I have pleasure in naming this species in honour of Sir Stanley Bois, Kt., whose interest in scientific matters relating to the Ceylon pearl banks has made the work possible.

RHINEBOTHRIUM INSIGNIA, n. sp. (Plate II., Fig. 7.)

Delicate worms 3 cm. long from the spiral valve of *Trygon uarnak*. The head measures 1·4 mm. across when fully expanded and bears 4 leaf-like bothridia carried on long delicate stalks. On each bothridium there are 34 areolas, one at each end, and 16 pairs. The latter extended to the centre of the bothridia. Each bothridium is constricted on both sides of its long axis, whilst centrally the areolas of each side are divided from each other by a little ridge of tissue running the length of the bothridium and terminating at the single areolas situated at each end. Each bothridium is thus divided into 4 parts, each with 8 areolas and a half of the terminal ones. The ridges separating the areolas from each other are convex on that half of the bothridium distal to the head and concave on the proximal part. The stalks are very long, and attached to the bothridia by their posterior centre. There is a neck 7 mm. long and ·2 mm. broad, which is thin and whip-like, and contains well-defined longitudinal muscles. Strobilization commences suddenly and definitely, and is marked by the worm becoming opaque under the microscope. The proglottides are at first broader than long; but posteriorly they become square, then cylindrical. The edges are slightly convex, and there is no overlapping. About 80 segments were counted, and the posterior ones were not ripe. The reproductive pores were therefore not noted. The reproductive glands are central and ringed, and a clear water vascular tube appeared to run longitudinally through the centre of the worm. Their breadth is ·4 mm.

The diagnosis of *Rhinebothrium insignia*, n. sp., is as follows :—

Four simple leaf-like bothridia, each with 34 areolas, and constricted at the middle of their length. They are borne on long slender stalks. Neck very long and whip-like. Proglottides at first broader than long, then square, and finally cylindrical, with slightly convex sides. No overlapping.

Habitat.—The spiral valve of *Trygon varnak*. Vankali Paar. March 13, 1910. One specimen.*

* Since obtained from *Trygon kuhli*.

This species bears a general resemblance to *Echeneibothrium minimum*, Shipley and Hornell, but differs from it in the shape of the bothridia, in the number of areolas, and in the respective lengths of the stalks and the neck

Our specimen did not bear ripe proglottides.

CYCLOBOTHRIUM, n. gen.

Worms 8 cm. long. Head shaped like a daisy, with a central myzorhynchus bearing a pair of suckers, and surrounded externally by a frill of about 14 long hollow unbranched digitate sucker-like tentacles, arising from the base of the myzorhynchus. Neck long. Segments not salient. Genital pores irregularly alternate and lateral.

CYCLOBOTHRIUM TYPICUM, n. sp. (Plate IV., Figs. 2*a*, 2*b*, and 2*c*.)

Length 8 cm. Head 1 mm. broad, ·5 mm. long, and consisting of a large, central, slightly bifid myzorhynchus bearing two small suckers near its base.

From its base about 14 hollow unbranched digitate sucker-like processes arise, which spread out in a plane almost at right angles to the long axis of the worm, but with their terminations directed towards the anterior. Neck fairly stout, 2 mm. long, and containing well-defined longitudinal muscles. Anterior proglottides shallow; and much broader than long, gradually becoming square, then longer than broad, with slightly convex sides Greatest breadth 1·7 mm. No overlapping. Length of posterior segments 2 mm. Reproductive pores lateral and irregularly alternate. The vas deferens and penis are indicated by a clear patch which runs from the side of the segment, anteriorly to the middle, then turns sharply backward in an acute angle and runs to the posterior end of the proglottid.

Habitat.—Intestine of *Ætobatis narinari*. One specimen. Portugal Bay. March 15, 1910.

This genus bears a close resemblance to the genus *Thysanobothrium*, Shipley and Hornell, and is equally remarkable. The chief point of difference *is the absence in Cyclobothrium, n. gen., of a cup-like shield bearing suckers*, and the presence of a pair of suckers on what obviously corresponds to the central "knob" of Shipley and Hornell. These differences are well defined, and are clearly distinctive. Other minor points of difference refer to the number and nature of the tentacles, and the contour of the vas deferens and penis.

I have compared my specimen with *Thysanobothrium uarnakense*, Shipley and Hornell, of which latter I have a collection of over 20 specimens from *Trygon walga*. In my specimens of their species there is a distinct and even pronounced overlap of the segments, but otherwise their description agrees perfectly.

TETRARHYNCHUS SPINULIFERA, n. sp. (Plate V., Figs. 12*a*, 12*b*, 12*c*, and 12*d*.)

Six specimens of this remarkable cestode were taken from the spiral valve of *Rhynchobatus djeddensis* as far back as November, 1908.

The length of the largest was 5·5 cm. The head measured 3 mm. across by 1·8 mm. long. Posterior ripe segments almost black and measuring 1·8 mm. long by 1·4 mm. broad.

There are two simple leaf-like bothridia or lappets, almost resembling those figured of *Tetrarhynchus carcharidis* in Vol. V., "Ceylon Reports." There are also four armed proboscides, but in no case could they be made to protrude, and the shape of the teeth was therefore not noted. The proboscides are coiled and long, and their sacs have the walls marked by lines of muscles crossing each other in minute regular rhomboids, and simulating a similar structure in *Tetrarhynchus rhynchobatidis* described on page 69 of Vol. V., "Ceylon Reports." The whole head, from the anterior to the base of the sacs of the proboscides, is covered on the exterior with excessively minute, simple, backwardly directed, slightly curved spines, having a broad base and a pointed extremity. This is a very characteristic feature, from which the species is named.

There is a short neck, after which indistinct segmentation commences. The first segments discernible can be seen to have irregular lines of division, and to be much broader than long. Later the segments become square, and then longer than broad, when it is seen that the proglottides are extremely salient, and have their posterior overlapping edges divided into eight very clearly distinct processes, shaped like isosceles triangles. This is a second very characteristic feature. As the proglottides elongate, these digitate processes become smaller and smaller, until in the very ripe segments the transverse lines of division are practically straight. The reproductive pores are lateral and irregular. The ripe proglottides are almost black, and I was unable to make out their internal structure.

The diagnosis of *Tetrarhynchus spinulifera*, n. sp., is as follows :—

Fairly long worms, with a very delicate head passing into a rather stout body. Head with two simple sucker-like lappets. Proboscides long, and the wall of their sacs marked by muscles crossing each other in rhomboidal fashion. The whole exterior of the head armed with excessively minute hooks There is a stout neck. The proglottides are characterized by their posterior edges being split up into eight well-defined digitate processes which overhang the succeeding segments. In the last two or three ripe segments this characteristic dies away, and the lines of division are practically straight. Reproductive pores lateral and irregularly alternate.

Habitat.—The spiral valve of *Rhynchobatus djeddensis*. Six specimens. Vankali Paar. November 15, 1908.

NOTES ON TETRARHYNCHUS UNIONIFACTOR. (Plate I , Figs. 8, 9*a*, and 9*b*.)

The only figure given of the adult of this interesting worm is a line sketch in Vol. V., "Ceylon Reports," Plate IV., figs. 63 and 64, and no details are shown.

The following additional notes were made from specimens obtained from *Ginglymostoma concolor*, which had been fed exclusively on pearl oysters for three weeks (*vide* "Ceylon Marine Biological Reports." Part IV.). These forms, it must be noted, were at most not more than 27 days old. The bothridia, although leaf-like in the living state, are almost circular when contracted, and bear a striking resemblance to the bothridia of *Tetrarhynchus carcharidis* shown on Plate II., fig. 37, of Vol. V., "Ceylon Reports" However, this is the only feature they have in common. In *Tetrarhynchus unionifactor* the posterior edges of the bothridia are occasionally slightly indented and have a little thickening or rim all round. The proboscides pass through the anterior extremity of the bothridia, a pair on each side, but their exits are all separate. The spines are slender and slightly curved. The sacs of the proboscides are evenly cylindrical and are a little shorter than the brothridia, the two together occupying about half the whole head. There is a granular deposition in the head, which is arranged in diagonal lines, crossing each other, and seen clearly near the proboscis sacs The first proglottides are but slightly "saucer-shaped," and no wrinkling was observed. My specimen being young. the posterior proglottides were scarcely ripe and no bagginess was noted In all other points the description given by Shipley and Hornell applied absolutely.

CESTODE, sp. (Plate IV., Fig. 11.)

I here include a figure of a peculiar form which was found in the spiral valve of *Trygon walga*, which at first I mistook to be a cestode, but which, on anatomical investigation proved not to be a cestode.

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No. 19.

DESCRIPTION OF A NEW SPECIES OF PINNOTERES, AND OF THE FEMALE OF P. MARGARITIFERÆ, LAURIE.

(*Plate III.*)

By T. SOUTHWELL, A.R.C.Sc. (Lond.), F.L.S., F.Z.S.

Large species of *Pinna bullata* and *Mytilus*, sp., abound on the Kondatchi Paar, Ceylon pearl banks.

The specimens of *Pinna bullata*, sp., often measure 14 inches in length, and lie with their pointed ends buried in the muddy sand to a depth of 4 or 5 inches, each with their byssus attached to very coarse quartz grains. The species of *Mytilus* usually measure 4 inches in extreme length, by 1 inch in thickness, and the shell is perfectly black.

A number of these forms were collected and examined, and the following table shows the numbers of *Pinnoteres* and *Conchodytes* obtained :—

Mytilus, sp.—Twenty-eight specimens yielded—

(*a*) Twenty-four, each with one symbiotic female *Pinnoteres margaritiferæ*, Laurie.
(*b*) Two, each with one male and one female *Pinnoteres margaritiferæ*, Laurie.
(*c*) Two, each with no *Pinnoteres*.

Pinnabullata, sp.—Forty-seven specimens yielded—

(*a*) Three specimens, each with one female *Pinnoteres ridgewayi*, n. sp., and no *Conchodytes meleagrinæ*.
(*b*) One specimen, with one male *Conchodytes meleagrinæ*.
(*c*) Forty-three specimens, each with a male and female *Conchodytes meleagrinæ*.

Pinnoteres ridgewayi, n. sp., Female. (Plate III., Figs. 1, 2, and 2*a*.)

Body soft and membranous. Carapace 15 mm. broad, 13 mm. long, oval transversely, smooth, and somewhat flattened. Lateral margins entire. Rostrum fairly pronounced and bent. Eyes, eye-stalks, and the whole of the orbit hidden in a dorsal view. Eyes exceedingly minute, but just visible to the naked eye, and sessile. Antennæ minute (1 mm.) and placed internal to the orbital hiatus.

Chelipeds smooth, equal, small in comparison to the body, and exactly equal in length to the breadth of the carapace; permanently bent at right angles dorso-ventrally at the junction of the carpopodite and meropodite. Propodite and dactylopodite equal in length to the rest of the cheliped. Dactylus barely as long as the carpopodite, and bearing a minute tooth proximally and a few fine silky hairs.

The first pair of walking legs are slightly shorter than the second pair, and the latter are shorter than the third pair, the fourth pair being smallest. The third pair of walking legs 21 mm. long, of which—

Dactylopodite is 3 mm. long.	Carpopodite is 5 mm. long.
Propodite is 5 mm. long.	Meropodite is 8 mm. long.

Dactylus and distal part of propodite covered with fine silky hairs. The other walking legs similar.

Abdomen very broad throughout, permanently flexed under the abdomen, and 7-jointed. Posterior edge of abdominal segments setose, and reaching anteriorly to the mandibles.

First, sixth, and seventh abdominal segments without appendages, the rest with paired appendages. Those on segments 4 and 5 are without exopodites, whilst those on segments 2 and 3 have both endopodites and exopodites. (Plate III., Fig. 2*a*.)

No males of this species were obtained.

Natural Colours.—Carapace, central part of abdomen, and legs, maroon. The rest dirty yellow.

Three females, from *Pinna bullata*, sp. Kondatchi Paar. February 18, 1910.

I have pleasure in naming this species in honour of Sir West Ridgeway, G.C.M.G., G.C.B., K.C.S.I., late Governor of Ceylon.

PINNOTERES MARGARITIFERÆ, Laurie. (Plate III., Figs. 3 and 3*a*.)

Female.—Carapace 10 mm. broad, 9 mm. long, soft, smooth, and slightly convex. Eyes hardly visible in a dorsal view, small, and sessile. Rostrum, of two projections, separated by a median furrow. Antennæ minute. Chelipeds equal, 8 mm. long, permanently bent at right angles dorso-ventrally, and covered with short, thickly-set minute hairs. Fingers one-third the length of the hand, and crossing at their tips. No hiatus between them when closed. Third pair of walking legs 9 mm. long. All the walking legs covered with short minute hairs, giving them a punctate appearance. Dactylus, sword-like and flattened. Abdomen permanently flexed, and not nearly reaching ventrally to the mandibles. Abdominal appendages as in *Pinnoteres ridgewayi*, n. sp.

Natural Colours.—Dirty yellow shading into pink in places. Eggs chocolate to maroon.

Habitat.—*Mytilus*, sp., and more occasionally *Margaritifera vulgaris*. Sometimes found free. Kondatchi Paar. February 18, 1910.

At first I regarded my specimens as new species, since my collection then consisted of females only. During further examinations of the same mollusc, however, two specimens were found, each containing both a male and a female *Pinnoteres*. The male is undoubtedly *P. margaritiferæ*, Laurie (Vol. V., "Ceylon Reports"), and the specimens described above are obviously the female of the same species. The female was not obtained by Laurie, and therefore it is described above for the first time.

It is important to note the preponderance of females over males, the more so since Laurie obtained a single specimen only. His specimen may have dropped from its partner, on the deck of the steamer engaged dredging during Professor Herdman's survey of the banks, although it also appears to occur free.

The occurrence of *P. margaritiferæ* in both the Ceylon oyster and mussel is notable. It appears often in dredgings on this paar, and has also been found by divers working under my supervision, who state that it occurs free on the sea bottom. It differs considerably from *P. ridgewayi*, n. sp., besides being only about one-third the size. It also differs from *P. placunæ*, Southwell and Hornell, in the shape of the rostrum, and in being more convex.

In both species the carapace of the male is hard, whilst that of the female is soft. The male is invariably the smaller, and not so brightly coloured.

APPENDIX.

A NOTE ON THE APPENDED CHART OF THE CHEVAL PAAR.

By J. C. KERKHAM, R.N.R.

THE new configuration of the Cheval Paar, as shown by the accompanying chart, gives the contour of the paar a somewhat different form to that in Captain Donnan's chart, which latter represents the Cheval Paar as horseshoe-shaped, the ends being to the north, and the East and West Cheval connected on the south.

During the inspection in 1908 (shortly after I had taken up the duties of Superintendent of Fisheries) it became apparent that the charted figure of the paar was not entirely correct, as the East Cheval was found to be entirely separated from the West by a narrow strip of sand extending north from the Karativu shoal, which practically entirely separates the East from the West Cheval, although a narrow run of rocky ground is shown connecting the two areas on the north.

It will be seen on reference to the chart that the rocky ground—paar—lends itself to the following natural divisions :—The West Cheval and the East Cheval, the latter having extensions to the north, north-east, and south-east.

The general features of the Cheval and other details will appear in Part VI., dealing with the method adopted in tracing out the rocky area known as the Cheval, as well as other paars or rock areas.

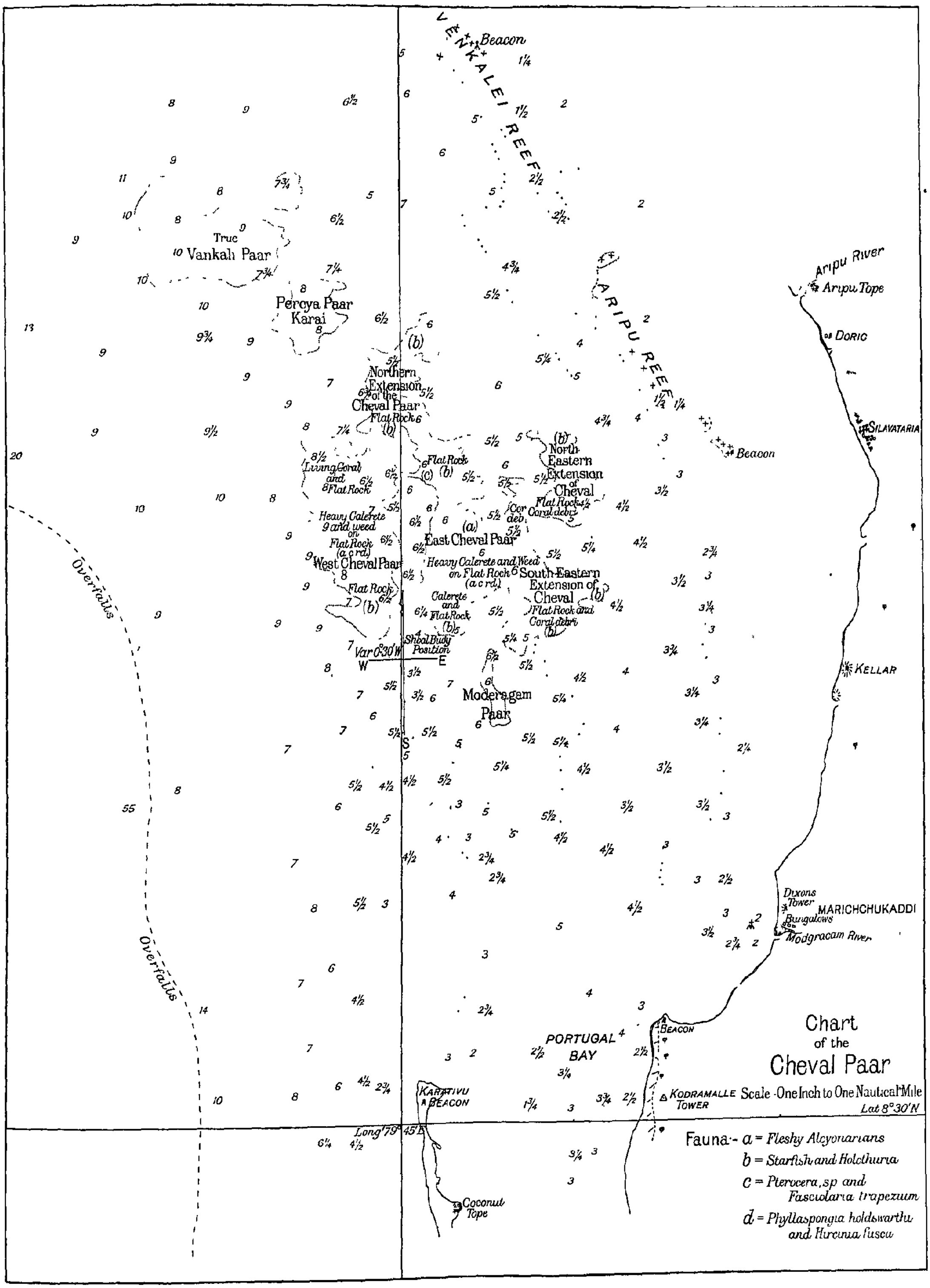


Chart of the Cheval Paar
Scale - One Inch to One Nautical Mile
Lat 8°30'N
Long 79°45'E
Fauna - a = Fleshy Alcyonarians
b = Starfish and Holothuria
c = Pterocera, sp and Fasciolaria trapezium
d = Phyllaspongia holdsworthi and Hircinia fusca
VENKALEI REEF
Beacon
ARIPU REEF
Beacon
Aripu River
Aripu Tope
DORIC
SILAVATARIA
KELLAR
Dixons Tower
MARICHCHUKADDI
Bungalows
Modgracam River
BEACON
KODRAMALLE TOWER
PORTUGAL BAY
KARATIVU BEACON
Coconut Tope
True Vankali Paar
Peroya Paar Karai
Northern Extension of the Cheval Paar
Flat Rock
North Eastern Extension of Cheval
Living Coral and Flat Rock
Heavy Calcrete and weed on Flat Rock
East Cheval Paar
West Cheval Paar
Heavy Calcrete and Weed on Flat Rock
South Eastern Extension of Cheval
Flat Rock and Coral debri
Calcrete and Flat Rock
Shoal Buoy Position
Var 0°30'W
Moderagam Paar
Overfalls
Overfalls

Explanation of Plates.

Plate I.

Fig. 5*a* .. *Cephalobothrium variabile*, n. sp. × 16.
Fig. 5*b* .. Single typical proglottis of same. × 20.
Figs. 5*c* .. Illustrate the varying forms of proglottides occurring in *Cephalobothrium variabile*, n. sp. × 10.
Fig. 8 .. *Tetrarhynchus unionifactor*, Shipley and Hornell. × 15.
Fig. 9*a* .. Head of same. × 20.
Fig. 9*b* .. Typical spine from proboscides of same, highly magnified.

Plate II.

Fig. 7 .. *Echeneibothrium insignia*, n. sp. × 40.

Plate III.

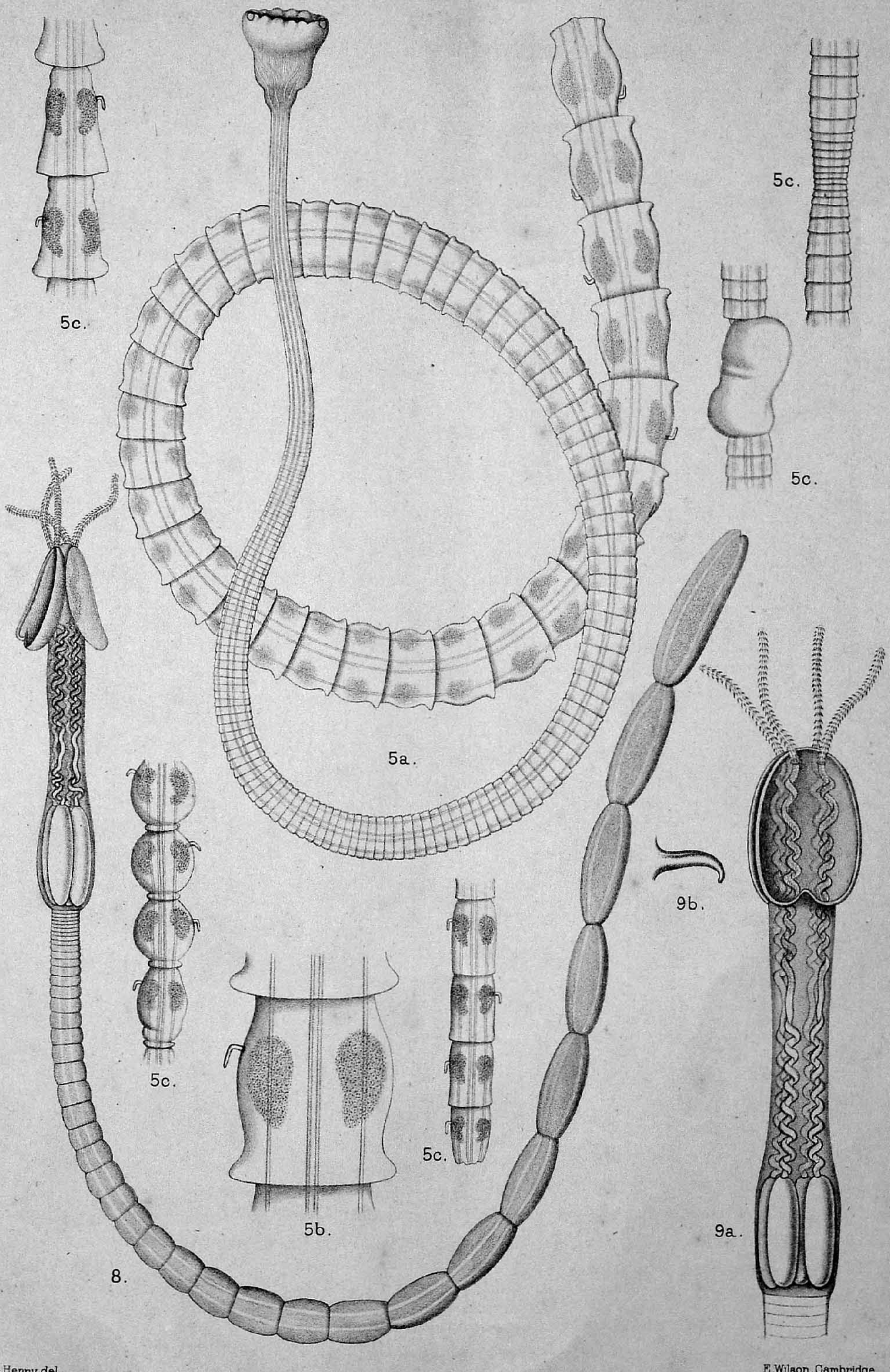
Fig 1 .. *Pinnoteres ridgewayi*, n. sp. Female. Ventral view. × 25.
Fig. 2 .. *Pinnoteres ridgewayi*, n. sp. Female. Dorsal view. × 25.
Fig. 2*a* .. Ventral view of tail fin of same. × 3.
Fig. 3 .. *Pinnoteres margaritiferæ*, Laurie. Dorsal view. × 4.
Fig. 3*a* .. *Pinnoteres margaritiferæ*, Laurie. Ventral view. × 4.

Plate IV.

Fig. 1*a* .. *Phyllobothroides kerkhami*, n. gen., n. sp. × 20.
Fig. 1*b* .. Termination of neck and first proglottides of same. × 50.
Fig. 1*c* .. Head of same. × 25.
Fig. 1*d* .. View of the bifurcated hooks on the head of same, highly magnified.
Fig. 2*a* .. *Cyclobothrium typicum*, n. gen., n. sp. × 4.
Fig. 2*b* .. Head of same. × 25.
Fig. 2*c* .. View of proglottis of same. × 16.
Fig. 10*a* .. *Phyllobothroides hutsoni*, n. sp. × 6
Fig. 10*b* .. Head of same. × 30.
Fig. 10*c* .. View of hooks on the head of same, highly magnified.
Fig 11 .. Cestode species (?). × 4.

Plate V.

Fig. 3*a* .. *Calliobothrium farmeri*, n. sp. × 5.
Fig. 3*b* .. Head of same. × 6.
Fig. 3*c* .. Hooks of same, highly magnified.
Fig. 6*a* .. *Echinobothrium boisii*, n. sp. × 10.
Fig. 6*b* .. View of spine surmounting the head of same, highly magnified.
Fig. 6*c* .. Three views of the spines on the neck ("Kopfstiel") of same, highly magnified.
Fig. 12*a* .. *Tetrarhynchus spinulifera*, n. sp. × 6.
Fig. 12*b* .. Head of same. × 50.
Fig. 12*c* .. View of a proboscis sac of same, highly magnified.
Fig. 12*d* .. View of spines on the head of same, highly magnified.
Fig. 4*a* .. *Cephalobothrium abruptum*, n. sp. × 6.
Fig. 4*b* .. View of anterior proglottides, showing the ringed cuticle. × 12.



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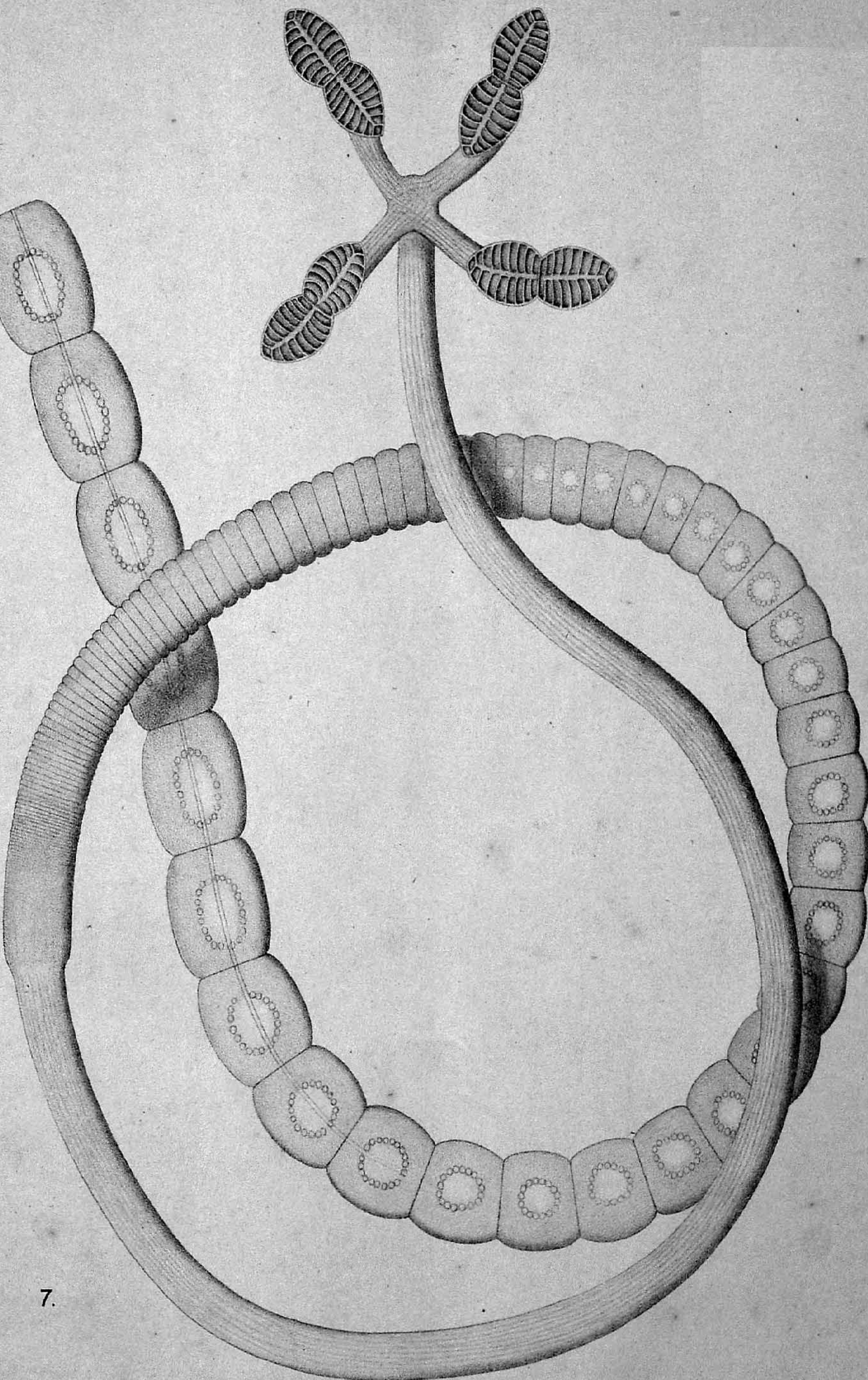

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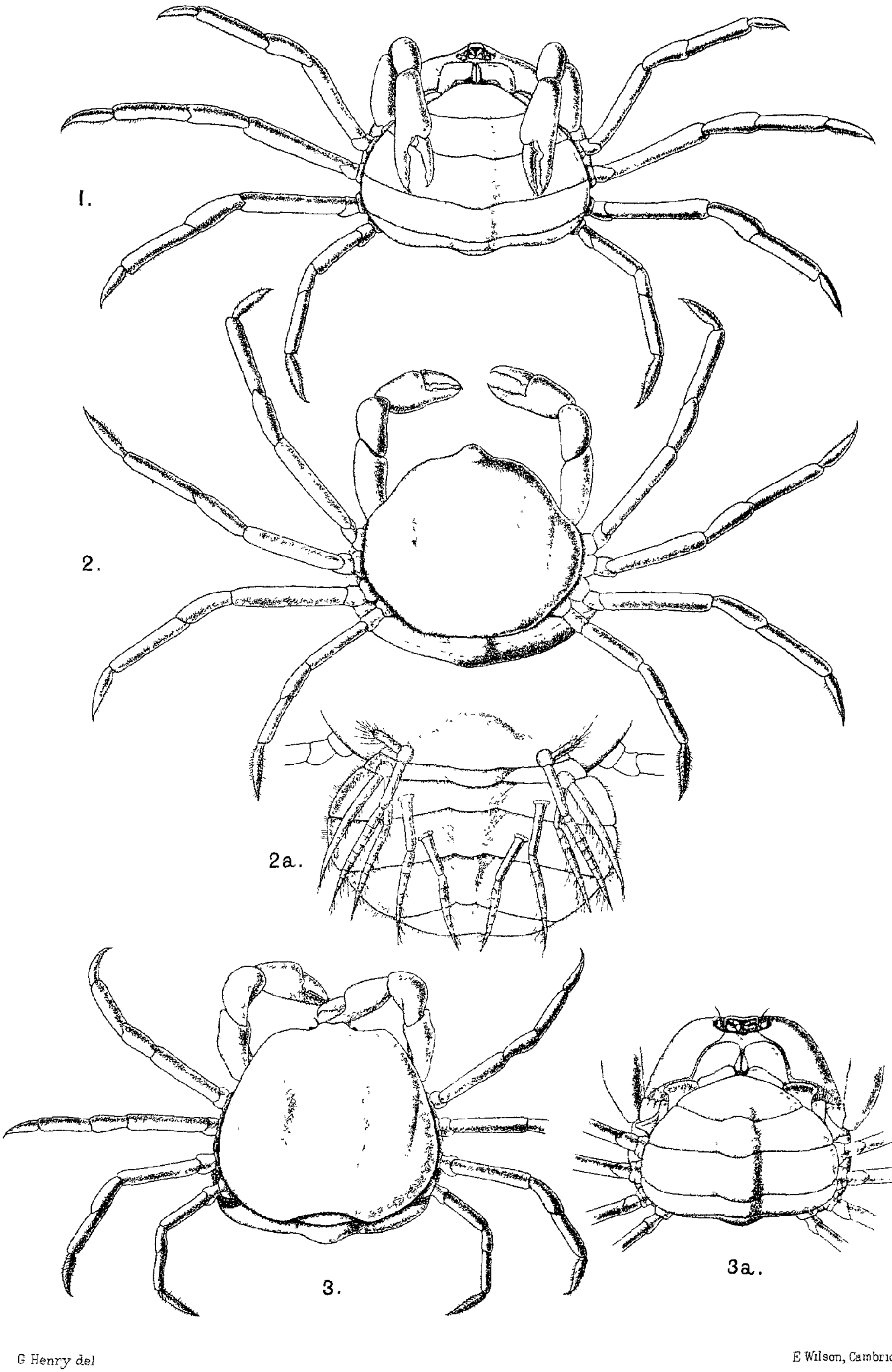

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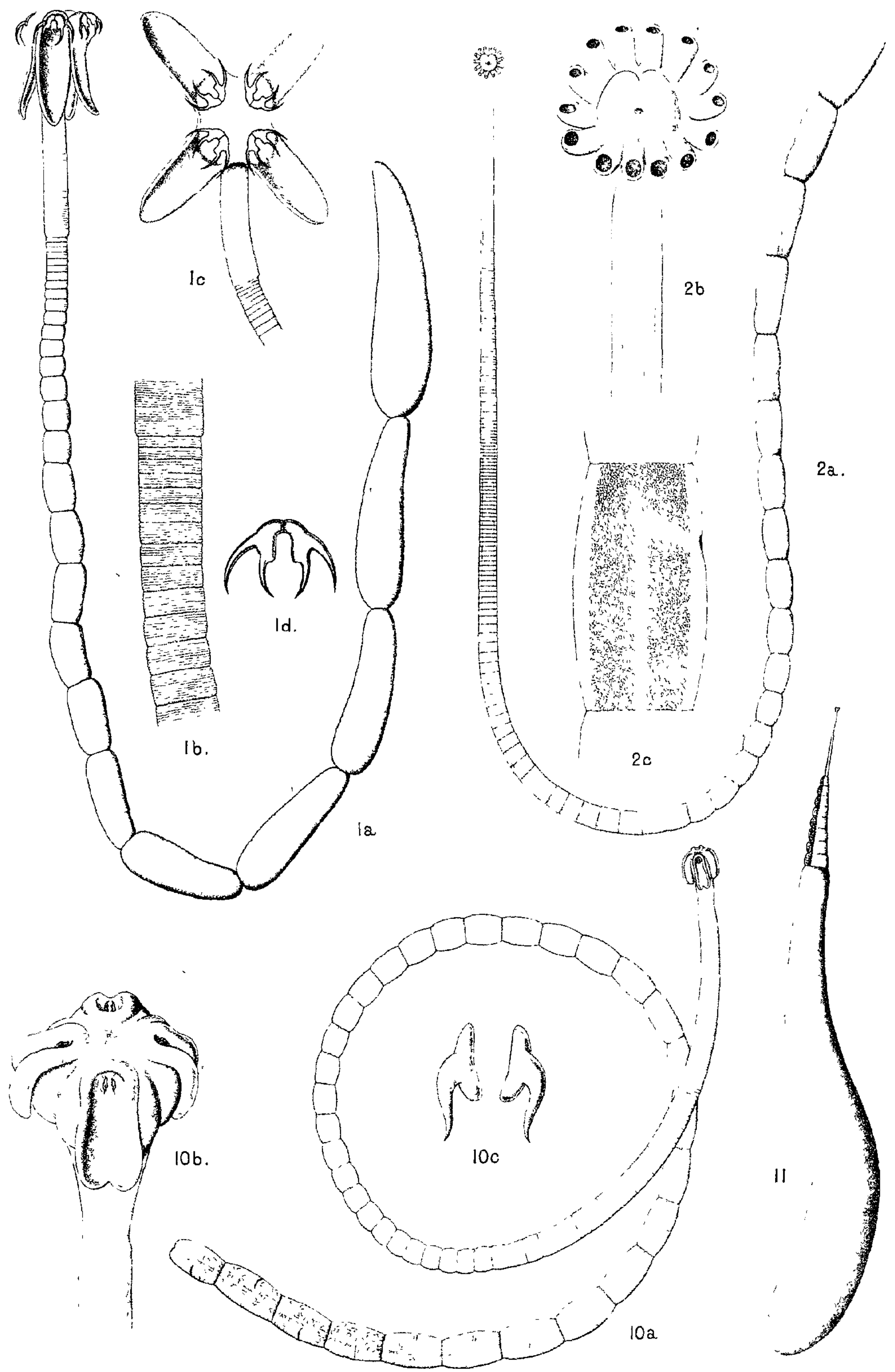

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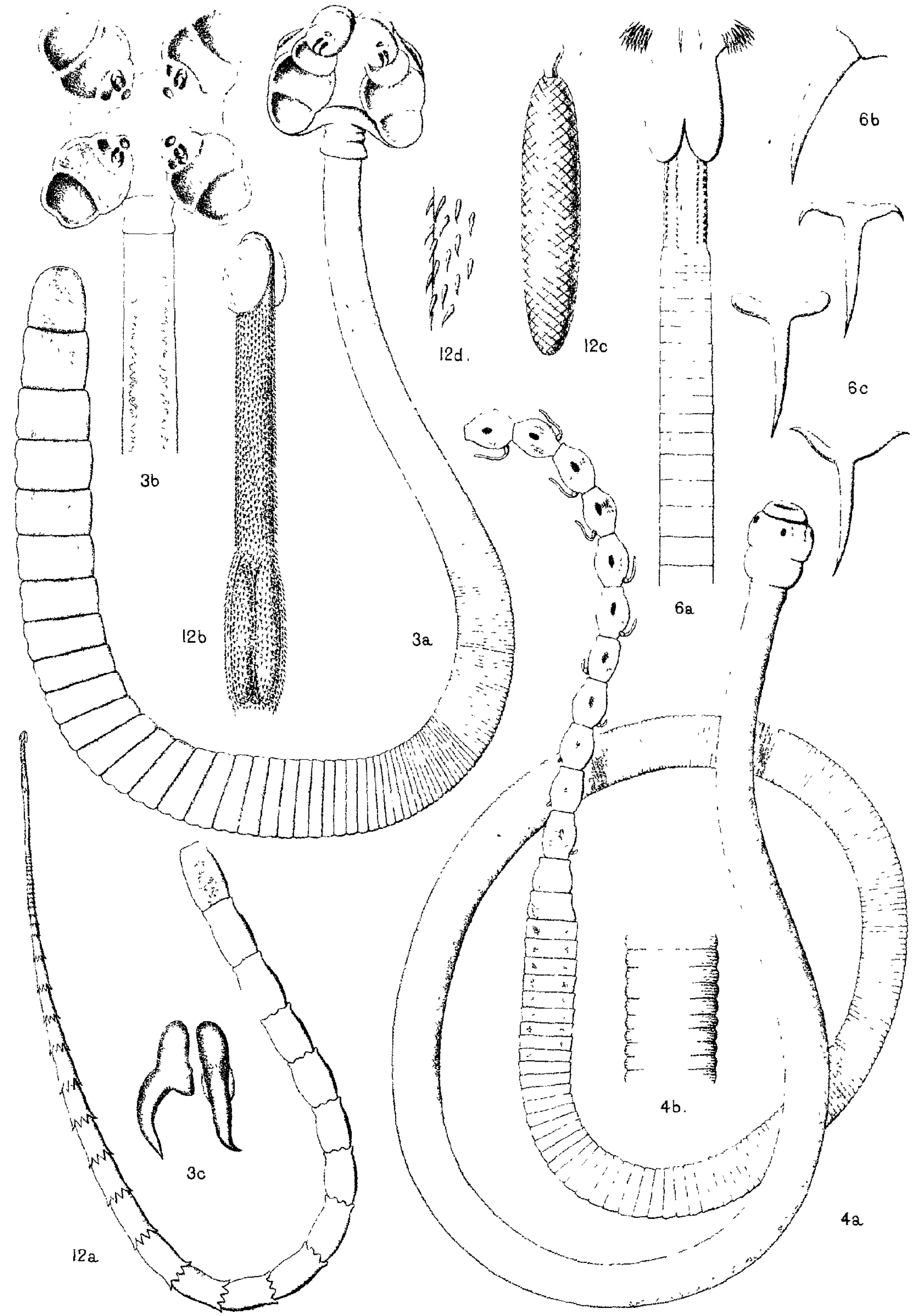


G Henry del E. Wilson, Cambridge

Reports from the Ceylon Marine Biological Laboratory.

PART VI.] **Nos. 20 to 22.**

SUMMARY OF CONTENTS.

With three Plates and three Charts.

INTRODUCTION.

I.—HISTORY OF THE LABORATORY.

WITH the publication of this Report (Part VI.) the Ceylon Marine Biological Laboratory ceases to exist. In 1902 Professor Herdman was deputed by the Royal Society, on behalf of the Colonial Government, to investigate the various problems relating to the pearl banks, and especially the reason of the erratic nature of the fisheries. His five voluminous Reports are well known. The Reports from this Laboratory were merely intended to supplement Herdman's Reports.

After Professor Herdman had finished his investigations in Ceylon, Mr. Hornell, who had acted as Assistant to Professor Herdman during his stay in Ceylon, was left to continue the work on the spot. The Ceylon Marine Biological Laboratory was thus founded. Its first headquarters were at Galle, but were subsequently changed to Colombo, although the great bulk of the work has been done out at sea on board the barque "Rangasamee Porawee." In 1903 Mr. Hornell was appointed Marine Biologist to the Ceylon Government; during his appointment the first two parts of the Reports from this Laboratory were published. In 1905 the pearl banks were leased out to the Ceylon Company of Pearl Fishers, Limited: Mr. Hornell left the service of Government and took up duties as Manager of this Company. The Ceylon Marine Biological Laboratory thus passed from the hands of Government and became controlled and carried on entirely by the Company.

In 1906 I came out to Ceylon as the Scientific Assistant to the Company. Early in 1908 Mr. Hornell left the service of the Company, and I assumed full executive duties. Later in the year Lieutenant J. C. Kerkham, R.N.R., was appointed Superintendent of Fisheries, and the scientific work devolved on me. This arrangement continued up to the end of 1911, and it was during this period that Parts III., IV., V., and VI. Reports were published. It will be noted that Parts I. and II. (which are now out of print) were published whilst the banks were under the control of Government. All the succeeding Reports represent a mere fraction of the work done by the Company. The Laboratory is being closed on account of the fact that the leasing of the banks by the Company has not proved a commercial success.

I assume duties as Deputy Director of Fisheries for Bengal in December, 1911.

2.—Causes which led to the Failure.

It is impossible to give more than a brief outline of a few of the causes which led to the failure Some of the factors are dealt with in Parts IV. and V. of the preceding Reports.

The uncertain nature of the fisheries has been fully recognized for many centuries. Periods of barrenness have always succeeded years of plenty, and the cause was never discovered. Steuart, whose writings contain shrewd observations mixed with spicy romance, remarked in 1843 that the intermittency of the fisheries was the act of God, and beyond the control of man. The investigations conducted by Professor Herdman and by the Company had for their object, amongst other things, the elucidation of this problem. How far the investigations have been successful will be gathered from the Reports.

As we have seen, the banks were leased out in 1905, and two successful fisheries resulted (1906 and 1907). Since then no fisheries have been held, and at the present time the banks are absolutely barren. Even when spat *is* found, it will be four years before it can be fished, excluding the event of its being lost in the meantime through a variety of causes. The Company were granted the lease of the banks for a period of twenty years, and were bound by the agreement *to carry out the recommendations which* had already been made by Professor Herdman. The yearly rental to be paid was £20,000, and a further smaller sum had to be expended in general scientific work. The working expenses were, of course, additional.

As the average profit on a normal fishery is about £60,000, it follows that in order to make the enterprise successful a good fishery must take place within every three years. The history of the banks abound with instances in which there are blanks of from four to fifty years, but in this connection it is to be noted that up to six years ago only certain paars, such as the Cheval and the Muttuvaratu, were ever inspected. Subsequent events have shown the high probability of oysters having occurred in times past at other places close by these paars, as the entire plateau is potential paar ground. These questionable blank years undoubtedly exaggerate the periods of time when oysters were really absent. In view of these facts the rental paid has been excessive, as history has shown.

For the continuity of fisheries the isolation and protection of breeding stocks is essential. It has often been pointed out that even after a most thorough fishery there are bound to remain a few scattered oysters which escape the vigilance of the divers. This is indeed so, but it has to be remembered that the Ceylon pearl oysters have the sexes separate. They depend for their continuity on their seminal products being wafted together by the movements of the water. Thus, although after a fishery thousands of oysters are left scattered about here and there, it by no means follows that their seminal products come together. A distance of even one yard *may* be fatal. Thus, if the best results are to be obtained, the necessity of leaving and protecting, say, ten compact beds of old oysters of about one acre in extent becomes obvious. During normal fisheries anything from 40 to 80 million oysters may be fished, and the number of oysters required to leave such compact and scattered beds would not be more than 1 to 2 million—an insignificant fraction of the whole. Since these facts were discovered there have been no oysters on the banks, and thus the observation has as yet had no practical fruition. It was to protect such beds as these, if found, that the Company purchased two years ago, at a cost of £3,500, wire netting sufficient to protect an aggregate of one-sixth square mile of oysters. As the pearl banks cover over 700 square miles, and as the cost of netting is prohibitive, to say nothing of the impossibility of dealing on a large scale with netting, it is clear that it could not be used very extensively, and it was never proposed to do more than protect breeding stocks to the extent indicated. Unfortunately the opportunity has never occurred.

The wire netting has been immersed in sea water and its durability tested. It was found to keep intact and effective for a proved period of eighteen months, and thus wire netting would be suitable for protecting spat for this period, after which time protection would not be so necessary.

The principal cause of the failure, however, has been the non-occurrence of a spatfall during the last few years. As no oysters were present on our own banks, it was obvious that if a spatfall did occur it would have to be derived from elsewhere. It has long been believed that young oysters (larvæ) travel over to our banks from Southern India, where a few scattered and unproductive oyster beds occur. The drift bottle experiment described in this Report proves that that is not only quite possible, but that it certainly does happen at times. Blank years on our own banks are due principally to one of two causes, either to the absence of oysters on the Tuticorin banks, or to the failure or sluggishness of the local south-west monsoon current during the critical breeding time, which results in the larvæ failing to reach the plateau, and, dropping into the abyss, being lost for ever.

These facts, however, do not explain why it is that when once the banks *have* oysters on them they should not be more or less independent of exotic spat, but maintain and develop their own. The reason is simple, and is to be found in the rapaciousness of man, whose avarice kills the goose that lays the golden egg, by omitting to leave breeding stocks; also to voracious fish, to whom a bed of oysters is a feeding ground, to be deserted for pastures new only when the supply is exhausted. So thoroughly have the banks been devastated that during the last two and a half years less than half a dozen "shell fish" (molluscs) have been obtained, in spite of the efforts of divers and the use of the trawl and dredge. Thus it is evident that other, and probably all, "shell fish" suffer equally with the pearl oyster, and it is only on account of the commercial importance of the latter that the loss is noted. Now that the banks are depleted of all molluscs, fish of all species are remarkably scanty; but one cannot doubt that, as in past ages, when the banks *do* recover the fish will return. A fuller and more detailed account of the ravages caused by fish will be found in Part IV.

We thus come to agree with Steuart that in some respects the continuity of fisheries is dependent on natural events which are beyond the control of man. But whilst this is so, we can almost escape this catastrophe, and in any case extensively mitigate it, by reserving breeding stocks of old oysters in the way indicated; and, although even thus one could not hope to emulate the luxuriant bounty of Nature, such breeding stocks would at least make the enterprise a successful one commercially.

The importance and significance of trawling, dredging, and transplanting were fully dealt with in Part V. Report, and need not be further considered here.

In the present Report the subject of currents is extensively dealt with. The importance of the surface currents prevalent during the spatting season, and their relation to the natural distribution of oyster larvæ, cannot be exaggerated. Assuming oysters are present on the Tuticorin side, a spatfall on our own banks is certain if the south-west monsoon continues strong at the critical breeding time. If the monsoon is weak or erratic, then the larvæ either drift through Paumben Pass, or drop into the abyss on their way to the pearl banks, depending, of course, on the topographical position of the larvæ when the fluctuations of the monsoon begin. It is very noteworthy that the facts which have been obtained fully and naturally explain why our banks usually retain their own spat as well as receive exotic deposits, whilst the Tuticorin banks and those banks still under Government control are not only destined to lose their own spat, but are situated in such a way that exotic falls of spat thereon are almost physically impossible. These facts are amply borne out in the history of the areas concerned.

Considerable misapprehension has existed during past years in relation to currents in general over the banks. If a bed of oysters has disappeared, the cause has been attributed to currents, no other explanation being obvious. Not only so, but the distinction between a top and a bottom current has not been appreciated. A strong drift may be present on the surface of the water, which is not felt at the bottom. Our experience, extending as it does over five years, has furnished no indication whatever of a bottom current, even though we have had access to the diving dress as well as the information afforded by skin divers. We are of opinion that bottom currents do not exist, and that the loss of beds of oysters in past years was probably never due to this cause, nor to silting over by sand.

Having thus outlined in merest detail some of the circumstances which have led to the failure of the enterprise, it would be well to now consider what ought, in our opinion, to be done in the future.

3.—The desirability of forming a Government Marine Department.

The pearl fisheries represent the oldest, and probably the largest, source of revenue to the Government that is, and its extensive nature fully warrants the attempt being made to make the banks as lucrative and successful as possible. What is required in Ceylon is a Government Marine Department, with a special staff of two or three suitably trained men, whose *only* duty would be to fully investigate and enhance the marine resources of the Island. The primary work would be a continuation of the scientific research initiated on the pearl banks. During the south-west monsoon, when operations are impossible on the pearl banks, there would be the investigation of the Placuna fisheries on the sheltered side at Tamblegam, or the investigation of the fresh-water fisheries. In addition to these, chanks are fairly plentiful on muddy ground, and this industry could be made profitable. Finally, fish trawling investigations could be carried on, and this industry placed on a scientific basis. It would be impossible to do this work without a special staff. A Marine Department could be run for from £2,000 to £3,000 per annum successfully, and if a single pearl fishery resulted *once* in from twenty to thirty years, the Department would have paid for itself, to say nothing of the other industries. Other fisheries over and above the one named would represent clear profit. One has only to turn to the Madras Presidency, and many other places elsewhere, to find that even the minor marine industries are placed on a proper and lucrative footing. Ceylon is unique in this respect in possessing the finest pearl fishery in the world, and this fact itself is sufficient reason why a special department should be established. What Peradeniya has done for agriculture in Ceylon—for tea, rubber, coconuts, &c.—can be done by a Marine Department with the pearl fishery and other marine industries.

The difficulties with the fisheries here when under Government control have almost always been that the various officials *pro tem. were merely casually deputed to reap the harvest of the sea*, and had no time nor business to seek to enhance its value, or to ensure its continuity.

There are instances on record, and not far remote, when by the merest chance Government conducted huge fisheries which might easily have been lost. We have no doubt whatever that these incidents have been numerous in the past, but there is necessarily no record to show. Instances are more numerous still in which beds of oysters two, three, four, and even five years old were discovered for the first time. If the inspections had been carried out with that thoroughness which so large a source of revenue warrants, these oysters would have been discovered before they were three months old. It is also equally clear that if beds have frequently been found of this age, other beds have never been found at all. The discovery of a bed of oysters two, three, four, or five years old indicates that the *necessity of an extensive* survey of the pearl bank area has not been thoroughly appreciated. No inspection is either satisfactory or adequate which does not every year systematically and fully cover the entire plateau; and so long as inspections are merely confined to a few paars, beds of oysters are bound to be lost. Oysters or spat, when they occur, ought to be discovered at once, and watched and tended with that care which the circumstances demand. The rectangular method of inspection adopted by the Company leaves no part of the ground unexplored. It is described elsewhere.

The pearl bank area is to be regarded as *wholly* potential, and not as consisting of a number of paars. The notoriety of the Cheval and Muttuvaratu Paars as very productive areas is merely incident on their having been more frequently examined. In fact, up to five or six years ago these were practically the only areas inspected. As the recent investigators went further afield, other productive paars were discovered, and there is every reason to believe that oysters flourished thereon occasionally from time immemorial, and were never sought for. As we have already noted, the area under lease covers over 700 square miles: there is still much potential ground not under lease. The entire area covers approximately over 1,200 square miles. The thorough inspection of this area would fully occupy six months. It thus becomes evident that there is employment for two trained and expert men, and I have no doubt in my own mind that the establishment of a Marine Department would not only be a successful venture, but that in a short time it would prove to be one of the principal and most lucrative sources of revenue to the Colony. When the banks revert to Government, it will be pathetic if those rough, ready, and casual methods of inspection and control which have come down to us with the banks themselves, are continued.

4.—General.

The legacy left by the Company to Government consists of the information contained in the various private reports sent in to them, of the four Marine Biological Reports, of a chart of the Cheval Paar drawn up from a recent survey, and of a large new nautical and biological chart of the entire plateau under lease, the latter having taken practically five years to prepare In addition to these, the positions of various trigonometrical and other stations have been verified and the structures repaired. Beacons have been erected on various reefs, and although these are not permanent structures, they will survive for many years. Hatchery and nursery tanks are fitted up complete at Marichchukaddi. A survey of Dutch Bay has been made and a chart published, and this information has conclusively shown the unsuitability of this place as a seaboard nursery. The general experimental work carried on by the Company at enormous expense has been of so extensive a nature, and so conclusive in its results, that it need not be repeated. The faunistic and other specimens collected during five years, including the tow net catches extending over four years, have been sent to the Government Museum, Colombo. These are some of the benefits other than purely pecuniary ones which have been derived by Government from the Company.

I take the liberty of referring here to the introduction of X-ray photography to oyster culture (?) in Ceylon, as considerable misunderstanding exists on this point.

Some years ago an X-ray plant was laid down by Mr. John I. Solomon in the vicinity of the pearl banks. The object was to X-ray oysters, to separate those containing pearls, and to put these back again into the sea for the pearls to grow. It is to be remembered that the Company only fish old oysters. It would seem a far cheaper way (even if less dignified) to proceed in the usual way in the determination of the pearl yield rather than to X-ray the oysters. If the oysters have pearls, they will not grow appreciably bigger during the short span of life which remains to the oyster. If pearls are not present, then these expensive operations are wasted. Even if young oysters are being dealt with, the X-rays will not manufacture or initiate pearl formation, and thus the operations appear useless and extravagant. When one considers that young oysters, when they *do* occur, are found in the quantity of at least half a million per acre, and that the maximum that can be X-rayed per minute is about sixty, the impossibility of the proceeding as a commercial undertaking is evident; and even if the oysters could all be X-rayed in one second, there seems to be no object in attempting it.

In Japan an extensive and successful industry is carried on in pearl culture. Small leaden images of the Buddha and other nuclei are inserted between the mantle and the shell, and these, setting up local irritation, in course of time become partially covered with pearly matter. After they have grown sufficiently large they are removed, and the basal part of this concretion (which has grown to the shell) is carved out of the shell. These artificial pearls are always used for mounting, the basal face being hidden in the mount.

Since probably not ·01 per cent. of the larvæ inhabiting the tissues of the pearl oyster ever become the nuclei of pearls, it would appear likely that future science will concentrate on so treating the oysters that a large percentage of these larvæ will form pearls, as it appears very probable that only such larvæ which for some unaccountable reason die in the tissues, and thus set up local irritation, form pearls. If this is found possible in future years, pearl fishing will be revolutionized.

Consequent on the entire absence of oysters on the Company's banks, numerous suggestions have been received from time to time advising the stocking of the banks with oysters from elsewhere—Mergui, Torres Straits, Persian Gulf, &c. Needless to add, all these suggestions have been passed by. It has taken ten years to collect what little we know of our own oyster. Apart from the expense and probable impossibility of successfully transplanting these exotic oysters over long distances to our banks, we have no reason to believe it would occupy a less time, if transplanting was successful, to acquire the knowledge concerning them that we possess about the pearl oyster. Mother-of-pearl oysters have totally different habits, and if success is doubtful with them in their own natural surroundings, it would obviously be more so here. The Mergui oyster lives in 20 fathoms on a muddy bottom, over which a 7-knot current flows, and where there is a rise and fall of 15 feet of water. Our banks are rocky, covered with only an average of 8 fathoms, and bottom currents are absent. The futility of transplanting such oysters is obvious.

The Ceylon pearl banks do not require supplementing with exotic oysters. Given a spatfall, only thorough inspection, care, and normal foresight in isolating breeding stocks, &c., are required to make the banks perennially productive. A spatfall is almost certain to take place at an early date, and to our successors will be given the opportunity of reaping where we have sown.

In conclusion, I beg to express my indebtedness to the Ceylon Government for kindly publishing these results; my thanks are also due to my wife, for correcting proofs and for really serious and extensive help in many other ways.

T. SOUTHWELL.

At Sea, Cheval Paar,
Ceylon. November 18, 1911.

No. 20.

CURRENTS ON THE CEYLON PEARL BANKS, SUPERFICIAL AND DEEP.

By T. SOUTHWELL, A.R.C.Sc. (Lond.), F.L.S., F.Z.S., and Lieut. J. C. KERKHAM, R.N.R.

With three Charts.

The interest attaching to currents on the pearl banks lies almost wholly in the relation they bear to the oyster, for it is commonly believed that beds of spat or adult oysters have from time to time been entirely swept away by the agency of bottom currents. It is important, in the first place, to note that the oyster is stationary, and almost defenceless against the vast majority of its natural enemies. Fish of various species devour them omnivorously. Subtle and fatal diseases attack them. A variety of other animals compete with them for food, and often grow on their shells, as if to purposely arrest and accommodate such food as the gentle undulations of the bottom layer of water may bring near by.

The outstanding character of the oyster (*Margaritifera vulgaris*) is its sedentary habits, and the power it possesses of holding on to rock and other solid objects in such a way as to remain securely attached. This condition is essential to the oyster's welfare, and so strong and powerful is this attachment that it is only with difficulty that divers are able during fishery times to dislodge them from their anchorage. The attachment is made by means of a beard or byssus, similar to that occurring in the ordinary English mussel (*Mytilus edulis*). A very considerable percentage of oysters lose their byssus in being pulled away from their attachment. This structure can, however, be replaced in a very short time, and if necessary many times in succession.

In dealing with currents on the Ceylon pearl banks, it is essential, in the first place, to carefully distinguish between surface and bottom currents, for they bear different relations to the oyster. Therefore, in order to understand these relationships better, we will deal with each separately.

I.—Surface Currents during the North-east Monsoon.

Investigations of the surface currents have been carried on intermittently during the last four years, but only during the north-east monsoon. The observations on the south-west monsoon have only been carried out during two seasons, viz., 1908 and 1910. The results during the latter monsoon were in every sense satisfactory. The percentage returns were high (51·5 per cent.), and the results of each year's work were similar. In 1910 alone 565 bottles were released at different stations during the south-west monsoon, of which 291 were returned; whilst in 1908 only 80 bottles were released, and 47 returned. The results from many bottles liberated during the north-east monsoons of the last four years have had to be discarded, owing to the fact that the management of these drift bottles changed hands, and the results of the first two years' work were useless, as the necessary data was not obtainable. This paper, therefore, embodies the result of two years' work during each monsoon, viz., those of 1908 and 1909 during the north-east monsoon, and those of 1908 and 1910 during the south-west monsoon. Full statistics are given at the end of the paper.

Apart from the drift bottle experiments, our knowledge and experience has been further extensively supplemented by the observations made by commanders of coasting vessels, some of whom have had many years' experience.

These investigations were carried out on the west side of the Island (between Galle and Adam's Bridge), where, of course, the pearl banks lie, and also on the Indian side, and in the Gulf of Mannar generally. It is necessary at the outset to understand that the pearl bank area of the Ceylon coast consists of a shallow water plateau, shelving out from the beach to about the 12-fathom line, and then rapidly deepening to several hundred fathoms. The overfall ranges from 1 to 18 miles from the beach. The bottom consists of alternations of sand and limey rock, which latter is derived from decayed coral re-organized into an exceedingly hard substance by the cementing growths of *Nullipore* and *Polyzoa*. At most places the rock is only covered by less than four inches of sand, and is often quite bare.

These details have been obtained as a result of continued dredging and trawling operations, combined with the extensive work of skin diving and also dress diving.

Practically parallel to the shore, which runs approximately north and south, there is a more or less continuous, fringing, coral reef, exposed at places during low water. The rise and fall of tide is limited to a few inches only. Towards the north of the plateau the submerged continuation of Karativu Island runs in a northerly direction for about 10 miles as a narrow sandy shoal, and terminates very abruptly. Reference to the appended chart will indicate the topographical relations of the mainland. To the north the pearl banks under lease lie in a *cul-de-sac*. The only exit to the gulf is Palk's Strait, whilst Southern India forms the western boundary. The influence of these varied factors on the surface current will, however, be dealt with later.

It is obvious that during the north-east monsoon the surface current over the entire plateau has a different trend to that existing during the south-west monsoon, so that in order to fully elucidate and understand the true condition of affairs we will deal with each monsoon separately.

(*a*) *North-east Monsoon.*

This monsoon commences about the beginning of November and extends until about the end of May. It is the fine weather season, as the wind is from the land. During November, December, and January strong northerly winds prevail during the day, usually becoming almost easterly at or during the night. In February these strong winds gradually die down.

During March and April dead (*Trichodesmium*) calms prevail about midday. An hour or more later a gentle breeze springs up from the west, and as it strengthens it veers to the north, and by nightfall is due east from the land, where it continues during the night, shifting again to the south in the morning hours and gradually dying away at daybreak.

These conditions have been noted during a great number of years, and although the sequence of these daily changes of the wind is occasionally broken, they still remain a very noticeable feature about this time. During the fishery season the westerly afternoon wind enables the fleet to sail ashore, whilst the early morning easterly winds waft them back again to the fishing grounds after they have disposed of their oysters.

In May these rhythmic winds are almost entirely broken up, and are succeeded by calm mornings and exceedingly squally afternoons, characterized by heavy rains with lightning and thunder. Thi condition marks the approach of the south-west monsoon.

In thus considering the currents prevalent during the north-east monsoon, it will be noticed from the chart that the pearl bank area under lease lies in a *cul-de-sac*, where it is entirely protected by the mainland and the line of fringing reefs.

The banks south of Tallaivillu Point are swept by an oceanic current, which, running north, is deflected at this point to the west and on to the Indian coast.

North of Tallaivillu Point, however, it may be said that there are no true surface currents, except far out at sea. What surface currents exist on the plateau are transient and temporary, and vary even during the day with the direction of the wind, by which they are controlled and to which they entirely owe their existence. This area lies securely under the lee of the land, and is further protected by the line of fringing reefs previously mentioned. The situation of the banks renders them immune from oceanic currents, and bottles liberated on this area took one of two courses. If liberated well inshore, they were drifted south as far as Dutch Bay by the prevailing northerly wind. If liberated a little further west to the overfalls or beyond, they eventually drifted over towards Cape Comorin, being first blown south by the prevailing wind, and eventually they became involved in the oceanic current named, which runs along the west Ceylon coast in a northerly direction as far north as Tallaivillu Point, and then takes a westerly direction to the Indian coast towards Tuticorin, from whence it runs south, and, rounding Cape Comorin, has been traced as far north as Calicut. The current thus sweeping west runs out into the Indian Ocean, where it is lost, but it is exceedingly interesting to note that we have had a bottle returned from the Maldive Islands. This current, as it sweeps round Cape Comorin, still runs in a westerly direction, although owing to the configuration of the land offsets from the main current have been traced as far north as Calicut. From the above it will be gathered that bottles liberated along the Indian side and the Ceylon side (except on the inshore areas under lease) have usually been lost. The percentage recovered is small (16·76 per cent.), and such bottles consist entirely of (*a*) those liberated inshore on the areas under lease, which merely drifted south on to the beach by the prevailing north wind, these form the bulk of those returned; (*b*) those which were liberated further out at sea, west of the above area, which first drifted south with the prevailing northerly wind, and eventually becoming involved in the westerly current, drifted over to the Tuticorin side; while (*c*) those which were liberated to the south became directly involved in the westerly oceanic current named and were carried up the east coast of India. As we have seen, however, the vast majority (83·24 per cent.) were lost, being carried away into the Indian Ocean by the oceanic current.

It is to be noted that during this monsoon a steady flow of water passes through the Paumben Pass, from the north to the south side, and has been noted by such steamers as regularly pass through. This current of water, however, passes out into the Gulf of Mannar and is never felt on the area under lease, which lies to the extreme north-east of the gulf.

The pass through the Mannar Channel may be altogether neglected. During the south-west monsoon this channel becomes silted up. With the advent of the north-east monsoon the water collecting to the north and north-east of Mannar island quickly scours out the channel, but the effect of this is only felt for a few days on the area under lease. After the channel is clear no further current is noticed. A reference to the chart will show how insignificant and temporary the effect of this channel is.

Over the area under lease then, occurring as it does in such a secluded position, away and protected from all disturbing oceanic influences, the essential conditions for a calm sea (save such as is caused by wind, and therefore temporary in character) prevail. On this section of the plateau alone 300 drift bottles have been liberated. Of these, 57, or only 19 per cent., were returned. We have in the above been referring purely to the northern head of the gulf.

South of Tallaivillu Point, however, an entirely different set of conditions prevail. Here, as we have seen, a very decided current runs along the coast in a northerly direction, and in the face of the north-east monsoon. This current is known to exist throughout the entire monsoon, and is reckoned with and allowed for by local vessels. Its origin is a little obscure, but its occurrence is beyond possible doubt. Its rate averages 0·3 knot per hour. It appears to rise as an offshoot from the current produced on the east side of the Island during the north-east monsoon, which, running in a general southerly direction, flows into the open sea to the south-west of Ceylon. A branch from this volume of water rounds the south end of Ceylon, and runs north along the West Ceylon coast. This current on reaching Tallaivillu Point takes a due westerly course towards Tuticorin in South-east India. From there it runs south, and rounding Cape Comorin flows north along the west coast of India, and has been traced as far as Alleppe and Calicut, although the main current passes west and is lost in the Indian Ocean. This current continues through January and February, and ceases as the strength of the monsoon declines in March. During April and May there is no current noticeable, and this condition continues until the south-west monsoon sets in. The explanation of these facts may be difficult, but the presence of the current under consideration is unquestionable, for not only have drift bottles liberated in the vicinities concerned been recovered on the Indian side and in the Maldive Islands, but, as before noted, commanders of vessels traversing this tract are perfectly familiar with its direction and have helped the writers considerably.

It is interesting to further find that Steuart in his "Notes on Ceylon" (1843) points out that "ships leaving Bombay in the height of the north-east monsoon, to load cotton at Tuticorin, after passing Cape Comorin find the southern current so strong as to induce them to stretch across the Gulf of Mannar, and beat up the western coast of Ceylon until they can steer for their destined port, and this they accomplish against what is called in Ceylon 'a long shore wind.'"

This old-time observation fully amplifies our statement of the prevalent currents, and falls in line absolutely with our own observations.

To summarize, then, on the west coast of Ceylon the surface disturbance falls into two sharply defined sets, each set being strictly limited to a particular area, as under :—

(1) North of Tallaivillu Point (which comprises the pearl bank area under lease) the conditions of entire protection from oceanic currents and from the north-east monsoon exist on the inshore areas. Such disturbances as there are are purely local, varying, and intermittent, and are entirely due to the wind, which is invariably from the north over the plateau. This surface drift running south finds a ready exit in Portugal and Dutch Bay, and the changes taking place in the latter backwater may in some measure be due to the presence of this surface drift.

Further out at sea, and to the west of the plateau, northerly winds still prevail, and consequently there is a definite surface drift, which runs south for some distance. Eventually this drift joins the current running north (in the opposite direction) along the West Ceylon coast, and from about Tallaivillu Point runs west. Some bottles liberated about this vicinity have been recovered on the East Indian coast. The majority, however, were lost. In some cases a few rounded Cape Comorin, and were recovered on the West Indian coast as far north as Calicut, but the main current passes west into the Indian Ocean, and the bottles were consequently lost. One alone was returned from the Maldive Islands.

(2) South of Tallaivillu Point a definite current runs from the south of the Island in a northerly direction at an average rate of 0·3 knot per hour, and in the face of the north-east monsoon. This current is deflected about Tallaivillu Point, and from there takes a westerly course towards the Indian coast, and then, turning south, rounds Cape Comorin, and has been traced north along the west coast of India as far as Calicut. But the main current runs west into the Indian Ocean.

It is certain that the secluded and sheltered position of the pearl bank area under lease as distinct from the pearl bank area still under Government control, and which latter lies south of Tallaivillu Point, owes its larger degree of productivity to the incidence of its protected position. It is also evident, *a priori*, that such surface disturbance as does exist there is not sufficient to affect oysters whose natural habitat is in from 5 to 10 fathoms of water.

It might be argued that on a shallow water plateau such as exists on the west of the Island no surface current or drift could exist at all which did not affect the bottom on which the oyster lives. There are certainly movements of the water on the bottom, otherwise stagnation would result. But these movements are undulatory. They are vertical, and not horizontal.

The total effect of the surface movements on the area under lease with regard to the oyster is nil. They certainly are not harmful. The relative productivities of the areas (*a*) under lease and (*b*) those still under Government control has a deeper origin. But before attempting to discuss the matter further, we must first understand the nature of the surface currents during the south-west monsoon, for these currents *in toto* have a very real relation with the pearl oyster.

II.—Surface Currents during the South-west Monsoon.

We have already pointed out in Part III. Report of this series that the south-west monsoon on striking Cape Comorin is deflected in such a way that it runs approximately east and reaches the Ceylon coast about Tallaivillu Point, and then runs south.

It will be noted that the current, therefore, runs exactly opposite to the one prevalent in the north-east monsoon, and not only has it a definite course, but a more definite origin. This oceanic current, running as it does in its easterly course from Cape Comorin (and which has been felt as far north as Tuticorin), plays a very prominent and important part in the determination of the currents prevalent in the gulf, for with its fluctuations in strength the whole trend of the flow of water in the entire gulf changes. When the monsoon is weak this oceanic current is scarcely felt, and the south-west monsoon has full play in the gulf, where the current then runs north. When the monsoon is strong and steady, this oceanic current has an easterly course from points between Cape Comorin and Tuticorin, and reaching the Ceylon coast about Tallaivillu Point, turns, and runs south.

These details have been repeatedly corroborated by commanders of local coasting steamers who have had long experience. And during the south-west monsoon of 1910, 565 drift bottles were liberated at various points in order to confirm the above facts. Of these 565 bottles, 291 were returned, giving a percentage return of 51·5 per cent. In this connection it is important to note that with reference to drift bottles liberated in other parts of the world the usual and average percentage return is one-third, or 33 per cent., so that our experiment was very successful.

The south-west monsoon usually commences in June, and we started liberating bottles at definite stations at the end of June, 1910, and continued until September. The following is a summary of the results.

Drift bottles liberated off Cape Comorin and off Colombo late in June, before the monsoon had become severe, were recovered in the vicinity of Paumben, indicating a northerly current on both sides of the gulf (viz., on the west side of Ceylon and the south-east side of India). Early in July, as the monsoon freshened, bottles liberated off Cape Comorin and Tuticorin took an easterly direction, and were recovered along the Ceylon coast, from south of Tallaivillu Point to Galle, and even Dondra Head, including Chilaw, Negombo, and Colombo. Bottles liberated off Colombo were also recovered to the south.

This result clearly indicates that the oceanic current in the full force of the monsoon runs east to the Ceylon coast and then turns south, following the contour of the land. The average rate of this current was found to be 0·5 knot per hour on its eastward course, and 1 knot when running south along the Ceylon coast. The reason for the increase in the speed of the current will be dealt with later.

It is significant that along the Ceylon coast south of Tallaivillu Point the current runs in the teeth of each prevailing monsoon. This current continued to flow until nearly the end of July, during which time the south-west monsoon blew strong and steady. At the end of July the monsoon moderated and fell light, and the current was then observed to reverse and to run north again along the Ceylon coast, and also along the Indian coast from Cape Comorin to Palk's Strait. During this lull, which continued until the middle of August, bottles liberated off Chilaw and Tallaivillu Point on the Ceylon coast were recovered north, at the head of the gulf, in the vicinity of Paumben and Adam's Bridge. Those liberated off Cape Comorin, Tuticorin, and Manapad were also recovered at the same place.

The monsoon strengthened again during the second week in August, and bottles liberated off Cape Comorin and Tuticorin were again picked up off the Ceylon coast as far south as Dondra Head. This recurrence of the oceanic easterly current during strong south-west monsoon conditions was felt at Tuticorin. The current continued steady up to the end of August, when the monsoon again began to abate. During this third lull in the monsoon the current again took a northerly course, running at a rate of 0·3 knot per hour; and bottles liberated off Cape Comorin were again recovered at Paumben, Delft island, near Kayts, also at Point Calimere, 70 miles north of the Paumben Pass, and even at Tranquebar, 120 miles north of the Paumben Pass, both the latter points being on the Indian coast. The explanation of these apparently anomalous results, which admit of perfect co-ordination, is not merely interesting, it is important.

As we shall shortly see, this oceanic current produces different effects on the Ceylon coast, for, as already pointed out, on the banks not under lease and south of Tallaivillu Point the oceanic current runs south when the monsoon is strong, and when weak it runs north with the wind; whilst on the area under lease there is merely a surface drift dependent, as usual, on the wind.

In now attempting to explain the irregularities of the oceanic current and the results relating thereto, we would draw particular attention to the charts appended, without which it will be difficult to follow the text.

The presence of an oceanic current from the west during the south-west monsoon is a well-established fact. During a weak or moderate monsoon this current never penetrates the gulf at all. It is only when strong and continued south-west conditions prevail that the oceanic current becomes as it were pushed up into the gulf by the continued effects of strong wind and south-west sea.

We have already seen that unless the monsoon is very strong there is a northerly current at the head of the gulf, particularly on the Indian side. This northerly current, aided by the wind, finds an exit through the Paumben Pass, through which a steady current runs to the north during this monsoon. This current through the pass represents the normal flow of water consequent on the monsoon effects in the gulf. When the monsoon is not particularly strong, the oceanic current does not penetrate the gulf, and the Paumben Pass under these conditions provides a sufficient exit for the volume of water which is continually being blown into the gulf during the south-west conditions. Consequently the northerly current is felt on the Indian side and on the Ceylon side south of Tallaivillu Point. We would here point out that the Mannar Channel and the passes through Adam's Bridge become silted up during the south-west monsoon. It will be seen that the banks under lease are situated in such a position that they are protected from this northerly current. What "current" there is on this area is due purely to the wind.

We, therefore, find that bottles liberated off Cape Comorin during a moderate monsoon find their way through the Paumben Pass, and have even been recovered as far north as Cape Calimere and Tranquebar; whilst bottles liberated off the Ceylon coast north of Tallaivillu Point merely drifted ashore with the wind north of the point where they were liberated. Bottles liberated south of Tallaivillu Point also merely drifted ashore during a light or moderate monsoon, and were recovered north of where they were liberated. These conditions are, of course, what one would naturally expect from the lie of the land.

During a strong south-west monsoon, however, the currents run quite differently. Then, owing to the force of the monsoon, the oceanic current partly penetrates the gulf, and the water at the head of the gulf becomes piled up. During a strong monsoon the sea level at the head of the gulf is 9 inches above the normal. The exit through the Paumben Pass is insufficient to carry away the volume of water which collects in the gulf. The stronger and more continued the monsoon, the further into the gulf does the oceanic current penetrate, and the larger the head or cushion of water formed there. This current is purely oceanic, and penetrating the gulf takes an approximately east and east-south-easterly course, and reaches the Ceylon coast south of Tallaivillu Point. It is here joined by a volume of water, which represents an overflow from the head or cushion of water which has become piled up in the gulf, due to the penetration of the oceanic current. So that there are two exits for the water which becomes piled up at the extreme north of the gulf during strong monsoon conditions. There is the Paumben Pass and the south-eastern extremity near Tallaivillu Point, at which latter point the oceanic current turns south. The drain of water at this latter place, together with the Paumben Pass, provide exits (without producing currents) for the volume of water which has collected north of where the oceanic current has penetrated the gulf. These exits are merely escapes for the water which has accumulated above its normal level and is therefore under pressure.

The rate of the oceanic current as it sweeps eastward is 0·5 knot per hour. South of Tallaivillu Point, where it is joined by water which helps to drain away the "head" of water referred to in the gulf, it obtains a speed of 1 knot per hour.

Bottles liberated in the height of the monsoon off Cape Comorin and off Tuticorin were recovered at points along the Ceylon coast from Tallaivillu Point as far south as Dondra Head, whilst those liberated off the Ceylon coast south of Tallaivillu Point were recovered south of where they were liberated, and those liberated north of Tallaivillu Point were recovered to the north, having been merely driven ashore with the wind.

When the oceanic current penetrates the gulf, it becomes evident that the northern current ceases to exist, for it is obstructed by the oceanic current. Those forces (wind and sea) which normally produce the northerly set are expended in pushing the oceanic current into the gulf. North of this point of penetration the surface movements in the gulf are purely due to wind, which near the Indian coast blows from the west, whilst further out at sea the wind becomes south-west.

It is important to note that during the south-west conditions a strong westerly wind is continually blowing with some force over Southern India, and is persistently recorded at Tuticorin. The oceanic current is thus assisted considerably in its easterly course by the prevailing wind.

We thus see that the surface currents during the south-west monsoon have two phases, and it will be well to here summarize them :—

(1) A light or moderate monsoon, when the currents run northerly towards the Paumben Pass, both along the Indian coast and along the Ceylon coast south of Tallaivillu Point (only), where the water finds an exit.

(2) A phase of strong monsoon, when the oceanic current penetrates the gulf, and the water at the head of the gulf consequently becomes piled up as a cushion. The oceanic current, aided by the westerly wind which prevails over Southern India, takes an easterly course, and eventually reaches the Ceylon coast about Tallaivillu Point. It is here joined by an overflow of water from the head of the gulf and then runs south on the Ceylon coast. This penetration of the oceanic current into the gulf destroys the northerly set towards the head of the gulf, for the forces which normally produce this northerly current have been expended in pushing the oceanic current north. The drift over the volume of water north of where the oceanic current penetrates is solely due to the prevailing winds; whilst at Paumben Pass and Tallaivillu Point there are exits for the water therefrom, which, being above the normal level owing to the penetration of the oceanic current, is under pressure.

In the table given at the end of this paper an interesting transition between the two phases of the south-west monsoon current is shown. (Chart B.)

On July 25 strong monsoon prevailed and the oceanic current ran east, as indicated on Chart A.

On July 28, 20 drift bottles were liberated just off Tallaivillu Point. These travelled on the head of the water north of the penetration of the oceanic current and were blown ashore at Mannar, where 18 were recovered.

This fact indicates that the water towards the head of the gulf during a strong monsoon is dead, and that the drains or outlets to this head of water at Paumben and Tallaivillu merely relieve the pressure without producing currents. The surface movement at such a time is merely due to the wind, as was shown by the bottles going ashore at Mannar.

A week later, as the lull in the monsoon continued, the head of water had had time to drain away, and a northerly set of the current was re-established. It was found that of 20 bottles liberated at the same station, 17 were recovered at Paumben. These facts are most instructive, and clearly corroborate the ideas regarding the currents during the south-west monsoon set forth in this paper.

During our investigations this year we found that the monsoon went through each phase twice and then died away. We attach no importance to these numbers at all, believing as we do that the phases named alternate with each other irregularly year by year.

Two things now become clear. On the pearl banks under lease, *i.e.*, those north of Tallaivillu Point, there are no true currents during this monsoon. There is a surface drift trending to the beach on inshore areas and due to the strong prevailing wind, but the banks are completely out of line with the direction of either phase of the surface south-west current. On the banks south of Tallaivillu Point, and still under Government control, the current runs south and in the teeth of the monsoon when the monsoon is strong; whilst when the monsoon is weak or moderate the current merely becomes a surface drift, due, as on the banks under lease, to the wind, and invariably running north towards the shore.

In our report to the Ceylon Government on the inspection of their banks, *i.e.*, those south of Tallaivillu Point (Part III., "Ceylon Marine Biological Reports"), we stated that the banks under lease owed their productivity to the fact that they were protected, and that owing to the deflected current above described being further acted upon by the south-west wind and sea, exotic spat drifted on to our banks, but never or seldom reached the southern paars. The statement is only partly true, but our investigations were at that time in their infancy, and the results of further investigations have enabled us to understand the situation better, even though the factors at work are still somewhat complicated.

It is to be remembered that pearl banks exist in the vicinity of Tuticorin, and it has been for a long time believed that spat from the oysters there drifted at times on to our own banks, *i.e.*, those under lease. This circumstance is by no means impossible, or even at times unlikely.

We must further note that oysters usually spat in July and August, and that their microscopic larvæ float about on the surface of the sea for about the first five to seven days. The exact period is somewhat uncertain. The larvæ are, therefore, liberated in one or other of the phases of the surface current during the south-west monsoon, and the whole interest attaching to surface currents lies in the distribution of these larvæ, which is effected by the surface current at the time of their liberation. The entire plateau on the West Ceylon coast is potential paar ground, and other and less productive tracts occur as noted near Tuticorin. It is evidently important to know what becomes of the spat shed by oysters living on the several areas. If the spat is retained on the area where it was liberated, the bank within limits continues to be productive. If the spat drifts away, the oysters tend to eventually become extinct. On the other hand, if well-defined currents exist, there is always the possibility of banks on one area being replenished with spat from other areas, which latter must of necessity be remotely distant. This phenomenon has been repeatedly witnessed on the pearl banks under lease. There have been periods when on this area scarcely a single oyster was to be found. Yet the banks recuperated and became stocked with countless millions of oysters. This rejuvenescence was certainly not due to their own recuperative powers. At present the banks are barren all along the coast, and no oysters are to be found. This circumstance has often been repeated during historical times. From where do the exotic spat come, and what brings them ?

With reference to the Tuticorin banks, it is easy to understand that should spat be liberated there when the south-west monsoon is light or moderate (when the current runs north), it is almost certain that the larvæ would be carried away through the Paumben Pass into Palk's Strait, or further north along the Indian coast.

If liberated during a strong monsoon, the possibilities are that the westerly wind would drift them out into the gulf, where they would become involved in the oceanic current and be carried towards Ceylon. Moreover, we have seen that during a strong monsoon the oceanic current actually sweeps the Tuticorin beds.

It follows from the nature of the currents that the Tuticorin banks receive no exotic spat, for, as far as we are aware, no other oyster beds exist round Cape Comorin. Moreover, their own resources are being continually drained, and it is not to be wondered at that they are unprofitable.

On the Ceylon side, and on the areas still under Government control, it is well known that they are markedly unproductive. Yet the bottom is very suitable, and a few scattered oysters have been found thereon from time to time. No living oysters occurred there when we inspected the area in March, 1909 (Part III., "Ceylon Marine Biological Reports"), and only three fisheries have been held south of Tallaivillu Point since 1800. They were all held on the Chilaw Paar, and took place in 1803, 1815, and 1884 We believe this sterility due also to the prevailing currents, which during the south-west monsoon either run south when the monsoon is strong, or north with the wind when moderate or weak. Local spat, whenever they occur, are swept away and lost. Moreover, the chances of this area being supplied with exotic spat are very remote indeed. It is only during an intensely strong and continued monsoon that the current penetrates far enough north into the gulf to sweep the Company's banks, and thus convey spat therefrom to the banks still under Government control, and even then it is highly probable that such spat would be driven ashore. Their chances of receiving spat from South India, whenever spat occurs there, is equally remote, for as we have seen, when the monsoon is only weak the currents on the Indian side run north and through the Paumben Pass. Even if a moderate monsoon persists, the easterly oceanic current which eventually reaches the banks still under Government control almost certainly does not sweep over the Tuticorin banks, or penetrates far enough north to allow of spat being drifted into it by the prevailing westerly wind.

It is only when a strong monsoon persists for some considerable time that the oceanic current penetrates far enough into the gulf to sweep the Tuticorin beds. In that case the easterly current stretching across the gulf reaches the Ceylon coast well north of Tallaivillu Point, carrying with it spat when present from the Indian side. Such spat appear to be deposited on the banks under lease, and to never reach the banks further south, as the distance in the latter case is too great (140 miles), and the larvæ mature and sink long before the current reaches so far south.

The pearl banks under lease which are situated in that beautifully protected *cul-de-sac* at the extreme north-east of the gulf now call for particular attention. Their productivity at times is marvellous, yet barren years intervene. Much of the barrenness is due to causes other than currents, but, on the other hand, it is quite certain that much of their productiveness is, and has been, due to the fact that they have been periodically stocked with exotic spat, which, added to their own inherent powers of production and recuperation, has more than amply satisfied the demands of rapacious men and predatory fish. They also owe much to their protected position, and a glance at the chart will serve to illustrate this fact.

The only surface movements on this part of the plateau are entirely dependent on the wind. Except in very strong and prolonged south-west monsoon no real current exists, and the tendency is for spat liberated in the vicinity to be retained thereon, and to be deposited near its source of origin. If strong monsoon persists, we have seen that the current penetrates further and further into the gulf until it sweeps the Tuticorin beds, and the possibilities are then present for spat being brought across and deposited on the banks under lease. The same current turning south and following the trend of the land would also carry away to the south the local spat from the banks under lease, but the likelihood is that such spat, instead of actually being deposited on the banks still under control, would merely drift ashore. On the more inshore areas, as on the Kondatchi Paar, succeeding spatfalls have gradually wandered closer inshore. The possibilities of the banks under lease receiving spat from the Indian side during a strong monsoon are very considerable, although as yet we only understand in merest outline a few of the factors which may conduce to bring about this result.

If the south-west monsoon is light or moderate, the spat from the Indian side runs with the northern current through the Paumben Pass. It is evident that under these conditions no spat could possibly drift on to the banks under lease. It is only when the south-west monsoon is very strong and prolonged that the oceanic current penetrates further and further into the gulf, until eventually it sweeps the Tuticorin banks. If oysters are present there, their spat is almost certainly brought across to the banks under lease by the current, which in strong monsoon most probably penetrates the gulf much further north than is indicated on the appended chart showing the results obtained during 1910, when the monsoon was not either very strong or continuous. The absence of an exotic spatfall this year, as in other years, has either been due to the moderate monsoon which prevailed, or to the absence of spatting oysters on the Tuticorin banks.

The larvæ of the oyster are pelagic, *i.e.*, they live on the surface of the ocean for about the first five to seven days of their existence. They then develop a shell, and dropping to the bottom become attached. There can be no doubt that many drop in deep water and are lost. The depth most suitable for oysters is 6 fathoms.

The distance from the Indian banks to the banks under lease is approximately 85 miles. Taking seven days as the maximum time occupied by the pelagic stage, a *continuous* surface drift to the east of 0·6 knot per hour for six successive days would place the spat on our banks. We believe that this does happen occasionally, but only during strong monsoon. Otherwise it would be impossible to explain the sudden transition from absolute barrenness to remarkable luxuriance which has characterized the area under lease through long periods of history.

Such in merest outline are the conditions of the surface current over the entire plateau. No doubt there are other factors at work, which subsequent research alone can elucidate, but we feel satisfied that the results and explanations given above have a very real significance, and that the broad general facts are as above stated. Although our results this year distinctly prove that the oceanic current reaches the Ceylon coast south of Tallaivillu Point during strong monsoon weather, the results of another year might show that the current struck either a little north or south of the point in question. This, however, would not in the least affect the main facts of its existence and general direction.

It is exceedingly unfortunate that in spite of all effects we have been unable to obtain any data regarding the oyster beds near Tuticorin. No systematic survey or inspection appears to be carried on round Southern India, and oysters are merely fished when present. Data concerning historical fisheries there (both recent and otherwise) would enable us to collect important data regarding spatfalls, for the monsoon conditions are recorded yearly, and on the Ceylon banks we have records of times when in all probability exotic spatfalls occurred on our own area.

In the investigation of these superficial currents we have relied almost wholly on sets or part sets of bottles which travelled quickly, or in bulk, as more likely to indicate the true nature and direction of the prevailing current and be free from extraneous and disturbing factors. Some bottles appeared to have had an erratic course, whilst others were, as expected, not recovered. However, the mass of the evidence was as given in the preceding pages.

It is remarkable how the productivities of the paar areas coincide with the evidence afforded by currents. Both the Tuticorin banks and those south of Tallaivillu Point are remarkably barren. This circumstance one would naturally expect to be the case on areas continually swept by currents at critical periods; whilst on the area under lease, not only are they protected and free from sweeping currents, but under certain circumstances they may even be replenished by spat derived from elsewhere.

Apart from the general trend and sweep of the oceanic current above named, there are, of course, innumerable minor and local eddies along the coast dependent entirely on the configuration of the land and the direction of the wind. They are in every case purely local, and in no way affect the general results just described. We, therefore, need not deal with them here, although we are cognizant of their existence.

We append a list of the stations where bottles were liberated during each monsoon, giving percentage returns, stations, &c., together with explanatory charts (A, B, and C).

We are strongly of opinion that drift bottles ought to be liberated in numbers every year over the Tuticorin banks during the spatting season. It is only by so doing, and by obtaining information regarding the condition of the Tuticorin beds at the time of liberation, that the question of exotic spat can be definitely settled and our results corroborated and enlarged upon. Even if the origin of exotic spat was fully and finally elucidated, the control of the elements in Nature producing the results would be beyond the power of man. As Steuart said in 1843 ("An Account of the Pearl Fisheries of Ceylon"), "the success of the pearl fisheries in the Gulf of Mannar depends primarily upon natural events beyond the control of man. Nevertheless, we may by the most vigilant attention and good management watch the progressive workings of Nature, and not fish up the oysters before they have reached maturity, nor, after they contain the pearl, suffer them to die on the banks and the pearl to be lost........ We may presume from past experience that unsuccessful intervals will continue to recur .... We cannot cause the spawn to settle down upon nourishing grounds. These are events beyond the control of man. The wind, the waves, and the uncertain currents of the ocean carry the embryo over unlimited space. It is only when in the infinite wisdom of the Creator of all things the oyster broods descend upon banks suited to nourish and support it that it comes within our limited power to watch its advancing age and to fish up the respective deposits in succession ...." A knowledge of the true facts is, however, essential to successful culture, as they enable us to lay and mature our plans accordingly.

III.—Bottom Currents.

Our knowledge concerning bottom currents over the plateau is confined entirely to the area under lease. Of the movements which the bottom layers of water may undergo on the ground still under Government control we have no information, and even on the northern area our knowledge is limited to the conditions existing during the north-east monsoon. These, however, give some indication of what the conditions must have been during the preceding south-west monsoon.

From what has been said in the foregoing pages on the surface drifts prevalent over the plateau under lease, it is evident that no serious disturbance at the bottom could accrue from the conditions existing at the surface. The loss of oysters through a bottom current implies a current sufficiently strong to actually tear oysters from their anchorage. Steuart, writing in 1843 ("Account of the Pearl

Fisheries of Ceylon"), stated that "there appeared to be no reason to believe that the oysters were subject to be covered with drifting sand." Any one who has endeavoured to remove a mussel or an oyster from its attachment will understand that considerable force is required to effect this. A *bottom* current of sufficient strength to sweep away and entirely annihilate whole beds of oysters must indeed be strong. It would appear that the disappearance of beds of spat or adult oysters has been curiously mixed up with surface currents, or rather with surface drift.

Whilst we attribute the disappearance to other causes, it is worthy of note that the distinction between surface current or drift and bottom current is most important. The oyster lives at the bottom, and the surface current or drift is only important in so far as it affects the bottom, or in that it is the agency whereby spat is brought or carried away. It is of course possible on a small scale for a bottom current to be independent of the surface current. Our investigations, however, even though limited in extent, have so far tended to prove that the water on the bottom of the area in question is calm and that currents do not exist. There *are* movements in the water, but these movements are vertical and not horizontal; they are gentle undulations, not currents; and we have been unable so far to collect any evidence to indicate that a bottom current exists either during the north-east or south-west monsoon. It would appear likely that if bottom currents exist which are strong enough to remove oysters from their anchorage, the evidence relating thereto would neither be scanty nor rare; but the dress-diving operations conducted by one of us over two seasons during the north-east monsoon has afforded no evidence of any current.

It is well known that from time to time beds of oysters or spat have entirely disappeared and left no trace behind. This disappearance has in every case been attributed to bottom currents. Yet in no single instance has any proof been adduced that such was really the case. The disappearance was merely attributed to currents because no other cause seemed apparent. In Part IV. Report of this series it was there shown that the annihilation of a bed of spat on the Periya Paar Karai, numbering 400,000,000, was due to predatory fish. The remains of the crushed shell on the area in question were only obtained when the dredge was lined with canvas, and the débris even escaped the notice of the divers. When these catastrophes occur on a rocky bottom, the clue to the situation remains obvious for a long time; but if it happens on sand, the broken shell *gradually* sinks into the sand and disappears. This circumstance is, however, not due to silting over by sand, but to the heavier shell débris gradually settling. It thus becomes clear how it may happen that a bed of oysters disappear and leave no trace behind them.

Whilst we are not prepared to state that every bed which has been lost has been devoured by fish, it appears very probable from the analogous case just quoted that such was the case, and that the apparently entire absence of any remains led to the conclusion that the bed had been swept away by a current.

It is impossible, however, with any degree of certainty to state why beds of oysters disappeared in the past. In this paper we shall deal with data collected during our own experience, and although our evidence is wholly negative, we recognize that bottom currents may have occurred spasmodically in the past, and may do so again, but during the last five years it is certain that none have existed or occurred.

It might be argued that on a shallow water plateau, such as the one under lease, any degree of surface current must of necessity produce a bottom current. This is most likely true, but, as we have already pointed out, no surface current exists on the banks under lease.

The almost regular appearance of spat on the Periya Paar, and its equally regular disappearance, presents an important question, which up to the present has not been sufficiently investigated. This bank is situated about 18 miles out at sea, towards the north of the plateau and due west of Tuticorin. The depth of water is from 8 to 10 fathoms, and within a cable's length there are the overfalls (200–300 fathoms). The spat so regularly found thereon are undoubtedly brought from the Tuticorin side by the oceanic current, which runs east during the south-west monsoon. These spat usually disappear before the end of the following January (or during the *north-east monsoon*). The oceanic surface current which at this time runs west from Tallaivillu Point no doubt produces some bottom current on the southern shallow water plateau over which it sweeps, but a reference to the chart will show that the Periya Paar is well north (30 miles) of the point from which the current takes a westerly direction. The disappearance of spat therefore from the Periya Paar is still very enigmatical, and the only conclusion one can arrive at in the present state of our knowledge is that in some way or other it is incident on the proximity of this paar to the overfalls. It is further to be noted (i.) a large portion of this paar is sand, where oysters could not possibly live; (ii.) owing to the immense deposits, large numbers, even if occurring on rock, die from overcrowding; and (iii.) that the bank is, *par excellence*, the home of large oyster-eating rays and teleosts, and is recognized as the best fishing ground on the entire plateau.

Finally, it is worthy of note that only one fishery has taken place on this paar (1879). The bank has been stocked with immense numbers of spat at least fifteen times during the last century, and in every case they have disappeared when about three to six months old. *The disappearance has always taken place during the north-east monsoon, and never during the south-west,* and that in the only case where the spat survived the first six months and thus acquired a firm foothold they lived to be adult and provided a good fishery. This latter point is of very considerable importance, for it shows to us that if *young* oysters occurring thereon *are* swept away by bottom currents, once they obtain a foothold they are safe. This fact lends an interesting side light on the impossibility of older oysters (one to five years) being swept away by currents on more protected areas.

In now dealing with bottom currents on the plateau in general, it is to be noted that our information has been derived principally from three sources, and, as previously noted, they refer only to the north-east monsoon and to the area under lease.

(1) Rough measurements of the bottom currents were made during two seasons by means of the following apparatus:—A tow net was sunk by means of a small iron ring round the mouth to within 3 feet from the bottom. The depth over which the observations were made varied from day to day between 5 and 10 fathoms. Assuming the depth to be $6\frac{1}{2}$ fathoms, the tow net was suspended by 6 fathoms of rope to a flat bamboo float at the surface. This was placed just astern of the ship and allowed to drift for one hour. The direction of the drift was noted, and the distance at the end of the hour measured. This was done three times per day during two north-east monsoons. The average rate of the current over the entire period was approximately 0·15 knot per hour. This method is of course far from accurate, for it was found that the surface float was acted upon by the surface wind and drift, and thus tended to drag the bottom net, which was but lightly sunk. The results were further complicated by the fact that during parts of March and April dead calms prevailed. Only on one occasion was it found that the bottom current was running in an opposite direction to the surface current. The above results are of too crude a nature to count for anything, save that if a strong bottom current had existed the indication would certainly have been noted.

(2) During the last six seasons (1906–1911) native divers have been continually at work on the banks. It is exceedingly difficult to obtain precise information from divers, but only on very rare occasions they have stated that there was a " little current " at the bottom.

(3) The whole of the data on which we rely for our knowledge of the bottom currents has been obtained by one of us by means of the diving dress, and this work has been conducted over two seasons.

Although, as noted, dress diving has only been carried on during the north-east monsoon, the bulk of the work was done very early, before the south-west monsoon had fully subsided, and when one would naturally expect to find the accumulated and undisturbed results of the monsoon on the floor of the ocean. It is on this account that we place some reliance on our data, for although our observations were not made during the actual south-west monsoon, still, if a bottom current existed for several months, there would certainly be some indication of it at the bottom, particularly over the sandy areas which here and there alternate with rock.

This sand is divisible into two kinds: a loose, coarse-grained, angular kind, usually occurring on rock, and mixed with shell débris, and a fine-grained kind. Usually they do not co-exist at the same place, but if they do, one kind is predominant. The fine-grained sand is more or less consolidated, and is hard, and caked, and not yielding when trod upon. The coarse-grained angular sand may be considered as water-logged, for owing to its angular nature there are considerable interspaces between the grains filled with water, which do not exist in the fine-grained variety. Consequently it is found, and has been proved over and over again by means of the diving dress, that the coarse-grained sand is more susceptible to bottom movements than the fine-grained sand.

This fact is of some importance, for descents made over the banks on the heels of the south-west monsoon showed that here and there the coarse sand was thrown into ridges, usually—almost always—about 2 feet apart, 4 inches high, and facing south-west. These ridges could not be produced by a bottom current, for such a current would tend to drift the sand to the north-east and toward the land, the accumulated result of which over many centuries would ultimately sweep landward the whole of the sand and eventually leave a clean bottom. No such result has, however, taken place.

The counter effect of the north-east monsoon may be entirely neglected, for not only are the banks directly under the lee of the land, but they are further protected by a more or less continuous fringing coral reef.

The production of these ridges is obviously due to the surface agitation affecting the bottom layer of water. But the bottom movement is vertical and not horizontal; it is undulatory and not progressive. In other words, it is a wave and not a current.

It has been previously shown that on the area under lease the full force of the south-west monsoon is not felt owing to the penetration of the oceanic current, and consequently the bottom is almost calm.

To the south of the plateau (on the area still under Government control) and on the west coast of Ceylon south of Tallaivillu Point, where the plateau is narrow and swept by an oceanic current during both monsoons, and where the water is shallow, it is most likely that a bottom current is usual. In fact, our experience on these banks corroborates this idea, and a sandy bottom is rare on these southern banks.

Referring in particular to the area under lease, the banks to the south of the plateau, and including the Muttuvaratu Paars, are for the most part made up of dead coral, and sand only exists close to the shore.

In the vicinity of Karativu shoal bottom disturbance is naturally more evident than elsewhere, due to the swell breaking on the shoal. But this effect is purely local.

On the southern extremity of the West Cheval there is also evidence of bottom disturbance. Here the rock is covered in places by a few inches of coarse sand mixed with shell débris, and this sand is thrown into ridges averaging 2 feet in length and 6 inches in height, leaving the rock bare between the ridges. In all cases the coarse sand is composed of angular quartz, oxidized on its outer surface, slightly impregnated with iron, and of a yellow appearance. The ridges all face south-west, and their sides are steep, suggesting that they can only have been formed by vertical motion.

Apart from the vicinity of the Karativu shoal, there is little evidence of any disturbance. The rock is practically bare on the Mid-west, Mid-east, and North-west Cheval. The North-east Cheval is also very free from sand.

On other area, such as the Periya Paar Karai and Vankali Paar, where the rock is covered in places by only a few inches of coarse sand, the ridges are usually 2 feet apart and up to 6 inches high. On the Moderagam Paar the ridges are 3 feet apart and only 2 inches high.

On the real sandy wastes (in contradistinction to paar ground covered only by a few inches of sand) the sand, as we have seen, is fine-grained and very compact. The ridges over such areas are very slight indeed, and are never more than 1 or 2 inches high and about 2 feet apart.

Besides the evidence afforded by the ridging of the sand, which all over the plateau is on the small scale indicated, there exist numbers of crevices and holes on the floor of the ocean. In some cases these holes are caused by disintegrated coral having become dislodged, whilst in other cases they are natural configurations of the rock. Many of these holes are quite 3 feet deep, and one would naturally expect to find that if considerable movements in the sand took place, that these holes would eventually fill up. Yet they have often been examined, and never more than 4 inches of coarse sand found in them.

On the West Cheval Paar, in 9 fathoms of water, the rock has been observed to terminate abruptly in places on the west seaboard with a drop of 2 feet on to a sandy bottom. Here, too, one would expect to find that if the sand was carried about by a bottom current in a progressive motion, the sand would silt up against such an elevation of the rock, particularly during the south-west monsoon.

Further, during the drift bottle experiments carried out over many years on the plateau, many bottles sank on located positions. At least four such bottles were picked up several months afterwards lying on the sand in the position where liberated.

The fallen beacon and the tanks marking the shoal buoy position have been examined on several occasions by one of us in a diving dress for evidence of bottom movement. The tanks have remained exposed to successive monsoons at least during the last twenty years, and there has been no segregation or piling up of sand. The three remaining tanks are as empty as when first examined two years ago, and stand on the bottom with no piling up of sand or evidence of scour such as might be expected. But the sand is heavily ridged.

The shoal rises very abruptly on the west from 9 to 4 fathoms, giving rise to a confused sea during the south-west monsoon, which breaks at times. So that here, if anywhere, one would expect evidence of bottom movement. The tanks, however, remain empty as when first examined, and stand on the bottom free from segregating sand. So that it appears that the ridging of the sand is due to vertical and not horizontal disturbance.

The preceding facts indicate some of the reasons which lead us to the conclusion that bottom currents do not exist on the pearl banks under lease, neither during the north-east or the south-west monsoon.

Inspection work is often commenced late in October, before the south-west monsoon has subsided. At such a time the bottom layer of water is invariably turbid. The cause of this turbidity has been microscopically examined, and has been repeatedly proved to be due to the disintegrated remains of sea-weed and Caulerpas. The turbidity renders it almost impossible for divers to see, but it subsides gradually as the north-east monsoon begins. This condition of the bottom water is by no means an entirely unhealthy condition, for it provides extensive organic material for oysters to feed upon.

It has been suggested using a Nanson's currentometer for observations on the bottom currents during the south-west monsoon. Such a meter however would, we believe, in any case only give the *rate* of the current, and not the direction, or the varying directions. The utter impossibility of mooring such a meter on the banks during the south-west monsoon will, however, be apparent to any one who is familiar with the conditions in the gulf during this monsoon.

In addition to the preceding data, a further 927 bottles in all were liberated during 1907, 1908, and 1910. The results therefrom have, however, been discarded. In the majority of cases the place where they were liberated is not known. In other instances they were liberated between the monsoons, when no definite result can be expected; whilst the balance includes bottles liberated at unsuitable places, or under unsuitable conditions.

The returns quoted in Part III., "Ceylon Marine Biological Reports," are not included in this report.

The following table gives topographical returns and percentages :—

South-west Monsoon.

Bottles liberated north of Tallaivillu Point (inshore), 1908 and 1909.—Bottles liberated went ashore and form part of the 927 discarded.

Bottles liberated south of Tallaivillu Point, 1910.—Liberated, 60; recovered, 49; percentage, 81·6 per cent.

Bottles liberated between Colombo and Tuticorin, 1910.—Liberated, 505; recovered, 242; percentage, 48 per cent (practically).

Total number of bottles liberated on the above positions, 1908 and 1910.—Liberated, 565; recovered, 291; percentage, 51·5 per cent.

North-east Monsoon.

Bottles liberated north of Tallaivillu Point, 1907, 1908, 1909, and 1910.—Liberated, 284; recovered, 48; percentage, 17 per cent. (practically).

Bottles liberated between Colombo and Tuticorin, 1909.—Liberated, 74; recovered, 12; percentage, 16·2 per cent.

Total number of bottles liberated on the above positions, 1907, 1908, 1909, and 1910.—Liberated, 358; recovered, 60; percentage, 17 per cent (practically).

Abstract.

Total number of bottles liberated	1,853
Total number of bottles discarded	927
Total number of bottles liberated at all stations during both monsoons ..	923
Total number of bottles returned during both monsoons.. ..	351
Percentage returned over both monsoons	38·1

Table I.—Drift Bottles liberated during the South-west Monsoon of 1910.

Date of Liberation.		Position of Liberation.	Station.	Bottles liberated.	Bottles recovered.	Average Velocity of Current.	Remarks on Place of Recovery, Monsoon Conditions, &c.
1910.			No.	Nos.	Nos.	Knots.	*Unsettled Monsoon Conditions.*
June	28 ..	Off Cape Comorin ..	1	20	13	0·36	All recovered on the Ceylon coast, at Tallaivillu Point, near Chilaw, and at Negombo.
June	29 ..	Manapad ..	2	5	2	0·25	Recovered in the vicinity of Jaffna.
July	2 ..	Cape Comorin ..	1	20	8	0·13	One recovered at Paumben, the others near Mannar and as far north as Jaffna.
							Strong Monsoon ; Current to the East.
July	9 ..	Off Cape Comorin .	1	20	9	0·6	All recovered on the Ceylon coast, in the vicinity of Barberyn and Galle.
July	10 ..	Do.	1	15	11	0·5	All recovered on the Ceylon coast, between Chilaw, Colombo, and Galle.
July	11 ..	Do. ..	1	5	5	0·5	All recovered on the Ceylon coast, between Mannar and Negombo.
July	16 ..	Do. ..	1	20	1	1·0	Recovered at sea off Galle.
July	19 ..	Do. ..	1	20	—	—	—
July	24 ..	Colombo ..	4	20	13	0·3	Recovered to the south of Colombo, as far as Kalutara.
July	25 ..	Tuticorin Pearl Banks	3	20	7	0·2	Recovered on the Ceylon coast, between Tallaivillu Point and south of Chilaw.
							Moderate Monsoon ; Current to the North.
July	28 ..	Off Tallaivillu Point ..	6	20	18	0·33	All recovered at Mannar.
July	30 ..	Manapad ..	2	20	8	0·2	Six recovered at Paumben and 2 at Mannar.
August	1 .	Cape Comorin ..	1	20	9	0·43	All to the north, 8 at Paumben, 1 at Jaffna.
August	3 ..	Tuticorin Pearl Banks ..	3	20	10	0·15	Recovered 1 at Kilakarai, the rest at Mannar and Vankali.
August	3 ..	Manapad ..	2	20	9	0·13	Recovered to the north, in the vicinity of Kilakarai and Paumben.
August	4 ..	Chilaw .	5	20	14	0·24	Recovered on the Ceylon coast north of station, 13 near Puttalam and 1 at Mannar.
August	5 ..	Tallaivillu Point ..	6	20	17	0·19	All recovered at Paumben.
							Strong Monsoon ; Current to the East.
August	15 .	Off Tuticorin Pearl Banks ..	3	20	9	0·7	Recovered on the Ceylon coast south of Colombo, in the vicinity of Kalutara and Barberyn.
August	15 ..	Manapad ..	2	20	12	0·15	Recovered to the north, in the vicinity of Paumben.
August	15 ..	Cape Comorin ..	1	40	22	0·7	Recovered to the south of Colombo, near Mt. Lavinia, and also between Barberyn and Galle.
August	18 ..	Do.	1	20	7	0·4	Recovered on the Ceylon coast, south of Colombo.
August	18 ..	Manapad ..	2	40	21	0·25	Recovered on the Ceylon coast, south of Tallaivillu Point to Colombo and as far as Galle.
August	18 ..	Tuticorin Pearl Banks ..	3	20	9	0·4	Recovered on the Ceylon coast, at Negombo, beyond Barberyn, and as far as Kosgoda.
August	26 ..	Manapad ..	2	20	14	0·25	Recovered on the Ceylon coast, from Chilaw South to Colombo.
							Moderate Monsoon ; Current to the North.
September	1 ..	Off Cape Comorin .	1	20	11	0·4	Recovered north, in the vicinity of Paumben and Jaffna.
September	3 ..	Do. .	1	20	18	0·4	Recovered north, in the vicinity of Paumben and Jaffna.
September	1 ..	Tuticorin Pearl Banks .	3	20	7	0·4	Recovered north, in the vicinity of Jaffna.
September	1 ..	Cape Comorin ..	1	20	7	0·1	Recovered north, near Paumben and Jaffna.
			Total ..	565	291		

Percentage return, 51·5 per cent. Total average surface drift, 0·38 knot per hour.

Note.—The current ran steady north during the rest of the month (September).

Table II.—Drift Bottles liberated during the North-east Monsoons, 1907–08, 1908–09, 1909–10.

Date of Liberation.	Position of Liberation.	Station.	Bottles liberated.	Bottles recovered.	Highest Velocity of Current.	Where recovered, Weather Conditions, &c.
		No.	Nos.	Nos	Knots.	*Typical North-east Conditions.*
November 20, 1907 ..	Off North-east Cheval Paar ..	2	14	1	0·3	At Alleppe, Travancore.
November 21, 1907 ..	Do.	2	13	—	—	—
November 23, 1907 ..	South-east Cheval Paar ..	2	16	10	0·4	All in the vicinity of Tuticorin
November 24, 1907 ..	Krusadai Paar	3	19	—	—	—
November 26, 1907 ..	Karativu Paar	3	12	1	Not traced.	Rajakumangalam Thura, Nagercoil, India.
November 28, 1907 ..	Periya Paar (south end) ..	2	16	2	0·3	One at Calicut and the other near Cochin, India.
November 28, 1907 ..	West Cheval Paar	2	12	1	0·3	Near Cochin.
November 29, 1907 ..	Moderagam Paar	2	14	—	—	—
December 12, 1907 ..	St. Anna's Church, 4 miles south of Tallaivillu Point ..	4	8	—	—	—
December 18, 1907 ..	Periya Paar (south end) ..	2	14	—	—	—
December 25, 1907 ..	Periya Paar	2	9	—	—	—
January 29, 1908 ..	Tuticorin Pearl Banks ..	6	10	2	0·46	Both at Kottar, Travancore.
January 29, 1908 ..	St. Anna's Church, 4 miles south of Tallaivillu Point ..	4	12	—	—	—
February 4, 1908 ..	North-east Cheval Paar ..	2	13	1	—	At Penang, 2 years and 8 months after date of release.
February 6, 1908 ..	West Cheval Paar	2	7	—	—	—
February 12, 1908 ..	Muttuvaratu Paar	3	8	—	—	—
February 14 & 15, 1908	Krusadai Paar	3	50	30	0·26	All in the vicinity of Tuticorin..
February 15, 1908 ..	Do.	3	10	1	1·3	Near Tuticorin.
						Typical North-east Conditions.
November 4, 1908 ..	Off Mannar or Nadukkudu Paar ..	1	16	5	1·0	All recovered near Colochel, beyond Cape Comorin.
January 27, 1909 ..	Muttuvaratu Paar	3	9	1	0·34	Milande Atoll, Maldive Islands.
February 16, 1909 ..	South Cheval Paar	2	10	—	—	—
March 10, 1909 ..	Cheval Paar	5	4	—	—	—
March 13, 1909 ..	Maraville Paar	5	8	5	0·10	All at Udappu.
						Typical North-east Conditions.
November 10, 1910 ..	Off Tuticorin Pearl Banks ..	6	20	—	—	—
January 4, 1910 ..	North Cheval Paar ..	2	18	—	—	—
January 13, 1910 ..	Alanturai Paar	3	16	—	—	—
		Total ..	358	60		—

Percentage returned, 16·76 per cent. Average velocity of current, ·476 knot per hour.

Since the preceding report on the currents prevalent in the gulf was written, 900 more drift bottles have been liberated at the same stations during the south-west monsoon of 1911.

The results are similar to those obtained in previous years, which they fully corroborate. This year (1911), however, the monsoon was extraordinarily light, and the consequence was that the oceanic current from the west was feeble, and never penetrated into the gulf at all. Consequently there was no "head" of water in that region. The currents, therefore, ran to the north and through Paumben Pass. On one occasion, when the monsoon was a little stronger than the year's average, this oceanic current, sweeping past Cape Comorin, caught a set of bottles liberated there. Passing in a south-easterly direction, it reached the Ceylon coast a little to the north of Colombo, where it caught and swept southward a set of bottles liberated near Colombo. The interest of this fact is that bottles liberated off Tallaivillu and Chilaw about the same time were drifted to the *north*. This interesting result shows that the oceanic current just reached Ceylon between Negombo and Colombo, and *that* only on one occasion.

The monsoon during July was very light and the current on both sides of the gulf, that is, off Manapad and Tuticorin on the Indian side, and off Colombo, Chilaw, and Tallaivillu on the Ceylon side. During the early part of August the monsoon freshened a little, and on this occasion bottles released off Cape Comorin were swept easterly by the monsoon ocean current, and were recovered on the south coast of Ceylon between Colombo and Galle. During the second week in August the monsoon fell light again, and the current off Cape Comorin and off Ceylon ran steadily north, until the monsoon finally died away in September.

Strictly speaking, there was practically no south-west monsoon during 1911. Consequently the bottles ran generally north and were lost. Only 23 per cent. were recovered, as against 51·5 per cent. last year. Theoretically, during a perfect south-west monsoon, bottles liberated on the stations shown on the charts appended ought *all* to be recovered on the Ceylon coast. The strength of any south-west monsoon may be measured by the percentage of bottles recovered The weaker the monsoon, the greater the percentage of bottles lost, and so with exotic larvæ.

Through the kindness of Captain Fysh, R.N.R., of the R.M.S. "Palitana," and Captain Dickinson of the R.M.S. "Putiala," we were enabled to collect plankton twice daily (5 A.M. and 7 P.M.) over the vicinity of the Tuticorin pearl banks. A net was devised to take the collections whilst the ships were under full way. The net consisted of a conical brass wire framework having a $\frac{1}{4}$-inch mesh. It was made of woven brass wire, and was suitably weighted with a brass ring round the top. This framework was intended to support the tow net when the ship was under way. Inside this net was fixed and fitted a net of jute hessian to prevent the tow net proper from chafing against the brass. The tow net itself was fitted and fixed inside the jute hessian. Splendid collections were made. The tow net had to be renewed almost every day, but the jute hessian net usually lasted for three or four days. We recommend this form of apparatus for collections of plankton under similar circumstances.

A few oyster larvæ were noticed in the plankton on July 28 and 29 only, and these were scanty. The experiment shows, however, that it is possible to obtain good plankton catches in this way, and thus to know whether the oyster larvæ which give rise to exotic spatfalls on our banks are present in the vicinity of Southern India.

The outstanding feature is however that, although oyster larvæ may be present in enormous numbers round Southern India, no exotic spat can possibly reach our banks unless the south-west monsoon continues *strong* during the critical period. The experiment during 1911 conclusively showed that, even if larvæ had been abundant, they would have drifted through Paumben Pass and been lost. When oysters *are* present on the Tuticorin side, their larvæ drift through Paumben Pass, or drop into the abyss on their way to the pearl banks, or successfully reach the plateau, depending absolutely on the strength of the monsoon.

As Steuart remarked, the factors controlling these natural events are at present beyond our control, but now that the facts are understood, we recognize that the intermittency of fisheries is dependent on the strength of the successive monsoons. We have often suspected that there were meteorological rhythm concerned in these periods of blankness, and we should not be surprised to find when the data comes to be carefully examined that this is so. The data already to hand appears to point to this conclusion.

To Ceylon the interest of the Tuticorin pearl banks lies in their being the area potentially supplying spat to the Ceylon pearl banks. As such they merit attention, and it is to be hoped that succeeding workers will have means of investigating these banks. With that information, and a knowledge of the nature of the south-west monsoon for any particular year, it will be possible to predict with a considerable degree of certainty whether an exotic spatfall has occurred on the Ceylon banks before the inspection has commenced.

In conclusion, we would tender the grateful thanks of the Company to all who have helped in this investigation by liberating drift bottles, and our special thanks are due to Captain Fysh and Captain Dickinson for the interest, care, and trouble they took in the collection of the plankton over a period of two and a half months.

Current Chart for South West Monsoon - A.

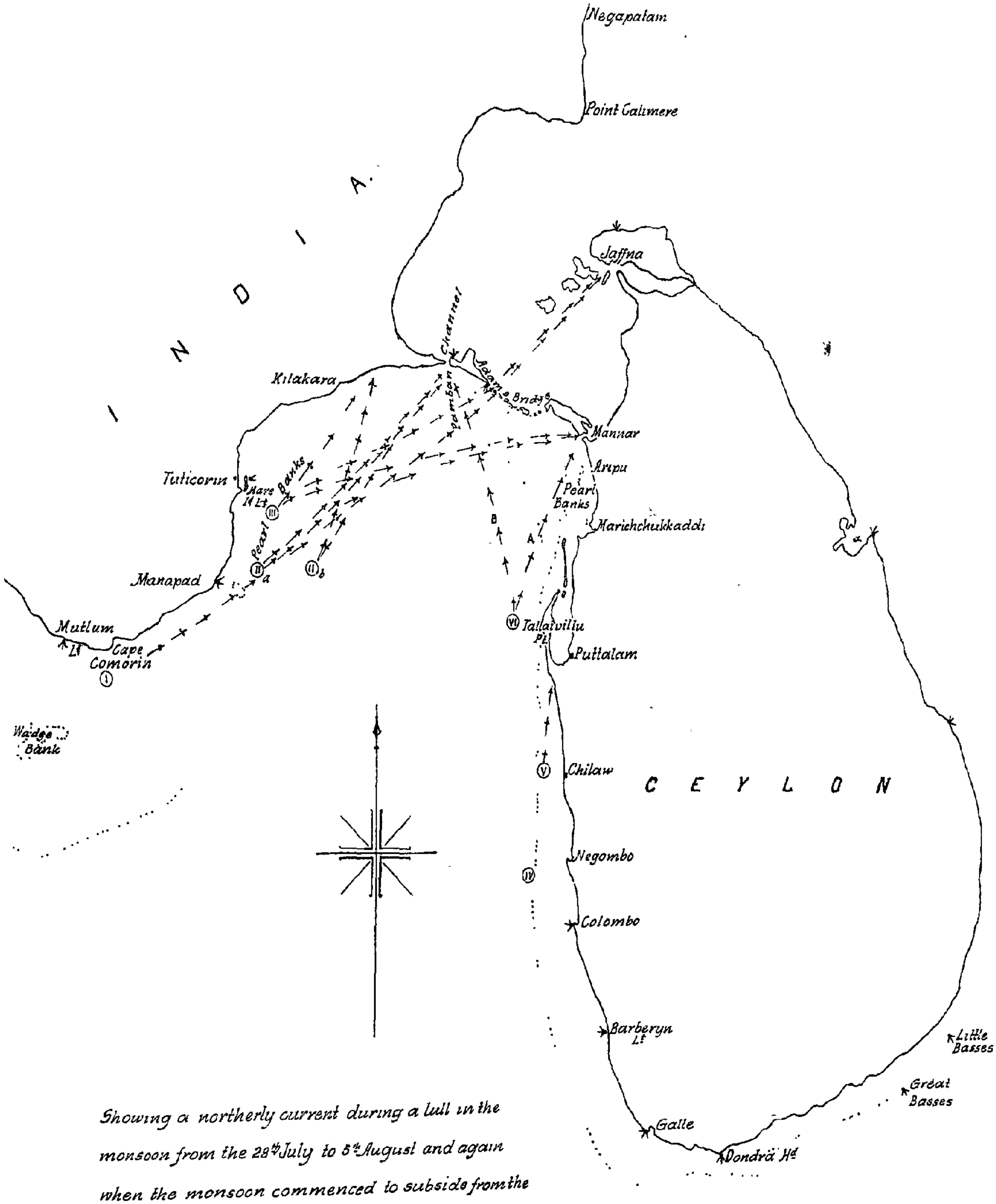
Current Chart

Showing the easterly set when the South West Monsoon was strong from 9th to 25th July and again from 15th to 26th August 1910.

Jas C. Kerkham
12 10. 11.

Lith S.G.O No.60 Nov 1911.

Current Chart for South West Monsoon - B.



Showing a northerly current during a lull in the monsoon from the 28th July to 5th August and again when the monsoon commenced to subside from the 1st September 1910, after which date the current ran steadily to the north during the month

Jas. G Kerkham

12 10 11.

Lith S.G.O. No 61 Nov 1911.

Current Chart for North East Monsoon - C.

Lith S G O No 62 Nov 1911

No. 21.

NAUTICAL NOTES AND OBSERVATIONS ON THE CEYLON PEARL BANKS UNDER LEASE.

By Lieut. J. C. KERKHAM, R.N.R.,
Superintendent of Fisheries.

1.—Introductory Remarks.

It has been my privilege since taking up duties as Superintendent of Fisheries to the Ceylon Company of Pearl Fishers, Limited, to participate in the carrying on of a work which has been intensely interesting, very unique, and wholly novel to me, and which promises to continue to be very fascinating; for although at present there is no promise of a fishery, still one has only to turn to the past history of the banks to see that Nature, though heavily taxed by rapacious men, has always made good such ravages, and also those of the oyster's natural enemies, by huge deposits of spat from outside sources. One may therefore look forward hopefully to the near future for a plenteous supply of spat in such quantities as to defeat all the efforts of predatory fish and other enemies of the pearl oyster, and which will remain in such numbers on the banks as to ensure future fisheries.

My duties, other than the actual inspection work carried on by skin and dress divers and general supervision, has been to co-ordinate all the nautical data up to date, to add what I have been able to collect during the last two seasons, and incorporate same in a new chart. A preliminary chart was drawn up at the end of the last season, *i.e.*, April, 1909. Another chart with further data is now completed. a good deal of fresh data has been obtained. Some considerable inaccuracies have been found referring to the positions and contours of the coral reefs, particularly those outside Dutch Bay.

2.—Notes on Anchorages, &c.

Dutch Bay.—The survey of Dutch Bay was carried out during October, 1908. It is the only land-locked anchorage on the area leased by the Company. The bay, if such it can be called, is one of the entrances to the extensive backwater which extends as far south as Oodoopekeret, 10 miles north of Chilaw, and affords small native craft safe and navigable waters sheltered from both monsoons, and is the natural highway for a considerable coastal trade. The only anchorage available in Dutch Bay for even light draught sea-going vessels lays immediately east of a sandy extension of Mutwal island called Dutch Bay Land, on which there are two conspicuous coconut topes, which form useful landmarks as far north as Karativu beacon and south to Tallaivillu Point. A beacon has been erected by the Company on Dutch Bay Land 1 mile north of the northern tope, which forms an additional landmark and marks the southern extremity of the Company's area.

The Company's attention was drawn to Dutch Bay, as it is the only protected area which appeared available for forming nurseries for oyster culture. Consequently, with that object in view, the bay was surveyed and an area selected, which, although far from offering what was desirable, was the best to be found there, having regard to depth of water, nature of bottom, and protection from the south-west monsoon. The area was marked off and cultched. On examination six months later the cultch was found to be silting over. A recent examination showed that the whole area was covered with a layer of coarse sand, with mud, and a sandy shoal which existed (stretching in an east-north-easterly direction into the bay from near the beacon) has extended out to, and partly over, the cultched area. This sand shoal is not shown on the original chart. It has formed on a small rocky patch, and of late has grown out into the bay and threatens to almost close the entrance. The shoal is a dangerous one, having only 3 feet on it at low water. It rises out of 3 fathoms of water, and is very abrupt on the north side. There are other striking changes taking place in Dutch Bay. Several very interesting characteristics were noted in Part III., "Ceylon Marine Biological Reports," June, 1909.

The severance of Ipantivu island from Karativu has taken place of late years. A shoal now marks the subsidence, and a sheet of water 2 miles in breadth separates the islands. Another remarkable change, concurrent probably with the subsidence, is that at the south-west extremity of Karativu full-grown trees of 3 feet circumference now stand in 9 feet of water at a distance of a cable and a half from the shore. As these trees do not appear to be more than twenty years old, it is evident that the subsidence is recent, and probably still going on, for when Dutch Bay was visited last it was found that a new channel had formed north of the present southern extremity of Karativu, so that the island is again divided.

The other striking change noted in the above Report was the formation of a channel, now a mile broad, cutting off Dutch Bay Land from Mutwal Island. The channel is still broadening, much to the sorrow of an enterprising Sinhalese fisherman, who has planted a coconut tope, which is slowly and surely being washed away by each succeeding monsoon. This new channel on the south probably accounts for the segregation of sand on ground hitherto kept clean by the velocity of the ebb and flow of tide, as doubtless a smaller volume of water passes through the main entrance now than formerly, when only one channel existed.

In the face of such rapid and striking changes Dutch Bay cannot be recommended as a safe anchorage, and should be entered with great caution. It is only available for vessels of very light draught—not over 12 feet. The entrance to the bay must be approached from the south of the Bar reef, the passage between the reef and Karativu not being safe, as sandy shoals form there.

Native craft frequently water from Ipantivu Island, where wells have been sunk at the north-west extremity, off which a depth of 12 feet is found at a distance of four cables. The water is good.

Portugal Bay affords anchorage sheltered from the south-west monsoon in 4 fathoms of water, with good holding ground, the bottom being stiff mud. This bay has no hidden danger, and the soundings are very even. It is only useful as an anchorage.

Marichchukaddi, 4 miles further north-east—the fishery headquarters—affords good anchorage for light draught vessels in 3 fathoms of water, and is sheltered from the full force of the south-west monsoon, although there is a very steep sea and considerable surf on the beach during the height of the south-west monsoon.

A good leading mark when approaching Marichchukaddi is the northern bungalow of the three built on a cliff, in line with a large conspicuous tree bearing east. This gives a leading line over Karativu shoal in 3 fathoms of water. The bungalows are very conspicuous, more so than Dixon's tower, which latter stands three cables north. The top of the tower is 95 feet above low water. Both form conspicuous marks over the East and West Cheval Paar.

At Marichchukaddi there is a good supply of fresh water from two reservoirs, one a quarter and the other three-quarters of a mile from the beach, but the water is not so good as that found at Silavatarai, which is obtained from concrete wells sunk close to the beach, and from which water can be readily pumped into a water boat.

Silavatarai Anchorage lays three cables south of an iron beacon erected lately on the Silavatarai coral reef, and is only used when calling for water. Of late a nursery—formed of expanded metal—has been erected under the shelter of this reef. The ground is flat rock covered with a little sand, and is not a safe anchorage.

Mannar South Bar Anchorage lays in from 2 to 3 fathoms of water: the latter depth is found 3 miles from the shore. The bottom is very shelving; the 2-fathom line is fairly close in about seven cables from the beach.

The only mark in making South Bar is one recently erected by Mr. Stevenson, the late Assistant Government Agent of Mannar.

There are no port marks visible at South Bar. One has only the mark referred to above, which is a post 30 feet high painted alternate black and white. It is situated at the sea end of the South Bar road. Vankali lighthouse makes a good cross bearing with this mark.

The anchorage is only available for small craft, which unload where the South Bar road ends at the beach. Dhoneys alone are able to across the bar. When making Mannar anchorage from the south. Talaimannar Point (which is very conspicuous) bearing north leads clear of the north-west extremity of the Vankali reef. The black and white post described above may be steered for when bearing east.

3.—Reefs and Shoals.

Bar Reef is fittingly so called, as it lies at right angles to the coast line immediately outside Dutch Bay, and at the southern extremity of the area under lease.

The reef is exposed to the full force of the south-west monsoon, and doubtless accounts for the segregation of sand and the sandy elevation on Karativu north of the Bar reef, which it shelters. The elevation occurs north of where the new channel has formed referred to under "Anchorages. Dutch Bay," and has an approximate elevation of 12 feet. The reef protects a considerable sea area north as well as Karativu Island, north of the sandy elevation mentioned. The passage between the reef and Karativu is not safe for other than small craft, as sandy shoals form, and the bottom is very uneven

The reef is formed of three coral patches, the south-west patch being the most extensive, and lying east and west. The other coral patches occur one on the north and one on the east. The three patches (all of which dry at low water) form a triangle, the base being to the south. The intervening space has patches of living coral in deep water, the coral nearly reaching the surface in places.

A striking feature about this reef is that, although it forms a natural barrier and breakwater, the sea, however rough, never breaks on it. In the height of the monsoon it is invisible, except at low water, when the coral can be seen, but there is no breaking sea. This particular characteristic is shared by the Vankali reef, and is accounted for by the coral extending out into deep water. A breaking sea only occurs where the coral grows and terminates in shallow water. The Bar reef in rough as in fine weather is invisible, except at low tide; consequently, as it lies in deep water, it is dangerous to approach. To obviate this two iron beacons have been erected, one on the south-west extremity, the other on the south-east.

The reef covers an area of about 1 square mile, and is formed principally of *Turbinaria crater*, which grows in dense masses, and which makes it all the more surprising that such a solid barrier does not cause a broken sea. The position of the reef has been found to be slightly different to that on the original chart. The reef has been re-charted, and the position of the beacons on it are now shown on the new chart. Dutch Bay beacon bearing east leads clear of the southern end of the Bar reef.

Karativu Shoal is a sandy shoal running north from the northern extremity of Karativu island. It narrows as it goes north, and deepens (which depression marks the channel across the shoal for vessels to Marichchukaddi drawing less than 18 feet). It then shoals again and broadens, terminating abruptly 10 miles north, where it deepens suddenly from 3 to 6 fathoms. The northern extremity is called the Shoal Buoy Position, and was marked at one time by an iron beacon, which, however, owing to the sandy nature of the bottom, did not withstand the strength of the south-west monsoon, and now lays at the bottom. The fallen beacon is buoyed when inspection work is going on, as the position affords a good southern mark. Deep draught vessels would need to round north of this position when approaching Marichchukaddi.

The shoal is clearly visible in fine and clear weather, as the white nature of the sandy bottom makes the water a light green. At such times the fallen beacon shows up as a dark shadow, as do several tanks sunk on the same spot. Karativu tope and beacon can just be seen, which, together with Kutrimalle tower and Kellar obelisk, form good marks to locate the position.

The sunken beacon mentioned above has been recently examined with a view to raising it, but it was found in a very bad condition. Such a beacon, with an iron tray between the legs at the base and heavily ballasted with a hundred tons or more of stone ballast, might perhaps stand the monsoon, but the position is very exposed, and the sand very coarse and loose. A station buoy meets all present requirements, and is removed at the end of the fishing season.

Aripu Reef lies due west of Aripu tope, at a distance of 4 miles, and occurs on the edge of the inshore overfalls of a shallow water plateau of from 2 to 3 fathoms, which extends out from the shore, and starting at Kutrimalle Point sweeps gradually in a curve to the north-west, and finally west-north-west. The coral reefs commence off Silavatarai, and are named Silavatarai, Aripu, and Vankali reefs. Silavatarai reef forms the southern extremity. These coral reefs, which extend in a north-westerly direction for a distance of 5 miles, cover an area of about 4 square miles, and terminate on the west in from 4 to 5 fathoms of water. On the north a deep arm of the sea runs in towards Vankali, and divides Aripu from Vankali reef.

The area on the inshore side of Aripu reef has been examined with a view to finding a suitable area protected by the reef, for another nursery like the one under the lee of the Silavatarai reef, where unfortunately there is only 12 feet of water; but although deep water was found on the northern extremity of the Aripu reef, it is not protected sufficiently.

The reef is made up of three groups of coral, including the Silavatarai patch, which dry at low water. *Madrepore* predominates, and occurs in great variety. On this reef the sea breaks in places, which is accounted for by shallow water, there being a depth of under 6 feet in parts.

Vankali Reef, lays off the port of that name and north of the deep arm of the sea mentioned as dividing this from the Aripu reef. It occurs on the edge of the overfall of the shallow inshore plateau, which here extends in a more westerly direction, and is at the northern extremity, 9 miles from the shore. The plateau inside is shallow, *i.e.*, 2 to $2\frac{1}{2}$ fathoms. The coral grows in dense solid masses on the overfalls, and terminates on the west face in from 5 to 6 fathoms. The most massive growths occur in from 1 to 2 fathoms. The reef covers an area roughly of 6 square miles, and is 6 miles long. It terminates north, where the shallow plateau ends, and soundings deepen to 5 fathoms.

The characteristic of the coral growth here is *Turbinaria cincerens* in huge masses, rising abruptly, and growing in separate dense growths with deep chasms between, which make walking over the reef (of which an extensive area dries at low water) a dangerous business, unless one is attended by a boat and companions, for one might get badly hurt by a sudden fall into the deep abysses, and as the coral overlaps, it would be an easy matter to find oneself fast under the overhanging edge. On this reef, as on the Bar reef, the sea does not break, due to the fact that the coral grows out into deep water.

An iron beacon has recently been erected on this reef, which has been placed on the highest and densest part of the reef, and in a position where it is hoped it will stand. The structure is of railway iron, and is surmounted by a black ball 6 feet in diameter over an inverted triangle, which can be clearly seen 8 miles. A beacon on this reef was necessary, as the only bearing available on the northern paars is Aripu tope, and a second landmark was much needed.

4.—Beacons and other Landmarks.

Since the Company took up the lease of the pearl banks considerable additions have been made to the landmarks, in order to facilitate the location of the various paars and rocky areas. The positions of the conspicuous natural landmarks have been fixed, and the positions of the original marks verified and corrected where necessary.

The beacons which the Company have erected are Kutrimalle, Karativu, and Dutch Bay beacons: and of late the two on the Bar reef, one on the Vankali reef, and another on Aripu reef.

Other small iron beacons have been put up, one on the Silavatarai reef and three others in Dutch Bay. Two of the latter have fallen owing to erosion and the loose nature of the sandy bottom where they were erected.

Besides the erection and maintenance of the above beacons, the Company have cleared Arunakalu tower of encroaching forest growth and cleaned and whitewashed it, as also Kutrimalle tower and Kellar obelisk—all original landmarks. Kutrimalle and Arunakalu towers, both trigonometrical stations, have furnished a base for fixing all landmarks as far north as Aripu tope. These two marks are masonry towers, and are to be seen a considerable distance owing to their high elevation. Kutrimalle tower is 230 feet and Arunakalu 280 feet above sea level.

Starting from the south, Dutch Bay Beacon marks the southern extremity of the Company's area. It is situated on Dutch Bay Land, 1 mile north of the northern of the two conspicuous coconut topes mentioned under "Anchorages, Dutch Bay." It is, like Kutrimalle and Karativu beacons, built of palmyra trees stepped in cement, and is 37 feet high from the base, which base is about 4 feet above low water level. The beacon is painted white.

Karativu Beacon is situated at the north end of Karativu island, and forms, together with Karativu tope, a useful mark to locate the Shoal Buoy Position. As previously mentioned, it can be seen clearly as far south as Bar reef. The beacon is 40 feet high and is coloured black.

Kutrimalle Beacon is situated on Kutrimalle Point, and has an elevation of 145 feet above sea level. It is painted black and white, one-third black from the top, the lower two-thirds white. The beacon, with Kutrimalle tower, makes a useful magnetic transit bearing for compass adjustment, as also does Karativu beacon with Kutrimalle tower.

The two beacons erected on Bar Reef mark the south-west and south-east extremities. The south-west beacon has a black ball 5 feet in diameter, the top of which is 18 feet above low water mark. The south-east beacon has a cask on top with a cross below. The top of the beacon is 12 feet above low water mark. The south-west beacon can be seen as far north as Karativu or Kutrimalle tope.

Aripu Reef Beacon is situated on the north-west extremity of Aripu reef, and marks the deep water channel which lays between the Aripu and Vankali reefs. It is built of railway iron topped with angle iron, and is triangular in form, having three uprights, which are bolted together at the top: the south and west sides are battered in and whitewashed. The beacon is surmounted by a staff and cross yard; the staff supports a conical cask, and a conical cask hangs from each yardarm, the whole being coloured black. The beacon stands in 3 feet of water at low water, and has a height of 30 feet above low water mark; it is clearly visible at a distance of 9 miles.

The Silavatarai Reef Beacon marks the southern extremity of this reef. It is a small beacon, and only serves as a guide when anchoring to the south of it, which position forms the most convenient anchorage for watering.

The Vankali Reef Beacon is built of railway iron bolted together. It is situated on the highest and most compact part of the reef, on a spot where the depth is only 5 feet. The rails have been driven through the coral well into the mud and securely bolted together. The beacon is surmounted with a 6-feet black ball, the top of which is 28 feet above low water; below the ball is an inverted black triangle. The beacon is clearly visible to the naked eye at a distance of 8 miles, and forms a useful and much-needed mark on the northern paars.

Kellar and Doric Towers—or more correctly obelisks—are both original marks, erected by Government on well-selected sites between Marichchukaddi and Aripu. They are visible all over the Cheval Paar. Aripu tope also forms a useful mark, and can be seen as far west as the Periya Paar, distant 16 miles.

The Vankali Light Beacon, which is an iron structure, has been boarded up by the Company on the west and south side and whitewashed; this was necessary, as owing to the nature of the structure it could not be seen by day from the banks, although the light at night is visible 11 miles. The beacon is now clearly seen a distance of 12 miles, and is, in conjunction with the Vankali reef beacon and the beacon erected on the Aripu reef, a most useful landmark for the northern paars, *i.e.*, Periya Paar Karai and the true Vankali. It is also a valuable mark when making Mannar anchorage. The height of the beacon is 46 feet from the base.

The next landmark north of Vankali is Talaimannar Point, on which the trees grow thickly and end abruptly, giving a well-defined landmark and a useful guide for clearing the north-west extremity of Vankali reef, where the point is clearly visible, although distant 12 miles. Talaimannar Point is also a useful bearing, coupled with the southern extremity of Mannar island, which latter from this point forms a good mark, distinguishable by the abrupt ending of the trees, to fix positions on Anaivilundun and Nadukadu Paars.

It is proposed to replace the palmyra beacons, *i.e.*, Kutrimalle, Karativu, and Dutch Bay, by masonry obelisks, as the palmyra beacons require frequent attention owing to the attack of white ants, and are therefore expensive in upkeep. Masonry obelisks require little attention, and are more conspicuous than beacons built of palmyra trees.

5.—Paars and other Rocky Areas.

The Cheval Paar, noted as being an area on which more oysters have been fished than the whole of the remaining paar ground, has always been carefully watched and examined, as here, if nowhere else, oysters may be looked for. Since the last fishery this ground has been most searchingly examined, in the hope that some portion of the late rich harvest of fishable oysters might still remain. These hopes, as is well known, were not realized.

During the course of this close examination of the rocky area, it became apparent that, although the paar ground was charted fairly correctly, several rocky areas shown as separate paars were extensions of the main paar. We had also reason to believe that the paar ground on the north of the Cheval was more extensive than shown. Consequently, a rectangular form of inspection was adopted in place of the old circular method. The latter form left intervening unexamined spaces between the circles, and was open to great distortion owing to the difficulty the boats had of making a true circular course.

The rectangular method of inspection means that the whole ground is examined, as each square abuts against the next. A greater area is covered daily, and the prevailing north wind can be utilized to assist the boats, which work across the wind east and west, starting from the windward or north side, where they are towed by the steam tender, which also picks them up on occasions, when the inspection is finished, to leeward of the ship's position and tows them back.

This rectangular method of examining the ground (which, as is well known, is done by skin divers) combines inspection work with survey, for it shows the exact lay of the rock and the contour very closely, and has revealed considerable differences in the configuration of the Cheval Paar.

The Periya Paar, and also the true Vankali, reveal similar differences, the latter being a much greater area than is shown on the old chart.

The Cheval Paar is formed of two large areas of rock. The one on the west, known as the West Cheval, is a compact, well-defined, oblong stretch of flat rock, only connected with the East Cheval by a narrow run of rocky ground on the north. A narrow stretch of sand runs north of the Shoal Buoy Position (mentioned before as being the northern extremity of the Karativu shoal). This stretch of sand carries the same depth of water as the paar ground on each side, and is in no way a shoal. The old horseshoe configuration is consequently not correct. The flat rock carries on it heavy calcrete in the centre, living coral on the north, and coral débris to the south.

The East Cheval has been found to have three extensions, which have been named northern extension, north-east extension, and south-east extension of the East Cheval. The East Cheval is also largely formed of flat rock, calcrete, and coral débris, the latter predominating, as shown on the chart furnished.

The northern extension is formed of heavy calcrete on flat rock, and it thins out north to cora debris, then sand. This extension appears to have been known as the old Aripu Paar, although it does not quite coincide with the original charted position of this paar, which position was found to be all sand.

The north-east extension is of coral débris alone with sand, and was formerly charted as a separate paar known as Kallatidel Paar. The south-east extension of the Cheval is of flat rock, heavy calcrete, and coral débris, and was known as the true Kondatchi Paar, and charted as a separate paar.

The entire area of the West and East Cheval, with extensions, is approximately 21 square miles. The depth of water over the West Cheval is from 7 to 8 fathoms, and on the East Cheval 6 fathoms. The extensions average a depth of 5 to 5½ fathoms of water. The most productive part of the Cheval has been the south part of the East Cheval.

The Moderagam Paar.—What has been known as the North and South Moderagam Paars, and charted as separate areas of rock, are practically a southern extension of the East Cheval, although separated from the latter. This area is nearly all sand with scattered coral débris, so scattered in fact as to hardly admit of being described as paar ground. A long narrow run of coral débris which extends due west from the East Cheval alone lends itself to configuration as paar ground, although scattered coral débris lies to the east and west. The rocky area lies in a deep water *cul-de-sac*, which probably accounts for oysters maturing here. A bed of 6,000,000 oysters matured on the Moderagam and was fished in 1904. The depth of water here, as on the East Cheval, is 6 fathoms.

The Periya Paar Karai.—This paar is a compact solid stretch of flat rock which lies due north of the Cheval at a distance of 2 miles, the intervening area being sand. A peculiarity of this paar is the prevalence of large potholes, varying from 12 to 15 feet across and from 3 to 4 feet in depth, with overhanging edges. These holes are the resorts of numbers of fish.

The existence of these holes is a striking proof of the absence of bottom currents and silting, for it is evident that the holes would be full of sand, and would appear as sand patches if there was any drift of sand. The prevalence of these potholes makes dredging difficult. The area of the paar is roughly 2 square miles, and the average depth 8 fathoms.

Calcrete and coral débris occur on the flat rock, and a great variety of weed. The Periya Paar Karai figures largely in the history of the banks as being a paar on which oysters have frequently matured. It was on this paar that a bed of spat was found in November, 1908, which unfortunately was demolished by predatory fish, as was amply proved by the quantities of broken shell and shell fragments dredged up by the "Violet," and also brought up by divers. The next paar of importance is—

The true Vankali Paar, which lays 2½ miles north-west of the Periya Paar Karai; it is separated from the latter by a narrow neck of sand. A bed of spat also occurred on this paar in November, 1908, which was considerably larger than the one which was found on the Periya Paar Karai, but shared the same fate. The area of this paar has been found to be much more extensive than shown on the original chart.

The paar lays roughly east and west. It is 3 miles long, and covers an area of about 6 square miles. The depth of water is 7 fathoms on the east; it deepens to 8 and 8½ in the centre, and to 10 fathoms on the west, where it approaches to within 2 miles of the northern extremity of the Periya Paar. Two-thirds of the paar has a depth of under 9 fathoms.

The paar is roughly made up of flat rock, with calcrete and coral débris. There is an extension to the north of coral débris, which thins out, and is too scattered to chart as true paar ground.

The whole of this paar is excellent ground for oysters. It is difficult to understand why it has not a better record, but it seems likely, as it is so closely adjacent to the Periya Paar Karai, that some of the fisheries attributed to the latter may have occurred on the true Vankali.

The general characteristics of the West Cheval, the Periya Paar Karai, and the true Vankali closely approximate each other, the nature of the bottom and the average depth of water being the same.

A northern landmark was much needed here. The beacons recently erected on the Vankali and Aripu reefs have met this want.

The Kondatchi Paar occurs on an area—now known as the Kondatchi area—east of the Cheval, extending to the 3-fathom line, and reaching as far north as the Silavatarai reef, and south to the Kellar obelisk. Scattered coral débris is found over a considerable portion of this area, but it is too scattered to be charted as paar ground. This scattered coral débris, together with the occurrence of beds of *Pinnas*, forms cultch on which oyster beds have frequently occurred and matured; but the oysters, although large, are known to be very poor pearl producers, incident on the shallow water on which they occur, *i.e.*, 4, 3½, and 3 fathoms, and the absence of infecting parasites.

The Muttuvaratu Paar comes next to the Cheval in productiveness. The Muttavaratu Paar starts north of the northern extremity of Karativu island, on the edge of the overfalls, and extends south as far as Bar reef. Starting at the north, where the paar narrows to a point on the edge of the overfalls, it broadens south, and approaches Karativu island to within a mile of the beach. It then runs roughly south-south-west until the Bar reef is reached. The west is bounded by the overfalls. This extensive rocky area includes—starting from the north—Karativu, Alanturai, and Krusadai Paars, also Hamilton's Muttuvaratu and Donnan's Muttuvaratu, the whole being one continuous rocky area covering approximately 28 square miles. This vast stretch of rocky area represents about 25 square miles of potential paar ground, the paars above named being those on which oysters have matured and been fished.

The bottom is flat rock, on which quantities of massive *Porites* grow, the ruins of which lie scattered over the whole area, forming excellent cultch. Isolated growths of *Turbinaria crater* and brain coral also occur in great quantities, but the *Madrepore* ground is practically useless for oyster culture, and represents 3 square miles.

To the south, just north of, and in the vicinity of the Bar reef, beds of *Madrepore* occur, which cover considerable areas. The feature of the paar north of the Bar reef is the absence of *Madrepore* and the large size and massive growth of *Porites*, which occur in groups and rise on their own ruins to 3 and 4 feet above the bottom, and is described by native divers as "peaky rock." These massive growths of *Porites* make dredging and trawling operations impossible over this area.

With the *Porites* and other massive coral growths, such as brain coral, *Galaxia*, and *Mussa*, quantities of *Foraminifera* and *Halimeda* occur, together with a great variety of weed other than the latter.

The depth of water on the inshore or east side of the paar averages 5 fathoms, which deepens gradually as the overfalls are reached to 9 fathoms, which is found on the edge of the overfalls, which here are very precipitate. The Muttuvaratu Paar ends the list of the historically productive paars. We now come to the great—

Periya Paar.—This paar is situated on the edge of the overfalls from the 9-fathom plateau to the 14- to 20-fathom plateau, distant 18 miles from the land. A succession of plateaus occur off the coast at this point, *i.e.*, due west and north of Kellar obelisk, starting with a 2-fathom plateau, with a fall to the 4- and 5-fathom plateau, on which the Kondatchi Paar occurs, then again to 6 and 7 fathoms, on which the Cheval Paar is situated. After this we get a slight depression to 9 and 10 fathoms, which decreases to 8 and 9 fathoms respectively as the Periya Paar is reached. The Periya Paar lies on the edge of the fall from what may be termed the Cheval plateau, which gradually deepens from 6 and 7 to 8 and 9 fathoms until the overfall is reached to the 14- and 20-fathom plateau, which latter finally ends at the overfalls proper, where we get a precipitate fall to 100 fathoms or more.

The slight depression noted between the Cheval and the Periya Paar resembles the depression or valley noted on the plateau off the south coast by Captain Somerville, R.N., in "Spolia Zeylanica," Vol. V., Part III., April, 1908.

The average depth of water over the paar is 9 fathoms, deepening rapidly on the west to 14 fathoms. The paar on the south is about 2 miles broad, 11 miles in length, and tapers on the north to a fine point. The paar takes the trend of the overfalls on which it occurs, which here run in a north-west by north direction. The northern extremity of the paar approaches, as is noted elsewhere, to within 2 miles of the true Vankali Paar.

The paar is represented by a rocky edge, on which living coral occurs on the north, but which has died out on the south, where there is a little less depth of water, *i.e.*, 7½ to 8 fathoms. It was on the southern part that a bed of oysters matured which were fished in 1879, and this is the only fishery recorded on this paar. The importance of the paar is solely due to the frequent and almost seasonal occurrences of large spatfalls; but only on the above occasion have oysters matured here.

Anaivilundun and Nadukadu Paars are the most northern, and represent one continuous stretch of rocky ground with living coral, coral débris, and weed. The paar is situated on the edge of an overfall, from a 5-fathom plateau to a 7 to 8 fathoms, which is a continuation of the overfall on which the Vankali reef occurs, although the reef ends where the 2-fathom plateau between the reef and the coast terminates.

The above 5-fathom plateau extends out in a southerly direction from Adam's Bridge, and is formed of mud and fine sand, with patches of living coral and quantities of prawns and shells. The paar itself is formed almost wholly of *Turbinaria crater*. Massive stony coral is rarely found here. The area of the paar is considerable, being approximately 6 square miles. The average depth is 5 fathoms. There appears no record of oysters maturing or of fisheries on this paar, although the rock where the coral occurs is clean and appears suitable for oysters.

The paar is about 6 miles long and 1 mile broad, and runs in a west-north-westerly direction from Vankali reef, from which it is separated by a 3-mile stretch of sandy bottom, on which the depth of water increases as the Vankali reef is left and the paar is approached.

6.—Method of Inspection by Divers.

The examination and inspection of the pearl banks is carried out by native divers under the superintendence of the Superintendent of Fisheries, who also checks and verifies the native divers' reports as to the nature of the bottom by personal inspection in the diving dress.

The present method of inspection is an improvement on the circular method inaugurated by Capt. Donnan, which latter necessarily left intervening spaces between the circles, to obviate which the present rectangular method has been adopted. The circular method was convenient for prospecting, but for systematic survey and accuracy the rectangular method adopted has many advantages, such being continuity, greater accuracy, and the avoidance of distortion, equalized labour; and a greater area covered daily ; the courses are straight, and full advantage can be taken of the prevailing north wind, and finally four areas can be inspected from one central position, which means that the inspecting vessel need only move to a new position every third or fourth day. The latter advantage is a great saving of wear and tear to the Company's vessels. Another advantage of the rectangular method is alinement, which means that lines of positions can be extended to the outside positions with great accuracy ; and a further advantage is that beds of oysters can be, as the paar is, accurately figured and the numbers estimated more nearly.

The four inspection boats, six-oared whalers, start from the windward side of the area to be inspected, and work across the wind east and west, between the buoys (which are laid down north and south, east and west), in such a manner as to direct the boats on their east and west course and prevent their getting out of position. Each coxswain is provided with a chart on which the result of each dive is recorded with the soundings.

The inspection chart is divided into six sections ; the top or north one is known as No. 1 section. Starting, we will say, from the north-west buoy, the four boats take up their positions and proceed to take a line of dives as they go east. The north boat steers for the north-east buoy, and the south boat for the intermediate north buoy of the centre line of buoys. The centre intermediate line of buoys are laid as a guide to prevent the boats getting set to leeward. No. 1 boat (No. 1 coxswain) takes the windward position and No. 2 (No. 2 coxswain) the lee, and these coxswains are responsible for keeping position. Fourteen dives are made from each boat, and as they go across the area six times a total of 336 dives are made over the entire area. An area covers $2\frac{1}{4}$ square miles, and represents a 9-mile course from each boat, although with turning and getting into position for each section the actual distance is $10\frac{1}{2}$ miles. The boats are towed into position or back according to the ship's position. Each boat has a crew of six boatmen with three divers and two linemen, which, together with the coxswain, makes a crew of twelve. The inspection work starts at 7 A.M., and an area is inspected by 1 P.M., the inspection occupying six hours, and each section one. The same area inspected by dredge occupies four hours.

The smaller charts known as coxswain charts are filled in by each coxswain as each dive is made, and it is from these that the inspection chart is drawn up.

Such, in brief, is the present method of inspection, which has led to the more accurate charting of the rocky areas known as paars, and, as pointed out above, also gives the correct configuration of oyster beds as well as the rock.

7.—General Observations and Remarks.

On visiting the pearl banks for the first time one is struck with the distance which the banks proper—such as the Cheval Paar—are from the land, and the featurelessness of the coast, which is here very low-lying.

The only conspicuous well-defined landmark is Kutrimalle Hill. The absence of other landmarks has been remedied by the erection of masonry towers, obelisks, and, of late, beacons, as described elsewhere. All landmarks are clearly seen after noon, but owing to the low elevation of the land, station or position buoys have had to be used to prolong lines of positions to the more northern paars in order to ensure accuracy. On such distant landmarks a slight error means perhaps half a mile out where an object is from 14 to 20 miles distant, as in the case on the Periya Paar Karai and the true Vankali Paar. Here a system of alinement and transit bearings has been adopted, together with masthead angles, ensuring accuracy where the landmarks are so distant; but we have the two new beacons, *i.e.*, Aripu and Vankali reef beacons, to work with.

On the southern paars, *i.e.*, those south of Kutrimalle Point, starting from the northern extremity of Karativu Island, this difficulty ceases, as the mainland has a good elevation. The paar ground, including the Karativu, Alanturai, Krusadai, and Muttuvaratu Paars, is bounded on the west by the overfall, which here approaches to within 6 miles of Karativu Island, so that all landmarks are clearly visible, both those on the mainland and on Karativu Island.

All nautical data accumulated during the last eight years, together with that obtained from the Admiralty chart of the Gulf of Mannar, the latest Government chart of the pearl banks, and other data obtained personally, has been co-ordinated within the last year, and are shown on a preliminary chart which has been drawn up of the whole area under lease. This chart embodies all nautical data collected up to date, and also shows the paar or rocky ground as revealed by the latest inspection, which, with the rectangular method of inspection as described, took the form of a survey. The chart also shows the fauna of the entire area, which has been determined by the Scientific Adviser to the Company; it is therefore a nautical and biological chart.

I may mention here that the positions of all landmarks have been fixed and verified from a base line between Arunakalu and Kutrimalle towers. The positions of these trigonometrical stations were furnished by the Government Survey Department on the latest chart of the pearl bank area. In addition to the above, a survey has been made of Dutch Bay, and a chart on a scale of 4 inches to one nautical mile drawn up.

Investigations on superficial currents in the Gulf of Mannar and immediate vicinity have been made and are being continued, which we have every reason to believe are of considerable importance, and will throw more light on the origin of exotic spat, which from time to time replenish the banks, the intermittency of which accounts for the failure of fisheries. These investigations are being made from independent data, together with information obtained from the liberation of drift bottles and the collection of planktonic forms over long periods of time.

An experimental nursery has been erected in the sea, under the lee of the Silavatarai reef. Unfortunately the depth of water is only 12 feet on this protected area. The nursery is built of expanded metal with railway iron uprights. It has withstood the south-west monsoons well, and answers all the purposes for which it was intended.

A masonry tank has been erected on the foreshore at Marichchukaddi, and is filled by a pump fitted with a filter. The pipe is carried well out clear of the foreshore into deep water. A second tank has been also fitted, and appliances—drain pipes, &c.—such as are necessary for the experimental scientific work carried on.

During recent trawling operations for certain fish required for scientific experimental work the small number of fish on the banks at present was apparent, and is incident doubtless on the absence of oysters and other shell fish.

No. 22.

A DESCRIPTION OF TEN NEW SPECIES OF CESTODE PARASITES FROM MARINE FISHES OF CEYLON, WITH NOTES ON OTHER CESTODES FROM THE SAME REGION.

By T. SOUTHWELL, A.R.C.Sc. (Lond.), F.L.S., F.Z.S.

With three Plates.

Trawling operations were continued, as usual, during the past year. The area under lease over which these operations were carried out cover the greater part of 700 square miles. At the present time fish are by no means abundant, a fact which is undoubtedly connected with the absence of suitable food "Shell fish" are remarkably scanty. Five years ago, when both oysters and other shell fish were abundant, fish were much more plentiful.

All the fish caught have been carefully and systematically examined for cestode parasites, particularly the Elasmobranchs. No adult cestodes have been found in any Teleosts, but cysts are very numerous in most species, and a few are described in the present paper. The habitat and the larvæ of the adult cestodes described from the pearl banks are generally not known. Most probably this is because they have not been sufficiently carefully searched for

It is almost certain that the larvæ of the adult forms described will be found later in the various crustacea and molluscs.

No parasites have been found in the *flesh* of any of the Teleosts examined. All the cysts obtained were found in the mesenteries, save in one case, where a few were discovered along with some *Trematode redia* (which measured about 20 mm. by 8 mm.) on the walls of the air bladder.

The position of the encysted forms found in Teleosts, with relation to the life-history of the parasite concerned, is very enigmatical. I am confident that in some cases these bony fish are merely parallel hosts, and that the life-history of the parasite is direct from the crustacean or molluscan host to the Elasmobranch. In some cases it may be found later that the infection of the Teleost is initial, and that the life-history is direct from the Teleost (particularly if this is a small form) to the Elasmobranch. The fact that no adult cestodes have ever been found in Teleosts lends favour to this theory.

With reference to the life-history of the pearl-inducing worm itself (*Tetrarhynchus unionifactor*) no further light has been adduced, but it seems practically certain that the life-history is direct from the oyster to the various Elasmobranchs which devour them, and that *Balistes*, *Serranus*, and possibly other genera of fish represent subsidiary or parallel hosts.

During an examination of Tamblegam Lake, which I recently made along with Dr. Pearson of the Colombo Museum, a few *Trygons* of various species were collected. In one species a few adult specimens of *Tetrarhynchus unionifactor* were obtained. There seems little doubt that the pearl-inducing larvæ of *Placuna placenta* is the same as in the pearl oyster, but the occurrence of the adult in a *Trygon* was surprising, as the adult form is so very rarely found.

A few of the genera, and many of the species, of cestodes described by Shipley and Hornell from the pearl banks have not been obtained by me.

I append to this paper a full list of the cestodes obtained by me from the pearl banks, and a comparison of this list with that of Shipley and Hornell (20) will show which genera and species I have not obtained.

I also append a list of parasitic Crustacea, Trematodes, Nematodes, &c. (mostly new species), collected during the last five years, which await description.

Owing to my leaving the services of the Company this paper has been prepared hurriedly. Few anatomical details have been dealt with, but it is hoped at some future time to fully describe the anatomical details of all the species dealt with, both in the present and in the preceding Reports.

In general, the classification adopted in this paper is that followed by Linton. According to this author, the pearl-inducing worm is a *Rhynchobothrium*.

The relations of the genera *Rhinebothrium* and *Echeneibothrium* require re-investigation, and our species *Rhinebothrium shipleyi*, n. sp., appears to require a new genus.

Larvæ of the genus *Otobothrium* are exceedingly abundant in the Teleosts found on the pearl banks, and it is very remarkable that only a few adult specimens have ever been collected, and these only recently.

In the present paper ten new species are described, and notes on seven other species are included. A note on a huge species of Trematode from *Diagramma crassispinum* is also added. The following is a list of the species described :—

Acanthobothrium herdmani, n. sp.
Platybothrium spinulifera, n. sp.
Anthobothrium floraformis, n. sp.
Anthobothrium ceylonicum, n. sp.
Orygmatobothrium tetraglobum, n. sp.
Rhinebothrium shipleyi, n. sp.
Spongiobothrium lintoni, n. sp.
Syndesmobothrium filicolle.
Tetrarhynchus gangeticus.
Otobothrium insigne.
Otobothrium linstowi, n. sp.
Rhynchobothrium, sp. I. Larvæ.
Rhynchobothrium, sp. II. Larvæ.
Rhynchobothrium, sp. III. Larvæ.
Rhynchobothrium, spp. A, B, and C. Larvæ.
Rhynchobothrium rossii, n. sp.
Paratænia elongatus, n. sp.
Trematode, sp.

I am indebted to my former Assistant, Mr. George Morrison Henry of the Colombo Museum, for all the drawings which illustrate this paper, and also for the descriptions of two or three species, and I tender my grateful thanks herewith. I would here correct an error made in Part V. of these Reports. The first cestode material from the pearl banks was collected principally by Mr. Hornell, and was described by Professor Shipley and Mr. Hornell, and not by Professor Herdman.

ACANTHOBOTHRIUM, Van Beneden.

Body articulate, tæniæform. Head separated from the body by a neck, quadrangular. Bothria four, opposite, attached to head by antero-dorsal side, neck with two transverse costæ on face and armed in front with two bifurcate hooks, and surmounted in front of hooks by a triangular pad bearing a supplemental disc which is capable of assuming diverse forms. Genital apertures marginal. (Linton 11.*)

Acanthobothrium herdmani, n. sp. (Plate I., Figs. 1, 2, and 3.)

Measurements.

Extreme length	63·0 mm.
Extreme breadth (at about ⅘ of the extreme length of the head) ..	2·5 mm.
Length of head	1·2 mm.
Breadth of head	1·7 mm.
Length of terminal proglottid	1·5 mm.
Breadth of terminal proglottid	2·0 mm.

* These numbers refer to the literature cited at the end of this paper.

Head.—The head is somewhat cubical in general shape. It is divided into four bothridia, which are sessile for the greater part of their length, only the terminal quarter or so being free. Each bothridium is divided into three loculi by two transverse septa. The loculi decrease regularly in size from the proximal one, which is the greatest. The loculi are rather shallow, and their lips and edges are broad in proportion to the area they enclose. A pair of bifurcated hooks overhang the proximal loculus of each bothridium. They are stout, brown, hollow structures, strongly curved. The two spines which compose a pair of hooks are united at their bases. The spines which are nearest to the longitudinal median line in each bothridium are very slightly larger than the outer ones. The degree of curvature appears to be the same in all the hooks. They are exactly like the hooks of *Acanthobothrium (Calliobothrium) crassicolle*, Wedl., figured by Zschokke (26, Plate 5, Figs. 93 and 94), but are much smaller. Above the four hooks each bothrium is provided with a small but well-marked accessory sucker, which is situated on a small knob-like projection. The neck is long and irregular in diameter. Its cuticle is very strongly wrinkled transversely, and it merges imperceptibly into the strobila.

The proglottides are remarkable, in that they are all broader than long. Over 200 proglottides were counted. Their sides are slightly convex, and their edges are salient. The greatest width of the strobila is anterior to its termination, the riper proglottides becoming slightly narrower. The worm is oval in transverse section. The cuticle is transversely wrinkled in the latter two-thirds of the posterior proglottides. Well-defined bands of longitudinal muscles can be seen to run through the worm.

The genital pores are lateral and irregularly alternate, the average being about four on the left side, then four on the right side.

The cirrhus is fairly long, bulbous at the base, but tapering towards the termination, and can be seen to be hollow. No internal structure can be observed without sectioning, owing to the extreme opacity of the worms. Several specimens when slightly pressed under a cover-slip extruded large masses of ova. These ova are very minute, being about 0·025 mm. in diameter. They consist of a clear spherical cell with a large granular nucleus. A number of calcospherules are irregularly dotted about on the periphery.

The diagnosis of *Acanthobothrium herdmani*, n. sp., is as follows :—

Stout opaque worm, 63 mm. long and 2 mm. broad. Oval in cross section. Head almost square, and comparatively small. The four bothridia are sessile for the greater part of their length. Each bothridium is divided by two transverse septa into three loculi, which regularly decrease in size from the proximal end, and is also surmounted by a pair of bifurcated hooks, proximal to which is a small sucker. Neck long and somewhat irregular in diameter. Proglottides always broader than long, their sides being slightly convex, and their edges not salient. Genital pores marginal and irregularly alternate, averaging four on the left side, then four on the right side.

Habitat.—The spiral valve of *Trygon kuhli*, Müll. and Henle. Fifteen specimens. Cheval Paar. November and December, 1910.

Following Linton, I have here adopted Van Beneden's classification in separating the genera *Calliobothrium* and *Acanthobothrium*, the latter genus being marked by the presence of bifurcated hooks, and the former genus by simple hooks. According to this classification *Calliobothrium farmeri*, Southwell (23), becomes *Acanthobothrium farmeri*. This classification, however, is not adopted by Zschokke.

Acanthobothrium herdmani, n. sp., closely resembles *Acanthobothrium crassicolle*, Wedl. The hooks are exactly similar, but are much smaller in *Acanthobothrium herdmani*, n. sp. Our specimens further differ from *Acanthobothrium crassicolle*, Wedl., in being four times larger, and in the size and shape of the scolex and areolas.

I have pleasure in naming our specimen in honour of Professor Herdman, whose kindly help and assistance I here gratefully acknowledge.

Professor Shipley (21, page 543) remarks that " A point of interest in the Helminthology of Elasmobranchs is the minuteness of the parasites. As Dr. Orly records, the tapeworms which infect the largest sharks, such as *Carcharias* and *Heptanchus*, never surpass 10 cms. in length. As a rule, the size of the Entozoon is inversely proportional to that of its Elasmobranch host. Both the small size and the comparative rarity of the parasites point to the fact that Elasmobranchs suffer little from the presence of cestodes, though doubtless the Teleosteans, in whose bodies for the most part the worms pass through the cystic stage, suffer considerably. When, however, they do occur in Elasmobranchs, they are often met with in great numbers, and this is especially the case with the genus *Calliobothrium*, which is sometimes found in enormous numbers on the spiral valve."

This hardly agrees with my experience on the Ceylon pearl banks. So far as I have observed, the cystic stages very often occur in various molluscs and crabs, and are by no means limited to smaller fish.

Cephalobothrium abruptum, Southwell, and *Cephalobothrium variable*, Southwell, measured respectively 12 and 13 cms. when preserved (23). *Rhinebothrium ceylonicum*, Shipley and Hornell, and *Prosthecobothrium trygonis*, Shipley and Hornell, measured 12 and 23 cms. (20). Cestodes of this length are, however, not very common. Ninety-nine per cent. of the Elasmobranchs I have examined, and they number many hundreds, were infected, and I have not noted that the parasites obtained therefrom were always smaller and more numerous than those obtained from smaller members of this family.

Platybothrium, Linton (11).

Body articulate, tæniæform. Head decidedly flattened, squarish, or trapezohedral. Bothria four, subtriangular, sessile, arranged in marginal pairs, armed with compound hooks, and each terminating posteriorly in a cup-like depression or loculus. A single indistinct circular depression (supplemental disc ?) on each bothrium in front of hooks. Genital pores marginal. (Linton.)

Platybothrium spinulifera, n. sp. (Plate I., Figs. 4, 5, 6, and 7.)

Average Measurements.

Extreme length	33 mm.
Length of head	·4 mm.
Breadth of head	·5 mm.
Length of terminal proglottid	·8 mm.
Breadth of terminal proglottid	·6 mm.

The head is provided with four sessile bothridia, which are arranged laterally. Thus the head in transverse section is oblong, with two bothridia on each of the larger sides of the rectangle. The bothridia are divided by a transverse septum into two loculi, and the proximal one is twice as large as the distal one. The edges of the bothridia are indented at the junction of the septa, and in the posterior loculus they are somewhat incurved, so that the loculus appears slightly pocket-shaped. Both loculi are deeply concave. On carefully examining each bothridium, it was found that in a few specimens there was a very faint indication of a second septum dividing the posterior loculus into two, and resulting in the bothridium appearing to have three loculi, whilst the rest of the three bothridia composing the head on the same individual bore no indication whatever of a second septum.

Each bothridium is surmounted by two hooks, each of which is strongly bifurcated and curved. The prongs or forks of the hooks are usually unequal in size. Where the prongs run into the basal part, there is often a blunt projection given off in another plane, which appears as a thick dwarf process, but it is not always present. The pair of hooks on each bothridium, which are situated on the middle line of the longer side of the scolex (when the latter is viewed in cross section), are slightly larger, and have a much longer subcutaneous basal trunk than those hooks which when viewed similarly are situated at the corners. The hooks on each bothridium are, therefore, not symmetrical. The basal parts of the two pairs of bifurcated hooks on each bothridium are widely separated from each other, and there is no intermediate bar or connecting piece which joins them, such as is figured by Linton (11) in *Platybothrium cervinum*. The hooks are all characteristically hollow.

Each bothridium is surmounted by a fairly large accessory sucker, the greatly thickened walls of which together form a squarish pad at the anterior extremity of the head. Linton refers to his specimen of *Platybothrium cervinum* as having "a single indistinct circular depression (supplemental disc ?) on each bothrium in front of the hooks," but in our specimens this accessory sucker is remarkably well defined.

The neck is long and covered with minute spinules, which are not apparently arranged in any definite pattern. The scolex is also covered with spinules. In some specimens this spinulation extends for some distance along the strobila, but it is a variable characteristic, and a few specimens show hardly any sign of it at all. It appears probable that this variation is due to the deciduous nature of the spinules, some of which have probably been abraded off during capture and preservation, because some of our specimens have large spineless patches in the midst of a spiny portion.

The proglottides, of which over 150 were counted, are broader than long, excepting the last three or four, which become slightly longer than broad. The sides are slightly convex, and more so in the last few segments. The edges are not salient. The genital pores are lateral and irregularly alternate. The internal anatomy was not investigated.

The diagnosis of *Platybothrium spinulifera*, n. sp., is as follows :—

Small worms, 3–4 cms. long. Head with four sessile bothridia disposed in pairs laterally. Each bothridium is divided into two loculi by a transverse septum, the proximal loculus being twice as large as the distal one. Incipient traces of a second septum were noticed in few isolated bothridia. Each bothridium is surmounted by two strongly-curved bifurcated hooks, which are not symmetrical, and the basal pieces of which are markedly unequally developed and are not connected with each other. In addition to the two forks of a single hook, there is usually present a third blunt and thick process which arises at the base of the fork. Each bothridium is further surmounted by a fairly large accessory sucker having thickened walls, the four accessory suckers together forming a squarish proximal pad. Neck long. Scolex, neck, and parts of the strobila covered with minute deciduous spinules. Segments broader than long, except the last three or four. Genital pores lateral, inconspicuous, and irregularly alternate.

Habitat.—The spiral valve of *Galeocerdo tigrinus*, Müll. and Henle. Forty-four specimens. Cheval Paar. December 14, 1910.

Linton established the genus *Platybothrium* on a single specimen, which he named *Platybothrium cervinum*, and, so far as I am aware, no other species of this genus has since been described. It seems fairly certain that the "single indistinct depression (supplemental disc ?) on each bothrium" of this specimen was an accessory sucker.

Linton's "objection to referring the specimen to the genus *Prosthecobothrium* is that the apparent homologue of the posterior bothrial appendage, which is characteristic of that genus, is in this (Linton's) specimen to be regarded as a loculus formed by a transverse costa near the posterior end of the bothrium" seems well founded, and the genera are not very similar, particularly since definite accessory suckers are now known to be present in the genus *Platybothrium* and absent in *Prosthecobothrium*.

The following list comprises a few of the distinct characters of the genera included in Bronn's family *Onchobothriidæ* (= *Phyllacanthiens*, V. Ben.), which may be useful :—

Genus.	Hooks.	Bothridium.	Accessory Suckers.
Onchobothrius ..	Rose thorn shaped, stout, four to each bothridium in two pairs ..	Each with two septa..	Absent
Calliobothrium ..	Four to each bothridium in two pairs	Each with two septa..	One to three
Acanthobothrium ..	Each with two bifurcated hooks ..	Each with two septa..	One
Prosthecobothrium ..	Each with two bifurcated hooks ..	Septa absent .	One posterior (not homologous ?)
Platybothrium .	Each bothridium with two strongly bifurcated hooks ..	Each with one septa..	One
Phoreiobothrium ..	Each bothridium with two hooks, each hook with three prongs ..	Septa absent ..	One
Ceratobothrium ..	Absent ? two curved simple hooks ..	Septa absent ..	One
Cylindrophorous ..	Each bothridium with two bifurcated or trifurcated hooks ..	Septa absent ..	Absent

Taking for granted (as appears likely) that Linton's specimen possessed accessory suckers, *Platybothrium spinulifera*, n. sp., then differs from *Platybothrium cervinum*, Linton, in being only half as large ; in possessing minute spinules on the head, neck, and parts of the strobila ; in the shape of the hooks, and in the proglottides being broader than long (save in the last three or four).

Linton (13) describes a second species of *Platybothrium*, without naming it. It differed from *Platybothrium cervinum* in having two faint costæ on the posterior end of each bothrium, in only being half the size, and in being densely beset with conical spinules.

As only a single specimen was obtained, he did not venture to bestow a specific name, and pointed out that the differences named might be due to the second types of this genus being young strobila.

Platybothrium spinulifera, n. sp., corresponds exactly with Linton's description of his second type, save that there is no intermediate middle piece or connecting bar which unites the antler-like pairs of hooks which overhang the bothridia. As our specimens are all adult, they are obviously new species.

The indications of a second septum on a few isolated bothridia in our specimens shows how nearly related the genera *Acanthobothrium* and *Platybothrium* are, the principal difference being that in the former the bothridia are divided by two septa into three loculi, whilst in the latter genus the bothridia are divided by one septum into two loculi. The general shape of the head and hooks in two genera are, however, very different. The presence of minute cuticular spinules has been noted in certain members of the genera *Phoreiobothrium* (*Phoreiobothrium lasium*) (11) and *Cylindrophorous* (*Cylindrophorous typicus*, Dies) (1).

Anthobothrium, Van Beneden.

Body elongated, articulate, depressed. Supplemental discs (auxiliary acetabula) none. Head separated from the body by a neck. Bothria four, opposite or unilocular, cup-shaped or subglobose, affixed by a contractile pedicel, highly versatile, unarmed. Genital apertures marginal. (Diesing.)

Anthobothrium floraformis, n. sp. (Plate I., Figs. 8, 9, and 10.)

Measurements.

Extreme length	9·0 mm.
Breadth of head	0·7 mm.
Approximate length of neck	3·0 mm.
Length of terminal proglottid	1·4 mm.
Breadth of terminal proglottid	0·4 mm.

Head.—The head consists of four deeply concave bothridia, with very thick rims, borne on contractile pedicels. The bothridia are variable in outline, some being almost circular, whilst others are somewhat kidney-shaped. Their pedicels are capable of a considerable degree of contraction and elongation. In the majority of specimens the bothridia present a somewhat "Maltese cross" appearance, but one specimen has the bothridia borne on very distinct stalks. Other specimens have the pedicels so contracted that they cannot be seen, the bothridia being drawn up close together, and apparently sessile. The general appearance of the head is that of a four-petalled flower, hence the specific name. There is no trace of a myzorhynchus, there are no auxiliary suckers on the edges of the bothridia, and the latter are not divided into areolas.

The neck is long and very slender, and is almost the same diameter throughout. It is apparently cylindrical, and it merges rather suddenly into the broader strobila posteriorly. The cuticle of the neck is markedly wrinkled transversely.

The proglottides are not numerous, their number averaging about twelve or thirteen. The anterior ones are very indistinctly differentiated, and their sides are straight and practically parallel. They are almost square, being very slightly broader than long. The sides of the riper proglottides are slightly convex. The strobila is oval in transverse section. It shows considerable variation, however, in all the characteristics, some abnormal specimens having the ripe segments almost globular, and others having them somewhat attenuated.

The genital pores are situated laterally in the anterior third of each proglottid. In the majority of specimens they are all on one side, but a few had one or two pores on the alternate side. However, the pores are very indistinct, and it is not easy to detect them. No cirrhi were observed.

The anterior of the ripe proglottides show very little structure, except a large mass of somewhat large eggs on each side, with a dark space between the two masses and another on the sides, which latter is succeeded by a clear space which surrounds all the internal organs. A clear oblong space—the cirrhus pouch—can be seen to run from the genital pore into the centre of each proglottid. Another smaller clear patch is situated in the posterior extremity of the ripe proglottides, which probably represents the uterus. The parenchyma of the entire worm is very loose.

This specimen appears to be near to *Anthobothrium musteli*, Van Beneden, but the lack of accessory suckers, and the continuous thickening of the rims of the bothridia in our species, to say nothing about the great difference in size, warrants its separation.

The bothridia are almost similar in shape to those of *Anthobothrium rugosum*, figured by Shipley and Hornell (20), and *Anthobothrium laciniatum*, var. *brevicolle*, figured by Linton (11). Our species differ from the former in the bothridia being only one-sixth the size and in the general features. It differs from the latter in the absence of laciniæ on the posterior edges of the proglottides.

Diagnosis.—Head with four deeply concave, unilocular bothridia, with thickened rims, of varying form in the contracted state. Bothridia supported peltately by well-marked pedicels. No accessory suckers or myzorhynchus. Neck long, fine, and apparently cylindrical, with its cuticle transversely wrinkled, posteriorly merging suddenly into the strobila.

First proglottides almost square, posterior ones elongated. Ripe proglottides with sides slightly convex; anterior ones with straight, almost parallel sides. Proglottides few in number, averaging twelve or thirteen.

Genital pores lateral in the majority of specimens, and all on one side, some specimens having one or two alternate, situated in anterior third of each proglottid.

Ovaries large, occupying the greater part of the ripe proglottides. Uterus small, situated posteriorly. Cirrhus pouch visible as a clear space running from the genital pore into the centre of each proglottid.

Habitat.—A single specimen of this species was taken from a specimen of *Carcharias bleekeri*, Day, caught by line on November 15, 1910, and seventeen specimens were obtained from a small *Carcharias*, sp., trawled on the Periya Paar Karai on the 27th of the same month.

Anthobothrium ceylonicum, n. sp. (Plate II., Fig. 15.)

The head consists of four simple boat-shaped bothridia borne on short pedicels. The margins of the bothridia are thickened and crenulate, but there are neither marginal nor transverse loculi. In preserved specimens the breadth of the head is 1 mm. There is no myzorhynchus or accessory suckers. The neck is very short, and about equal in length to that of the head. The first segments are much broader than long, but they soon become square, and then much longer than broad. The terminal segment measures 1·8 mm. long and ·5 mm. broad. About sixty segments were counted in the mature worm. The entire worm measures 25 mm., and the anterior part is narrow and attenuated. The posterior extremity has a tendency to become curled. The genital apertures in the adult are enormous, and are lateral and irregularly alternate.

Habitat.—The spiral valve of *Trygon kuhli*. Eighty-six specimens. February 2, 1911.

According to Linton the genus *Anthobothrium* differs from the genus *Spongiobothrium* in having no marginal loculi round the bothridia. In our specimens the edges are merely frilled, but no loculi are present: they are accordingly referred to the genus *Anthobothrium*. Of this genus eight species are known, viz., *Anthobothrium cornucopia*, Van Ben., *Anthobothrium elegantissimum*, Lonnbg., *Anthobothrium giganteum*, Van Ben., *Anthobothrium musteli*, Linton, *Anthobothrium perfectum*, Van Ben., *Anthobothrium pulvinatum*, Linton, *Anthobothrium crispum*, Shipley and Hornell, and *Anthobothrium rugosum*, Shipley and Hornell. The present Report adds two new species, viz., *Anthobothrium floraformis* and *Anthobothrium ceylonicum*.

ORYGMATOBOTHRIUM, Diesing.

Body elongated, articulate, depressed. Head separated from body by a neck, with four opposite cup-shaped bothridia, attached by short, contractile pedicels highly versatile, each provided with a single supplemental disc on anterior end of border. Border of bothria entire, without loculi. Genital apertures marginal. (Linton, 11.)

Orygmatobothrium tetraglobum, n. sp. (Plate I., Figs. 11 and 11*a*.)

Measurements.

Extreme length	95 mm.
Length of a bothridium	1·6 mm.
Breadth of a bothrium	1·6 mm.
Breadth of head	4 to 6 mm.
Length of neck	10 mm.
Length of posterior proglottid	3 mm.
Breadth of posterior proglottid	·9 mm.

The head consists of four globular bothridia, which are attached by a broad and rather long stalk, which runs parallel to the long axis of the worm. Each bothridium is hollow, and opens both anteriorly and posteriorly to the exterior by a wide slit. Anteriorly each bothridium is surmounted by a single accessory sucker, which in our contracted specimens appears to have been drawn in towards the centre of the subglobular bothridium. This accessory sucker is circular, ·5 mm. in diameter, and is situated on that edge of the bothridium which is nearest to the centre of the head. Opposite to each sucker is a semicircular flap-like fold, which presents the appearance of a valve guarding the anterior entrance to the hollow bothridium. Its base is half the diameter of the bothridium. No trace of a second sucker could be found, in spite of frequent and continued search. The rim of the anterior aperture of each bothridium is only slightly thickened and muscular.

The diameter of each bothridium is 1·6 mm. The bothridia are quite separate from each other. They can be easily seen with the naked eye. Depending upon the state of contraction, the diameter of the head varies from 3·5 to 6·5 mm. There is no myzorhynchus.

The neck is roughly triangular in shape, tapering posteriorly, opaque, and 10 mm. long.

The first proglottides are almost square, with slightly convex sides. They become square and transparent at 2 mm. from the head. They gradually increase in length, until the posterior proglottides measure 3 mm. long and ·9 mm. broad. The sides are almost straight and parallel, and the strobila is almost transparent throughout. The edges are not salient, and the reproductive pores are lateral and irregularly alternate. Sixty-five proglottides were counted in one specimen.

Habitat.—The spiral valve of *Rhynchobatus djeddensis* (Forsk.). Three specimens. Ceylon pearl banks. February 3, 1911.

It is with considerable hesitancy that I have referred these specimens to the genus *Orygmatobothrium*, Diesing.

Diesing's original description of this genus was: "Body elongated, articulate, depressed. Head separated from body by a neck, with four opposite cup-shaped bothria attached by a contractile pedicel highly versatile, and each provided with two scrobiculiform supplementary discs (auxiliary acetabula). Genital pores marginal."

Linton (11), judging from Mohn's figure of *Orygmatobothrium crispum*, concluded that a second sucker was not present, and re-defined the genus accordingly, including in it his species *Orygmatobothrium augustum*. There appears to be considerable variation in the form assumed by the bothridia. In *Orygmatobothrium augustum*, Linton, they are stated to be "hollowed out or boat-shaped" (11). In *Orygmatobothrium paulum*, Linton, they are said to be "from long to short oval, each with two pits" (12). In *Orygmatobothrium crenulatum*, Linton, they are stated to be "globular, each provided with an auxiliary acetabulum and an accessory disc of strong circular fibres" (12). The bothridia of our species closely resemble the figures given of the *Orygmatobothrium crenulatum*, Linton, but the "strong circular fibres" were not noted, and our worm is almost twelve times as large. There is evidently need for revision in the genus *Orygmatobothrium*, and my specimens are accordingly doubtfully referred here.

RHINEBOTHRIUM, Linton (11).

Body articulate. Head continuous with the body or separated by a neck. Neck merging into segmented body or separated by a constriction. Bothria four, opposite or in lateral or marginal pairs, faces divided into loculi by several or many transverse and one or few longitudinal muscular partitions, mounted on slender pedicels, very versatile, unarmed, myzorhynchus none. Genital apertures marginal.

Rhinebothrium shipleyi, n. sp. (Plate I., Figs. 12, 13, and 13*a*.)

The head consists of four bothridia borne on long, triangular, flattened, and very versatile stalks. The face of each bothridia is long and narrow, and is divided by transverse septæ only into ten unpaired areolas. There is no longitudinal septum. Each bothridium is 1 mm. long, and approximately ·3 mm. broad. The ends are rounded, and the whole bothridium is fringed with a delicate irregular membrane. In the contracted state the bothridia are often roughly semicircular in shape, with the areolas either on the concave or the convex surface. The breadth of the head varies with the state of contraction and with the disposition of the bothridia, but averages about 1·8 mm. There is no myzorhynchus. Immediately posterior to the head is a swollen bulbous portion, triangular in shape, with the apex passing into the proglottides. There is no neck, although the first few transverse divisions between the proglottides are faint and indistinct. The first segments are shallow, ·3 mm. in breadth, and much broader than long, and they continue so up to the last few (6–8) ripe segments, which latter are square, and then slightly longer (1·2 mm.) than broad (·9 mm.). The largest of our specimens was 60 mm. long, and the smallest 42 mm. Most specimens were whip-like in appearance, the maximum breadth being attained at a distance of about 20 mm. from the head, and they continued the same breadth to the end. This anterior part of the worm is apt to be of uneven breadth, which fact is doubtless due to irregular contraction. The posterior and ripe proglottides in our specimens are of varying shades of a dark brown colour. The genital pores are lateral and irregularly alternate. In some specimens the edges of the proglottides in the middle region of the worm were slightly salient.

Habitat.—The spiral valve of *Trygon kuhli* (Müll. and Henle). Seventy specimens. November and December, 1910.

The diagnosis of *Rhinebothrium shipleyi*, n. sp., is as follows :—

Worms about 60 mm. long. The head consists of four stalked, leaf-like bothridia, which are compressed in a plane at right angles to the axis of the worm. The free surfaces of the bothridia are of an elongated oval shape, and are divided by transverse costæ into ten unpaired areolas. This feature is distinctive of the species. The pedicels of the bothridia arise from a bulbous portion immediately anterior to the proglottides. There is no myzorhynchus and no neck. The proglottides are broader than long, except the terminal few, which are square, then slightly longer than broad. The genital apertures are lateral and irregularly alternate. About the middle length of the worm the proglottides tend to be slightly salient. The maximum breadth of 1 mm. is attained at a distance of about 20 mm. from the head.

I have pleasure in naming this species in honour of Professor Shipley, F.R.S., D.Sc., who described the first cestodes from the Ceylon pearl banks, and thus laid the foundations for future work.

The species described above are only provisionally placed in genus *Rhinebothrium*, Linton, pending an opportunity for further work on the Cestoda in general.

The genus *Echeneibothrium*, Van Beneden, was described by Diesing as follows : "Body elongated, articulate. Head continuous with the body or separated by a neck, with a terminal retractile myzorhynchus. Bothria four, opposite, transversely costato-plicate, sometimes provided with longitudinal partitions, attached by the posterior margin to the head by means of a contractile pedicel, versatile, unarmed. Os in apex of myzorhynchus. Genital apertures marginal."

It will thus be seen that our species are intermediate between the genera *Echeneibothrium* and *Rhinebothrium*. They cannot be included in the genus *Echeneibothrium* as described by Diesing on account of the absence of a myzorhynchus, nor can they be included in Linton's genus *Rhinebothrium* on account of the fact that the faces of the bothridia are not divided by "one or a few longitudinal muscular partitions."

It may be necessary later to refer these specimens to a new genus, in which the unpaired character of the areolas on each bothridium and the absence of a myzorhynchus are characteristic. Otherwise Diesing's description of the genus *Echeneibothrium* must be modified so as to include forms in which a myzorhynchus is absent, or else Linton's genus *Rhinebothrium* must be modified to include forms in which the bothridia may or may not be divided by "one or a few muscular partitions."

On the whole it would appear wiser and simpler to establish a new genus for the forms just described.

SPONGIOBOTHRIUM, Linton (11).

Characters amended (1891).

Body articulate, tæniæform. Head separated from body by a neck. Bothria four, in lateral pairs, pediceled, with crisp, folded, or auriculate edges, which are crenulate, and the auriculate flaps finely costate on account of a marginal row of loculi with muscular borders; unarmed, and without transverse costæ on face. No myzorhynchus, no supplemental discs. Genital apertures marginal.

Spongiobothrium lintoni, n. sp. (Plate II., Fig. 14.)

The head consists of four bothridia, with a row of tiny loculi round the edges. Each bothridium is roughly oval in shape, and is attached by a rather short stalk. Opposite the point of attachment each bothridium appears to be almost divided transversely into two halves, and their edges are indented. Placed centrally and opposite to the point of attachment is a minute flask-shaped depression on the face of each bothridium, which at first was mistaken for a sucker. Careful examination, however, showed that the two halves of a bothridium are capable of movement, simulating the movements of the parts of a hinge. When the faces of the two parts of the bothridium are apposed the central depression is noticeable, but when they are separated from each other and flattened, this structure is hardly visible under a low power. In shape the bothridia resemble those of *Rhinebothrium insignia*, Southwell (23), but the areolas are very differently distributed. The number of loculi round the margin vary greatly. In some specimens they are very pronounced, whilst in others they are only found with difficulty. There are no transverse or longitudinal septæ and no myzorhynchus. The average breadth of the head is 1 mm., and the length ·6 mm. The neck is very short, being about ·4 mm. long and about ·2 mm. broad. The anterior half of the neck is usually clear and transparent. The length of the worm is 20 mm. The average number of proglottides is twelve. The first segment is square, or nearly so. They elongate rapidly, however. The sixth segment is twice as long as broad, and the last segment is 4 mm. long and ·5 mm. broad. The sides of the proglottides are slightly convex. The genital apertures are lateral and irregularly alternate. Only the last two segments appear to be mature. The penis is ·6 mm. long, very narrow, with a bulbous base.

The diagnosis of *Spongiobothrium lintoni*, n. sp., is as follows: Small worms, 20 mm. long and ·5 mm. broad. Head with four leaf-like bothridia borne on short pedicels. Each bothridium has a marginal row of loculi, and is divided transversely at the centre. From this point the halves of each bothridium move like the parts of a hinge. When apposed a flask-like depression is to be seen, which is difficult to observe when the two halves are not apposed. Myzorhynchus absent. Neck very short. Usually twelve segments present. First segment square. Last segment 4 mm. long, and eight times as long as broad. Genital apertures lateral and irregularly alternate. Usually only the last two segments mature.

Habitat.—The spiral intestine of *Rhynchobatus djeddensis* (Forsk.) and *Urogymnus asperrimu* (Bl. Schn.). Eight hundred and fifty specimens. February, 1911.

So far as I am aware, only one species of this genus has been described, viz., *Spongiobothrium variable*, Linton. Our specimens answer perfectly to Linton's description of the genus, but differ from *Spongiobothrium variable*, Linton, in the nature of the bothridia and the segmentation, and in the presence of a flask-like depression on the face of the bothridia.

I have pleasure in naming this species in honour of Dr. Edwin Linton, whose work on American Marine Cestoda is so well known.

SYNDESMOBOTHRIUM, Diesing (11).

Body articulate, tæniæform. Neck tubular, rounded at base. Head tetragonal, with four terminal prominent bothria attached to the head by posterior margin, cruciformly disposed, oval, slightly convex, joined with each other at the base by a membrane, proboscides four, filiform armed, each one running through a bothrium (pedicel) excurrent at apex, long, retractile in the neck. Genital apertures marginal (?). In intestines of marine fishes of tropical America.

Syndesmobothrium filicolle, Linton. (Plate II., Figs. 16 and 17.)

I have no hesitation in referring to this species a number of larval forms obtained from the intestines of *Cybium guttatum* and *Chorinemus lysan*.

The head is squarish in front view, with a bothrium at each corner. The bothridia are oval or cup-shaped. The larvæ agree in every detail with Linton's figure of this species, save that in our types the exit of the proboscides was closed. The proboscis sacs were marked with fine criss-cross lines, only visible under a high power.

Habitat.—(i.) The mesenteries of *Chorinemus lysan*. February 25, 1911. Forty-five specimens. These larvæ were enclosed in tadpole-shaped cysts, the cysts measuring on an average 25 mm. by 2·5 mm. The larvæ was contained in the "head" part of the cysts, which in preserved specimens were of a yellow colour. The rest of the cyst was white, membraneous, and transparent. The larvæ measured 2 mm. by ·5 mm.

(ii.) The mesenteries of *Cybium guttatum*. November 27, 1910. Fifty-five specimens, same as preceding.

I believe these specimens to be the same as those described by Shipley and Hornell from *Cybium guttatum*, in Part V., "Ceylon Pearl Oyster Reports," Plate III., Fig. 43.

It is interesting to note that Linton states that he has "met with encysted forms similar to this (*Syndesmobothrium filicolle*) in various species of the *Teleostei*, such as *Pomatomus saltatrix*, *Cybium regale*, &c. One from Spanish mackerel (*Cybium regale*) was described by me in the 'American Naturalist' for February, 1887, under the name of larval *Tetrarhynchobothrium*."

The occurrence of this larva in these *Teleosts* raises the question as to the position of this stage in the life-history of the parasite. On the whole, I feel confident—and I have every reason to believe—that the larvæ normally inhabit the tissues of either crabs or molluscs, and have their adult stage in some Elasmobranch. The presence of the larvæ in these *Teleosts* is due to their feeding on crabs or molluscs, but the larvæ does not develop any further in them than in crabs or molluscs. But if either the fish containing these cysts derived from crabs and molluscs, or the crabs and molluscs themselves, be eaten by an Elasmobranch, then in every case the larva would attain the adult form in the Elasmobranch.

The stage found in these fish is probably not intermediate, but casual and accidental. These fish are not to be regarded as intermediate but as accidental hosts.

TETRARHYNCHUS, Rudolphi.

Body articulate, tæniæform. Neck tubular. Head with four bothria in two lateral pairs, parallel with the head. Proboscides four, terminal, filiform, armed, retractile in the neck, free, *i.e.*, not running through the bothria. Genital apertures marginal or lateral.

Tetrarhynchus gangeticus, Shipley and Hornell (20). (Plate II., Fig. 18.)

I refer with some hesitation four larval forms to the above species. They correspond with *T. gangeticus* in size, in the proboscis tubes being bent in and out and not spirally twisted, and in the size and shape of the bothridia. The hooks are also similar.

Habitat.—The mesenteries of *Sphyræna jello*. February 27, 1911. Four cysts, measurements as follows: (1) 32 mm. long, 6 mm. broad; (2) 30 mm. long, 5 mm. broad; (3) 26 mm. long, 5 mm. broad; (4) 14 mm. long, 4 mm. broad.

The larvæ themselves were large and fleshy, each measuring 7 mm. long and 3·5 mm. across the proboscides. Strobila absent.

Shipley and Hornell (Part V., "Ceylon Pearl Oyster Reports," page 70) describe cysts obtained from *Sphyræna commersoni* as follows :—

"The cysts are large forms varying in length between 8 mm. and 30 mm., with a breadth of about 3 mm. They belong to Vaullegeard's *Tetrarhynchus erinaceus* series, being enclosed in a vescicle as well as in a cyst, which latter is apparently formed by the tissues of the host. The teeth were very crowded and the excretory opening was visible, but little else could be made out."

Most probably these larval forms are similar to ours.

The adult *Tetrarhynchus gangeticus*, Shipley and Hornell, was obtained from *Carcharias gangeticus*, Müll. and Henle.

So far as I have been able to make out, these specimens fall naturally into the genus *Rhynchobothrium*, Rudolphi, which genus, according to Linton, is characterized as under :—

"Body tæniæform. Neck tubular. Head continuous with the neck, with two opposite bothria, parallel or converging at the apices, lateral or marginal, entire or undivided, or either bilocular with a longitudinal partition or bilobed or divided. Proboscides four, terminal, filiform, armed, retractile in the neck, for the most part longer than the head. Genital apertures, male marginal, female lateral, or male and female marginal approximate."

Otobothrium insigne, Linton (14 and 15). (Plate II., Figs. 19, 20, and 21.)

Except the species described in this Report, no adult forms of the genus *Otobothrium* have ever been recorded from the pearl banks, but the encysted larvæ of this species are the most common larvæ obtained from certain marine fishes in the gulf.

They occur in immense numbers encysted in the pharynx and in the mesenteries of all the species of *Balistes* and *Serranus* recorded from here. They are also common in *Diagramma*, spp., and *Stomateus niger*. The cysts measure on an average 30 mm. by 7 mm., but many forms are less. The cysts are roughly club-shaped, the narrow end being clear and transparent, whilst the broader end is gray black, due to the presence of a somewhat brittle layer of black pigment. Other cysts are perfectly transparent. Possibly these are younger forms.

Both these kinds of cysts occur together, and along with them there often occur numbers of what appear to be degenerate cysts. These are usually flattened, black, and have a powdery, limey consistency. No trace of a larva is to be found in them.

The larvæ in the healthy cysts measure 4 mm. in length. The breadth across the bothridia and the posterior end is 1·5 mm. The breadth is rather less behind the bothridia. No strobila are present. The larva can easily be seen as a milky-white object within the cyst. The specimens answer perfectly to Linton's description of *Otobothrium insigne* and to his figures. The bothridia are lateral and diverging, and there are four accessory bothridial organs. The hooks are of various shapes. Linton gives the length of the adult head and neck as 4·2 mm. Our larval forms measure 3 mm. The adult form was obtained from *Carcharhinus obscurus*.

The habitat of our larval forms was as follows :—

(1) *Diagramma crassispinum*. Twenty-five specimens. February 10, 1911.
(2) *Balistes*, spp. Twelve specimens. January 20, 1911.
(3) *Stomateus niger*. Eight specimens. February 10, 1911.
(4) *Serranus undulosus*. Over two hundred specimens. February 10, 1911.

Otobothrium linstowi, n. sp. (Plate II., Figs. 22, 23, and 24.)

The head consists of two undivided saucer-like bothridia, the edges of which are usually reflected back round the bothridium into an overhanging ledge. At the posterior margin of each bothridium are two very small sucker-like pits. The four proboscides are a little longer than the head and neck. The proboscis sacs are one-third the length of the head and neck, whilst the bothridia are two-ninths the length. The spines on the proboscides are of several kinds. Near one edge the spines have a wide base, and are short and strongly recurved. Over the rest of the proboscis the spines are much more slender. The length of the head and neck is 3 mm. The breadth of the head is 1 mm. Segmentation begins immediately behind the proboscis bulbs, which latter are much broader than the first proglottides. The first segments are much broader than long. The tenth segment is square. The last segment measures 3 mm. long and ·75 mm. broad. The genital pores are lateral and irregularly alternate.

The entire worm measures 19 mm. long.

Habitat.—The spiral valve of *Pristis cuspidatus*. Nine specimens. February 19, 1911.

This species differs from *Otobothrium crenecolle*, Linton, and *Otobothrium insigne*, Linton, in the disposition of the bothridia, in their relative proportions to the length of the head, in the shape and disposition of the spines, and in the general proportions of the head and neck.

I have been unable to obtain a description of the only other known species of this genus, viz., *Otobothrium dipsacum*, Linton, and it may be found later that my specimens are identical with *Otobothrium dipsacum*. They are referred to a new species only provisionally, and I have pleasure in naming them in honour of Dr. von Linstow.

Rhynchobothrium, sp. I. (Plate II., Figs. 25, 26, 27, and 28.)

Large numbers of cysts of an unknown species of *Rhynchobothrium* were obtained from the mesenteries of *Chorenemus lysan* and *Cybium guttatum*. The cysts measured 11 by 3 mm., and were milky-white in appearance. The larvæ measured 7 mm. by ·6 mm. The bothridia are two in number and are concave. Each bothridium appears to be divided by a faint longitudinal septum into two halves. At the posterior end each bothridium is indented. The bothridia and proboscis sacs are almost equal to half the entire length of the head and neck. The proboscides are coiled. The hooks are all similar, and are long and slender, and bent suddenly almost at right angles at their extremity.

Habitat.—(i.) The mesenteries of *Chorenemus lysan*. Eighty-six specimens. February 27, 1911.

(ii.) The mesenteries of *Cybium guttatum*. Nine specimens. February 25, 1911.

Rhynchobothrium, sp. II. (Plate II., Figs. 29 and 30.)

Large numbers of cysts containing larvæ of a second species of *Rhynchobothrium* were obtained from the mesenteries of various fishes caught during 1908 to 1911. The cysts when preserved are often globular, and measure 15 mm. in diameter. The outer part of the cyst is sometimes gelatinous in nature, and is usually absent. Inside the gelatinous covering is the cyst proper, which measures 5 mm. by 3 mm., and is either of a milky-white or golden-yellow colour.

The larva itself lies bent in two inside this cyst. It measures 5 mm. long and 1·5 mm. broad posteriorly. The posterior part is 3·5 times the breadth across the bothridia, and the sacs measure almost half the length of the head and neck. The proboscides are coiled, and are not protruded to the exterior, their external openings being closed. The spines are of various sizes and shapes, and do not appear to have any definite arrangement. There are two very small, undivided, saucer-like bothridia, having a diameter of barely ·5 mm. There are no strobila.

Habitat.—(i.) Walls of the air bladder of *Lutjanus argentimaculatus*. Twelve specimens. November, 1908.

(ii.) The mesenteries of *Drepane punctata*. Nine specimens. February 28, 1911.

(iii.) The mesenteries of *Diagramma*, sp. Twenty specimens. November, 1910.

(iv.) The mesenteries of *Serranus undulosus*. Over one hundred specimens. November, 1910.

Rhynchobothrium, sp. III. (Plate II., Figs. 31 and 32.)

Larvæ of a third species of *Rhynchobothrium* were obtained from cysts found on the mesenteries of *Balistes mitis*.

The cysts are long, cylindrical, firm, and opaque. They measure 14 mm. by 2 mm. The larvæ measure 2 mm. by ·6 mm. The bothridia are circular in outline, concave, with thickened overhanging rims, and are indented anteriorly and posteriorly, and each bothridium is divided into two halves by a shallow ridge running parallel to the body. They measure one-third the length of the head and neck. The proboscis sacs also measure about one-third the length of the head and neck. The proboscides are spirally coiled, and do not protrude to the exterior, the pores being closed. The spines are of various sizes and shapes. Some have narrow bases, and are long and slender, with the extremity bent at right angles. Others are short with a broad base, and are strongly recurved. The arrangement of the hooks could not be ascertained.

Habitat.—The mesenterics of *Balistes mitis*. Twenty-seven specimens. November, 1910.

Rhynchobothrium, spp.

I include here a note with figures of single specimens of larvæ obtained from cysts

Species A. Plate III., Fig. 33. From oval cysts 9 mm. long and 3 mm. broad. Larva measuring 6 mm. by ·7 mm. A single specimen from the mesenteries of *Serranus undulosus*. February 27, 1910

Species B. Plate III., Fig. 34. From oval cysts 7 mm. long and 2 mm. broad. Larva measuring 5 mm. long and ·4 mm broad. A single specimen from the mesenteries of *Lutjanus gibbus*. December 8, 1910.

Species C. Plate III., Fig. 35. From oval cysts 4 mm. long and 1·2 mm. broad. Larva measuring 3 mm. long and ·3 mm. broad. A single specimen from *Psettodes erumei*. February 27, 1911. Possibly this is the same species as species B.

In none of these larvæ was the nature of the spines on the proboscides determined, as this could not be done without destroying the specimens.

Rhynchobothrium rossii, n. sp. (Plate III., Figs. 36, 37, 38, and 39.)

This worm, which measures 60 mm. long, consists of a very small head and a whip-like body, which broadens and thickens greatly posteriorly. Except the last 6–11 proglottides, which are pigmented brown, the rest of the worm is clear and very transparent. The head consists of two somewhat oblong, concave, undivided bothridia, with thickened rims, which are slightly indented both posteriorly and anteriorly, and measure approximately ·5 mm. long. They diverge slightly posteriorly. The head and neck, which are ·4 mm. broad and 2 mm. long, pass into the strobila without any alteration in breadth, and thus, except under a magnification of 30 diameters, the posterior termination of the proboscis sacs cannot be seen. The bothridia and proboscis sacs together measure half the length of the head and neck. The proboscides are loosely coiled spirally. The hooks are arranged spirally and have a broad base, and are short and strongly recurved. The whole surface of the head, neck, and first proglottides is marked by a series of straight lines crossing each other and giving a characteristic appearance. The head and neck together measure 2 mm. There is a short unsegmented portion between the proboscis sacs and the first proglottides. The first segments are very crowded. shallow, and much broader than long. They elongate very gradually. About one-third the length of the worm, from the posterior extremity, the segments thicken and become pigmented and opaque. The last segments measure 2·5 mm. long, breadth 2 mm. The proglottides are not salient. The genital apertures are lateral and irregularly alternate.

The diagnosis of *Rhynchobothrium rossii*, n. sp., is as follows :—

Long and fairly stout worms, 60 mm. long and a maximum breadth of 2 mm. The head is very small, and consists of two somewhat oblong, concave, undivided bothridia, with thickened rims, which are slightly indented both anteriorly and posteriorly. Each bothridium is ·4 mm. long. Neck not swollen where the proboscis sacs occur. Head and neck 2 mm. long. The hooks on the proboscides are arranged spirally, and are all alike. They are small, short, stout, with broad bases, and are strongly recurved. Head and neck covered with lines arranged in a criss-cross fashion. Short unsegmented portion between proboscis sacs and first proglottid. First segments crowded, much broader than long. They elongate gradually. Last one-third or one-fourth of the worm thick, and pigmented brown in preserved specimens. Last segment 2·5 mm. long, 2 mm. broad, and ·6 mm. thick. Genital apertures lateral and irregularly alternate.

Habitat.—The spiral valve of *Trygon kuhli*. Fourteen specimens. November 27, 1910.

Paratœnia elongatus, n. sp. II. (Plate III., Fig. 40.)

The head is exactly similar to that of the only other species of this genus, viz., *Paratœnia medusia*, Linton.

The head is globular. There are four small bothridia. From the terminal os at the anterior extremity about sixteen mobile tentacles may be protruded. Our species has a short neck, equal in length to the head. First segments shallow, and all the segments broader than long, the anterior ones being slightly salient. The worm is whip-like and very narrow until the ripe segments are reached.

The following are the measurements of our longest specimen :—

Length	50 mm.	Length of head ..	·5 mm.
Breadth of last segment .	1 mm.	Breadth of head ..	·4 mm.
Length of last segment ..	·4 mm.	Length of neck ..	·5 mm.

The riper segments broaden suddenly.

Some specimens were strongly contracted, and these measured 39 mm. Our species thus differ from *Paratœnia medusia*, Linton, in being ten times longer, in possessing a neck, and in the ripe segments being broader than long.

The diagnosis of *Paratœnia elongatus* is as follows :—

Head globular or subglobular, with four small bothridia. From the terminal aperture there may protrude about sixteen tentacles, which are as long as the head. Neck short, as long as the head. First segments much broader than long. Anterior segments slightly salient. All segments broader than long. The posterior segments widen and thicken suddenly, and are quite opaque.

Habitat.—The spiral valve of *Trygon kuhli*. Forty-four specimens. 1910 and 1911.

TREMATODE (?), sp. (Plate III., Fig. 41.)

During the examination of a number of specimens of *Diagramma crassispinum*, three specimens were found to contain a most remarkable free living parasite in the cœlom.

Unfortunately I have not had the time to make a careful examination of this parasite, and I am at present uncertain of its strict zoological position. The worm is to all appearance a huge *Trematode*. In the living condition it measured 15 inches long and $1\frac{1}{8}$ inch broad. It was quite flat, and had a thickness of $\frac{1}{16}$ inch. The preserved specimens, of which I have three, measure $9\frac{1}{2}$ inches long, $\frac{3}{4}$ inch broad, and are about $\frac{1}{8}$ inch thick. The extremities are rounded, and terminate in a minute acute point. At one extremity there is a minute sucker-like aperture situated centrally, whilst at the other extremity there is a similar but slightly larger aperture situated laterally. This latter aperture appears to open to the interior of the worm. The edges of the worm are straight and parallel. A pair of narrow blackish tubes run along the lateral margins—one on each side. Down the centre of the worm, and stretching from one extremity to the other, is an opaque milky-white mass $\frac{1}{4}$ inch broad. On each side of this mass there are a series of black coiled tubes $\frac{1}{16}$ inch in diameter disposed in bunches, also running the entire length of the worm, but situated for the most part on one side. The rest of the worm is quite transparent.

No other apertures could be detected. In consistency the worm is that of a stiff jelly.

A full description of this enormous parasite, which is in all probability a *Trematode*, will be published as soon as the anatomical details have been worked out.

Habitat.—The body cavity of *Diagramma crassispinum*. Three specimens, only one in a fish. February, 1911.

I append herewith a list of parasitic material collected in Ceylon from various sources during the past few years. The list comprises all the cestodes I have up to the present collected from the marine fishes of Ceylon.

Many of the species described by Shipley and Hornell (20) I have not obtained. The other cestodes have been collected from the sources named. A few specimens were obtained from the Indian Museum, Calcutta.

Probably most of the parasitic Copepoda, Trematodes, and Nematodes collected are new species, and it is hoped that these as well as the other material named will be worked out and described at some later period.

General.

	From
Ticks	*Testudo elegans.*
Solitary corals, n. spp.	Ceylon pearl banks.
Halimeda gracilis in fructification	Ceylon pearl banks.
Dermal cysts	*Testudo elegans.*
Intra-uterine embryos, young	*Trygon kuhli.*
Do. slightly older	*do.*
Do.	*Rhynchobatus columnæ.*
Worms	Coral.
Sarcocystis tennella	Muscle of buffalo.
Echinorhynchus tenor	*Scops bakkuamun* (owl).
Do. n. sp., with cysts	Lungs of rat snake (*Zamenis mucosus*).
Do. n. sp.	*Aster badius.*

Parasitic Crustacea.

Cymothoæ, n. sp.	*Serranus undulosus.*
Do. n. sp.	*do.*
Cilicicæa lattreilli (?)	White *Leptoclinid.*
Gnathia, n. sp.	Gills of *Trygon kuhli.*
Do. n. sp.	*Galeocerdo tigrinus.*
Do. sp.	*Urogymnus asperrimus.*
Ecto-parasitic Copepoda	*Trygon kuhli.*
Do.	*Tæniura melanospilos.*
Parasitic Copepoda	*Rhynchobatus columnæ.*
Do.	Root of mouth of *Lutjanus gibbus.*
Do.	*Serranus undulosus.*
Do.	*Lutjanus argentimaculatus.*
Do.	Gills of *Rhynchobatus djeddensis.*
Do.	*Tæniura melanospilos.*

Nematodes.

Filaria digitata (?), Von Linstow	*Bos indicus.*
Nematodes	*Tæniura melanospilos.*
Do.	*Chiloscyllium indicum.*
Do.	*Lethrinus miniatus.*
Do.	*Galeocerdo tigrinus.*
Do.	*Varanus*, sp.
Do.	Turtle (*Chelonia midas*).
Do.	do. (*do.*).
Do.	*Myliobatis nieuhofii.*
Do.	*Pristis cuspidatus.*
Do.	*Chorinemus lysan.*
Do.	*Urogymnus asperrimus.*
Do.	*Tetrodon stellatus.*
Nematode cysts	*Caranx*, sp.
Do.	*Caranx melanpygus.*

	From
Nematodes in large cysts	*Bos indicus.*
Nematodes	*Diagramma crassispinum.*

TREMATODES.

Anaporrhutum largum	*Chiloscyllium indicum.*
Amphistoma conicus	Bile duct of buffalo.
Paramphistomum bathycotyle	*Bos indicus.*
Schistorchis carneus	*Tetrodon stellatus.*
Trematodes	*Ætobatis narinari.*
Do. (Ecto-parasites)	*Chelonia viridis.*
Do.	*Pinna bullata.*
Trematodes with Redia	*Tetrodon stellatus.*
Trematode	*Diagramma crassispinum.*
Trematode, 3 specimens 15 in. long	*do.*
Redia and Trematode	*Diagramma*, sp.

CESTODES.

Solenophorus megalocephalus	*Felis tigris.*
Do.	*Python reticulatus.*
Tœnia globipunctata	Sheep.
Tœnia serrata	Wild jackal.
Do.	*Felis tigris.*
Do.	*Nesokia bengalensis.*
Tœnia serialis	Dog.
Chittotœnia bursaria	*Lepas ruficaudatus.*
Dutheria fimbricata	*Varanus exanthematicus.*
Plagiotœnia gigantea	*Rhinoceros unicornis.*
Pterocercus, spp.	*Bentorphis pictus.*
Cysticercus pisiformis	*Mus rattus.*
Cysticercus fasciolaris	*do.*
Do.	Rat.
Cœnurus serialis	Goat.
Cysticercus polymorphus	*Bos indicus.*
Cysticercus cellulosæ	Human brain.
Echinococcus polymorphus	Goat.
A Cyst (*Echinococcus polymorphus*) (?)	*Bos indicus.*
Dipylidium caninum	Rat (Dog ?).
Hymenolepis, n. sp.	*Corvus macrorhynchus.*
Tœnia marginata	*Bos indicus*
Tœnia, sp.	*do.*
Davania, n. sp.	*Centrococcyx rufipennis.*
Davania polyalcaria	*Corvus macrorhynchus.*
Davania, n. sp.	*Petragopeis gurial.*
Do. sp.	*Tockus gingalensis* (hornbill).
Do sp.	*Corvus splendens.*
Oragmatobothrium tetraglobum, n. sp.	*Rhynchobatus djeddensis.*
Cyclobothrium typicum	*Ætobatis narinari.*
Adelobothrium ætobatidis	*Rhynchobatus djeddensis.*
Thysanobothrium uarnakense	*Trygon walga.*
Acanthobothrium herdmani, n. sp.	*Trygon kuhli.*
Platybothrium spinulifera, n. sp.	*Galeocerdo tigrinus.*
Prosthecobothrium trygonis	*Trygon kuhli.*

	From
Spongiobothrium lintoni, n. sp.	*Rhynchobatus djeddensis.*
Spongiobothrium variabile	*Trygon kuhli.*
Syndesmobothrium filicolle	*Cybium guttatum.*
Dibothrium hastatus	*Trygon kuhli.*
Dibothrium, sp.	*Sterna bergii.*
Otobothrium linstowi, n. sp.	*Pristis cuspidatus.*
Cysts containing *Otobothrium insigne*	*Diagramma crassispinum.*
Echinobothrium rhinoptera	*Trygon kuhli.*
Echinobothrium boisii	*Ætobatis narinari.*
Myzocephalus narinari	*Chiloscyllium indicum.*
Do.	*Galeocerdo tigrinus.*
Phyllobothroides hutsoni	*Ginglymostoma concolor.*
Phyllobothroides kerkhami	*Chiloscyllium indicum.*
Do.	*Ginglymostoma concolor.*
Rhinebothrium flexili	*Pristis cuspidatus.*
Rhinebothrium ceylonicum	*Chiloscyllium indicum.*
Do.	*Trygon kuhli.*
Rhinebothrium shipleyi, n. sp.	*do.*
Calliobothrium eschrichtii	*do.*
Do.	*Chiloscyllium indicum.*
Calliobothrium filicolle	*Pristis cuspidatus.*
Calliobothrium farmeri	*Trygon kuhli.*
Echeneibothrium simplex	*do.*
Echeneibothrium insignia	*do.*
Echeneibothrium walga	*do.*
Anthobothrium pulvinatum	*Ætobatis narinari.*
Anthobothrium ceylonicum, n. sp.	*Trygon kuhli.*
Anthobothrium floraformis, n. sp.	*Carcharias*, sp.
Anthobothrium crispum	*Trygon walga.*
Anthobothrium laciniatum	*Carcharias bleekeri.*
Tylocephalum uarnak	*Trygon kuhli.*
Do.	*Trygon*, sp.
Tylocephalum trygonis	*Trygon kuhli.*
Tylocephalum kuhli	*do.*
Tylocephalum dierama	*do.*
Do.	*Pteroplatea micrura.*
Cephalobothrium variabilis	*Trygon kuhli.*
Do.	*Pristis cuspidatus.*
Cephalobothrium ætobatidis	*do.*
Do.	*Ætobatis narinari.*
Cephalobothrium abruptum	*Trygon kuhli.*
Do.	*Pteroplatea micrura.*
Phyllobothrium lactuca	*Galeocerdo tigrinus.*
Do.	*Trygon kuhli.*
Phyllobothrium blakei = *Anthobothrium pulvinatum* (?) ..	*do.*
Phyllobothrium foliatum, n. sp.	*Rhynchobatus djeddensis.*
Phyllobothrium pammicrum	*Urogymnus asperrimus.*
Larvæ of *Rhynchobothrium*, sp.	*Lutjanus argentimaculatus.*
Tetrarhynchus larvæ from cysts	*Trygon walga.*
Tetrarhynchus unionifactor	*Ginglymostoma concolor.*
Do.	*Urogymnus asperrimus.*

	From
Tetrarhynchus unionifactor	*Trygon*, sp. (Tamblegam).
Tetrarhynchus leucomelanus	*Trygon walga.*
Do.	*Trygon sephen.*
Do.	*Rhynchobatus djeddensis.*
Tetrarhynchus macrocephalus	*do.*
Do.	*Trygon walga.*
Tetrarhynchus ruficollis	*do.*
Do. .. .	*Trygon kuhli.*
Tetrarhynchus rubromaculatus . ..	*do.*
Tetrarhynchus spinulifera	*Rhynchobatus djeddensis.*
Parataenia elongatus, n. sp.	*Trygon kuhli.*

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EXPLANATION OF PLATES.

Plate I.

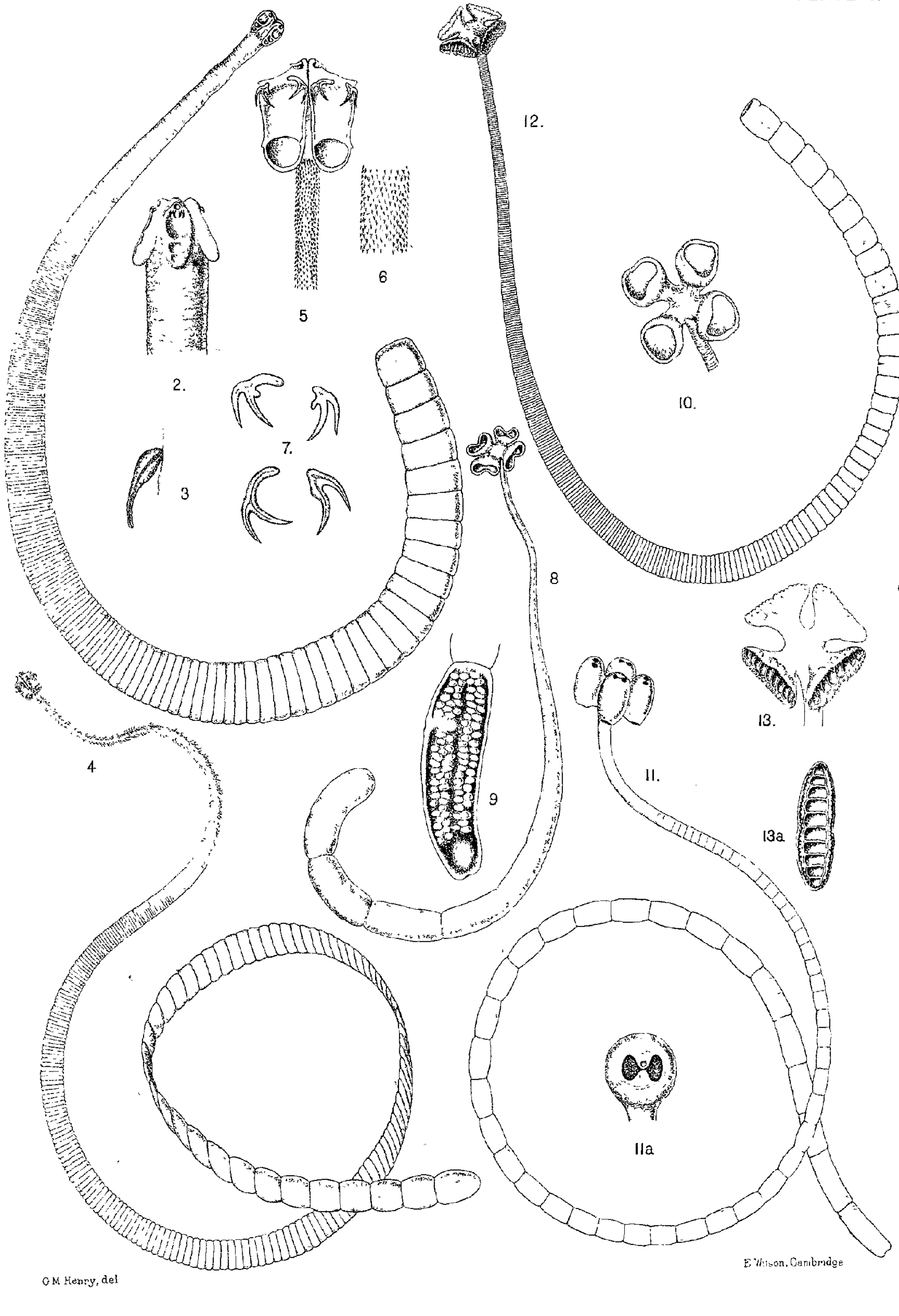
Fig. 1 .. *Acanthobothrium herdmani*, n. sp. Entire cestode. × 4.
Fig. 2 .. Head of same. × 10.
Fig. 3 .. Cirrhus of same. × about 40.
Fig. 4 .. *Platybothrium spinulifera*, n. sp. Entire cestode. × 11.
Fig. 5 .. Head of same. × 50.
Fig. 6 .. Portion of neck of same. × 90.
Fig. 7 .. Bothridial hooks of same. × about 100.
Fig 8 .. *Anthobothrium floraformis*, n. sp. Entire cestode. × 20.
Fig. 9 .. Terminal proglottid of same. × 40.
Fig. 10 .. Head of same. × 40.
Fig. 11 .. *Oragmatobothrium tetraglobum*, n. sp. Entire cestode. × about 30.
Fig. 11*a* .. A single bothridium of same from above. × about 9.
Fig. 12 .. *Rhinebothrium shipleyi*, n. sp. Entire cestode. × 4½.
Fig. 13 .. Head of same. × 10.
Fig. 13*a* .. One bothridium of same. × 16.

Plate II.

Fig. 14 .. *Spongiobothrium lintoni*, n. sp. Entire cestode. × 8.
Fig 15 .. *Anthobothrium ceylonicum*, n. sp. Entire cestode. × 12.
Fig. 16 .. *Syndesmobothrium filicolle*. Cyst. × 1⅓.
Fig. 17 .. Larva of same. × 24.
Fig. 18 .. *Tetrarhynchus gangeticus*. Larva. × 8.
Fig. 19 .. Cysts containing *Otobothrium insigne*. × 2.
Fig. 20 .. A second, with transparent cyst containing same. × 2.
Fig. 21 .. Larva of same. × 15.
Fig. 22 .. *Otobothrium linstowi*, n. sp. Entire cestode. × 10.
Fig. 23 .. Head of same. × 16.
Fig. 24 .. Part of proboscis of same. Highly magnified.
Fig. 25 .. *Rhynchobothrium*, sp. I. Larva. × 16.
Fig. 26 .. Cyst containing larva of same. × 2½.
Fig. 27 .. A second larva of same. × 14.
Fig. 28 .. A hook from the proboscis of same. Highly magnified.
Fig. 29 .. *Rhynchobothrium*, sp. II. Cyst. × 4.
Fig. 30 .. Larva of same from cyst. × 13.
Fig. 31 .. *Rhynchobothrium*, sp. III. Cyst. × 2½.
Fig 32 .. Larva of same from cyst. × 25.

Plate III.

Fig. 33 .. *Rhynchobothrium*, sp. A. Larva from cyst. × 18.
Fig. 34 .. *Rhynchobothrium*, sp. B. Larva from cyst × 20.
Fig. 35 .. *Rhynchobothrium*, sp. C. Larva from cyst. × about 25.
Fig. 36 .. *Rhynchobothrium rossii*, n. sp. Entire cestode. × 6.
Fig. 37 .. Head and neck of same. × 15.
Fig. 38 .. Termination of the proboscis of same. × 100.
Fig. 39 .. A hook from the proboscis of same. Highly magnified.
Fig. 40 .. *Paratœnia elongatus*, n. sp. Entire cestode. × 10.
Fig. 41 .. *Trematode*, sp. × ⅔.



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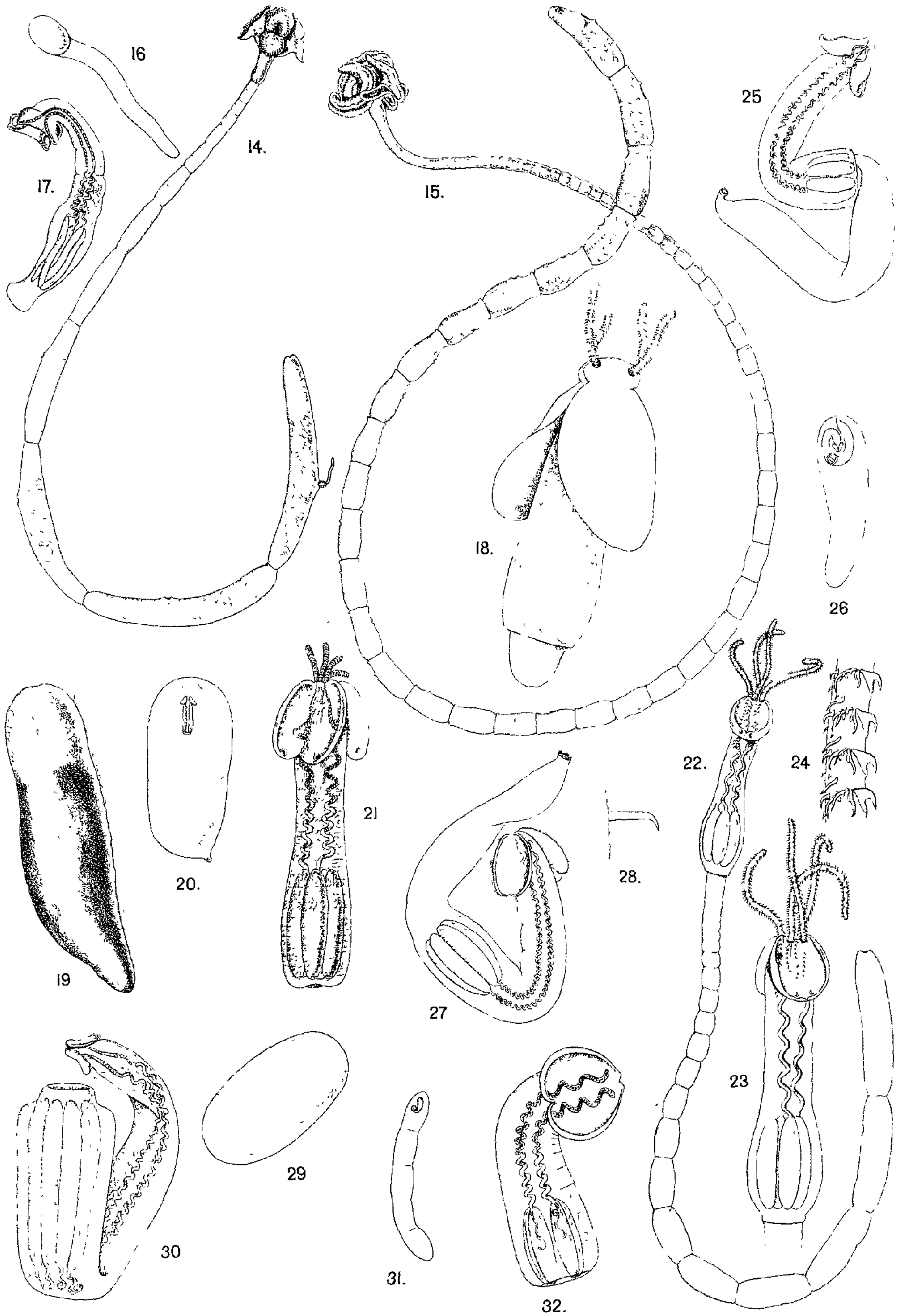

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