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FRESHWATER AS A NATURAL RESOURCE IN SRI LANKA

by

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FOREWORD TO THE SERIES

The dissemination of scientific information is one of the main functions of the Natural Resources, Energy and Science Authority. The Journal of the National Science Council published by this Authority provides a medium for the publication of scientific research papers, and "Vidurava", the quarterly science bulletin contains scientific articles of a general nature which are of interest to the public.

There is still a wide gap in the availability of reading material on scientific subjects of local interest. One result of this is that science students confine their reading only to their school notes and to the few available text books which are mostly published abroad. In an attempt to improve this situation, the Working Committee on Science Education Research of the Natural Resources, Energy and Science Authority decided to publish a series of booklets on scientific topics of local interest as supplementary reading material for students and the general public. The authors who have been selected by the Committee to prepare these booklets are experts in their respective fields. The manuscripts that were submitted by the authors were examined by referees before being accepted for publication. The views expressed in these publications are those of the authors and are not necessarily those of the Natural Resources, Energy and Science Authority.

I must thank the Working Committee on Science Education Research of the Natural Resources, Energy and Science Authority, and in particular Prof. V. Basnayake who is the Hony. Director of the Working Committee for the work they have done to make this project a success.

R. P. Jayewardene
Director General

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1.0 Introduction

Freshwaters cover one fiftieth of the earth's surface. Lakes, rivers, streams, ponds and pools are but islands of water in a sea of land. Yet these comparatively tiny blobs and winding lines on the map have an importance out of all proportions to their area. The total stock of world water is fixed but the locally available water can be used up or made unusable by mismanagement. Increased concentration of people and industries in large urban areas, proliferation of water consuming industrial processes, greater consumption of energy and increased agricultural activity and food production as a result of population growth are all causing serious inroads into the quality and quantity of available water so that developing countries as well as developed countries can no longer regard freshwater as an inexhaustible gift of nature.

2.0 Morphology and geology

The interior of the island (area 65,610 km²) is occupied by the central highlands, a complex of plateaux, mountain chains and basins at a general elevation of 1,400 to 1,800 m.

The highland is surrounded by two peneplains, the lower of which extends from the coast inland (the lowland) where it rises to 100-150 m. above sea level. The second peneplain (the upland) has a general elevation of 500-700 m, but in some places it is irregular and heavily eroded.

Sri Lanka is a detached part of the continental Deccan plateau of ancient precambrian rocks and only the peninsula of Jaffna and the North West coast is covered by miocene limestone (Cooray, 1967).

3.0 Climate

Sri Lanka is situated within the equatorial belt of calms. The intensity and the narrow amplitude of insolation is an important factor controlling the climate. There are only slight variations in temperature, air humidity and day length.

3.1 Temperature

The annual mean temperature measured at station level for a period of three decades was 27.2°C in the lowland (Colombo, Jaffna, Hambantota and Anuradhapura), 24.4°C in the upland (Kandy) and 15.4°C in the highland (Nuwara Eliya). The mean temperature of the months varies only slightly; the yearly amplitude is only 1.7 - 1.8°C in the coastal lowland (Colombo), 2.7°C in the upland (Kandy) and 2.4°C in the highland (Nuwara Eliya). The coldest month is December or January with about 26.1°C in the lowland (Colombo), about 23.3°C in the upland (Kandy) and 14.4°C in the highland (Nuwara Eliya).

3.2 Precipitation, runoff and water budget

Sri Lanka is fortunately endowed with sufficient water. This water is received as rainfall and is the only form of precipitation. Rainfall in Sri Lanka is unevenly distributed (Fig. 1) and has a bimodal pattern determined by the tropical monsoons. Alternating regularly, the monsoonal winds blow in two directions, from the North East during the period of October to February and from South West during May to July. During the period of the North East monsoon, warm moist air which passes over the island surfaces are lifted, primarily by convection, and deposit their moisture over the entire island. During the South West monsoon, on the other hand, moist air is lifted abruptly by the mountains of South and Central Sri Lanka causing it to deposit most of its moisture over the South Western sector of the island.

South Western quadrant of the island (Wet Zone) receives the maximum amount of precipitation as rainfall from both seasons ranging from 2,540 to 5,715 mm. (100-225 inches) with peaks in May and October while the Dry Zone receives about 1,270-1,905 mm (50-75 inches) mainly during the period of the North East monsoon. During the intermonsoonal periods the island experiences convectional rain. In the Wet Zone there are two marked dry periods each year; February to

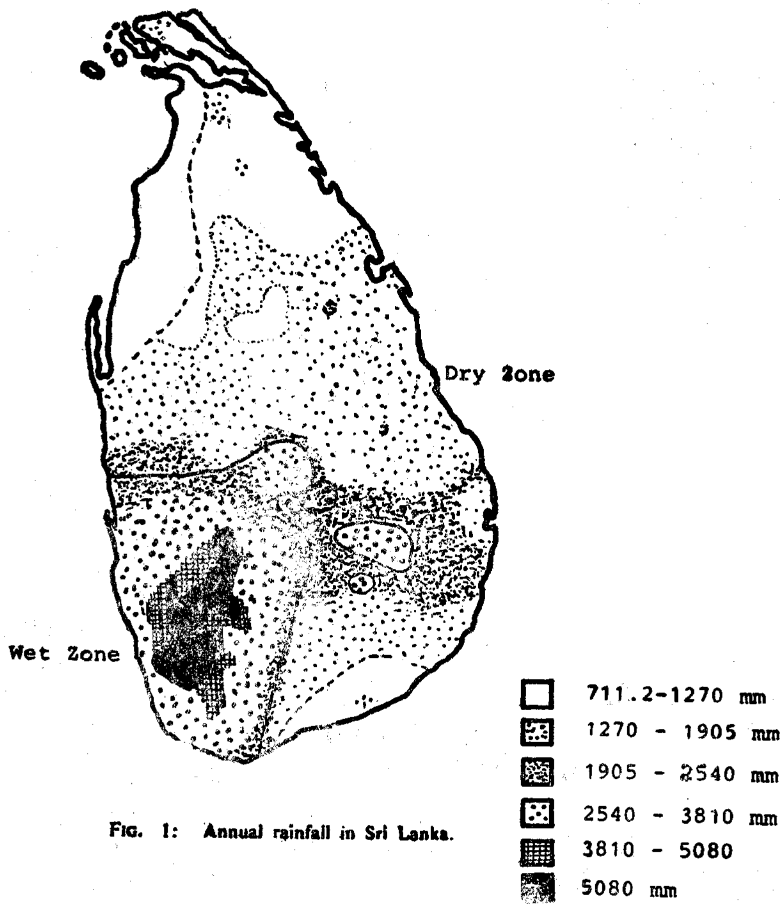


FIG. 1: Annual rainfall in Sri Lanka.

March and August to September. When discussing water as a resource, it is necesssary to visualize that water is one element in a complex watershed system also involving air, land, plants and animals. The water circulation from the clouds to land and back to the atmosphere is another complex system of transpiration, evaporation and precipitation.

The total annual precipitation over Sri Lanka has been estimated to be about 123,000 million m^3 (100 million acre feet) of water. The surface water resources in terms of total mean annual escape to the sea and lagoons from the 103 river basins have been estimated to be of the order 36,900-49,200 million m^3 (30-40 million acre feet). The total ground water resources available in the island have been estimated by Fernando (1973) to be around 7,380 million m^3 (6 million acre feet) per annum (Fig. 2) which is about one sixth of the country's surface water resources. Most of the residual precipitation is lost by evapotranspiration through the luxuriant vegetation.

In order to conserve and utilize some of this large runoff, a number of reservoirs have been constructed both in the Dry Zone and in the Wet Zone of Sri Lanka. These consist of ancient irrigation reservoirs such as Parakrama Samudra and Minneriya Wewa (popularly known as "tanks" and constructed more than a thousand years ago), reservoirs constructed recently to conserve water under the river basin development projects and several hill country reservoirs such as Castlereagh, Kotmale and Victoria for the generation of electric power.

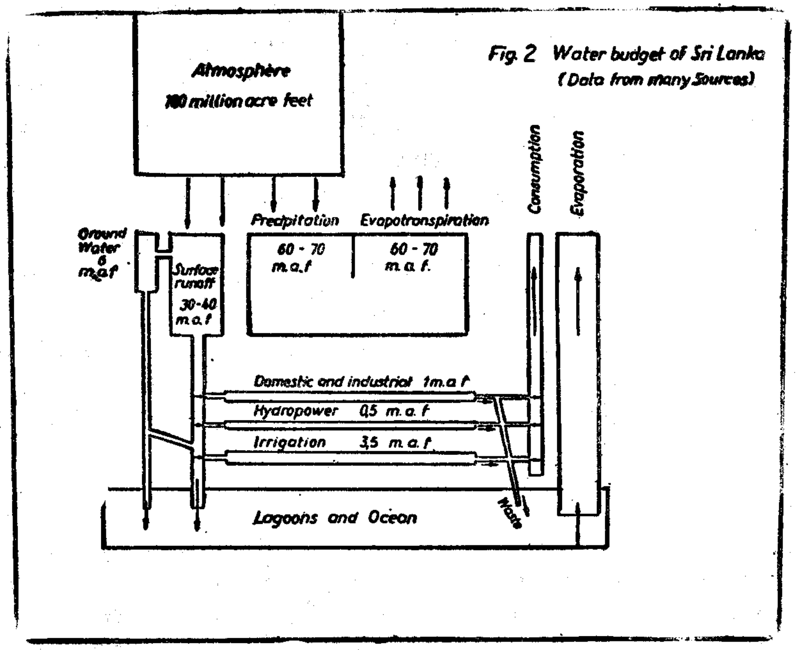


Fig. 2 Water budget of Sri Lanka (Data from many Sources)

The major uses of the surface water resources are for domestic, industrial, irrigation. and hydropower generation. Approximately 1,230 million m^3 (1 million acre feet) of water are presently utilized for domestic and industrial purposes while the irrigation schemes and hydroworks consume around 4.920 million m^3 (4 million acre feet) of water (Fig. 2). The installed reservoirs such as Laxapana, Norton and other reservoirs together have a storage capacity of around 246 million m^3 (0.2 million acre feet) while the reservoirs constructed under the multipurpose Mahaweli Development scheme will hold around 2000 million m^3 of water.

Table I: Runoff (discharge) to the sea from some of the major rivers in Sri Lanka (Arumugam, 1969)

River	*Acre feet*	*Cubic meters*	*% of precipitation*
Wet Zone:			
Kalu ganga	6 160 000	7 576 800 000	64
Kelani ganga	4 510 000	5 547 300 000	64
Gin ganga	1 597 000	1 964 310 000	59
Nilwala ganga	1 142 000	1 404 660 000	45
Maha oya	1 020 000	1 254 600 000	34
Dry Zone:			
Mahaweli ganga	7 205 000	8 862 150 000	40
Walawe ganga	1 366 000	1 680 180 000	35
Deduru oya	955 000	1 174 650 000	27
Maduru oya	648 000	797 040 000	26
Kala oya	543 000	667 890 000	17
Total runoff from all rivers	31.6 mill.	38 868 mill.	31

It is estimated that there are 300 major and medium (Fig. 3a) scale irrigation reservoirs (almost all consl tructed during the ancient times) with an approximate

Fig. 3: *A*: One of the irrigation reservoirs constructed in the ancient times in the Polonnaruwa District.

Fig. 3: *B:* **Tilapia mossambica** an introduced fish caught from one of these reservoirs.

water storage capacity of 3,690 million m^3 (3 million acre feet) (Table II). In addition there are approximately 17,000 ancient minor irrigation reservoirs, channels and works with an estimated capacity of about 984 million m^3 (0.8 million acre feet).

On the whole it is estimated that the inland waters cover about 867 km^2 (335 square miles).

Table II: Major and medium-scale ancient irrigation reservoirs in Sri Lanka (Area at full supply level (FSL) (Mendis, 1977)

District	*Major*	*Area in acres at FSL*	*in ha*	*Medium*	*Area in acres at FSL*	*in ha*
Amparai	11	36 687	14 858	21	8 109	3243.6
Anuradhapura	11	39 404	15 958	12	8 505	3402.0
Badulla	3	2 147	869	9	1 883	753.2
Batticaloa	5	7 637	3 092	16	4 237	1694.8
Hambantota	7	8 824	3 537	11	1 237	494.8
Jaffna	3	9 654	3 909	10	4 894	1957.6
Kurunegala	7	5 795	2 346	7	2 535	1014.0
Mannar	2	8 200	3 321	7	2 025	810.0
Matale	3	3 500	1 417	3	113	45.2
Matara	2	2 790	1 129	4	725	290.0
Moneragala	2	9 690	3 924	13	1 477	590.8
Polonnaruwa	5	21 641	8 764	4	500	200.0
Puttalam	1	1 140	461	8	2 800	1200.0
Ratnapura	2	19 535	7 911	5	147	58.8
Trincomalee	4	10 754	4 355	10	2 361	944.4
Vavuniya	6	9 442	3 824	21	4 538	1815.2

Approximate Water storage 3 690 million m^3 (3 million acre feet)

4.0 Chemistry of the freshwaters

The chemical composition of the freshwaters of reservoirs, streams and rivers is mainly determined by the prevailing geological structure and meteorological conditions. The dissolved substances not only determine the level of biological productivity but also may even determine the distribution of species. The chemistry of the freshwaters of Sri Lanka has been discussed by Costa and Starmuhlner (1972), Weninger (1972), Costa and De Silva (1978), Gunatilake (1983), Amarasinghe et al. (1984) and Daniel et al. (1986). The spring waters of Sri Lanka appear to be slightly acidic (range of pH: 5.7-6.7) while the waters in the lower courses of the rivers tend to be slightly alkaline (range of pH: 6. 5-7.8) probably as a consequence of the removal of CO_2 and HCO^-_3 by

Table III: Water chemistry of Kelani ganga, the fourth longest river in Sri Lanka, from the estuary to the source (Weninger, 1972)

	Estuary (Colombo)	*Hanwella*	*Kitulgala*	*Ginigath-hena*	*Maskeliya*	*Mountain forest*
Altitude (m)	0-1	20	64	650	1 200	1 85C
Tem °C	28	26.5	25.4	23	19	15-17
Conductivity µs/cm	288.0	27.0	33.4	36	11	8.8
pH	6.4	6.4	6.0	6.0	6.3	5.4
Hardness °German	1.83	0.36	0.71	0.82	0.15	0.08
Ca·· pm	1.15	1.81	3.23	3.71	0.65	0.24
Mg·· ppm	5.81	0.48	1.10	1.30	0.26	0.26
Na· ppm	1.00	2.00	1.80	2.60	0.70	0.60
K· ppm	3.50	0.95	1.10	0.40	0.15	0.20
Fe··· ppm	0.04	0.01	0.01	—	C.005	0.01
Al ·· ppm	0.09	0.03	0.09	0.40	0.03	0.10
NH_4 ppm	0.04	0.01	0.08	0.04	0.15	0.25
NO ppm	0.21	0.16	0.13	0.05	0.04	0.05
Cl· ppm	8.52	2.84	2.41	1.99	1.70	1.14
F · ppm	0.04	0.05	0.04	—	0 03	0.05
P_2O_5 ppm	0.08	0.02	0.18	—	0.00	0.00
SiO_2 ppm	6.95	3.50	6.40	12.3	3.15	2.61
HCO_3 mval	0.04	0.08	0.28	0.4	0.15	0.05
Humic acids ppm	0.15	0.0	0.113	0.0	0.11	1.02
$KMnO_4$ consumption	13.3	22.1	15.8	10.7	9.2	28.8

Note: The approximate length of the river is 140 km (88 miles).

photosynthesis. Table III gives the water chemistry for several stations beginning from the source waters for a major river in the Wet Zone in Sri Lanka. The water courses show changes in their water chemistry due to monsoonal conditions including changes in the quantities of dissolved oxygen. In the lower course of the Kelani river this is mainly due to the discharge of sewage borne organic materials (de Silva, Chandrani & Jayaweera, 1984). Generally the waters in the man made reservoirs specially those in the northern part of the country are alkaline with pH^s ranging from 8.0 to 9.5 (Amarasinghe et al, 1984).

The rivers of the Wet Zone have soft water even near their flowouts into the sea (Weninger, 1972). In their lower courses the electrolyte contents increase (Mg··, Al···, Cl·, SiO_2) as well as the amounts of humic acids and other dissolved yellow - brown substances. Increased NH_3 in water and $KMnO_4$ demand results from influences of sewage discharged into the rivers flowing through highly populated urban areas.

Water from some ancient reservoirs contain medium salinity irrigation water (Amarasiri, 1972). Use of saline irrigation water may lead to the formation of saline soil. Such soils are generally unproductive and also restrictive in the type of crops which can be grown in them. The United States Department of Agriculture (1954) has classified irrigation waters on the basis of electrical conductivity as follows:-

Conductivity (Micromhos/cm at 25°C)	*Class*
0 — 250	low salinity water
250 — 750	medium salinity water
750 — 2250	high salinity water
> 2250	very high salinity water

Using the above classification Amarasiri (1972) has shown that Giant's Tank, Pavatkulam, Maha Willachiya, Nuwara wewa, Kalawewa, Huruluwewa and Nachchaduwa contain medium salinity water. Such waters can be used for the cultivation of crops with moderate salt tolerance if a moderate amount of leaching occurs. If drainage is restricted, salinity could become a major problem of the irrigation schemes in the dry zone of Sri Lanka.

5.0 Primary productivity

Production in water as on land begins with the primary production of plant matter. This is dependent on many factors such as the intensity of irradiation, depth of the water, transparency, temperature etc.

There are two main sorts of autotrophs or primary producers. They can be categorized as (1) chemolithotrophic forms (chemosynthetic bacteria) and (2) photolithotrophic types (photosynthetic forms). For growth they both require a source of energy and usable inorganic carbon.

The most important lacustrine producers are the phototrophs; photosynthesis creates the bulk of new organic compounds. Littoral macrophytes, benthic algae and phytoplankters convert radiant energy to potential chemical energy. Except for shallow reservoirs, the phytoplankters assume the most importance as producers.

Production is usually considered as the net production (growth increment). This would be the difference between gross production and the respiration of zooplankters, bacteria and algae tested during a certain time period.

The practical man, the fisherman, is able to tell us which reservoir or river is productive. Early Chinese carp pond farmers discovered by trial and error that it paid to manure fish ponds. Today we know that aquatic productivity like land productivity is dependent on the supply of nutrients.

In recent times, studies on primary productivity of freshwater ecosystems in tropical countries have assumed practical importance because of the stress on the freshwater fish (specially herbivorous fish) culture programmes. Recently several studies on primary productivity have been conducted on Sri Lankan freshwaters by Costa et al (1986), Schiemer (1983), Amarasinghe et al (1984) and Daniel et al (1986).

Most of the lentic water bodies in Sri Lanka are eutrophic (Gunatileke, 1983; Amarasinghe et al, 1984). This is in consequence of the physical conditions such as shallowness and high temperature as well as due to washing in of nutrients and fertilizers. Because of the eutrophic nature of the waters, the primary productivity is moderately high. The annual yields show similar productivity values to those worked out in India (Vijayaraghavan, 1977). These values decrease during the rainy months and increase during the drier months. The gross productivity values range from 1.20 to 5.63 g $C/m^2/day$ for the different times of the year (Amarasinghe et al, 1984; Daniel et al, 1986).

6.0 Secondary productivity

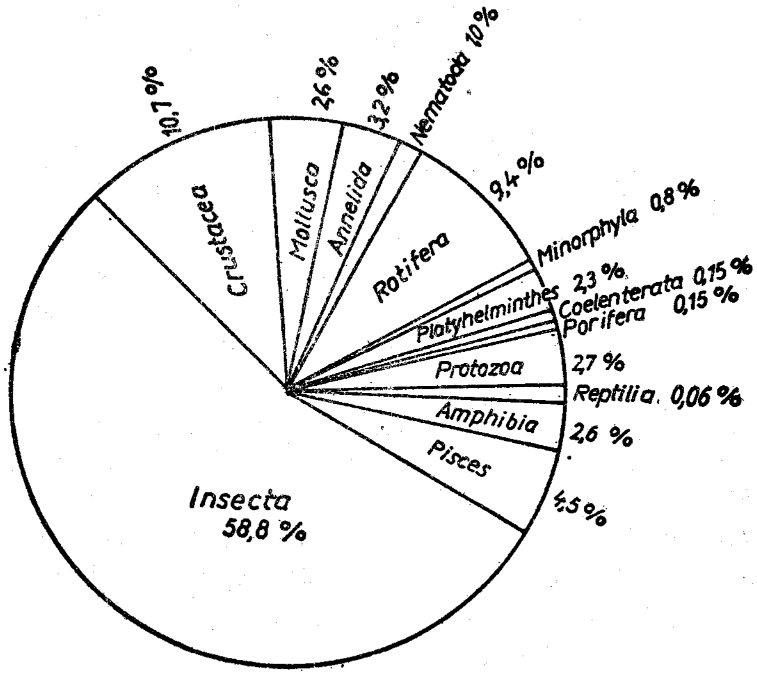
The plant matter that is produced in the aquatic system, is in turn, directly or indirectly the source of food of the animal species which form the secondary level of productivity. The plant matter is directly used by herbivorous heterotrophs, that require the autotrophs for food. Above these are the predaceous heterotrophs that feed on the herbivores. Secondary carnivores make up the next higher level and so on. Because much energy is expended in metabolism at each level, the mass of living material produced decreases at each higher level.

6.1 Freshwater aquatic fauna

The species composition of Sri Lankan freshwaters, except for a few groups is now fairly well known. To date around 1,332 species are known to live in the freshwaters of Sri Lanka; more than half of the described species so far have been aquatic insects (Fig. 4).

Intensive biological studies carried out on torrential streams and on the upper parts of the major river systems originating from the central highlands have indicated a high productivity and an unusual richness in the fauna (Costa and Starmuhlner, 1972). Recently high productivity values for faunal groups such as Rotifera and for benthic fauna have been shown for the man made irrigation reservoirs (Duncan, 1983; Kannankage, 1986). Faunal surveys recently carried out show that the freshwaters of Sri Lanka are rich in groups such as the Trichoptera (Schmidt, 1958), Odonata, Hemiptera, Coleoptera (Jach, 1983) and Decapoda Crustacea (Costa, 1983). The decapods are mainly represented by nine species of *Macrobrachium* and species of *Ceylonthelphusa*, *Spirothelphusa* and *Perbrinckia* (Costa, 1984). The shrimps, prawns and crabs are sometimes present in very large numbers both in the standing and running waters. Some insect groups are so richly represented in the Sri Lankan freshwaters that Wroblewski (1960) described one of the Sri Lankan aquatic groups, the Family Micronectinae, as a group unmatched in any other

Fig.4 showing the faunal spectrum of the freshwaters of Sri Lanka (Total number of species described to date : 1332)



land with respect to richness of species. On the other hand, due to the absence of natural lakes in Sri Lanka there is a paucity of typical lake fauna specially the lake cladocerans and lake copepodans of oligotrophic lakes.

These aquatic animals form a bewildering, complex network of food relations (Fig. 5 gives a simple food web.) Some species are herbivores, others feed on detritus of which large amounts come into the waters from the adjacent countryside; still others are carnivores of ascending sizes.

6.2 Freshwater fish and fish production

Of particular interest for human welfare, however, is the production of fish and other edible organisms in the aquatic environment. Whether he is seeking sport or food, man is keenly interested in fish. Fish species may be herbivorous, carnivorous or omnivorous in their food habits. In the last category they may have several links in their food relations.

There are about fifty five species of indigenous freshwater fish of Sri Lanka. Many of these are small in size, herbivorous and of no economic importance. The species of some economic importance are unfortunately slow growing and not very abundant. They are mostly carnivorous. The paucity of herbivorous species of economic importance (Table IV) has distinctly contributed to the low productivity of utilizable indigenous species of freshwater fish.

Fig. 5 showing the food web existing at Horton plains streams; Sri Lanka. Altitude 1900m, Temp. 15°C. (Note - There are no indigenous fish in these streams)

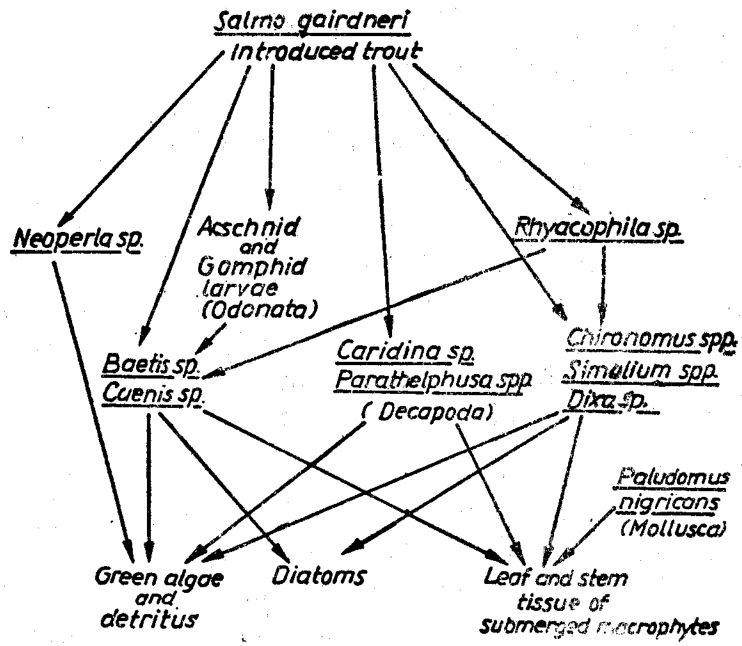


Table IV: Indigenous food fishes of Sri Lanka (Costa, 1978)

Species	*Food habits*	*Size (cm)*
Labeo dussumieri	Herbivorous	35
Puntius sarana	Omnivorous	30
Puntius dorsalis	Herbivorous	23
Wallago attu	Carnivorous	150
Tor khudree	Omnivorous	75
Ompok bimaculatus	Carnivorous	38
Clarias teysmanni	Omnivorous	30
Heteropneustes fossilis	Omnivorous	25
Macrones vittatus	Omnivorous	10
Ophiocephalus striatus	Carnivorous	68
Etroplus suratensis	Omnivorous	30
Glossogobius giuris	Carnivorous	35
Macrognathus aculeatus	Carnivorous	25

The greater the number of links in the food chain means greater the waste of energy at each level. At each link in the food chain from solar energy to fish large conversion losses occur. Only about 1% of the initial energy bound in the organic substance is likely to reach the final level. It becomes evident that to make the fullest use of Sri Lanka's innumerable reservoirs (around 17,000), streams and rivers for fisheries development, it will be necessary to introduce into Sri Lankan freshwaters fast growing species of herbivores and omnivores having short food chains and moderate fecundity which could utilize the plankton, higher plants and bottom fauna which are abundantly present in them.

Fifteen such species of exotic food fishes which showed promise in other countries as suitable fishes for establishment of freshwater commercial fisheries have been imported within the last few years for stocking the freshwaters of Sri Lanka of which about eight species have now established themselves.

The spectacular break-through in the increase of freshwater fishery production, however, came with the introduction of the fast breeding plankton feeder (Fig. 3b) *Oreochromis mossambicus* (*Tilapia mossambica*) by Sri Lanka's Department of Fisheries into the natural waters in 1951 and subsequently into the large irrigation reservoirs such as the Parakrama Samudra in 1952. Tremendous increase in fish production was achieved within a few years of its introduction which for the first time led to the commencement of small scale freshwater commercial fisheries. Success with *Oreochromis mossambicus* led to the introduction of complementary omnivorous species such as *Tilapia randalli* and *Oreochromis niloticus* to fill the unutilized niches in man made reservoirs. However, presently there is no evidence for their successful establishment. *Oreochromis mossambicus* now form about 90% of the catch by weight in the low country irrigation reservoirs (Daniel et al, 1986). The tremendous increase in freshwater fish production could be gauged from the statistics for Parakrama Samudra, a major irrigation reservoir constructed by the Sinhalese kings in the north east of Sri Lanka about 1,000 years ago, maintained by the Department of Fisheries, Sri Lanka since 1949. Although these statistics are not very reliable they showed that from a mere 10 kg ha^{-1} yr yield of fish taken by subsistence level by

fishermen in 1949, the production of fish has risen to about 4×10^2 kg ha^{-1} yr^{-1} (Fig. 6) in 1980. The most recent studies however indicate that the real production is around 100 kg ha yr^{-1} in this reservoir (Amarasinghe, 1984). The present fish yield figure of 20,000 metric tons given by various workers for major reservoirs will **need** revision in the future. Suitable species of fish have not yet been found for stocking the waters in the recently constructed hydroelectric reservoirs in the hilly regions of Sri Lanka. Plans are now being initiated by the Ministry of Fisheries to stock the seasonal tanks with Indian carps such *Labeo rohita*, *Catla catla* and *Cirrhinus mrigal* and the cold water streams in the hill country with trout (*Salmo gairdneri*).

7.0 Aquaculture

Ponding for culture of freshwater fish and prawns is now an established practice in many countries. In Sri Lanka, culture of *Tilapia* spp. was initiated as far back as 1952, but there was no impetus to culture these species as these fish established themselves as natural populations in the major and the medium perennial irrigation reservoirs in the Dry Zone as well as in the Wet Zone. However, some success in the culture of the Chinese carps *Ctenopharyngodon idellus* (grass carp) and *Aristichthys nobilis* (big head carp) has been achieved recently at Uda Walawe fish breeding station in the South West of Sri Lanka and of

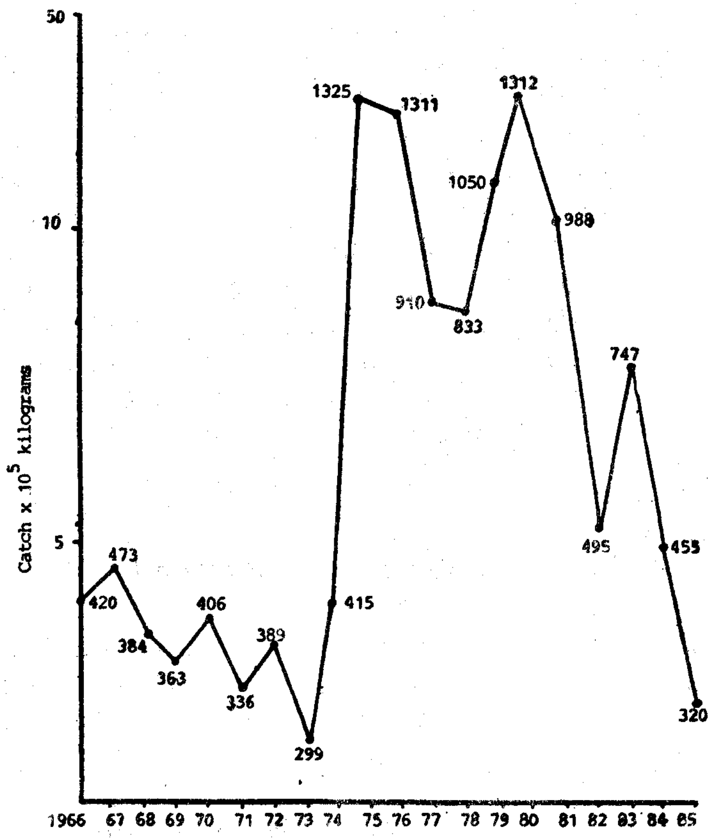


Fig. 6 Fish yields from Parakrama Samudra for the period 1966-1985.

the Indian carps *Labeo rohita*, *Catla catla* and *Cirrhinus. mrigal* at the Rambodagalle and Dambulla fish breeding stations. Experiments have been successful, under local conditions, in the culture of different species of carp, occupying different ecological niches in the same pond, thus maximizing the use of the water column. The several ancient minor irrigation reservoirs (about 17,000 in number) which dot the dry zone where the filling is seasonal are beginning to be exploited as sources for fish production (Thayaparan, 1983). With the onset of rains fingerlings could be introduced and the fish could be harvested before the reservoirs (or the irrigation channels) could get dried up during the dry season. An experimental study carried out at Thunkana tank has shown that the production can be as much as 1153 kg/ha (Thayaparan, 1983). As almost every village in the Dry Zone has one or more minor irrigation reservoirs, they could be utilized to serve as community fish ponds. The whole village community could participate in preparing the ponds at the beginning of the rainy season, stocking the fingerlings and harvesting the fish at the end of the dry season. These numerous minor irrigation works could therefore serve not only in providing the potable water and the water required for irrigation purposes but also could provide the necessary protein that these communities so badly require.

The importance that is to be given to the development of inland fishery as well as to freshwater aquaculture development can be gauged from the following ten year aquacultural development plan drawn up by the Ministry of Fisheries, Sri Lanka (Table V).

Table V: The projected production figures for inland and marine fish from Sri Lanka (in metric tons)

	1976	1980	1985	1990	2000
Marine	133 633	190 000	251 500	335 000	500 000
Inland	21 703	44 535	75 540	104 545	122 544
Total	155 341	234 353	332 040	439 545	622 544

Source: E. G. Goonawardene - Proceedings of Development and Planning (FAO) Bangkok, 1975.

It is envisaged that by the year 2000 AD about 1/6 of the fish production will be from inland waters (from irrigation reservoirs and aquacultural practices).

8.0 Environmental impacts on freshwater resources in Sri Lanka

As one of the principal natural resources, water serves man for domestic purposes, agricultural production, fisheries, power production, recreation and to a small extent in Sri Lanka for industrial purposes and river navigation. In the fulfilment of all these functions the two basic parameters of quantity (distribution of water in space and time) and quality (physical, chemical and biological properties) are always important. However, there are many impediments to the rational utilization of this resource, mostly as a result of human impact.

8.1 Exotic aquatic weeds

Natural aquatic ecosystems are complex and exhibit a web of inter-relationships between living organisms and environmental factors. Aquatic higher plants play an important role in the stability of the system. They are primary producers on which the secondary producers depend. In addition, they provide habitats for other plants and for animals. They absorb nutrients from the system and release nutrients when they decay. By accumulating detritus and other material they also stabilize the substrate. However, aquatic vegetation not only has positive effects but also show negative ones on the ecosystem. Sometimes, due to excessive nutrient enrichment of the water bodies, explosive growth of aquatic plants occur which make them noxious weeds.

In the past few years the rapid invasion of the freshwater bodies (reservoirs, ponds and channels) by two exotic aquatic weeds *Eichhornia crassipes* and *Salvinia molesta*, introduced into the Sri Lankan waters relatively recently, has given cause for alarm. Another aquatic weed *Limnocharis flava*, also an exotic, has not spread as fast as the former. The loci of infestations of these weeds have been very small in extent but their capacity to multiply rapidly has been mainly responsible for their rapid spread. (Table VI).

Table VI: Areas of different types of water bodies and estimated areas of infestation by *Salvinia* and *Eichhornia* in Sri Lanka (in hectares) (From I. Kotelawala, 1976).

Total land area including inland waters	6 560 988
Total area of inland waters	204 610
Total area of swamp (reeds and rushes and marsh including salt marshes)	3 634
Total area of paddy land	526 029
Total area of water	763 273
Estimated extent of *Salvinia* infestation	20 260
Estimated extent of *Eichhornia* infestation	5000

8.1.1 *Eichhornia crassipes* which was introduced to Sri Lankan waters as far back as 1905 has since multiplied so rapidly that according to the latest estimates (1977) it covers around 5,000 hectares of water courses at present (Fig. 7). Its invasion of new areas has been largely due to human agency. This spread was mainly due to three reasons:

1. The beautiful flowers of *Eichhornia* began to be used as offerings in Buddhist temples
2. The erroneous belief of its pharmaceutical properties as a drug in local "ayurvedic" medicines
3. The flowers yield a mauve coloured dye

In shallow water, *Eichhornia* gets anchored in the soil and prevents the flow of water. Silting up and deposition of organic matter caused by the weeds reduce the storage capacity of irrigation reservoirs. This is also true for the irrigation channels. Through similar silting the flow of water, badly needed for irrigation, is retarded by decreasing the cross section of the channels.

Fig. 7: Shows dense carpets of Eichhornia crassipes covering an irrigation channel.

In 1922, the government of Sri Lanka at its expense cleared 20 major irrigation reservoirs and their waterways but this could not halt the spread of this noxious weed. Since then the government has been organizing weed clearing operations in re-infested areas and in new areas to which this weed had spread and has spent millions of rupees in this process without much success and without a permanent solution to this problem.

8.1.2 *Salvinia molesta* introduced to the island just prior to the Second World War has turned out to be such a serious pest that it now covers, according to the latest estimates, around 20,000 hectares of water bodies. (Table VI). *Salvinia* attracted the attention of the government in 1943 when the water inlets to the condensers of the Stanley Power Station in the capital city of Colombo were choked by this weed. Since then it has spread to the whole of the Western and South-Western coastal areas and these plants have been detected up to an altitude of 1,500 meters above sea level.

Their spread in Sri Lanka has been mainly due to the following reasons:

1. Floods
2. The use of fresh *Salvinia* as packing material for fish
3. Transport by migratory fishermen who carry plant material entangled in their nets from infested areas to new areas

4. The use of this plant as a mulch for crops
5. The use of this plant in fish tanks and ornamental ponds.

Upto 1950 no effective steps were taken to control *Salvinia.* Chemical spraying using Paraquat at a concentration of 2.1 kg active ingredient per litre at the rate of 1,125 litres per hectare (2,362.5 kg/ha) was started in 1961 at an enormous cost to the government. It was reported that there was a reduction in the infested areas to 12,800 hectares from an estimated 20,260 hectares. However, the freed areas have been reinfested as the government had to suspend spraying of herbicides due to foreign exchange difficulties. Large scale attempts to control *Salvinia* by mechanical means have not been successful although the local people practise it on a small scale (Fig. 8).

8.1.3 Impact of exotic water weeds on water resources of Sri Lanka

The following may be mentioned:

1. Exotic weed plants upset the natural equilibrium and upset the biological balance as their new habitats are free from natural enemies and other controls.

2. They provide substrata on which large sudd forming vegetation can establish themselves.

Fig. 8 *A*: Shows dense carpets of **Salvinia molesta** covering irrigation channels.

Fig. 8 ***B*****:** Shows the manual clearing of this aquatic weed from paddy fields.

3. The mats of floating weeds cause deoxygenation of water which renders it inimical to the pro ductivity of fish and in combination with light screening also to rice seedlings. As growth of submerged plants is inhibited, there is no food basis for fish.

4. Physical interference with fishing.

5. Increased evapotranspiration losses; there is evidence that transpiration from these plants is higher than evaporation from an equivalent area of free water surface.

6. In irrigation reservoirs, irrigation channels, streams and rivers infested with these weeds, the flow of water is retarded and silting promoted,

7. *Salvinia* and *Pistia* infestations provide ideal breeding places for *Mansonia* mosquito, the carrier of filariasis. This disease is spreading rapidly along the coastal belt. However, unlike *Salvinia*, *Pistia* infestations are not as widespread and are confined to a few areas in the low country.

8. *Salvinia* competes with paddy plants for light and nutrients. They use up the fertilizers applied to paddy, multiply faster and render large areas out of production.

9. They increase flood damage by choking irrigation channels and drainage systems during heavy rains.

10. Interference with recreation and navigation.

8.1.4 The management of aquatic weeds in Sri Lanka

Sri Lanka recognized the noxious nature of certain aquatic weeds as far back as 1909 when "The Water Hyacinth Ordinance" was enacted. The provisions of this enactment have not been implemented with vigour with the result that this weed continues to plague the various water bodies in the country. "Plant Protection Ordinance" of 1924 prohibits the introduction of exotic plants. Nevertheless, *Salvinia* has been introduced and has become a pest since then.

The first step towards controlling the spread of noxious weeds will have to be the vigorous implementation of the existing ordinances. Since *Eichhornia* and *Salvinia* are already established and since controlling aquatic weeds is costly (both mechanical and chemical) it is important to make provisions for suitable preventive measures and to integrate them in the general management of the water bodies. Legislative measures will be necessary for monitoring aquatic vegetation and for prohibiting the introduction of specific aquatic plants from one place to another. Monitoring has to be a permanent task, since river basins, reservoirs, canals once cleared from infestation are likely to be subjected to reinvasion by water weeds.

Ecologists should be made to collaborate by administrative measures with planning engineers from the very early stage of planning of water development schemes specially reservoirs and irrigation systems.

Nutrient enrichment should be continuously monitored in the main water body as well as in effluents as changes in these will promote the growth of aquatic vegetation.

Steps should be taken to eradicate the existing weeds by utilization of the weeds, after processing as compost, and other products of agricultural and industrial importance such as pulp for making paper, chlorophyll as a protein source and as cattle feed. Also measures should be explored for utilization of the weeds for generation of biogas and as a fertilizer following biogas generation. In special circumstances *Eichhornia* plants could also be used as filters for filtration of dangerous metals such as lead, arsenic, cadmium as well as pesticides from toxic effluents. Insects which have been used as control agents elsewhere such as *Cyrtobagous salviniae* should be utilized for the control of *salvinia*.

Finally, information about the noxious nature of the aquatic weeds should be conveyed by propaganda compaigns to the farmers, fishermen and to the general public.

8.2 Pollution of freshwaters

Putrid water is not only repellent to animals living in it but also to man. Water can become polluted by the unintended or by the unexpected effects of the release of a pollutant, most often as waste. Even in

Sri Lanka this has gone on for decades without substantial reactions from man possibly because he does not see directly what goes on below the surface of water. Man believed that water bodies and water ways could indefinitely absorb, assimilate and dilute the discharged wastes.

This vital resource in Sri Lanka is endangered from many sources, a few of which are mentioned here:

1. From environmental problems of human settlement; pollution due to underdevelopment and consequently problems arising from this such as insanitary conditions resulting from inadequate waste disposal facilities. The surface waters could get polluted with faecal matter during heavy rains.

2. From the use of weedicides and insecticides; specially the use of chlorinated hydrocarbons in the control of pests and disease vectors.

3. From the large scale destruction of forest cover; specially for the increase of agricultural acreage for food production and for the resettlement of increasing human populations.

8.2.1 Sewage and fertilizers

In Sri Lanka, in villages and even in urban cities like Colombo, wastes including raw sewage are deliberately dumped into irrigation reservoirs, streams

and rivers. Before man became numerous in our villages and in our cities, this caused little damage; man's excrements broke down and liberated their nutrients which were recycled through plants and animals without doing any ecological damage. However, now a different situation prevails in Sri Lanka where the irrigation reservoirs, streams and rivers have become grossly polluted with sewage. Table VII gives a year's determination of the dissolved oxygen and BOD for the upper course and lower course of Kelani ganga while Table VIII gives the total bacterial count for some areas of the Kelani estuary. The region of determination for the lower course was near the point of discharge of the sewage disposal system of the city of Colombo.

Except in Colombo, the capital city of Sri Lanka, excreta disposal is still the individual householder's responsibility. While the higher income groups have private water connections (from private wells) and waste disposal facilities discharging into septic tanks, a large proportion of the populations is not served.

In a recent study of the community water supply and excreta disposal situation in the developing countries, Pineco and Subramanyam (1975) indicated that one of the features that distinguish the developed countries from developing countries is the contrast in the extent and quality of the provision of basic sanitary facilities and services. They concluded therefore that differences should exist among developing countries

Table VII: Showing dissolved oxygen content (DO) and the biochemical oxygen demand (BOD) determined per month for the year 1973 in mg/1 for the upper course (Kehelgomu oya at Maskeliya) and lower course (Victoria Bridge at Colombo) of Kelani ganga (From W. Gunatilleke, 1975 — Unpublished work)

Date	DO Mask-eliya	DO Colombo	BOD Mask-eliya	BOD Colombo	NH_3 - N Mask-eliya	NH_3 - N Colombo	NO_3 - N Mask-eliya	NO_3 - N Colombo	PO_4 - Mask-eliya	PO_4 - Colombo
13 January 1973	6.60	4.00	0.88	3.20	0.08	1.15	0.07	0.45	0.01	0.15
10 February	6.80	3.50	0.44	2.45	0.10	0.85	0.28	0.24	0.03	1.04
17 March	6.40	3.80	0.36	2.30	0.10	0.65	0.09	0.44	0.05	0.57
12 April	6.50	3.60	0.34	2.00	0.05	0.74	0.07	0.56	—	0.40
5 May	5.80	2.50	0.66	0.65	0.08	0.44	0.63	0.22	0.01	0.56
23 June	6.00	4.00	0.62	4.00	0.06	0.66	1.40	0.16	0.03	0.46
28 July	6.40	4.80	0.04	7.65	0.03	1.04	0.28	0.12	0.01	0.65
22 August	6.70	4.30	0.12	3.50	0.10	1.85	0.11	0.20	0.01	0.65
28 September	6.44	4.00	0.18	4.60	0.26	0.69	0.46	0.18	0.02	0.60
26 October	6.47	6.00	0.34	5.00	0.40	0.66	0.42	0.20	0.03	1.20
29 November	6.56	3.50	0.56	4.45	0.26	0.95	0.16	0.14	—	1.40
27 December 1975	6.75	3.50	0.22	5.50	0.10	1.02	0.12	0.12	0.02	1.60
Mean	6.47	4.00	0.39	4.02	0.13	0.89	0.34	0.25	0.02	0.77

Table VIII: The bacterial counts of surface waters in the lower estuary of Kelani ganga.

	Sampling station	Total Coliforms/100*ml* 24.9.84	Total Coliforms/100*ml* 4.6.84	Faecal Coliforms/100*ml* 24.9.84	Faecal Coliforms/100*ml* 4.6.84	E. Coli/100*ml* 26.9.84	E. Coli/100*ml* 6.9.84
01	Lagoon end	540,000	54,000	540,000	—	70,000	35,000
02	Open lagoon	280,000	54,000	70,000	—	31,000	17,000
03	Lagoon mouth	160,000	240,000	1,600,000	—	34,000	35,000
04	River mouth	1,600,000	170,000	920,000	—	170,000	17,000
05	Leather corporation discharge	2,400,000	2,400,000	2,400,000	—	1,600,000	2,400,000
06	Sewage discharge	2,400,000	2,400,000	2,400,000	—	2,400,000	2,400,000
07	Point of entry of Jadiela	110,000	110,000	79,000	—	140,000	70,000
08	Point of entry of canal from Kelani Tissa Power Station	49,000	160,000	33,000	—	13,000	54,000
09	Railway bridge at Kelaniya	49,000	17,000	49,000	—	11,000	17,000
10	Close to Kelaniya temple	170,000	92,000	49,000	—	33,000	7,000
11	Close to discharges of Fertilizer Manufacturing Corp. & Petroleum Refinery Corp.	240,000	92,000	130,000	—	22,000	7,000
12	Close to water intake of the Kelani Tyre Corporation	110,000	28,000	21,000	—	5,000	4,600

From De Silva et al (1984) Mass mortality of fish in the Kelani river, a preliminary report (unpublished). NARA at different economic levels. Using GNP per capita as a criterion, they also showed that the poorer countries have high proportions of their populations still to be served with safe water or adequate excreta disposal.

Countries such as Sri Lanka with less than about US$ 280 GNP *per capita* have uniformly high levels of their populations remaining to be served. Pollution with organic matter is very complex as it not only involves deoxygenation but also the addition of suspended solids and also poisons such as ammonia and sulphides. The biochemical degradation of organic matter absorbs the oxygen and encourages fungal and bacterial growth at the expense of fish and other aquatic animals. In these oxygen consuming processes by the bacteria, the nutrient salts (P + N) originally contained in sewage are set free. These nutrients are essential for plant life but in too high concentrations cause over fertilization or eutrophication which results in explosive algal and plant growth which on decomposition causes the quality of water to deteriorate rapidly. Many of Sri Lanka's seasonal reservoirs from which the villagers sometimes get their drinking water are gradually becoming highly eutrophied (Costa, unpublished work).

Even in cities like Colombo, treatment of domestic wastes has been developed from the point of view of protection of public health and no consideration is given to the damage that is being done to the environment. In the first stage of treatment of sewage, a

large percentage of the solid material is removed while only about 10% of the phosphorus is eliminated. In the second stage of treatment about 30% of the phosphorus is removed but the nutrients contained in the effluents are very high, several times higher than the natural nutrient content of the water bodies into which the effluents are diverted. Fish populations are good indices of eutrophication. Species of fish react differently to various degrees of secondary pollution. When algae and other aquatic plants decompose producing hydrogen sulphide, they consume the oxygen so vital to fish and other aquatic organisms sometimes producing catastrophic fish kills.

People in Sri Lanka now use large amounts of farm manure and inorganic fertilizers in their endeavour to grow more food to feed the ever increasing population. This new pattern together with the increased discharge of nutrients through leaching and by soil erosion is contributing further to the eutrophication of the irrigation reservoirs and the streams as seen at Horton Plains (altitude 2000 m) where due to the use of fertilizers in the cultivation of potatoes some time ago the crystal clear streams are now covered with thick carpets of aquatic vegetation consisting of filamentous algae (Costa, 1973).

In Sri Lanka, even a lower input into the water may produce effects equal to those arising from a higher input in temperate regions, since higher temperatures stimulate turnover and thus accelerate the production of biomass.

8.2.1.1 Impact of eutrophication on the water resources of Sri Lanka

1. Endangers the utilization of water for drinking bathing and for fishing.

2. Brings about changes in the plant and animal species inhabiting the water. Algae which can be utilized in the food chain are replaced by those which cannot be used.

3. Creation of anoxic zones which bring about mortality of fish.

4. Encourages the spread of the vector of malaria.

5. Brings about silting and alluviation by promoting excessive growth of aquatic plants.

6. Produces foul smelling odours by bringing about death of animal and plant biomass and rapid decomposition.

8.2.1.2. Management of pollution of waters by sewage and fertilizers

As long as there is under development of the country and as long as there are no proper measures for sewage disposal available in the towns and villages, there will be to some extent pollution of the freshwaters by sewage and as a consequence of this a certain amount of eutrophication. However, prophylactic measures for the protection of the water supported by

administrative decisions and legislation should be initiated as long term efforts to resolve the problem of eutrophication. These should include:

1. Ban on the input of sewage into irrigation reservoirs, streams and rivers. Technical solutions could include ring canalization around the man made lakes, discharging into downstream from sewage treatment plants, etc. In designing sewage plants consideration should be given to the availability of materials and local man-power. Consideration should be given to installations with a high self-regulation capacity such as sewage ponds and primary reservoirs for primary, secondary and tertiary operation under the climatic conditions of the tropics. Digestion of sludge can also be performed using radiation as the only source for maintaining a high temperature for digestion and for sludge drying.

2. Where there are sewage disposal systems most of the nutrients, particularly phosphorus and nitrogen contained in the sewage should be eliminated by low cost treatment in ponds.

3. Monitoring of the surface waters and sewage discharge points should be maintained to detect signs of eutrophication. Monthly sampling (concentration and discharge) for a three year period could give a good basis for planning.

4. The application of erosion reducing methods of cultivation in new lands opened for agriculture and the spreading of fertilizers and manures in such quantities, at such times and by such means as will ensure that the sorption capacity of the soil is not exceeded and that surface erosion and leaching out is minimized and plant nutrient utilization maximized.

5. Using the protective function of forests against erosion on steep slopes by preventing clear felling of trees.

6. Utilization of aquatic plants from eutrophic waters as manure and for industrial and other economic purposes.

7. Dissemination of the knowledge on the eutrophication problems to the general public by means of newspapers, exhibitions, films and radio in order to enhance the understanding of the economic and ecological relations involved.

8.2.2 Weedicides, insecticides and industrial wastes

In a country like Sri Lanka, modern techniques are necessary to furnish the food supplies required by the growing population but the very tools we are using to increase our food supplies and eliminate disease can also pose environmental hazards. Weedicides and insecticides are necessary and critical to the development of our economy and to enhance the health of our people but unfortunately these also could cause environmental side effects.

In Sri Lanka, weedicides and insecticides are indiscriminately used in agriculture and in the control of the vectors of malaria and filaria, without any consideration of their detrimental effects. DDT has been in continuous use since the early 1950s in Sri Lanka. The continued use of DDT has produced strains of *Anopheles* mosquito with increased resistance necessitating the application of stronger dosages and even necessitating the switching on to costlier insecticides such as malathion. Insecticides such as DDT get washed into streams and rivers and are resistant to decomposition by bacteria or other organisms and remain in the environment. DDT is accumulated in the tissues of aquatic organisms. The absorption and enrichment of DDT takes place through algae and lower animals. Once they have become absorbed through the food chain, these substances could be separated from it again only with great difficulty mainly because they get stored up in fats. They are passed on within the food chain to higher consumers.

In an international survey of the DDT in rainwater by the University of Lund, Sweden, in which the University of Sri Lanka, Kelaniya, participated it was found that the DDT in the rainwaters at Kelaniya was several times that of even places such as Kenya (Table IX). This is something to be noted as this rainwater will ultimately get into the streams and rivers.

Table IX: DDT in rainwater expressed as ng/m2 (Costa, 1978 unpublished work)

Sri Lanka (Kelaniya)	*Sweden (Lund)*	*Iceland (Myrata)*	*Africa (Kenya)*
260	85	85	158

Insecticides less persistent in the environment are available, but these are very costly and because of their lack of persistence more frequent applications are necessary. Sri Lanka is a developing country with acute foreign exchange difficulties and to increase her food production, she will have to use cheap insecticides at least for some time and DDT is one such product.

Sri Lanka has only a few major industries. Many of these industries viz. the tyre manufacturing corporation, (Fig. 9) the steel mills, the leather manufacturing corporation, the textile corporation and the petroleum refinery complex are all situated close to the city of Colombo and they discharge their wastes into Kelani ganga. In the installation of these, very stringent measures have been taken by the Government of Sri Lanka to ensure the quality of the discharged waste products and standards have been laid down which are expected to be rigidly implemented for the prevention of pollution of the freshwaters.

Fig. 9: The tyre factory near Colombo. Note the protective discharge pipe built by the Corporation authorities to carry cleaned factory discharge to a stream.

However, occasional fish kills including species of large fish such as *Lates calcarifer*, *Macrones gulio* and *Etroplus suratensis* have been reported in the Kelani river. Values as high as 101.1 ppm NH_3 in the region of the river close to the discharge of the effluent from Fertilizer Corporation have been reported during the time of the fish kills. (de Silva et al, 1984) It is doubtful whether the standards laid down are rigidly maintained and monitored continuously although monitoring discharges causing changes in the environmental quality of water is one of the functions of the newly established Central Environmental Authority.

8.2.2.1 Impacts of the use of weedicides, insecticides and industrial wastes on the freshwater resources of Sri Lanka

Two major classes of ecological disruption likely to be caused by DDT and similar substances are:

1. Destruction of fisheries in reservoirs, and estuaries. Crustaceans are extremely sensitive to DDT and in Sri Lanka the fishery for *Macrobrachium* spp. (Palaemonid decapods) is endangered specially in the water bodies in the low country.

2. Destruction of predator populations both fish and birds which may play a crucial role in regulating the structure and function of the ecosystem.

3. Endangering the utilization of waters for human needs.

8.2.2.2 The management of pollution of freshwaters by weedicides and insecticides

Admittedly, in the present pest control practices much reliance has been placed on technology so that means of control other than by insecticides and weedicides have been underestimated and even neglected. However, it should be stated that a complete ban on the use of pesticides is not practicable in Sri Lanka as this will have a negative impact on food production and increase the prevalence of diseases such as Malaria, Filaria, etc. Therefore the following measures could be taken.

1. to examine all types of pest control methods and to identify the present level and extent of their application

2. pesticides to be used only under the direction of specialists and records kept

3. to define ways and means for the development, testing and application of bioenvironmental methods, including ecological and habitat modifications and land and water management in the control of agricultural pests and disease vectors, in order to replace and/or reduce the degree of dependence on chemical methods Success in the control of the larvae of *Culex quinquefasciatus* using the larviorous fish *Poecilia reticulata* in the drains and ditches of Colombo has recently been reported (Costa, 1984).

8.2.3 Deforestation and silt

Haphazard agricultural projects and unplanned clearance of jungle areas are sometimes responsible for the large scale destruction of forest ecosystems. These result in soil degradation and soil erosion. A look at the Sri Lankan rivers even after a single shower of rain (tropical downpours) would bring home to any one how severe the problem of soil erosion is. The top soils in the hill country are slowly depleted. Not only do these denuded soil particles have damaging effects on the fauna but deposition of these in the lower courses of rivers lead to silting of the river beds thus resulting in irregular floods.

Presently, Sri Lanka is losing annually about 15% of its forests for agriculture and new settlements. The area under forest cover in 1981 was generally estimated to be about 25% of the total area or 1.7 million hectares compared to 2.91 million hectares in 1956 (Pushparajah, 1981). The estimate of deforestation per year for the last two decades is about 64751 hectares. It has been pointed out that in Wet Zone of Sri Lanka (where the tropical rain forests are found) the corresponding current figure for area under forest cover is only 9% or even less. The extent of Sinharaja forest remaining at present is estimated at 5000 hectares (Gunatillake and Gunatilleke 1981). In India the area under forest cover is around 40% which is considered to be adequate.

The suspended matter carried by the streams and rivers form one of the important hazards to Sri Lanka's aquatic organisms. The flood waters carry heavy loads of silt. The silt could eliminate much of the life in the freshwaters or in the alternative could reduce its amount without greatly altering its composition simply by shading out all or some of the plant life. The silt could damage fish and other aquatic organisms. The gills of fish are delicate structures which can suffer mechanical injury and also there is the danger of the gill system being clogged by an excessive amount of suspended matter even producing coagulation film anoxia. The second effect of silt occurs when they settle out of the water into the stream bed when the particles are large and heavy or when the current is slack. The deposits smother all algal growth, kill rooted plants and alter the substratum. The heavy layers of mud on the edges of pool zones of Sri Lanka's streams and rivers are now a conspicuous feature (Costa, 1975). Further, sedimentation falling into the eroding substrata fill up the interstices between the stones depriving the cryptic animals of their hiding places. In the lower courses of Sri Lanka's rivers, typical fauna are beginning to be replaced by forms such as *Tubifex* and chironomid larvae which are indicative of decreased oxygen content at the mud/water interface (Costa and Starmuhlner, 1973). Finally, the suspended silt also causes serious effects on the spawning of fish; most suitable areas for egg laying may be covered by silt.

Most of the saw mills in Sri Lanka are sited on the margins of rivers (Fig. 10). This is mainly for convenience as the logs are floated down the rivers to the saw mills. The saw dust left over after sawing is disposed of by dumping into the rivers. The saw dust causes a type of pollution akin to silt. The difference may be that being organic particles with a high content of degradable compounds such as carbohydrates, they may eventually bring about the deoxygenation of water.

8.2.3.1 Impacts of silt and deforestation on the water resources of Sri Lanka

1. Large scale deforestation has led to the reduction of stream flow and depletion of water sources during drought periods and increased stream flow and heavy and sudden flooding during rainy periods.

2. Logging operations have resulted in soil destruction with the simultaneous removal of litter, the soil structure breaks down and the soil loses its resistance to erosion and the products are carried into streams and rivers.

3. The stream flow irregularities can reduce the irrigation potential of rivers and has necessitated the construction of water reservoirs providing for long term and seasonal stream flow regulation as in the case of Gin ganga.

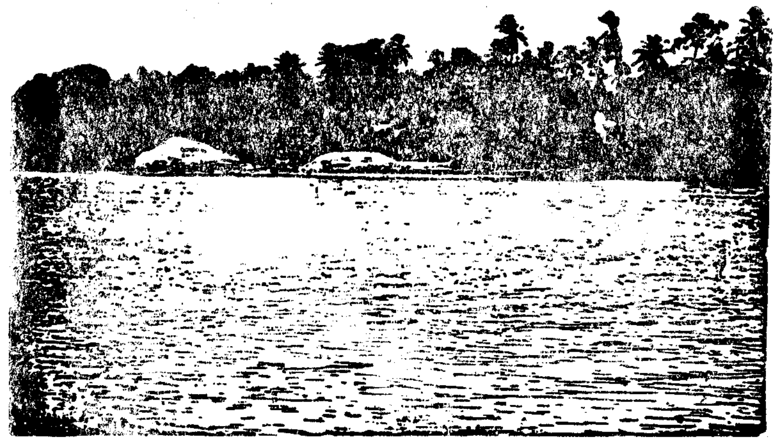


Fig. 10: Saw dust dumps along the Kelani ganga, the fourth longest river in Sri Lanka.

4. Endangers the survival of larval and adult stages of organisms by the mechanical action of silt particles resulting ultimately in a reduction in fisheries.

5. Large scale silting has resulted in changes in the physical nature of stream and river beds.

6. Increase of silt in the waters has produced an explosion of detritus feeding animals both in the torrential streams and in the lower courses of rivers (Costa, 1975).

8.2.3.2 The management of forests for prevention of pollution of water courses by silt

The montane rainforests of Sri Lanka regulate much of the hydrography of the mountain slopes and regions below. Most of the large rivers originate in the Wet Zone forests. The present indiscriminate and unplanned exploitation of rainforests such as the Singharaja forest for timber and haphazard deforestation for agricultural and land development processes have already brought about changes in the hydrological cycles and has resulted in the erosion of river banks, sedimentation of rivers and hydro-power reservoirs and even in adverse flooding. Some perennial streams in Sri Lanka have already become seasonal. All these have disastrous effects on the aquatic ecosystems and eventually on the aquatic productivity.

1. Action must be taken for the efficient management of the forests on which the conservation of the water supplies depends. This would amount to a rigid control of felling of trees.

2. Further, the legislative basis must be created (laws, standards, guidelines) for the protection of rivers, streams and reservoirs and they must be rigidly enforced.

3. Carry out a planned programme of afforestation of the catchment areas of the regions of sources and protective afforestations on linear establishments.

9.0 General comments :

It is now an accepted principle that environmental trends per se do not appear to be quite as cataclysmic as they once did. The water resources in Sri Lanka do not face imminent doom because of the present unplanned use of this resource or because of pollution. Yet many forms of degradation have been shown to have ominous long term implications for the society and some are undermining human well being right now.

At the global level, a United Nations Environmental Programme (UNEP) was established to help the world's governments in drawing up sound programmes which would result in better environmental management. At the national level a Central Environmental Authority (CEA) has been established but the tasks that once seemed straight forward such as monitoring of trends in pollution and development of resources has turned out to be still not within our reach because of the complications and expenses involved. Still we are uncertain of what should be monitored, for what purpose and at what cost. Because of the links between resource trends and prevailing political, social and economic structures known solutions become difficult to be applied. However, the basic principle of public regulation of activities that threaten the aquatic environment has become firmly established in laws with the recent enactment of the Environmental Protection Act although special interests sometimes still subvert the decision making process. Nevertheless the enactment of these laws has led to a convergence of ideas about environment and development although in the past people concerned with the preservation of nature was at loggerheads with people concerned about economic progress.

The present approach by many conservationists is to recognize the need for development as a prerequisite of successful conservation. This is reflected in the world conservation strategy drawn up in 1980 by International Union of Conservation of Nature and Natural Resources (IUCN). Among the major obstacles to sustainable development singled out in

the strategy is "the failure to deliver conservation based development where it is most needed notably in rural areas of developing countries".

It should always be the position that the wealth of the country must be utilized for the benefit of the people and the country's economy. However, purely economic considerations must not determine the final decisions. It may be apt therefore to quote a recent address by the late Mrs Indira Gandhi, former Prime Minister of India to the Indian National Committee on Environmental Planning: "Our attention cannot be diverted from the main question before us which is to bring basic amenities within the reach of our people and to give them better living conditions without alienating them from nature and their environment, without dispelling nature of its beauty and of the freshness and purity so essential to our lives. The time has come for us to think deeply about the kind of progress we want. Should we not recast out priorities and ask ourselves what facilities are worth the price for us or for future generations?"

For effective development of the country it will be necessary to harmonize economic development with the natural conditions. Science will have to help resolve competition in demands on the use of natural resources, particularly water resources.

It is evident that there will be a growing demand for water. The most frequent demands by the society in future will be securing water for primary use, control of run off, improvement of water quality and last but not the least, improvement of the environment. The several thousand ancient irrigation reservoirs which dot Sri Lanka's landscape, the many rivers that wind their way slowly into the sea are all important sites of biological productivity which could be fully utilized for the benefit of man, with proper scientific management. Conservation and management of fresh waters is not new to Sri Lanka. It may be most apt to conclude with the words of King Parakramabahu, the builder of giant irrigation reservoirs that have astounded even the present day hydrological engineers:

"Let not a little bit of water that falls on my kingdom flow into the ocean without it being made useful to man."

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