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Section D - Life and Earth Sciences

Presidential Address

MANAGEMENT OF LIVING AQUATIC RESOURCES OF SRI LANKA

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Living aquatic resources of Sri Lanka can be classified according to their habitats as marine, brackishwater and fresh water resources.

The major living resource in all three habitats is undoubtedly the fin fish. About 850 marine fish species are recorded from coastal and off-shore regions of Sri Lanka (Jinadasa 1991) of which most are edible. The major species contribut ing to the marine fisheries are large pelagics such as Spanish mackerel *(Cybium sp.)* skipjack tuna *(Katsuwonus pelamis)*, Yel lowfin tuna *(Neothunnus macropterus)*, Barracudas *Sphyraena sp.)*, Bill fish *(Histiophorus sp)*, Trevallies *(Caranx sp)*.,Sharks (*Carcharhinidae sp*), small pelagics such as flying fishes *(Exo coetus sp.)* sardines, herrings *(Clupeidae sp)* mackerel *(Rastrel liger kanaqurta)* and demersal species such as ribbon fish *(Tri churis spp)*, groupers *Fam: Serranidae)*, Snappers *(Lutianus sp.)*, skates *(Raja sp)* and rays (*Trygonidae sp*).

From the marine environment of Sri Lanka, 31 species of prawns have been recorded (De Bruin 1970). Of these the most important species are *Penaeus monodon*, *P. semisulcatus*, *P. indicus*, *P. merguiensis*, *Metapeneaus dobsoni* and *Parapeneopsis stylifera* (Jayakody 1984).

Other marine organisms which are important from the consumer view point are lobsters, crabs, molluscs, sea turtles and some marine mammals. Of the lobster species recorded from Sri Lankan waters, the most important is *Palinurus homarus* (Jayakody 1987). An important crab species recorded in marine waters is *Portunus pelagious* (Pillai 1965). Of the molluscs species, the oysters (*Cassostrea madrasensis*). Mussels (*Perna viridis* and *Perna perna*), cuttle fish and squids are important as edible species. Sometimes sea turtles are also harvested for food despite their being protected by law. There are four major species of turtles which are killed for human consumption. They are the leatherback turtle, green turtle, Pacific ridley and hawkbill turtle. Sometimes, marine mammals such as the dolphins and porpoises are also killed by the commercial fishermen.

Marine fisheries are classified as coastal, offshore and deep sea resources. Coastal resources within 40km of the coast, offshore resources extend from 40 to 100km and deep sea resources are those beyond 100km.

The total fishery production from the coastal marine environment in 1988 has been recorded as 155099 MT. About 97% of this comprised of fin fish and, crustaceans contributed for about 3%. No records are available on the production of molluscs. In 1988, the production from offshore and deep sea fisheries was 4425 MT which was about 3% of the total marine production (Anon. 1988).

The fish production recorded from freshwater for 1988 was 38012 MT (Anon. 1988).

The total fishery production from Sri Lankan waters in 1988 was 197536 Mt (Anon. 1988). This excludes the catch of live fish and other organisms for exportation as ornamental organisms and aquaculture seed. 80% of the total fishery production in 1988 was obtained from the marine environment and 20% came from the freshwaters. The contribution from the brackishwater environments was also included in the marine production.

The highest catch from coastal waters for the last ten years, which was 184049 MT, was recorded in 1983 (Fig. 1). In 1984, the catch decreased drastically mainly due to declined fishing operation in the North and East, and then gradually increased until 1989.

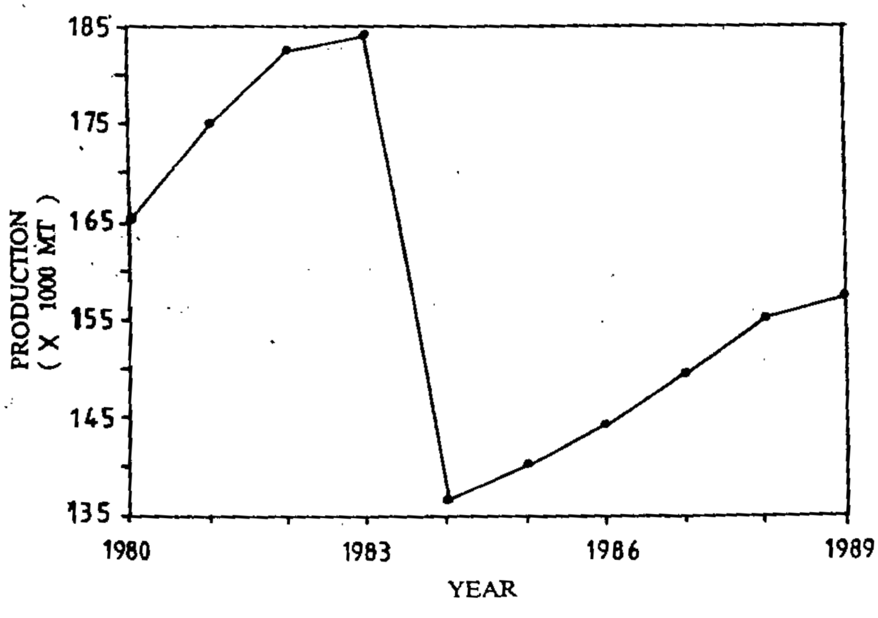

Figure 1. Total fish production from the coastal waters of Sri Lanka from 1980 to 1989.

The need for management of the living aquatic resources has now received the attention of many scientists, economists and policy makers throughout t! ᵌ world to obtain the maximum sustain able benefits from these resources (Panayotou 1982).

The potential yield of fish from different aquatic environments has been estimated by several workers. The values calculated for the potential fish yield from coastal waters vary from 250,000 MT/year to 850,000 Mt/year (Weerakoon 1965, Joseph 1984, Jinadasa 1991). The potential production from the offshore regions has been estimated to be around 30,000 MT (Joseph 1984). These estimates are based on primary productivity data and catch and fishing effort statistics.

The potential fish catch from the brackishwater environments has not yet been estimated. However, the brackishwater environments has not yet been estimated. However, the brackish water environments such as estuaries, lagoons and tidal flats have been identified as the most productive ecosystems in the world. In Negombo estuary, which is one of the heavily exploited brackishwater environments in Sri Lanka, the annual production of fin fish and shell fish has been estimated to exceed 150 kg/ha/year (Samarakoon and van Zon 1991). The mean annual fish yield for productive lagoons and estuaries in the tropics has been estimated to be around 100 kg/ha/year (Kapetsky 1984).

There are 45 basin estuaries and lagoons in Sri Lanka (Anon 1991). The total area of these brackishwater environments has been estimated to be around 100000 acres (Pillai 1965) which is about 40,000 ha. Therefore taking these figures into consid eration, the potential yield from these environments can be estimated to be at least around 4000 MT/year.

The potential fish production from freshwater environ ments has been estimated by several workers (Amarasinghe *et al* 1983, Wijeyaratne and Amarasinghe 1987, Daniel *et al* 1988, Wijeyaratne 1989). Their results have shown that it would be possible to increase the present fish production from the fresh water capture fisheries to a level around 600000 MT/year.

Many factors affect the production of living resources in the aquatic habitats; these can be categorized as physical, chemical and biological. The major physical factors are water temperature, tides, water currents, turbidity, nature of the bottom and climatic factors such as rainfall. The major chemical factors are salinity, dissolved oxygen content, pH, dissolved ions and the amount of pollutants. The biological factors include the primary productivity of the environment, availability and size of food and the characteristics of the fish and fisherfolk. The characteristics of the fish which affect the yield are the size, age, growth rate, size at maturity, age at maturity and their abundance. The characteristics of the fishermen are their skill,motivation,type of gear used and the efficiency of the gear.

The water temperature will affect the growth rate, speed of attainment of sexual maturity, reproduction and many other biological functions of fish. Although the water tempera ture is more of less constant throughout the year in tropical regions, sometimes in certain shallow waterbodies it may increase to level which will adversely affect the life of fish and other aquatic fauna.

The tides are important in the brakishwater and coastal marine environments. Water currents are mainly important in the marine environment. Due to these currents, sometimes young stages of fish and other organisms may be carried away to areas unfavourable for their survival. Turbidity is an important factor in coastal marine, brackishwater and freshwater environments. Turbidity occurs mainly due to suspended particles which have been washed into the aquatic systems due to erosion. These particles will mechanically injure the fish and may also clog their gills. In addition, high turbidity will reduce the pene tration of light resulting in a decrease in the primary produc tivity which will affect the total productivity of the whole environment. Nature of the bottom is important mainly in fresh water and brackishwater environments. Nature of the bottom influences the reproductive success of many species. For exam ple, if the bottom is muddy or covered with silt many species of fish do not select such habitats for breeding, thus making repro duction less successful. Rainfall is an important factor which affects production in freshwater and brackishwater environments.

During the months in which the rainfall is low, fish productivity in these environments have been observed to be low mainly due to low primary productivity (Amerasinghe *et al* 1983, Daniel *et al* 1988) and migration of fish to areas with favourable environmen tal conditions (Mcdowall 1988).

Salinity is an important factor in brackishwater environ ments. The productivity in these habitats is mainly affected by the migration of fish. During the periods of high salinities, fish production in these environments has been observed to be high mainly due to immigration of fish from the sea. Dissolved oxygen content is an important factor mainly in the freshwater habitats where it may decrease to a value smaller than the lower tolerance limit of many species of fish. When this happens fish kills may occur resulting in a decrease in production. Decrease in dissolved oxygen content is caused by high BOD and COD which results mainly from organic and inorganic pollution. pH is also am important factor affecting productivity mainly in freshwater environments. Low pH values are due to the nature of the soil and also due to discharge of acid wastes into the aquatic envi ronment. High pH values are also unfavourable for aquatic produc tion. High values are mainly due to the limy nature of the soil.

Pollution is another factor which affects the productivity in aquatic environments. Pollutants are harmful to aquatic life and large fish-kills may occur resulting in a decrease in produc tivity.

These physical and chemical factors affect fish produc tioı. e' ..ır directly as described above or indirctly by adversely affecting the food organisms of fish and other commercially important fauna.

The fish productivity of a particular environment depends mainly on the amount of primary productivity. In the coastal waters around Sri Lanka, the fish productivity is esti mated to be around 0.015% of the primary production (Jinadasa 1991). However, in fully exploited areas of the world, it is estimated to be around 0.25% of the primary productivity.

In addition to primary productivity, size of the food particles available in the environment is also important for the productivity of fish and other fauna.

These living aquatic resources should be properly managed in order to obtain maximum benefits from them and also to maintain these benefits at the maximum sustainable level. It is possible to increase the yield from these resources by increasing the effort of harvesting but such an increase will not last for a long time and will lead to overexploitation of the resources resulting in a decrease in the future. Therefore, the principal objectives of management are to obtain the maximum benefits from the resource and to maintain the benefits at the maximum possible level.

In the management of living aquatic resources such as fisheries, certain objectives are pursued through the direct or indirect control of the activities of man or some other component of the resource. This control is necessary to prevent the over exploitation of the resources. However, if the resource is underexploited, priority should be given to develop it to a level where maximum sustainable benefits are obtained.

When the yield is considered, the objective of manage ment of living aquatic resources is to obtain the maximum sus tainable yield (MSY). (Fig. 2). Maximum sustainable yield is the maximum catch that can be obtained from a resource on a sustained basis. When the catch is less than the MSY due to insufficient fishing effort exerted on the resource, the resource is said to be biologically underexploited. In such situations, further development of the fishery can be carried our. However, the catch will also be less than the maximum sustainable level when the fishing effort is higher than the optimum level. In such cases, the resource is overexploited and management is necessary.

When the maximum economic benefit is considered, the objective of management of an aquatic resource is to obtain the maximum economic yield (MEY). Maximum economic yield is the maximum sustained surplus of revenue over the cost. This is a modification of the MSY considering the value of the catch.

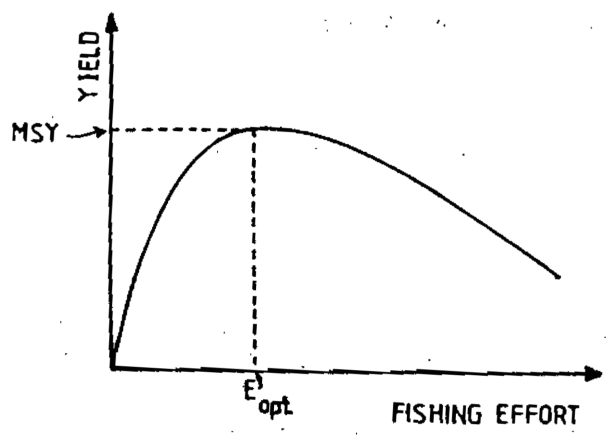

Figure 2. The relationship between yield and fishing effort.
(MSY = Maximum Sustainable Yield,
E_{opt} = Optimum fishing effort)

When socioeconomic conditions are considered, the objective of management of the resource is to obtain the maximum social yield (MScY). This is the level of the catch and corre sponding effort to provide the best possible solution to social problems such as unemployment, poverty and uneven distribution of income (Panayotou 1982).

The concept of MScY is very applicable to developing countries such as Sri Lanka where socio-economic considerations often override the biological and economic concerns. However, maximum social yield cannot be estimated independently of maximum sustainable yield and maximum economic yield.

Due to the multispecies nature of fisheries, it is very difficult to estimate the maximum sustainable yield and the optimum fishing effort for these resources. The optimum fishing effort required for one species may result in overexploitation or underexploitation of another species. Therefore as the fishery expands, it is quite possible that there will be a sequential collapse of certain species and exploitation of some species which has failed to achieve dominant role earlier in the presence of more efficient and better adapted species.

In addition to this technical interaction in tropical multispecies fisheries, there is a biological interaction among the species such as interspecific competition and predator-prey relationships, therefore, exploitation of one species may affect the population size of other species.

Selection of a single optimum size at first capture for management and development purposes is also difficult due to the multispecies nature. Optimum size selected for one species may be too small or too large for another species. Therefore, it is very difficult to determine the optimum mesh size for the nets operated in a multispecies fishery. Hence, in multispecies fisheries a compromise mesh size is required.

In multispecies fisheries of a developing country like Sri Lanka, MSY appears to be a poor goal for fisheries management. MSY appears to be a more appropriate goal because it aims at maximization of the net social benefits from the fishery and also at the same time it reduces the risk of collapse of certain species. In such a management, it is necessary to con sider the motivations and attitudes of fisherfolk towards the contemplated interventions and also the distribution of benefits between the fishermen and nonfishermen and among the fishermen themselves.

The declaration of 200 mile exclusive economic zone has increased the area over which a coastal nation has exclusive control of fisheries. Therefore, the extent of maximum sustain able yield from the marine fishery of Sri Lanka should also increase. However, to a nation like Sri Lanka, it is very difficult to control the entry of foreign fleets into her EEZ. The Sri Lankan fishermen are now complaining that their catches have decreased due to overexploitation of the resources within our EEZ by foreign fleets. Therefore, it is necessary to carry out investigations on this matter and take appropriate action to prevent this poaching at the international level if it occurs.

Most of the fishing activities of Sri Lanka marine fisheries extend only to few kilometers from the coast. 97% all marine fish production is obtained from the coastal fishery which extends only to 40 km from the coast (Anon 1991). The occurrence and migration of fish in this limited area determine the resource available for the fishing activity. The abundance of this re source is greatly dependent on the environmental conditions as well as on the exploitation in the offshore region.

The resouce limitation can be relaxed to some extent by several means. It is necessary to expand the fishing range in our marine waters by technological upgrading. At present, fish ing activity in the offshore and deep sea regions is not yet fully exploited (Anon 1991). Therefore, it is necessary to develop strategies and upgrade technology to exploit these re source to the sustainable levels.

Control on gear selectivity and regulation of mesh size can also be carried out to raise the unit value of the catch. In multispecies fisheries, by changing the mesh size, the composi tion of the maximum sustainable yield can be changed towards more valuable species. Changing the mesh size sometimes may not change the level of

MSY but selection of an appropriate mesh size can increase the value of the catch appreciably. Thus the regulations on mesh size and fishing methods are very important for mitigating resource limitations.

The value of the catch can also be improved by a more efficient marketing system and improved ulilization. The catch from multispecies fisheries consists of number of species of varying sizes. The commercial value of the catch varies with the species and also with the size of the fish. Some species and sizes of the catch may be totally unconventional as human food. These are classified as trash fish. In Sri Lankan marine fisher ies there are very few species of trash fish. However, in brack ishwater environments about 20% of the species present are not consumed (Pillai 1965). In addition, some undersized fish are also caught in some gear and are discarded as trash fish.

Waste and spoilage of catch sometimes take place due to high perishability of fish in the tropical climate. Lack or inadequate supply of ice and freezing facilities is another reason for high spoilage. In addition, dispersion and remoteness of landing sites especially of the small scale fisheries is also a reason for waste and spoilage of catch.

It is possible to reduce the waste and spoilage of catch by increasing the supply of ice and freezing facilities and also by reducing the market margins.

In the management of living aquatic resources in the sea, consideration should also be given to minimize the conflicts between large scale and small scale fishermen. Sometimes small scale fisheries have to compete for the limited resource in the coastal regions with the fishermen using more advanced technolo gies and more efficient gear.

In most cases, the species avilable for small scale fishermen in the costal regions are exploited also by the large scale fishermen in the offshore regions. Therefore, large scale fisheries in the offshore regions will reduce the resource avail able for small scale fishermen. Similarly, the operations by small scale fishermen in the coastal areas may reduce the re cruitment of some species to the offshore stocks. This happens mainly because the juvenile stages of some of the species con tributing to the offshore fisheries inhabit the coastal waters including the brackishwater environments. Therefore in the management of fishery resources, regulations should not only be imposed on regulating the catch, size of the fish and mesh size but also on the protection of habitats which are important as nursery grounds for juveniles. Overexploitation of some species, especially some species of prawns in the brackishwater environ ments such as lagoons and estuaries will not only affect the MSY and the MSY of the lagoon environment but also the catch in adjacent coastal marine environment and offshore regions.

Large scale fishing units such as purse seines are prohibited by law from operating in the coastal areas reserved for small scale fishing operations. However in Sri Lanka, as in other tropical regions, high value species such as shrimps are present in high densities in the coastal waters. This, together with increasing fuel costs result in encroachment and open compe tition between the large scale and small scale fisheries. This will lead to overcrowding and physical conflict between the gear, and between the fishermen as already have been recorded from time to time in the coastal waters of Sri Lanka.

The large scale and small scale fisheries are always in conflict in the market because both fisheries use the same inputs and catch the same species on most occasions. Massive landings of large scale fishermen may depress the fish price resulting in a socially undesirable distribution of income.

Therefore, it is important that large scale fishermen carry out their operations without conflicts with small scale fishermen. The extended jurisdiction provides an opportunity for easy allocation of fishery resources between the two groups of fishermen to avoid conflicts.

In the management of living aquatic resources another factor which needs consideration is the open access and easy entry. People are attracted to the fishery by the prospects of earning higher income and due to rising unemployment. It has been estimated that around Negombo lagoon, there are about 3000 persons involved in fishing (Samarakoon and van Zon 1991). Therefore, the unemployment problem in this area is mitigated to some extent due to the fishery resources, both in the marine and brackishwater environments.

Marine fisheries provide employment to about 95000 persons and contribute about 1.9% to the gross domestic produc tion (Anon 1991).

However, due to open access and easy entry, the re source may be biologically overexploited. In the long run and under static conditions the catch of each fisherman may get reduced gradually as experienced by small scale fishermen in the Negombo lagoon.

Therefore, open access fisheries make only a small contribution or no contribution at all to the country's economic development. In addition, further development of such fisheries will result in entry of additional fishermen and therefore, further depletion of the fishery may takes place.

It has been found that large pelagics in the coastal regions and the sardine stocks on the west cost are exploited at optimal levels (Anon. 1991). Therefore, it is necessary to take steps to stop any increase of fishing effort of these fisheries. The fishery resources in the offshore and deep sea regions, small tuna stocks in the continental shelf area and sardine stocks in the south and south west coastal areas are not yet exploited to the maximum sustainable levels (Anon. 1991). Therefore, exploitation of these resources should be further encouraged.

Another reason for overexploitation of fishery re sources is that when one enters this occupation it is very diffi cult to leave it. for the people engaged in fishing, leaving the fishery is changing a way of life more than merely changing occupation. Chronic indebtedness and related obligations to fish traders and money lenders in order to continue fishing is very common among fishermen. This may also impair mobility. In addition, fishermen may have insufficient information on the location and nature of more lucrative employment opportunities due to the fact that they are isolated in the small fishing community. In addition, they do not have sufficient time to spend on finding new occupations because they have to carry out fishing almost every day to eke out a subsistence income.

Furthermore, traditional fishing communities have a way of life and subculture of their own and therefore it may be very difficult or impossible for them to adapt to other employment. These may be the obstacles for fishermen to gain entry to other occupations. In Sri Lanka, exploitation of most fishery re sources is carried out by closed fishing communities. Persons from outside the community are not allowed access to the fishery which is considered property of the community. Therefore, in most cases, overexploitation occurs due to increased population size of that closed community and due to the use of more efficient gear or gear with smaller mesh sizes. for example, the use of trammel nets has caused overexploitation of the lobster fishery in the South resulting a heavy decline in the catches within two years (Anon 1991).

In the management of living aquatic resources in Sri Lanka, lack of alternative employment opportunities to the fish erfolk should also be considered. This happens due to factors such as unemployment in non fishing sector and surplus labour and lack of nonfishing employment within the fishing communities. If attractive employment opportunities outside the fisheries is available, outflow of labour from the fishery to other nonfishing sectors will take place. However, if unemployment is high in other sectors, there will be an inflow of labour into the fisher ies.Since new-comers do not have much capital and experience, they operate mainly in coastal marine waters, lagoons and esu aries on a small scale. This will lead to overexploitation and depletion of the resources. Therefore, in the management of fisheries, it is necessary to provide employment opportunities to the members of the fishing community outside the fishing sector if the resource is facing the threat of overexploitation. There are a few other persuits within the fishing communities them selves such as agriculture, animal husbandary, small business and trade along with net mending, fish drying and fish processing. However, if exploitation of the resources in our exclusive eco nomic zone which are not yet fully exploited is carried out effectively using appropriate vessels and effective gear, more employment could be generated in addition to obtaining a larger catch.

When the management of living aquatic resouces in the marine environment is considered, attention has to be given to the management of coral reefs too. The objective of the manage ment of this resource is to preserve reefs as a part of natural habitat and a buffer against coastal erosion. In addition, fish and other organisms inhabiting coral reefs are exploited live for exportation as aquarium organisms. Approximately 139 species of marine fish are exploited as ornamental fish which is about 80% of the total marine species exported. The balance consists of corals, bivalves, holothurians and other echinoderms (Anon 1991). Management of these resources is necessary to maintain them as a scientific, educational and aesthetic resource and also to ensure that removal of reef organisms does not exceed the sustainble levels (anon 1986). Today, the coral reefs are being steadily destroyed mainly due to reef mining for manufacturing lime. Unsuccessful efforts have been made for the last several years by the Coast Conservation Department to discourage this activity. Recently, fresh efforts have been launched to provide alternative employment to the people invoved in reef mining (Anon 1919). The other causes of damage are the use of trammel nets to catch reef fish and lobsters, fishing with explosives, break ing of corals to net reef fish, clearing of coral reefs for boat passage, trampling of coral at low tide, anchor chains of boats, souvenir collection, extraction of reef fishes and coral organ isms beyond the maximum sustainable level and water pollution due to sewage, oil and silt (Anon 1991).

Collection of marine ornamental fish often occurs near the coral reefs by skin divers and scuba divers. Heavy exploita tion of these organisms may cause depletion or extinction of this resource (Anon 1919).

The management measures identified for these living re sources include, banning of coral mining, control of collection of ornamental fish, other tree fauna and corals, banning of destructive fishing practices such as dynamiting and operation of bottom set nets, banning of blasting of reefs for boat passage, taking necessary steps to minimize water pollution by sewage and oil, minimize sedimentation and fresh water inflow, and public education (Anon 1986).

It has been observed that opposition to coral mining is building up within the local community not involved in this activity mainly due to environmental awareness. This has become a major factor favouring the efforts of the Coast Conservation Department to stop further destruction to our coral reefs (Anon 1991).

Another living resource in the coastal areas is the sea grass beds. These are important as suitable habitats for various organisms living in the coastal environment. These organisms include various species of fish, prawns, dugongs and turtles. Sea grass beds also help to minimize coastal erosion. Collection of aquarium fish is also carried out in the sea grass beds using push nets which are destructive to these resources. Juveniles of important fish and prawn species are also abundant in these habitats. Recently, it has been recorded that extraction of polychaete worms important as food for aquarium fish is also carried out in the sea grass beds (Samarakoon and van Zon 1991). As a management measure, use of destructive types of fishing gear such as push nets, drag nets and bottom trawling should be banned in these habitats. In addition, practices such as digging of poychaete worms should also be banned. Furthermore, management measures should also be taken to minimize siltation and sedimen tation.

When the management of living resources in brackish waters is considered, it is evident that very little attention has been given to the fisheries and other resources in these environments throughout the world compared to the attention paid to marine resources. This is mainly due to the relatively low contribution they make to the national productivity.

In lagoons and estuaries, fisheries are based on mul tispecies resources which vary widely in time and space. The living resources in these environments depend on the fauna coming from the marine and freshwater environments and euryhaline perma nent residents.

In the brackishwater environments of Sri Lanka, about 100 fin fish species, 7 prawn species, 4 species of molluscs and 1 species of crabs have been recorded as edible species (Pillai 1965).

The most important species of edible fish are grey mullets (*Mugil* and *Liza sp.*), rabbit fishes (*Siganus sp*), giant sea perch (*Lates calcarifer*), pearl spot (*Etroplus suratensis*), glassy perchlet (*Ambassis sp.*), spotted butterfish (*Scatophagus arqus*), carangids (*Caranx sp.*) and milk fish (*Chanos chanos*).

The most important prawn species in the brackishwater environments are *Penaeus monodon*, *P. indicus*, *P. semisulcatus* and *Metapenaeus dobsoni*.

The most important molluse species are the oyster (*Cassostrea madrasensis*) and the mussels (*Pema pema* and *P. virdis*).

The crab species important as a living resource in the brackishwater habitat is *Scylla serrata.*

Due to this multispecies nature, it is very difficult to estimate a value for optimum fishing effort for estuarine and lagoon fisheries as in the case of multispecies marine fisheries. In addition, a variety of fishing methods are also used in these environments which vary in efficiency and mode of operation. Therefore, it is very difficult to quantify the total fishing effort in terms of a single unit such as manhours of fisherman days.

These environments serve as nutrient traps and there fore, are highly productive. These provide nursery areas for many species of fish and crustaceans which spend the latter part of their life in the sea or freshwater. In addition, these provide avenues of entry and exit for migration of anadromous and catadromous organisms.

The fisheries of brackishwater environments are of small scale and are labour intensive. It has been estimated that in Negombo lagoon, which is one of the highly exploited estuaries in Sri Lanka, about 3000 persons are involved in fishing and other related activities (Samarakoon and van Zon 1991). Recent studies have shown that the exploitation of living resources in this lagoon is reaching the level of maximum sustainable yield and steps have to be taken to limit further entry of new fisher men into this fishery. Therefore, as mentioned earlier, alterna tive employment has to be provided to the young members of these fishing communities who will probably step into the lagoon for fishing as a livelihood. This can be easily done by increasing the exploitation of offshore and deep sea resources so that these persons can be employed in those fisheries.

In the management of these resources, it is necessary to pay attention also to the fishing methods used in these habi tats. It is necessary to limit the operation of dishing gear which block the access channels to the sea. Such gear will adversely affect the migration of fish and crustaceans between the lagoon and the sea. This will not only affect the fish production within the lagoon by reducing the inward movement of young individuals of fish and prawns but also their production in the coastal areas by hindering the outward migration of these organisms into the sea.

In lagoons and estuaries, it is also necessary to restrict the use of active gear which catch large quantities of fish and prawns. In some lagoons and estuaries, sometimes a rope to which tender coconut leaves are attached is used to chase fish towards a seine or gill net. This operation results in a large catch. Such catches will easily exceed the level of maximum sustainable yield and also will be destructive to the sea grass beds in the lagoon. Therefore, it is necessary to discourage or ban such operations.

In addition, it is necessary to have a minimum mesh size for the gear used in the lagoons and estuaries; research must be undertaken to determine this and legal provision be made for its enforcement. At present, the mesh size of nets used in lagoons and estuaries varies from 1.25 cm to 9.00 cm streched mesh. Large quantities of small fish are caught in small mesh sized. These fish are not commercially important as they fetch a very low market price. Small meshed nets also catch the juvenile stages of shrimps which will migrate to the sea and contribute to the marine fishery. Therefore, operation of small meshed nets will also affect the coastal and offshore marine fisheries of certain species.

Brush piles is another major type of fishing methods employed in brackishwater environments especially in the Negombo lagoon. These piles of mangrove twigs and branches provide sheltor for fish and also act as a substrate for epiphitic fauna and flora which are important as food for many species of dish. In addition, due to decaying of these brush wood, nutrient pro ductivity (Kapetsky 1981). Due to these factors, brush piles appear to be beneficial to the lagoon environment.

However, there are some disadvantages in the operation of brush pile fisheries. The greatest of these is that large quantity of branches is required to establish and maintain the brush piles. This will be harmful to the environment because it will contribute to deforestation of mangrove habitats. In addi tion to be used in the construction of brush piles, mangroves are widely used as firewood and also to prepare charcoal. Poles of some mangrove species are used in the construction of houses and leaves of *Nypa* are used to thatch roofs. In addition, some are used to make masks and also as fodder for cattle. Tannin ob tained from some species are used to tan fishing nets and sails of traditional fishing crafts (Anon 1991).

Deforestation of mangrove forests for the above purpose will destroy the micro-environment required by the larvae and juveniles of many species of commercially important fish and prawns. In addition, this deforestation would result in environ mental degradation due to erosion. Increased sedimentation loads will ultimately affect the productivity of the water body.

Therefore, it is recommended that mangrove species be planted in the lands surrounding the lagoons to cater to the requirements for brush piles and for other purposes. In this way, some people in the fishing community can secure an addition al income by selling mangrove wood to the people who require them.

In the management of living aquatic resources in brack ishwater environments, attention should also be given to the exploitation of young individuals of certain fish species as ornamental fish and seed for aquaculture. The major species collected are *Monodactylus argenteus*, *Scatophaqus arqus*, *Epineph elus sp.* and *lates calcarifer.*

The quantity of live juvenile fish collected from the Negombo lagoon alone was estimated to be around 30000 Kg per year which is valued at Rs. 50 x 10^6 (Samarakoon and van Zon 1991). These fish are collected as a by-catch of brush piles and seines and also by a special type of push net operation of these push nets may destroy the sea grass beds and management measures should be taken to stop the operation of these gear which is harmful to the environment. Although push nets provide addi tional income to few people, in the long run it will be harmful to the entire system. At the same time, research should be carried out on captive breeding of these fish species so that the harmful effects caused to the environment by the capture of a large number of juveniles could be reduced or stopped. In addition, if captive breeding could be done successfully, addi tional employment opportunities can also be generated.

Brackishwater aquaculture is another method by which the fishery yields from lagoons and etuaries could be increased (Edwards 1972, Honma 1980). This can be achieved by the more efficient use of water surface available. At present, brackish water aquaculture for prawns is done in Sri Lanka in a commercial scale.

These aquaculture products very rarely reach the local market because most of the yield is exported. Therefore, at present, there is no economic conflict between aquaculture and capture fisheries. These aquaculture practices are not carried out in the lagoons or eatuaries but are done in specially con structed ponds in the coastal regions. Therefore, conflicts for space with capture fisheries also do not arise. These aquacul ture ventures have created many employment opportunities and therefore, have assumed socio-economic importance as well.

However, there can be some environmental problems associated with large scale aquaculture. These may include pollution and alternation of the environment. The consequences of pollution from aquaculture are the changes in composition of natural plant and animal populations and pH, decreased amounts of dissolved oxygen content and the toxic effects on fauna by the exotic chemicals used for disease or predator control.

Experiments have shown that raft culture of mussels such as *Perna perna* can be carried out successfully in brackish water environments of Sri Lanka (Wanninayake and Sarath Kumara 1990). This will increase the production and also will provide additional employment and income to the fishing community. However, large scale raft culture may also adversely affect the environment. It may result in lowering the dissolved oxygen content of water and also decrease the densities of phytoplankton (Kapetsky 1984). Similarly, benthic infauna below the raft may be adversely affected by the mussel feaces (Chesney and Igleas 1979).

Closing of sections of lagoons for aquaculture purposes should not be allowed because it will limit or change the circu lation pattern and increase the sedimentation due to dredging and filling. Such activities may also interfere with freshwater input and destroy the productive habitats of mangroves and sea grasses.

Recent studies have shown that brush pile cum pen culture could give increased fish and prawn catches. This will cause little interference to the lagoon ecosystem and could be used to increase the production by reducing the natural mortality of important edible species. (Samarakoon and van zon 1991).

Management of brackishwater resources should also be aimed at mitigating the pollution too. Today, lagoons and estu aries are used as disposal sites for sewage and industrial efflu ents. In addition, sand mining is also carried out in some estuaries. Estuaries supply sand which helps to stabilize the beaches. Thus sand mining in the estuaries could disrupt the beaches causing increased sea erosion. Therefore, in the manage ment of brackishwater environments steps should be taken to lessen or ban such activities.

Fishery resources in the freshwater environments in addition to contributing about 20% of the total fish production of the country provide employment to about 13,600 families. With an estimate of 4 individuals a family, more than 50,000 individuals are dependent on inland capture fisheries (de Silva 1991). This clearly indicates that, when socio-economics of Sri Lanka is considered, the impact of freshwater fisheries is significant. Therefore, although state patronage for freshwater aquaculture has been stopped, it is absolutely necessary to manage the fresh water capture fisheries in order to obtain the maximum social yield from these resources and also to prevent overexploitation.

In Sri Lanka, reservoir fishery is the most important source of inland fish. There is no riverine fishery and fresh water aquaculture done on a large scale. Extensive research on the fish production of freshwater reservoirs in Sri Lanka and their management has been carried out in the recent past (Amara singhe 1987, 1988a, b, 1990, Amarasinghe and Pitcher 1986, Amara singhe and Samarakoon 1988, Amarasinghe and Upasena 1985, Amara singhe *et al* 1983, 1989, Chandrasoma 1986, 1988, Chandrasoma and Kumarasiri 1986, Chandrasoma and Wijeyaratane 1987, Daniel *et al* 1988, De Silva 1988, de Silva 1991, de Silva and de Silva 1991, Wijeyaratne and Amarasinghe 1987).

It has been estimated that there are more than 7000 usable reservoirs in Sri Lanka today (De Silva 1988). These are all man made reservoirs built 800-2500 years ago for irrigation purposes. Most of them are small seasonal tanks which dry up almost completely during the dry season. The total area of seasonal tanks is estimated to be around 40,000 ha (Chandrasoma 1988). The others are perennial reservoirs and have a total area of about 122,000 ha. Few of them are major reservoirs with a surface area exceeding 300 ha at full supply level. Others are medium sized reservoirs with a surface area ranging from 10 ha to 300 ha. Most of these ancient reservoirs are shallow with a mean depth less than 6 M (Amarasinghe *et al* 1986, Daniel *et al* 1988).

A few deep reservoirs have been constructed recently in the uplands and highlands primarily for hydro-electric purposes. The area of these reservoirs is about 9000 ha (de Silva 1991).

The main species contributing to the fisheries of these reservoirs is the exotic species *Oreochromis mossambicus* intro duced to Sri Lanka in 1952 (Fernando and De Silva 1984). This species contributes 60-100% to the fish production of individual reservoirs (De silva 1988). The fish production of these reser voirs prior to the introduction of *O. mossambics* was very low due to the absence of true lacustrine fish species in the island (Fernando and De Silva 1984). After the introduction of *oreo chromis mossambicus* several other species such as common carp (*Cyprinuscarpio*), *Chinese carps* (*Ctenopharyngodon idella. Aris tichthys nobilis, Hypopthalmichthys molitrix*), *cichlid species* (*Oreochromis niloticus, Tilapia homorum, Tilapia rendalli, Tilapia zilli*) and major Indian carps (*Labeo rohita, Catla catla* and *Cirrhinus mrigala*) have been introduced into freshwater bodies as food fishes.

The other major fish species which are important as food fishes in the freshwater environments are banded Etroplus (*Etroplus suratensis*), freshwater shark (*Wallago attu*), butter catfish (*Ompok bimaculatus*), stinging cat fish (*Heteropneustus fossilis*), spotted cat fish (*Clarias teysmanni*), common labeo (*Labeo dussumieri*), goby (*Glossoquobius qiuris*), Olive barb (*Puntius sarana*), long-snouted barb (*Puntius dorsalis*), filament ed barb (*Puntius filamentosus*), striped snakehead (*Ophicephalus striatus*), giant snakehead (*Ophicephalus marulius*), eel (*Anquilla bicolor*) and mahsier (*tor khudree*).

The giant freshwater prawn (*Macrobrachium rosenberquii*) is also important in the freshwater as an edible species.

Some fresh water species are also exploited live as ornamen tal fish. These include black ruby barb (*Puntius nigrofascia tus*). Cuming's barb (*P. cumingii*), cherry barb (*P. titteya*), reside barb (*P.bimaculatus*), swamp barb (*P. chola*), blacklined barb (*P. pleurotaenia*), striped rasbora (*Rasbora daniconius*), golden rasbora (*R.veterifloris*), combtail (*Belontia signata*), spiny loach (*Lepidocephalus thermalis*) and tiger loach (*Acantho cobitis urophthalmus*).

These species together with many others are collected live from the wild. However, heavy exploitation of these may cause depletion or extinction as has already been observed for some species (Pethiyagoda 1991). Therefore, close monitoring and management is required to maintain their populations at the sustainable levels. In addition, efforts should also be made to captive breed these species which will provide more employment opportunities to the people involved in this activity.

Fish catch statistics of some major reservoirs indicate that their fisheries have reached the sustainable level (Amara singhe et al 1991). Therefore, management measures have to be carried out to discourage further entry of fishermen into these reservoirs and also to maintain the efficiency of the gear at the present level. Recent studies have shown that it is necessary to maintain a minimum landing size of 20 cm for *Oreochromis mossam bicus* in some reservoirs to overcome the threat of overexploita tion (Amarasinghe 1988b).

The fish production in other major reservoirs could be further increasing the fishing effort because their catch has not yet reached the level MSY (Amarasinghe et al 1983, Daniel et al 1988). In addition, there are large number of cyprinid species in inland reservoirs which are not properly exploited. Experimental studies have shown that this resource of minor cyprinids can be exploited using gill nets of appropriate mesh sizes at deeper regions of the reservoirs (Amarasinghe 1990). Therefore, manage ment should also be aimed at exploiting these presently unuti lized resources so that yield from inland capture fisheries could be further increased. Recent studies have shown that in the Anuradhapura district, the present catch of 2800 MT/year from major reservoirs could be increased to about 5800 MT/year with proper management(Amarasinghe et al 1983). Similarly, present catch of 660 MT/year from major reservoirs in Hambantota district could also be increased upto about 2000 MT/year with suitable management measures (Danial et al 1988).

It has been found that effective management strategies can implemented through properly organized extension societies of fisherfolk (amarasinghe 1988c).

Stocking programmes carried out recently in the season al reservoirs by the Department of Inland fisheries before its abolition have shown that these reservoirs could successfully be used as aquaculture ponds and with proper management high yields could be obtained. The potential of seasonal tanks for fish culture and the methodology used are described by several workers (Chakrabarty and Samaranayaka 1983, Thayaparan 1983, Chandrasoma 1986). The average production from these reservoirs in the Ratnapura and Monaragala districts has been estimated to be 534.5 $Kg/ha/annum^{-1}$ (Chandrasoma and Kumarasiri 1986). It is estimated that about 25000 MT of fish could be obtained from these reser voirs with proper management (Anon 1980).

The major management measure identified for seasonal tanks is stocking them with appropriate fish species at the time of filling of the reservoir. The ideal species suitable for stocking are common carp, Chinese carps and Indian carps (chan drasoma and Kumarasiri 1986). Other management measures identi fied are prevention of loss due to predation and poaching, and harvesting at the proper time to reduce mortality due to decreas ing amount of water when the dry season is approaching (Chandra soma and Kumarasiri 1986).

The daily individual intake of protein in Sri Lanka today is about 29g. of this 70% comes from the fish. However, the daily individual protein requirement in Sri Lanka is about 45 g (de Silva 1991). Therefore, for a healthy population of 20 million by the year 2000, the total amount of fish required is 230,000 MT/year. Efficient management of living resources in our marine, brackishwater and freshwater environments will undoubt ably produce a yield very much higher than this and the addition al production could be used to increase the amount of foreign exchange earnings. In addition, proper management, through a better distribution of resource and income, will help also in the alleviation of poverty among the fisherfolk.

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