ECOLOGY OF A TROPICAL POND

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CONTENTS

PREFACE

There is a dearth of literature on the tropical pond although research is being done on the biology of lakes. This is therefore an attempt to fill the gap in a small way. The aim of this book is to provide a basic understanding of the ecology of the tropical pond, especially for undergraduates.

The book deals with the physico-chemical characteristics and the type of fauna and flora found in the pond at Vaddukoddai, Sri Lanka, investigated by the author for a period of seven years (1974 to 1980).

A section deals with the practical aspect of water chemistry for the dissolved gases and certain minerals in the water.

The drawings on the rotifera were made by the author and the others by Miss V. Rajaratnam, a former student and now a colleague in the department of Zoology, University of Jaffna. I wish to thank her.

Chiefly I wish to thank Dr. K. Chitravadivelu who read the manuscript and made useful criticisms.

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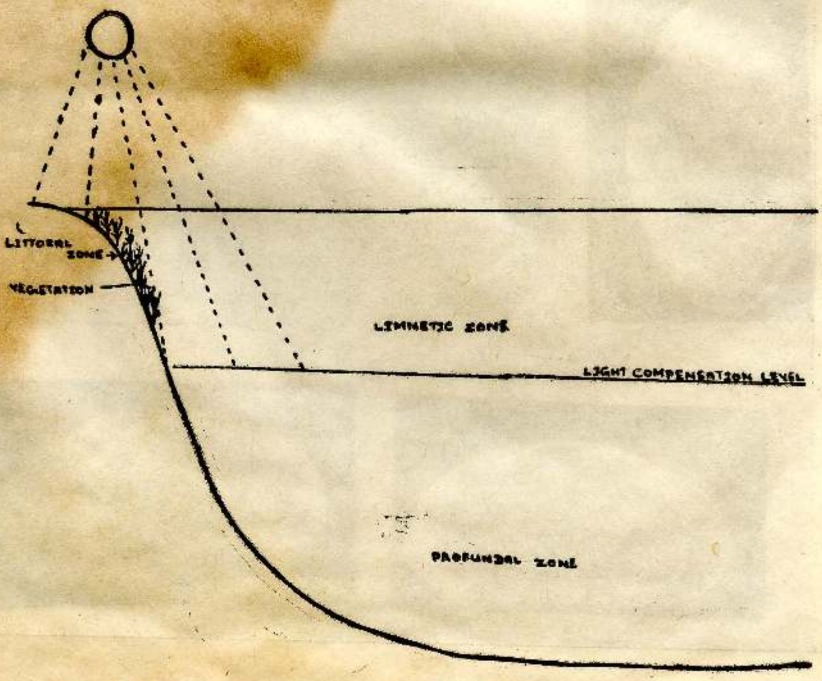
Dedicated to my late
beloved husband
Luther James Selvarajah

Introduction

The pond under consideration is tropical temporary and of fresh-water. The pond chosen is in the dry zone inthe Northern Province of Sri Lanka at Vaddukoddai in the Jaffna Peninsula at longitude 79.58° and latitude 9.45°. It starts filling with the North East Monsoon in October or November and dries up in June, July or August. The water is stagnant and it has no waves; the temperature and pH vary within a narrow range. Tests carried out by the author give the



ZONATION OF A POND

Fig. I

following results. The temperature ranges from 23° C — 34° C and pH from 6.7 — 7.2. The salinity varies from 0.197 gms/litre — 3·203 gms/litre ; carbondioxide being around 0.002 mg/l ; oxygen content varies from 5.04 cc/litre — 12.88 cc/litre. Nitrate and Ammonium nitrogen is around 7.8 ppm. The depth of the water when full is 176.5 cm. and the area is 0.5 hectare approximately. (one hectare is equal to 2.5 acres).

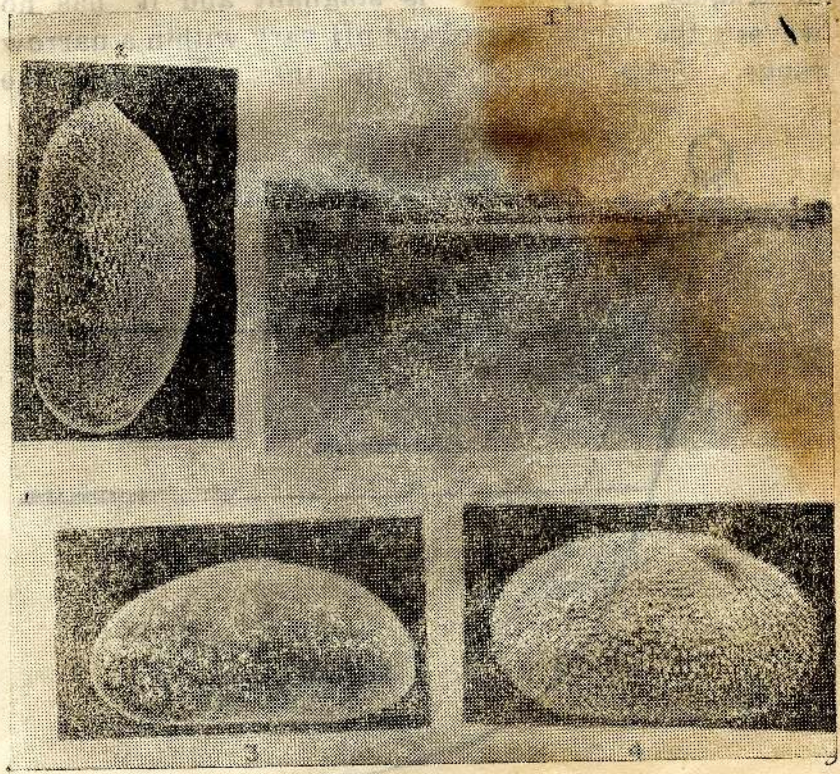


Plate 1

1. Vaddukoddai pond
2. Cypris subglobosa Sowerby
3. Heterocypris dentatomarginatus Baird
4. Centrocypris viridis Neale

General Characteristics

The habitat may be subdivided into water surface, littoral zone, limnetic zone and profundal zone as in Fig. I. The fauna consist of pneuston plankton, pelagic forms and benthic forms.

The pond is not a body of water containing nutrients but an equilibrated system of water and solids, and under ordinary conditions nearly all of the nutrients are in a solid state. In a pond the Producers may be of two types, rooted or large floating plants generally growing in shallow waters and floating phytoplankton distributed throughout the pond as deep as light penetrates. In this particular pond rooted vegetation was lacking. Organisms in temporary ponds should be able to survive in a dormant stage during the unfavourable periods or be able to move in and out of ponds such as can adult insec's and frogs. The fairy shrimps are especially remarkable crustaceans which are well adapted to temporary ponds. The eggs survive in the dry soil for many months and development occur in a short time during the rainy season while water is present. The cyclopoid copepoda survive in the dry season as rolled up copepoid stages. The cladocerans surviving as ephippial eggs. Although the temporary pond contains water for only a few weeks a definite seasonal succession of organism occurs thus enabling a large variety of organisms to utilize a very limited amount of physical habitat. A plankton net mesh size 65/u is used to collect the plankton. Although inhabitants of temporary ponds tide over drought in the egg stage they have developed mechanisms that ensure that one filling does not cause all the eggs to hatch.

The Surface Film

Some small animals, mostly insects, are so light that they can exploit the surface tension and walk or skate on the surface of the water without penetrating the surface film. Their lightness together with the presence of hydrofuge or water repellant hairs that cover their bodies especially their tarsi enable them to move on the surface. The commonest surface animal is the water skaters. These surface dwellers take in air through their spiracles opening into the tracheal system.

The animals of the *open water* are of two types, partially aquatic and totally aquatic animals. These have to come up to the surface at intervals to renew their air supply. Others have developed gills of different kinds which make use of the oxygen dissolved in water.

Most of the aquatic beetles, many insect larvae and some molluscs are partially aquatic animals. The beetles have their legs fringed with hairs which help in locomotion. The great diving beetle for example comes to the surface at intervals break the water surface with the help of the hairs at the tip of the abdomen. The wing cases are slightly raised and the air hidden beneath them is replenished. The spiracles at the tip of the abdomen surrounded by hydrofuge hairs also take in air.

In the water boatman the air is carried on the outside of the body sometimes beneath a cover of hydrofuge hairs on the ventral surface of the abdomen. In others it is taken as a bubble of air at the end of the abdomen. In these cases the superficial air bubble of "plastron" is in direct contact with the water and functions as a physical gill. When submerged these insects withdraw oxygen from the air bubble for their requirements.

Of the totally aquatic animals, in protozoa the larger surface area to volume ratio causes an effective exchange of gases. Also fresh water oligochaetes and small crustaceans like cladocera and ostracods have exchange of gases this way. The latter have their limbs modified in various ways to create a current of water which flows over the soft parts of the body and respiration takes place through the skin.

Larger crustacea and fish which are totally aquatic have gills for exchange of gases. In addition the climbing perch, cat fish and snake head have accessory respiratory organs above their gills which can be used in mud when the dry season sets in.

Physico-chemical factors

Physico-chemical factors in the pond are light, temperature, hydrogen ion concentration, dissolved minerals and dissolved gases.

The influence of light in the pond community is three fold. Firstly there is an indirect effect by controlling the growth of the plants. Ponds are usually shallow and well illuminated. Thus they support an abundance of plant life which constitutes the base of the animal food chains. Lentic that is static waters often contain a rich phytoplankton including myriads of diatoms. In most ponds whose waters tend to be turbid there is hardly any growth of plants below three feet.

Secondly light enables the animals to see and be seen. A major proportion of the larger animal population occuring in pond consist of insects which have the compound type of eye, which is well adapted for functioning at low levels of illumination particularly among weeds.

Thirdly light evokes certain characteristic responses which are vital in the organisms concerned.

Generally a combination of two or more factors control a single reaction among fresh water animals. For example the characteristic vertical movement of plankton by day and night — Cladocerans such as Simocephalus exhibit a marked variation in distribution at different times of the day. The majority of the population come to the surface at night and move downwards during day time as light intensity increases.

Temperature

The peculiar thermal properties of water such as a high specific heat, a high latent heat of fusion and the high latent heat of evaporation all combine to provide a medium for life. Most aquatic organisms are eurythermous that is they are well able to tolerate the normal range of seasonal fluctuations. The vertical movement of plankton is also affected by temperature. The high temperatures of noon drive them away to the bottom or shelter among vegetation.

Hydrogen in concentration

Although pH varies within a narrow range of tolerance of all animals living in inland waters, in ponds and lakes a certain amount of vertical stratification subject to seasonal change is seen. The activities of bacteria in breaking down detritus tend to promote acid conditions. There is slight seasonal fluctuation in pH due to variation in the amount of carbondioxide present. Photosynthesis among green plants cause conditions to become more alkaline. The normal limit of pH in fresh water lie between 4.7 and 8.5 which range most species are able to tolerate.

Dissolved gases

Oxygen and carbondioxide are the common gases dissolved in water. There is generally a distinct gradient of oxygen from top to bottom which continues into the mud below. Where there is an abundant growth of plants, the concentration of oxygen will tend to reach a maximum.

In acid water CO_2 will be present in solution while under neutral alkaline conditions CO_2 is combined mainly in the form of bicarbonates. In the brightly illuminated zone containing an abundance of green plants, the CO_2 concentration will bear an inverse relationship to that of oxygen. In the anaerobic organic mud continuous bacterial activity tends to maintain the CO_2 at high level. In stagnant waters bubbles may appear at the surface indicating the accumulation of gases below. These include in addition to CO_2 methane, nitrogen,

Temperature and pH in 1975/76

Date	*Temperature of water*	*pH*
01-01-75	26·5°C	
03-01-75	26·5	6.9
07-01-75	27·5	7.2
10-01-75	25·0	
13-01-75	27·5	6.7
17-01-75	27·0	
20-01-75	26·0	
24-01-75	29·0	
28-01-75	30·0	
31-01-75	29·0	
03-02-75	29·5	
07-02-75	32·0	
10-02-75	32·0	6·6
14-02-75	29·5	
12-02-75	30·5	
21-02-75	29·0	6·7
24-02-75	32·0	
28-02-75	29·0	6·7
31-03-75	34·0	
07-03-75	32·0	
10-03-75	28·0	
14-03-75	30·0	
17-03-75	29·5	
21-03-75	30·5	
24-03-75	34·0	
27-03-75	35·0	6·5
31-03-75	34·0	
04-04-75	33·0	
06-04-75	36·0	
11-04-75	37·0	
18-04-75	37·0	

Date	*Temperature of water*	*pH*
21-04-75	36·0	
25-04-75	34·0	
28-04-75	35·0	6·3
Pond dry 22-07-75		
Rain in September 1975		
29-10-75	33·0	
12-11-75	31·0	6·7
19-11-75	26·5	6·7
26-11-75	27·6	6·7
04-12-75	28·8°C	6·7
11-12-75	28·2	6·7
19-12-75	27·0	6·7
24-12-75	27·4	6·8
07-01-76	25·5	6·8
17-01-76	27·5	6·7
22-01-76	27·7	6·7
28-01-76	28·4	6·8
04-02-76	30·0	6·8
11-02-76	28·4	6·8

hydrogen, hydrogensulphide and hydrogen phosphide.

Dissolved minerals

Many minerals are dissolved in small quantities in water and their influence on the animal populations is largely indirect in controlling the extent of plant growth. Investigations in plant physiology in recent years have shown that besides C, H, O, N, P, S, Ca, Mg, K, Fe a considerable number of others not only stimulate growth but are also absolutely necessary although in inconceivably small amounts.

The distribution of a few species of fresh water animals is directly dependent upon the presence of certain minerals in sufficient amounts for example the cray fish *Astacus fluviatilis* requires adequate amounts of calcium compounds and is never found in lime free conditions.

Primary Productivity

Primary productivity of a community is the rate at which energy is stored by photosynthetic and chemosynthetic activity of producer organisms, that is green plants, in the form of organic substances which can be used as food materials.

There are two kinds of primary productivity Gross Primary Productivity which is the total rate of photosynthesis including the organic matter used up in respiration during the measurement period. While Net Primary Productivity is the rate of storage of organic matter in plant tissues in excess of respiration by the plants during the period of measurement.

Photosynthesis can be measured by the oxygen released. Thus the equation is $6CO_2+6H_2O=6O_2+C_6H_{12}O_6+$energy. Rate of oxygen release can be converted to rate of carbondioxide uptake by calculation from the summary equation of photosynthesis given above in which production of one mg oxygen is equivalent to uptake of 3.7 mg C.

With regard to phytoplankton of a pond gross primary productivity can be measured using light or clear glass bottles and dark or black painted or taped bottles.

The light and dark bottles (three light and three dark bottles may be taken) are completely filled with water without any air space and incubated (that is left in the pond for photosynthesis) for several hours. Since light is cut off from the dark bottle no photosynthesis takes place in it, The initial photosynthesis is measured (by measuring separate sample of water of the pond immediately before incubating the other samples). After incubation the dissolved oxygen levels are measured by the Winkler method.

In the light bottle, oxygen has been produced in photosynthesis. The change in O_2 concentration is $O_2^{LB} = O_2^{LB} - O_2^{I}$ where O_2^{LB} and O_2^{I} represent the concentrations of oxygen in the bottle at the end and at the start of incubation respectively. In the dark bottle no oxygen is produced but oxygen is absorbed by respiration of phytoplankton, zooplankton and micro-organisms The decrease in oxygen concentration in the dark bottle is $O_2^{DB} = O_2^{I} - O_2^{DB}$ where O_2^{DB} is the concentration of oxygen in the dark bottle at the end of the incubation. It is assumed that the respiration of the plankton community is similar in both dark and light bottles. Total oxygen production equivalent to gross photosynthesis, is the amount by which the oxygen concentration in the light bottle has increased plus the amount of oxygen which has not appeared in solution because it has been used in respiration that is the amount by which the oxygen concentration has decreased in the dark bottle.

$GPP = O_2^{LB} - O_2^{I} + (O_2^{I} - O_2^{DB})$ Hence the difference in oxygen concentrations between the bottles at the end of the incubation gives the gross photosynthesis of gross primary productivity during the incubation.

The zooplankton belong to the groups Protozoa, Rotifera, Cladocera, Copepoda, Conchostraca, Anostraca and Ostracoda.

Table: I. *Succession of microcrustacea in the pond*

Time (Days after filling up with water)	Fauna
2	Copepoda
28	Cladocera
56	{ Conchostraca Anostraca
84	Ostracoda

Key for the Identification

1. Body made up of a single cell — Phylum Protozoa
   Body made up of many cells — Metazoa - 2

(i) Presence of corona, mouth and anus — Phylum Rofifera

(ii) Absence of a corona, but with flattened body with only mouth to gut — Phylum Platyhelminthes

(iii) Presence of a segmented tubular body — Phylum Annelida

(iv) Fresh water & terrestrial — Oligochaeta & Hirudinea - 3

(v) Segmented body exoskeleton of chitin — Phylum Arthropoda - 4

(vi) Unsegmented soft body covered with shell — Phylum Mollusca

(vii) Presence of pulmonary chamber — Gastropoda

(viii) Presence of dorsal tubular nerve cord visceral clefts in embryo — Phylum Chordata - 6

3. Absence of sucker — Oligochaeta
Presence of sucker — Hirudinea - 4

4. Mainly terrestrial — Insecta
Mainly aquatic — Crustacea - 5

5. (i) Carapace absent, phyllopod limbs — Anostraca
(ii) Carapace present bivalved with dorsal hinge — Ostracoda
(iii) Carapace present bivalved without hinge — Cladocera
(iv) Carapace present bivalved with more than 10 pairs of limbs — Conchostraca
(v) Body divisible into metasome & urosome presence of median eye — Copepoda

6. (i) Chordates with exoskeleton of feathers — Aves
(ii) Chordates with exoskeleton of horny epidermal scales — Reptiles
(iii) Chordates with moist skin rich in gland cells absence of scales, double occipital condyles — Amphibia
(iv) Chordates with exoskeleton of dermal scales and presence of fins. — Pisces

Pollution and Zooplankton

In the food web of aquatic ecosystem the zooplankton organisms occupy a central position. This together with their sensitivity to both natural and artificial environmental factors makes the cladocera, particularly, species of *Daphnia* of considerable significance to studies on pollution.

They are especially useful as biological indicators in the detection of low levels of toxins.

The limbs of cladocera create a current of water through the carapace which serves both for feeding and respiration, thus bringing the body surface into close contact with large volume of the surrounding water which makes them particularly sensitive to changes in the environmental conditions. Hence they serve as indicators of pollution.

As the water dries up the pond becomes filled by land plants. These are not erect. The plants found are :-

Cynodon dactylon
Cynodon species
Cyprus rotundus
Launea samentosa
Lipia nudiflora
Member of Portulacae family

The animals obtained from the pond are dealt with below.

1. Phylum *Protozoa*

Unicellular animals which have one or several nuclei. Body is covered by a plasma membrane or a thick pellicle or test. They have pseudopodia cilia and flagella for locomotion. Some are colonial. Reproduction is by binary fission or sexual reproduction may occur.

Example: *Arcella* sp.
Diflugia sp.
Ciliates
Actinophrys sp.

2. Phylum *Platyhelmenthes, Turbellaria*

Order Tricladida

These are flat worms which are free living which usually have rhabdites, have a cellular ciliated outer covering to the body. Gut is divided into three main divisions with numerous lateral diverticula from each division. The mouth is situated in the middle of the body. *Dugesia* belong to the division paludicola or fresh water forms.

3. Phylum *Rotifera*

These are minute animals with a pseudocoel and a unsegmented body and typically with a ciliate trochal disc for locomotion and food collection. Alimentary canal is complete with a mouth and anus. Pharynx is muscular with jaws of a special type or trophi which are a diagnostic feature. Excretory system is with flame cells and join the hind gut to form a cloaca. No blood or respiratory system, simple nervous system is present; sexes are separate. They produce parthenogenetic and fertilized eggs. The latter is thick shelled and develop only after a resting period. There are two Orders Monogononta with single ovary, Digononta with paired ovaries.

Members of the monogononta form the great majority of the known species of rotifera. The lorica may be present or absent. The Rotifera found in the pond are:

Hexarthra intermedia
Euchlanis dilatata
Brachionus angularis angularis
Brachionus patulus
Brachionus caudatus var. sculeatus
Brackionus calciflorus
Brachionus urceolarus
Brachionus leydigi
Brachionus rubens
Polyarthra vulgaris
Testudinella patina
Polyarthra dolichoptera
Trichocera cylindrica
Platyas quadricornis
Anuraeopsis fissa
Keretella lenzi
Keretella tropica
Lepadella rhomboides
Macrochaetus collinsi
Pompholyx complanata
Dicranophorus robustus
Dipleuchlanis propatula
Lecane luna
Lecane curvicornis
Lecane bulla
Lecane sympoda
Phylodinid sps.
Asplanchna brightwelli
Trichocerca rattus
Rotifera vulgaris

Cephalodella forficula
Filinia terminalis
Mytilina sps.
Asplanchnopus multiceps
Lepadella patella
Conochilus sps.

4. Phylum *Arthropoda* Class Crustacea

These are segmented bilaterally symmetrical animals jointed with paired limbs on most segments. Perivisceral cavity is a spacious haemocoel. A chitinous cuticle is present At the joints are soft arthrodial membranes. Coelomoducts function as excretory and gonoducts.

Crustacea are mostly aquatic arthropods with two pairs of antennae and one pair of mandibles. Most fresh water crustaceae belong to sub-class Branchiopoda which are free living with compound eyes, usually a carapace is present with at least four pairs of trunk limbs which are phyllopodia that is flattened and leaf-like. Their edges are fringed with bristles.

Sub-class: Branchiopoda

Order Conchostraca

Carapace is present with 10 - 27 pairs of trunk limbs. Body is laterally compressed and enclosed in a bivalved shell which has concentric growth lines and the total number of these lines varies with the species and are of importance in taxonomy. Transverse adductor muscles control the opening and closing of the valves of the shell. The body is divisible into head and trunk. The anterior part of the head is known as the rostrum. The trunk limbs help the organisms in locomotion, nutrition and respiration. The centre of the head bears a pair of compound eyes situated close together. The first pair of antennae arise from the lateral side of the head and bears sensory papillae. The second antennae are biramous and larger than the first, with two flagella provided with short spines on the dorsal side and long setae on the ventral side.

The shape and structure of the trunk appendages are similar but in the male the first two pairs are modified into strong stout and curved hook-like structures in used holding the female while mating. In female the epipodites of the 9th, 10th and 11th appendages are largely extended and used in holding the eggs in position in the space or brood pouch between the carapace and body. The trunk ends in a broad telson which terminates in a pair of elongated spines known as furcal claw, whose dorsal surface in most bears hair like setae and a row of small short spines. The dorsal surface of the telson possess two lateral ridges which bear unequal spines called denticles.

Example: *Eulimnadia micheali*

Order Anostraca

Compound eyes are present carapace is absent. They are transparent and gaily coloured animals. Body is divisible into head, thorax and abdomen. The first antennae are small unsegmented bearing sensory setae. The second antennae are large segmented and are modified in males to hold the female during mating. They are flat and fringed with setae in the females. The character of the second antennae are of taxonomic value. Between the second antennae arise a process known as frontal organs. It is well developed in some, but found only in the larvel stage in some.

The thorax of eleven segments bear a pair of phyllopodia and are the organs of locomotion, feeding and respiration. Posterior to the eleventh segment is the fused genital segment. In the males are found fused membraneous tubes acting as penis while in the female there is a brood pouch in which the eggs are found.

The genital segment is follwed by the abodomen which is devoid of appendages, the telson bear two rami or cercopods which are provided with long setae. Sexes are separate and fertilization is internal. They feed on phytoplankton. Hatching of eggs is usually preceded by desiccation and temperature too has an influence.

Example: *Streptocephalus spinifer*

Order Cladocera

They have 4-6 pairs of trunk limbs. Some are planktons while a vast majority of them are littoral living among vegetation and few live in the bottom mud.

Body is covered by a bivalved carapace made of a single piece lacking hinges dorsally. The shape and size of the head varies and compound eyes are present. Males are rare and mainly the females reproduce parthogenetically. Hence two types of eggs are formed and the second being ephippial. The parthenogenetic eggs remain in the brood pouch found dorsolaterally and undergo development releasing young oncs resembling the adult, Each female may produce several such broods which help in rapid building up of the generation in a short period. The ephippium is a resistant stage and withstands drought and adverse conditions.

The males are small but have longer antennules than that of the female. The first leg is usually provided with a hook. The post abdomen, abdominal processes, claw and spine, are diagnostic features used in taxonomy.

Some cladocerans exhibit cyclomorphisms where the carapace change shape and size.
Examples are:

Moina micrura
Ceriodaphnia cornuta
Leydigia australis
Alona pulchella
Diaphanosoma sarsi
Simocephalus vetulus
Gurneyella odiosa
Macrothrix spinosa
Alonella karua
Simocephalus serrulatus
Latanopsis australis
Dunhevedia serrata
Alona davidi
Chydorus parvus
Oxyurella singhalensis
Leydigia acanthocercoides

Order Ostracoda

These are bivalved organisms with a group of adductor attachment for opening and closing of the valves. They are specially found in shallow places where weeds or algae are abundant When the animal swims the valves are kept open and the locomotors appendages protrude. They vary in size from 0·5 to 2 mn. The surface of the shell may be smooth or bear markings. They lack growth lines on the shell. An eye either single or double may be present and visible through the somewhat transparent valves.

The cephalic region is not marked but bear four pairs of appendages, antennules antennae, mandibles and maxillae. The first antennae are uniramous, five to seven segmented with short stiff claw-like bristles for digging and climbing or bear long setae for swimming. The second antennae are also uniramous four to six segmented and are used in locomotion and feeding. Mandibles have a toothed base, a branchial plate and a three segmented palp. Maxilla has a large branchial plate and four basal processes, the outermost of which is largest and palp-like.

The thoracic region bears three pairs of appendages which are legs. They are of taxonomic importance. The abdomen is represented by two long caudal or furcal rami which are articulated with the body. Each ramus is provided with two terminal claws and two terminal setae. In some species the rami are reduced or lost.

Eggs remain dormant during drying of the ponds and when favourable conditions set in the eggs hatch into a shelled nauplius usually with three pairs of appendages namely antennules, antennae and mandibles. There are about eight to nine instars each accompanied by a moult. Copulatory organs appear in the eighth instar and they mature sexually in the ninth instar.

The size, shape of the shell character of shell surface, presence or absence of natatory setae of the second antennae, nature of the spines on the maxillary process, armature of third thoracic leg and caudal furca and spines or whorls on the ejaculatory duct of the male are diagnostic features.
Examples are:

Strandesia elongata ceylonica
Cypris subglobosa sowerby
Heterocypris dentatomarginatus
Centrocypris viridis
Ilyocypris australiensis

Sub-Class Copepoda

These are one of the most important constituents of plankton; both free living and parasitic forms are found.

There are three orders-Calanoida, Cyclopoida and Harpacticoida.

Copepods range in size from less than 1 mm. to several mm. generally the size range is between 2 and 3 mm. long. The body consists of head, thorax and abdomen. Median naupliar eye is present. The first thoracic segment is fused with the posterior of the head to form a cephalosomite. The abdomen is narrow cylindrical and ends in two plates like caudal rami bearing long caudal setae. In the male it is composed of four segments and in the female it consists of two or three.

Due to the distinct articulation the body may also be distinguished into an anterior metasome and posterior urosome. The former consists of head and most of the thoracic segments while the urosome include the last one or two thoracic and the entire abdominal segments.

In Calanoida the articulation of the metasome and urosome is between the somites of the fifth leg and the genital somite. The metasome is clearly broader than the urosome.

In Cyclopoida and Harpacticoda the articulation is between the somites legs 4 and 5. In the former the metasome is broader than the urosome and the latter both are of almost the same width. The appendages are specialised for various functions.

The sexes are separate and they exhibit sexual dimorphism. Females are usually larger than the males. The antennules of the male either the right in Calanoida or both in Cyclopoida and Harpacticoida are modified for grasping the female during mating. The fifth legs in both sexes are also specialised for mating and transferring the spermatophores from the male to the female. Mature female usually carries one in Calanoida and Harpacticoida and two in Cyclopoidia, ovisacs enclosing about ten to fifty eggs. The female carrying an ovisac is called ovigerous female. They hatch into typical nauplii. Six naupliar and six copepodid stages are seen of which the last is the adult. Development may take just one week or may even be one year depending on climatic conditions. They produce continuously several generations in one year that is polycyclic. Some fresh water calanoids and harpacticoids produce thin shelled normal eggs and thick shelled resistant eggs. The latter helping to tide over dry seasons. Some fresh water cyclopoids such as *Mesocyclops leukarti* become curled up in their copepodid stage and survive during the dry season. Calanoids are exclusively pelagic harpacticoids are mostly benthic cyclopoids are intermediate between the two. Often several related species of Copepods, especially fresh water calanoids, live in the same body of water and is known as congeneric occurence.

Calanoid examples are :-

Phyllodiaptomus annae
Rhinodiaptomus indicus
Heliodiaptomus viduus
Paradiaptomus greeni
Neodiaptomus smackeri

Cyclopoid example :-

Mesocyclops leukarti
Macrocyclops distinctus

Order Decapoda

Includes prawns, crabs and shrimps. A cephalothorax consisting of a fused head and thorax is present. They have a pair of stalked compound eyes. They have five pairs of "typical legs" and function in walking and swimming. Abdomen of the macruran suborder bears six pairs of swimmerets. Telson is present with a tail fan.

Sub-Order Brachyura

Example: *Paratelphussa ceylonensis*

Sub-Order Macrura

Example: *Caridina nelotica*

Class Insecta

These are arthropods with trachea for respiration. The body is divided into head thorax and abdomen. They have three pairs of legs in the thorax the meso and metathorax bear wings. Single pair of antennae is present. The abdomen has eleven segments, genital apertures are situated near the anus. Five orders namely Coleoptera, Diptera and Lepidoptera, Odonata and Hemiptera have aquatic members which may have only the larvae aquatic or the adult too may be aquatic.

Examples are:-

Water skater-*Gerris*
Water measurer-*Hydrometra*
Anisops sp. Back swimmer
Lethocerus indicus (Giant water bug)
Laccotrephes grossus (Water scorpion)
Collembola
Dytiscus adult and larva
Dragonfly nymph
Damselfly nymph
Chironomous larva

5. Phylum *Mollusca*

Body divided into head, foot and visceral hump. The last being protected by a shell, soft skin is produced into mantle containing a small cavity.

They are unsegmented coelomate animals. A pair of ctenidia or gill may be present. Alimentary canal has a buccal mass and radula and salivary glands. Development with a trochophore larva.

Class Gastropoda

Order Pulmonata - Some are large aquatic members. Within the visceral hump is a special chamber where air is stored It is kept moist and actsas a lung. Periodically they come to the surface of the water to replenish the supply of air in the lung.

Example :- *Pila globosa*

6. Pylum *Chordata*

They have a dorsal tubular nerve cord and a notochord and visceral clefts and arches in the embryo. Class Vertebrata have a cranium and vertebrae. Presence of a heart which has at least three chambers. Excretory system consists of kidney.

Class Pisces

Order Teleosti with gills covered by an operculum and fins for locomotion.

Examples are :-

Ophiocephalus (snake head)
Anabas (Climbing perch)
Macroneus gulio (Cat fish)
Tilapia mozambica
Puntius dorsalis
Lepidocephalus thermalis

Class Amphibia

Order Anura

Live both on land and water. Larvae with a tail. Two pairs of limbs.

Examples are :-

Rana sp.
Bufo sp. larva only

Class Aves

The stork and kingfisher visit the pond and they are at the summit of the food Energy Pyramid as secondary carnivores.

In addition invertebrates like Nematodes, Gastrotrichs and Aschelminthes were found among the collections.

The phytoplankton found are: *Navicula* sp., *Euglena* sp., *Rivularia* sp., *Paediastrum* sp., *Volvox* sp., *Microcystis* sp., *Anabaena* sp., *Cocconeis* sp., *Ulothrix* sp., *Spirogyra* sp., and *Pinnularia* sp.

Phytoplankton

The commonly occuring algae in fresh water may be placed in four groups. (1) Cyanophyceae (Blue green), (2) Chlorophyceae (Green algae), (3) Bacillariophyceae (Diatom) and (4) Euglenaceae.

Cyanophyceae. are the simplest form of algae with no well developed and well defined plastids, Pigments are blue green or brownish distributed throughout the entire protoplast. Each plant is composed of individual cells surrounded by mucilaginous material or a chain of cells enclosed more or less in cylindrical sheath. No motile forms are known. No sexual reproduction.

Chlorophyceae. Members possess chromatophores which are green in colour. They have cell wall in which cellulose is often the prominent constituent. The motile forms possess two or four flagella which arise from the front end. Majority of the members exhibit sexuality.

Bacillariophyceac. Unicellular algae characterised by cell wall of silica. Wall consists of two valves more or less flat surfaces held by a broad band or girdle. Diatoms may live singly or form colonies. The cell wall sclupturing is remarkable and form diagnostic characters. Reproduction is normally vegetative.

Euglenaceae. Free swimming unicellular with avoid star shaped or plate-like chloroplasts which are green in colour. One or two flagella present at the apex in the gullet. Eye spot usually evident.

Water Chemistry

Detemination of dissolved O_2 by Winkler Method

This consists in adding manganous hydroxide to a known volume of water containing dissolved oxygen, a proportion is converted to manganic hydroxide. This is dissolved in an acid and made to react with potassium iodide. An equivalent quantity of iodine is then liberated and this is titrated against a standard solution of sodium thiosuphate with starch solution as indicator.

The reactions taking place are as follows:

$2Mn(OH)_2 + O + H_2O$ —— $2Mn(OH)_3$

$2Mn\ OH)_3 + 6HCl$ —— $2MnCl_3 + 6H_2O$

$2MnCl_3 + 2KI$ —— $2MnCl_2 + 2KCl + I_2$

$2Na_2S_2O_3 + I_2$ —— $Na_2S_4O_6 + 2NaI$

The following reagents are required:

(a) Manganous chloride solution

Pure crystalline $MnCl_2 \cdot 4H_2O$	100 g
Distilled water	to 200 ml

(b) Winklers Reagent

Potassium hydroxide	100 g
Potassium iodide	60 g
Distilled water	to 200 ml

(c) N/10 Sodium thiosulphate

Crystalline $Na_2S_2O_3 \cdot 5H_2O$	24·82 g
Distilled water	to 1000 ml

(d) Starch solution

To prepare a solution that will keep well suspend 2 g potato starch with 30 ml 20% potassium hydroxide in 400 ml distilled water, and stir until almost clear; to preserve add one ml Glacial acetic acid.

(e) Hydrochloric acid concentrated

(f) N/10 Potassium iodate KIO_3 3·567 g in 1 litre

Estimation of O_2

Fix the water sample by adding 0·5 ml manganous chloride and 0·5 ml Winkler's reagent for every 100 ml of water sample. Introduce 0·5 ml of concentrated hydrochloric acid per 100 ml of sample and replace the stopper firmly. Shake well.

Transfer 10, 50 or 100 ml to a conical flask and titrate with the thiosulphate solution.

Standardise the thiosulphate using potassium iodate.

In taking the water sample care should be taken to immerse the bottle into the water and stopper it underneath the water.

Calculation

1 cc of N/80 solution thiosuphate solution is equivalent to 0·1 mg oxygen.

If V is volume of thiosuphate used and v the volume of the sample then

$$\frac{V \times 0{\cdot}1 \times 1000}{v} = \text{mg oxygen per litre}$$

1 cc of N/80 thiosulphate = 0·0001 gm oxygen

$$\therefore \text{1 cc N/80 thiosulphate} = \frac{0{\cdot}001 \times 22{\cdot}4000}{32} \text{ cc oxygen}$$

$$\text{Hence } \frac{V \times 0{\cdot}001 \times 22{\cdot}4000 \times 1000}{32 \times v} = \frac{V \times 70}{v} =$$

cc oxygen per litre at N. T. P.

Determination of total hardness (Ca+Mg)

It depends on the ability of EDTA ie. disodium Ethylene Diamine Tetra-acetate (Sodium versanate) to form stable un-ionized complexes with calcium and magnesium ions.

The indicator used is erichrome black T, which when added to solutions containing calcium and magnesium ions a complex is formed which is pink in colour. This can be changed back to blue again by the addition of sodium versanate solution which removes the calcium and magnesium ions from the dye complex to form corresponding versanate complex once more. The change in colour of the indicator provides an accurate end-point.

Also ammonium purpurate dye reacts to form a pink complex only with calcium ions (and not with magnesium ion). This is reverted to the normal purple colour of the dye by the addition of EDTA.

Reagents

(a) Standard solution of EDTA.

Dissolve 2·5 mg EDTA in two litres of distilled water. Add 13·5 ml N NaOH (solution d) and make up to 2,500 ml.

(b) *Indicator for* Ca^{++} *and Magnesium*$^{++}$ *titration*

Add 1 gm erichrome black T and 1 ml N Na_2CO_3 to 30 ml distilled water, mix well and make up to 100 ml with isoprophyl alcohol.

(c) *Buffer solution*

1. Dissolve 40 mg borax in 800 ml distilled water
2. Dissolve 10 gm caustic soda and 5 gm sodium sulphide in 100 ml distilled water (This acts as an inhibitor). Mix these two solutions and dilute to a litre. This solution both controls pH at the appropriate level (pH 8-10) and also to eliminate the effect of the copper ion and manganese ions. If these are present at the same time in the sample.

(d) *Standard Calcium chloride* (Stock solution)

Add 0·125 gm calcium carbonate to 100 cc distilled water and 25 cc N/10 HCl. Make up to one litre. This solution is equivalent to 50 mg per litre of Ca^{++} ie. 50 parts per million.

(e) *Caustic soda solution*

N Sodium hydroxide that is containing 40 gm per litre.

(f) *Indicator for* Ca^{++} *only*

Grind together in a mortar 0·20 gm ammonium purpurate and 100 gm NaCl. Keep dry in a well stoppered bottle since the aqueous solution is unstable.

Estimation of total hardness

100 ml of the sample of water is slightly acidified by adding N/10 HCl and then boiled for a few minutes. 0·5 ml buffer solution (c) is now added and about 5 drops of erichrome black T indicator (b). The sample is then titrated with standard EDTA. The end point being reached when the blue colour appears. The temperature of the sample has little effect on the accuracy of the test with fairly hard water, but in soft waters titration at approximately 70°C is recommended for a precise end-point.

Procedure for Calcium only

A colour standard is first prepared for matching that of the unknown. 10 cc of standard calcium chloride solution (d) are diluted to 100 cc with distilled water (equivalent to 5 ppm of Ca^{++}). 2 cc N NaCH are added together with about 0·2 gm of calcium indicator (f), 5 cc of standard EDTA solution (a) are now run in so that the indicator assumes the purple end point. This is not stable and fades in a few hours but the difficulty can be overcome by preparing a dilute solution in in isoprophyl alcohol

Figure II

1. Turbellarian feeding on cyclops
2. Spirogyra
3. Pinnularia
4. Turbellarian
5. Mycrocystis
6. Selenastrum
7. Volvox
8. Navicula
9. Cocconeis
10. Fuglena sp.
11. Turbellarian
12. Anabaena sp.
13. Anabas sp.
14. Ophiocephalus sp.
15. Tilapia sp.

Drawings not to scale

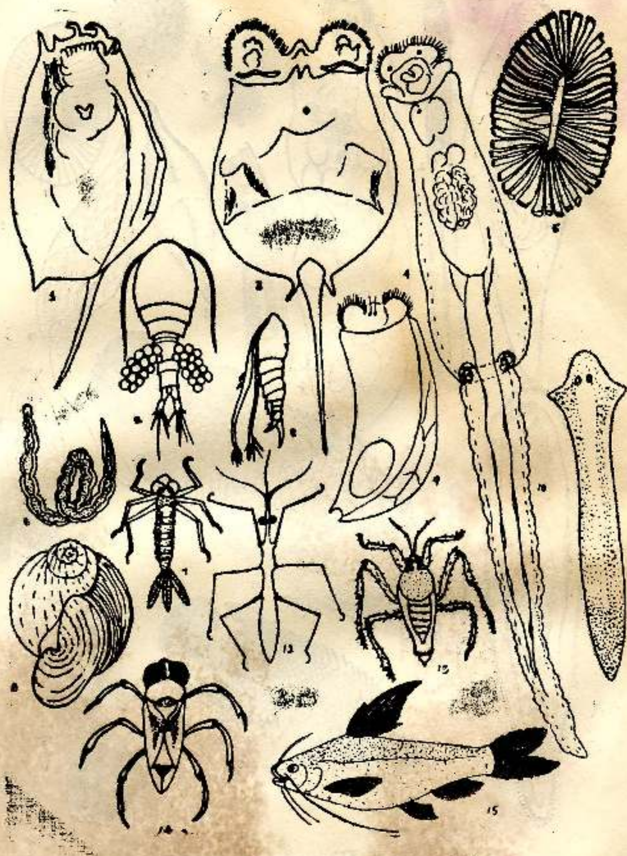


Figure III

1. *Keretella tropica* 40μ
2. Cyclopoid copepod
3. *Brachionus caudatus* 175μ
4. Conochilus sps. individual 900μ
5. Conochilus colony 2,000μ
6. Oligochaete worm
7. Damsel fly nymph
8. Calanoid copepod
9. *Keretella lenzi* 10μ
10. *Dugesia*
11. *Pila globosa*
12. Water measurer, *Hydrometra*
13. *Gerris*
14. Water boatman
15. Macroneus sp.

Drawing not to scale

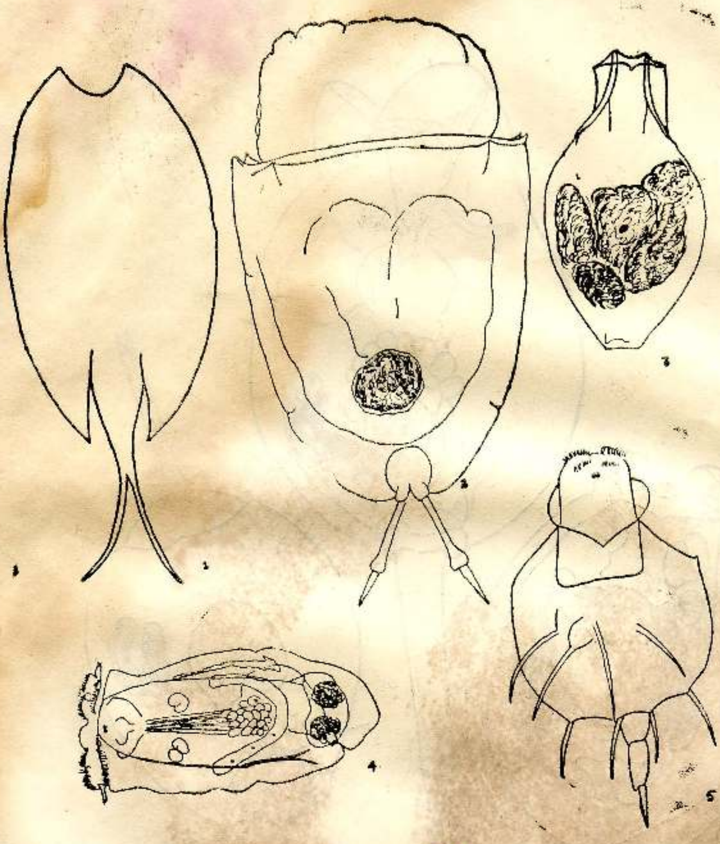


Figure IV

1. Lepadella 62μ
2. Lucane curvicornis 98μ
3. Anuraeopsis fissa
4. Asplanchna sp. 1,250μ
5. Macrochaetus collinsi 100μ

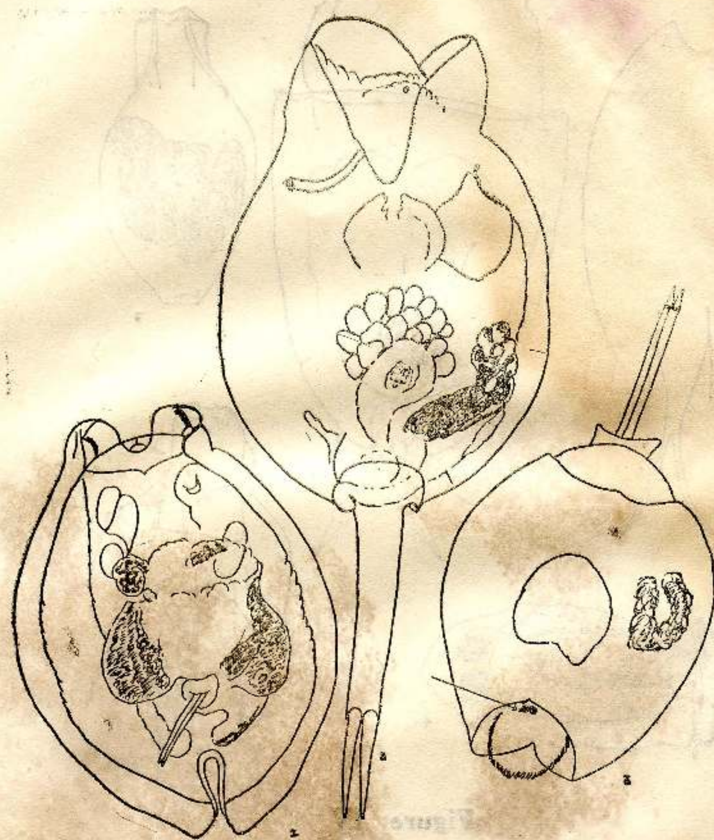


Figure V

1. Euchlanis dilatata 90μ
2. Lecane bulla 99μ
3. Dipleuclanis propatula 60μ

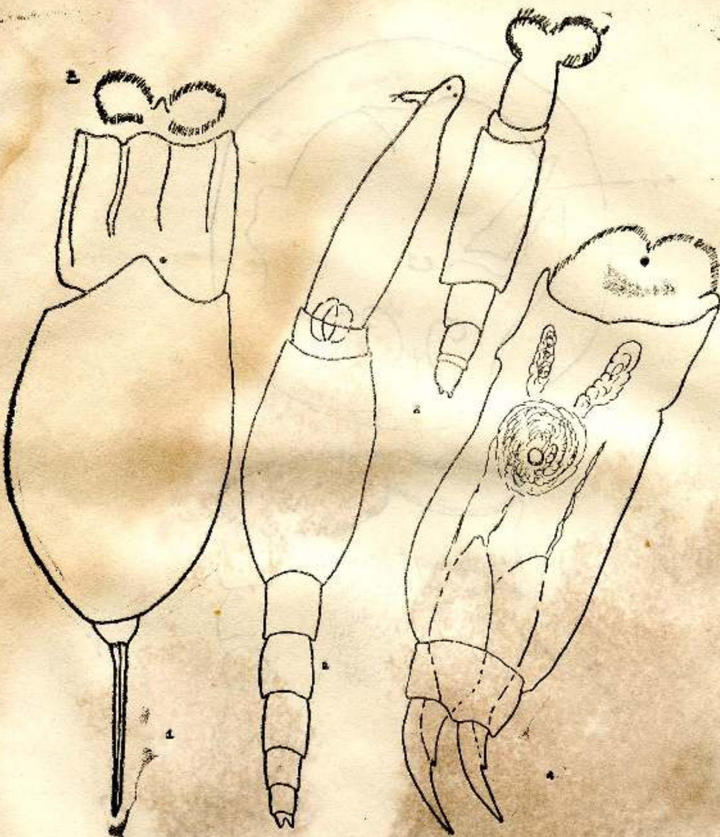


Figure VI

1. Trichocerca sp. 300μ
2. Rotifer vulgaris, extended 2,500μ
3. Rotifer vulgaris contracted
4. Cephalodella forficula 275μ

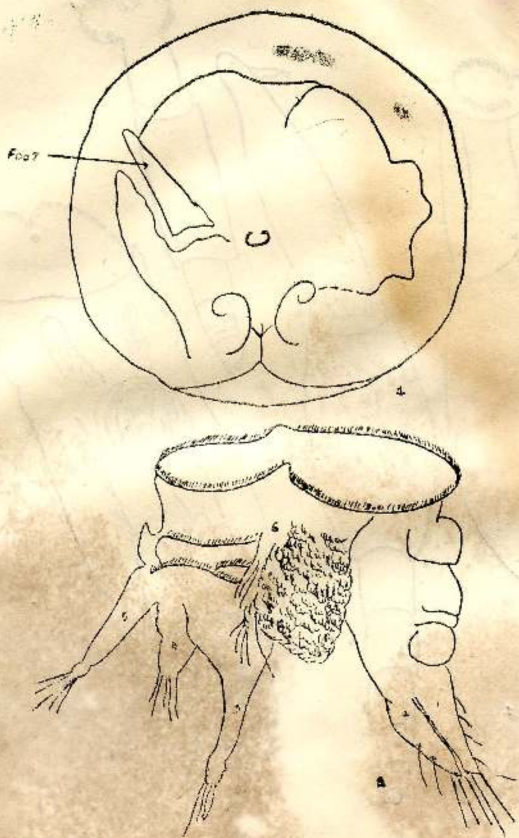


Figure VII

1. Testudinella patina 175μ
2. Hexarthra intermedia 220μ

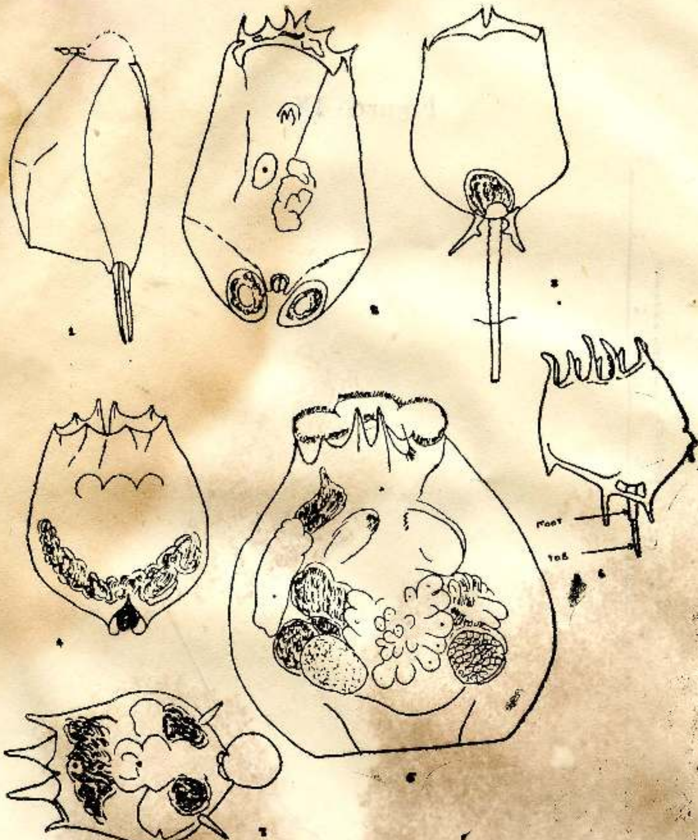
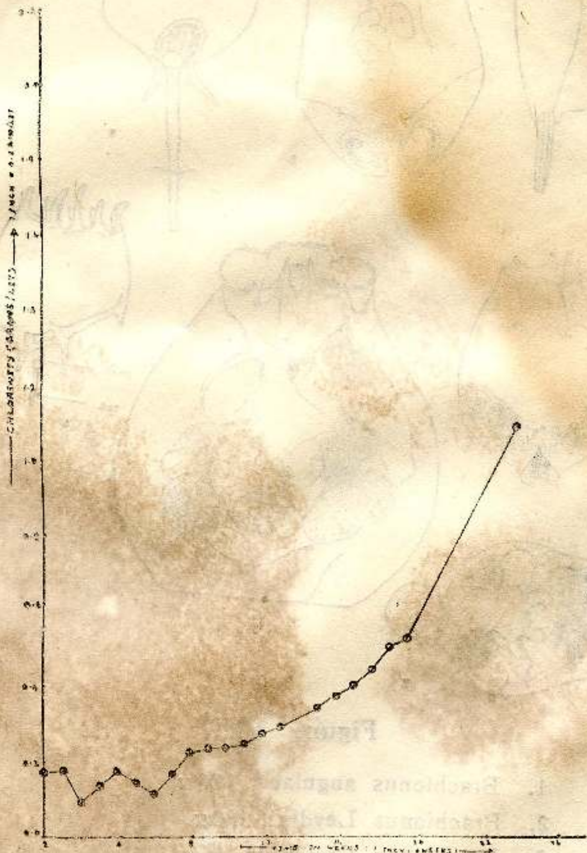


Figure VIII

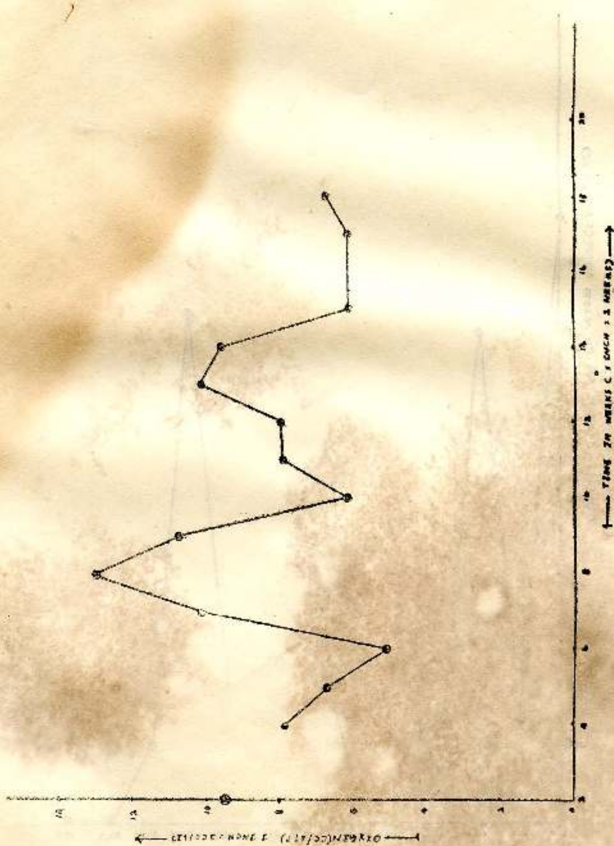
1. Brachionus angularis 100μ
2. Brachionus Leydigi 280μ
3. Brachionus Caudatus vara culeatus 135μ
4. Brachionus nilsoni 195μ
5. Brachionus urceolaris 245μ
6. Brachionus patulus 265μ
7. Brachionus calcsflorus 495μ

Figure IX



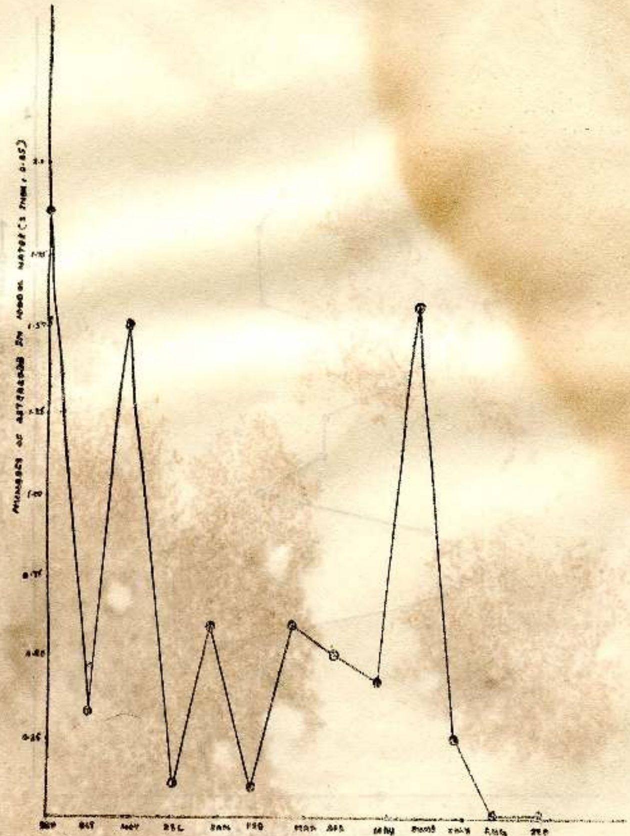
Variation in chlorinity with time

Figure X



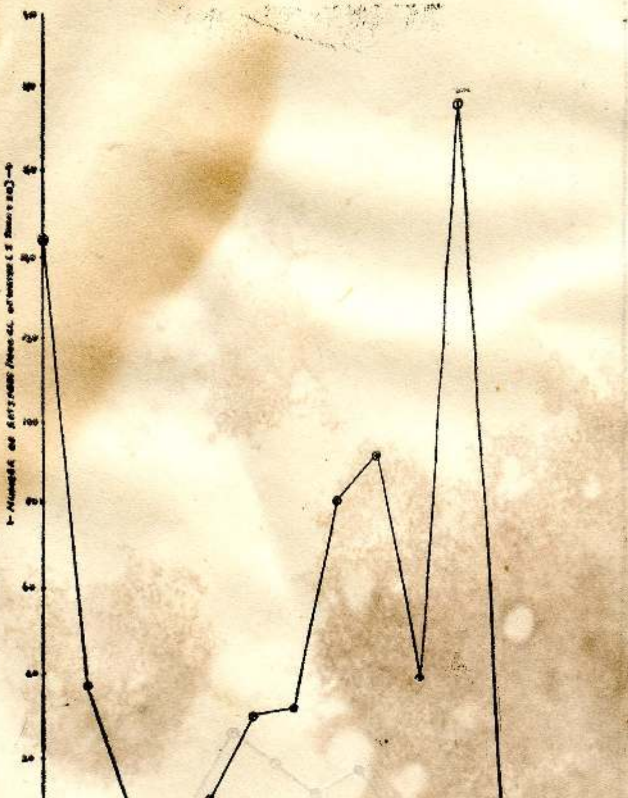
Variation in oxygen content with time

Figure XI



Variation in number of ostracods with time

Figure XII

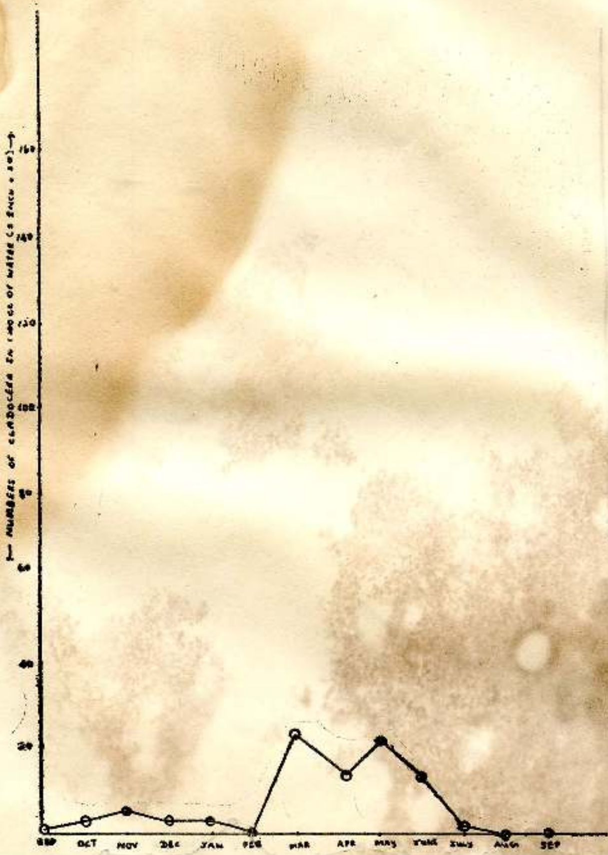


Variation in number of Rotifers with time

Figure XIII

Variation in number of cyclopoida with time

Figure XIV



Vartation in number of cladocera with time

Figure XV

Variation in number of calanoids with time

FOOD WEB IN THE POND

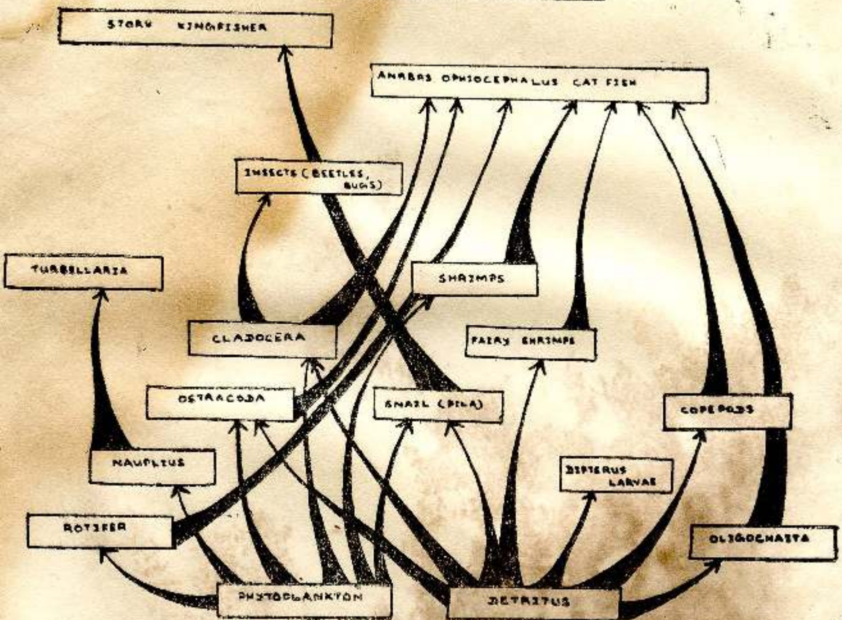


FIG. 16

Food web of the fresh water pond

of the dye dahlia violet. The two coloured liquids are poured into Nessler tubes standing on a white background and a match obtained by looking down on to the columns from above. In order to obtain perfect colour resemblance to the colour of ammonium purpuraate end point add a trace of methyl red.

A standard being thus obtained 100 cc of the unknown sample are treated in the same way. EDTA solution being added until the colour exactly matches that of the standard. Each cc of standard EDTA required to titrate 100 cc sample is equivalent to 0·1 mg Ca^{++} in 100 cc ie. one part per million.

The volume of EDTA used per 100 cc samples in the calcium only titration is substracted from the amount used in the Calcium and Magnesium titration.

1 cc difference ≡ 0·61 Mg^{++} per 100 cc
ie. 0·61 part per million

Determination of Salinity

Weigh out accurately 4·28 gm of Silver nitrate (or any other covenient weight) dissolve it in distilled water make up to 25 ml in a volumetric flask. This gives a 0·100 N solution (if some other weight is used normality has to be calculated.)

Take 25 ml of the sample of water into a 250 ml conical flask and add 1 ml of potassium chromate solution as indicator (to prepare indicator solution dissolve 5 gm of potassium chromate in 100 ml of water. Add the silver nitrate solution slowly from the burette swirling the liquid constantly until the the red colour formed by the addition of each drop begins to disappear more slowly. This is an indication that most of the chloride has been precipitated. Continue the addition dropwise until a faint but distinct change in colour occurs. This faint reddish brown colour should persist after brisk shaking.

Calculate the normality of the sample. This multiplied by 35·5 gives the grams per litre of chloride ion as chlorinity.

Salinity = Chlorinity × 0·03 + I·805

Determination of Carbondioxide content

The distribution of carbon dioxide differs in acid waters and neutral or alkaline waters. Therefore firstly the pH of the sample should be determined.

(1) **Acid water**

Free carbon dioxide will occur only in acid waters. If a solution of sodium carbonate is added to the sample the carbon dioxide will form bicarbonate.

Reagents required are:

(a) N/100 Sodium carbonate solution. This can be prepared dy dissolving 0·53 gm of pure anhydrous Na_2CO_3 — dried in the oven at 103°C for an hour — in a litre of distilled water since the solution does not keep well each time before use it should be standardised against N/100 Hydrochloric acid.

(b) One per cent phenolphthalein solution ie. 50 of alcohol neutralised with dilute sodium hyroxide. Phenolphthalein is colourless in the presence of bicarbonate but turns pink when free carbonate appears.

Procedure

Add 10 drops of phenolphthalein to 100 cc of the water sample. Titrate against sodium carbonate. To prevent the formation of bicarbonate by contact with air, gently stir during the titration and use a narrow mouthed container which prevents minimum surface of the water sample to the air.

If x is the number of cc of N/100 sodium carbonate required by 100 cc of the water sample that the normality of the carbon dioxide equals $\frac{x}{10,000}$

A normal solution of carbondioxide contain 22 gm per litre. Therefore the sample cotains 2·2 xmg per litre.

(2) Combined carbon dioxide and neutral and alkaline water. Here the carbon dioxide present will be in the form of bicarbonate mainly that of calcium and magnesium.

Reagents required

(a) N/100 Hydrochloric acid

(b) A mixture of 0·02 per cent methyl red and 0·1% bromo-cresol green in 95 per cent alcohol as an indicator. The colour change is from blue through grey to a pale greyish pink.

Procedure

To 100 cc of water sample add a few drops of the indicator and titrate against N/100 hydrochloric acid shaking well. The amount of combined carbon dioxide is usually expressed as the equivalent quantity of calcium carbonate per litre. Let x be the number of cc of N/100 hydrochloric acid required for 100 cc water sample. The equivalent weight of calcium carbonate is 50. Therefore the amount of CO_2 expressed as calcium carbonate will be 5x mg per litre.

Ammonia and Nitrate Nitrogen

250 ml of the sample and excess 40% sodium hydroxide solution is taken in a litre flat-bottomed flask and the ammonia is distilled into 25 ml of boric acid (4%) containing 3 drops of mixed indicator bromosol green and methyl red until about 60 ml of of distilled water is collected. Then another receiver containing 25 ml of 4% boric acid with 3 drops of indicator is connected and 2·5 - 3 gm of Devadas alloy and excess sodium hydroxide solution (40%) is added to the contents of the flask. Distillation is continued until 60 ml of the distillate collected. The distillate is titrated with standard hydrochloric acid and end point being colour change of indicator from greenish blue to red. The amount of ammonia and nitrate are calculated using the volume of the hydrochloric acid needed.

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