Vidyodaya J., Sci., (1991) *Vol.* 3, *No.* 1, pp: 1—21

A REVIEW OF MARINE FIN FISH FISHERIES RESEARCH IN SRI LANKA FROM 1902 TO 1990

J. JINADASA

Department of Zoology
University of Sri Jayewardenepura
Nugegoda

Abstract

Fisheries Research in Sri Lanka started to gain momentum in the 1950's from a low ebb prior to independence. It was because colonial rulers before 1948 paid very little attention to develop fisheries. They were exploring possibilities to develop pearl oyster and window pane oyster fishery as it was a good source of revenue to their own countries.

About 850 or more species of marine fishes are found in Sri Lankan waters. Taxonomic studies of some selected genera had indicated more species are present now than the number reported about 50 years ago. The biology, distribution, migratory behaviour and catching methods potential resources for some of the commercially important large and small pelagics of the western coast have been studied. Relatively more research information are available on medium size pelagics such as tuna which forms about 10% compared to the small pelagics which form about 80% of the total catch. Very little attention has been paid to study the species on the north and the east coasts.

Attempts have been made to improve certain types of fishing gears and catching methods. studies in population dynamics, mathematical models, stock assessments, bio-economic studies are in their infant stages due to lack of long term catch and effort data base. Further, information on demersal species are very scanty.

One major reason for the lack of research information could be attributed to lack of long term integrated research plan according to the need of the nation. At present research is mostly done on some selected aspects of a limited number of species of fish and the work is also confined to south and west coasts of Sri Lanka.

Key words: Marine Fin Fish; Fisheries Research, Sri Lanka

1. Introduction

THE total area of world oceans is about $365 \times 10^6 km^2$ of which about $40 \times 10^6 km^2$ or about 11% belongs to coastal waters (Gross, 1972). The food resources, in particular fish, is directly related to primary productivity (Raymont, 1943, Rhyther, 1969, Odum, 1959, Gross, 1972). The amount of carbon fixed in the ocean of the world is about 20×10^9 or Twenty billion tons/year, of which about 4×10^9 tons or about 20% comes from the coastal waters. The world fish production was about 90×10^6 tons in 1990 of which 90% came from the coastal waters. According to estimates the total fish production of the world would be around 100—200×10^6 tons in the year 2000 (Gross, 1972). This is about 0.5 to 1.0% of the total carbon fixed by the entire oceans. The quantity of fish quoted above has also been partitioned separately into quantities per species. Such information for the separate oceans and also of the separate seas have been determined experimentally. In the Indian Ocean such information have been gathered for the coastal waters of India (Prasad and Nair, 1960, 1963). According to them the fish harvested annually is about 0.03%of the total carbon fixed in their waters. Such information is vitally important for the development of a fishery.

Sri Lanka has a relatively narrow coastal sea, according to the definition of Gross (1972). Its width ranges from about 30km to 40km on the west coast to 12km to 60km on the east coast, and about 15km on the south coast (calculated from Curray, 1984). Based on acoustic surveys by a Norwegian vessel the fish resources of the coastal waters contribute about 90% to the total marine fish catch (obtained from Joseph, 1984). However, the above figures are estimates. This should have been cross-checked with the primary productivity data because findings based on acoustic surveys could be affected by the presence of migratory species. Such information for Indian waters has revealed that the fish harvested is about 0.03% of the total carbon fixed and the results for the North Sea was about 0.2 to 0.3% (Nielson and Jensen, 1957). Unfortunately, for Sri Lanka such research findings for coastal waters is hitherto not available. The basic information on carbon fixation is lacking for coastal and high seas in Sri Lanka, although such information is available for some selected brackish water bodies (Perera, 1987) Lack of such basic information is a severe drawback in Fisheries Research in Sri Lanka. Only with the help of such information, would it be possible to estimate the potential fish production in our waters. Then only is it possible to partition fish resources into different categories for effective exploitation and management.

2. Initiation of Fisheries Research in Sri Lanka

Fisheries research in Sri Lanka was initiated during the early part of the Twentieth Century, although the initial notes on some aspects of the fishes and marine mammals of Sri Lanka were published as far back as 1861 (Tennent, 1861). According to the available records the very first survey of fish resources around Sri Lanka was undertaken in 1902 (de Zylva, 1950). Under this program experimental trawling was carried out off the Pearl Banks of Mannar by Herdman, although no significant information was forthcoming from this venture. Information on pearl oysters and demersal fishes of the Pearl Bank region had, however, been highlighted. Similarly, in 1923 a similar oyster survey was undertaken. (Bull, Ceylon Fisheries, 1923). Then in 1926, research into fishing grounds around Ceylon was undertaken and the results of the survey were published as a research session paper in 1926. As a result of these findings commercial trawling was initiated in 1926 (Administrative Report, Director of Fisheries for 1940-50). The very first survey using standard fishing gear like Danish Seines, long lines and drift nets were undertaken in 1949 by Blegvard, Director Danish Biological Station. The reason why fisheries research was at a very low ebb at that time could be attributed to a lack of recognition of fisheries as being important because the British Government was more interested in fisheries such as the pearl fisheries, window pane oyster fisheries which were generating revenue for the Government. Actually, prior to 1950, more research was done on "Marine Biology" and not fisheries the station itself being called "Marine Biological Research Station", attached to the Museum. Further, very few from Universities were involved in Fisheries Research. The very first course in fisheries biology at a University was started in 1966 at the University of Sri Jayewardenepura. The Department of Fisheries itself was under the Ministry of Local Government, although it should have been under the Ministry of Agriculture as happens in many other developed countries like the USA and UK. It also lacked even an Assistant Director who should have been in charge of Research, instead of an Assistant Director in the Division of Development in 1950, after the Department was transferred to the Ministry of Industries in 1948. Even then, it lacked its own office. Its office was brought to the Colombo Museum in 1941, by P. E. P. Deraniyagala, who worked as a Marine Biologist when he was made an Assistant Director of the Museum and he wanted to be in charge of both Marine Fisheries and the Museum. Once again the Fisheries office was temporarily transferred to Mr. Lavinia and then shifted again to the Galle Face Laboratory where it was stationed until 1978. The Division of Development included the following personnel: one hyydrologist, one research chemist, two research officers, and one gear technologist. This laid the foundation for organised Marine Fisheries research in Sri Lanka although by then a fair number of papers on various aspects of fisheries such as identification and biology of some local species of fish had been already published by Deraniyagala (1932—1952).

His excellent work brought in a wealth of information of the fishes of Sri Lanka, which has gained due recognition as well as high praise from local as well as foreign fisheries scientists. (Collette, 1975 Smithsonian Institution; Professor T. J. Andrews, Ichthyologist, University of Massachusetts, USA, 1979, personal communication).

In 1949 research was undertaken to understand the species composition and biology of large Sharks by Gunawardena (de Zylva, 1952; Gunawardene, 1971). He reported 8 species of large Sharks of which 96% was ahimora (s) or *Carcharhinus* sp. around Kudawella. Similarly, studies on the bonitos (*Euthunnus pelamis*) and seer *Scombromorus commersoni* were initiated (de Zylva 1952). The above research was based on the landed catch of fishermen and shows the historical development of fisheries research. From then research activities in fisheries started to build up rapidly in Sri Lanka. The Director of Fisheries from 1943 to 1959 was C. Amirthalingam. He was able to organize the Research at a relatively higher level. During his period major investigations into the Wadge Bank (Sivalingam and Medcof, 1955) and exploratory bottom long line were initiated (Jean, 1955). In 1953 there were seven untrained Research Officers working under a Canadian Fisheries Scientist (de Zylva, 1953).

The very first Assistant Director in charge of Fisheries Research Dr. A. C. J. Weerakoon was appointed in 1962. Since then research activity started to grow at a rapid rate and in order that the researchers publish their own research findings, he started the Bulletin of the Fisheries Research Station, which was earlier referred to as Bulletin, Ceylon Fisheries and it was not a Research Journal.

3. Potential Fish Production

Fish are either primary, secondary or tertiary consumers. Therefore, based on primary productivity data and using ecological principles (Odum, 1959; Dajoz, 1971) it is possible to calculate potential fish production from the waters around Sri Lanka. But the information on the primary productivity of the waters round Sri Lanka is yet not fully known, except for the work of Perera (1987) which was also only on the estuarine systems. According to his information, the total fish harvested from the estuarine waters is about 0.015% of the primary production. If the above results are extrapolated to the coastal waters although this is strictly not quite accurate, then the fish harvested in Sri Lanka is 0.015% of the primary production. The above results are quite close to the findings of the Indian Fisheries Scientists for the Gulf of Mannar. (Prasad, and Nair 1960, 1963) According to them the fish actually harvested from the coastal waters is about 0.02-0.03 of the total carbon fixed. This does not take into account, the primitive fish catching methods that exist both in Sri Lanka and India. Therefore, our potential fish production could be much more than the above estimated percentage based on primary production. The actual fish harvested in a fully exploited sea, like the North sea, is about 0.2-0.3% of the primary production. If the same principle is applied here then the potential fish catch could be about 10-15 times than what it is now. However, tropical seas have a large number of species and a few fish from each species. If tropical seas are also fully exploited, then the amount of fish harvested could be at least about 50% calculated from Prasad and Nair (1960). Which means the potential fish production in our waters could be much more.

Potential Fish production in Sri Lankan waters has also been estimated by many workers. Weerakoon (1965) estimated the total production from a 6 1/2 mile strip of sea around the Island to be between 267,000-382,000 tons, or about 40 to 70 tons/sq. mile/year. de Silva (1964) had estimated the production for the entire continental shelf as 850,000 or about 50 tons/sq. mile/year. He had used primary productivity and fishing trial data for his studies. The Fisheries Corporation in its draft 10 year plan for the Development of the Fishing Industries (1965) had estimated the production for the entire shelf waters and beyond as 583,575 tons or about 38 tots/sq. mile/year. Recently, Joseph (1984) using Dr. Nansen's results had estimated the total production for the. coastal waters up to a width of 25 miles (37km) (Total area 11C0x25=27:C0 sq miles, 64713 km) as 250,000 tons or about 9 tons per square mile or 3.86 tons per km.

The methodology adopted by Weerakoon and de Silva is almost the same. But Weerakoon combines both depth and width of the strip of sea, as depth could both vary within the strip. However, there is no need to use both, as it is misleading. To be more accurate he had also used production data from the North Sea, but one draw-back in his calculations is that he had not made any attempt to eastimate the production beyond the 6 1/2 mile strip of sea. de Silva (1964) on the other hand had omitted the productivity data for the deep sea. The Fisheries Corporation in this respect had incorporated even the deep sea data in its estimation and had given the production as 126,000 tons for the deep sea. It had also decided the entire sea around the island into sub-areas for such an estimation. Usually, estimates are more accurate when they are given on an area basis. This has been done by Sivasubramaniam (1965 c) for larger scombroids in the Indian ocean. The estimate made by Joseph (1984) was based on findings of the Norwegian research vessel using acoustics. However, this survey had not paid enough attention to the seasons and also had not accounted for the migratory species. The intensity of sampling was also not sufficient. The intensity of sampling has a direct bearing on the estimates made. Discrepancies also existed on the length of the coast line. All workers, except Joseph, consider it as 850 miles whereas he had considered it as being 1,100 miles, a 30% increase in the length of the coast line. None of the authors indicate the methodology used in their calculations. Some old publications gives the length of coast line as 850 miles. The recent ones are using a length of 1760 km (1100 miles). According to Fisheries Master Plan of 1990-94 refers to a coast line of 1561 km. According to Department of coast conservation, it is 1650 km. The above workers have used different criteria in their estimations. Coastline changes continuously. For example Dala ware River mouth in the USA is Delaware Bay now coastline varies with time (Gross, 1972). Therefore, all the above estimated valves could be corrected. Estimates of fish production of Weerakoon, de Silva and the Fisheries Corporation are fairly similar but that of Joseph is far too low. Most of these workers except Nansen have not made any attempt to partition the production according to the type of fish such as small pelagics, medium palagics large pelagics and demersals. According to Joseph (personnel communication) Dr. Nansen had estimated the biomass of fish separately for demersals and different types of small pelagics. Weerakoon (1965), based on his estimate of 267,000 tons of fish per year, predicted that it would take about 30 years (ie. from 1965, to 1995) to exploit the above potential catch from the coastal waters. At present the catch from the coastal waters to about 36 km (25 mile) is about 180,000 tons per year and the rate of increase in catch is about 15,000 tons per year, which means it would take another about 7 years from now (1991) to achieve Weerakoon's target. This is what he had predicted in 1965 for the coastal waters up to 6 1/2 miles. The off-shore and deep sea which encompasses water out-side the coastal waters (=27,500 sq. miles) is roughly equal to 62,500 sq. miles. Joseph (1984) had estimated the total area, both coastal and oceanic in the Exclusive Economic Zone (EEZ) as being 90,0C0 sq. miles. The potential production from the off shore and deep sea area as being 30,CC0 tons or 0.45 tons per sq. mile or about 2.1 kg/ha/year. (Sivasubramaniam, 1978) Jinadasa (1984 and 1985) had estimated the production for bill fishes and spanish mackerels alone for off shore waters as being 100 kg and 60 kg per km per year respectively. His findings had been subsequently supported by Dayaratne (1989 c). According to the statistics of the Ministry of Fisheries, the mean seer fish catch for Negombo is 350 tons per year for an area of about 4,500 km or about 60 kg/km/year. This was also the calculated amount by Jinadasa (1984). Therefore, the above estimate is very close to the actual catch reported by the Fisheries Department. However, results obtained for coastal waters cannot directly be extrapolate to off-shore waters. Therefore, all the above estimates nearly always tend to be over estimates, and one estimate could not be inferior to the others. Similar estamations could be made from the findings of Dayaratne (1989 c). Estimations of fish resources in the sea around Sri Lanka needs further study.

As far back as 1985 an Anonymous Fisheries Scientist indicated that Sri Lanka is exploiting its resources to the maximum. Yet, the total annual fish catch goes up by as much as 15,000 MT and it keeps on increasing, while there are not indications of a decline in the catch per unit effort or decline in L∝, which are the indices used to assess over exploitation (Ricker 1975). However, the fish stocks of speecies have to be managed separately, studying especially the age structure of the exploited stocks (Gulland, 1975). If the age structure declines, then correspondingly the L∝ too declines as these are species specific characters. These types of studies must be carried out annually on fish stocks for only then could fishery biologists forecast whether or not a particular species is being over exploited or not, (Hewalath Lowestoft Laboratory, personal communication, 1988).

Therefore, it can be concluded that much work has yet to be carried out in the area of fish resources and the individual species that contribute to it.

4. Taxonomy

Studies on the taxonomy of marine fishes of Sri Lanka is very scanty. The very first complete study on marine fishes had been by Munro (1955); who had reported about 846 species of both marine and freshwater fishes.

His studies lack proper sampling procedure covering all shores of Sri Lanka. Therefore, it is far from complete. Deraniyagala from 1932 to 1952 also reported a large number of species of marine fishes. The work of those authors have been subsequently improved by other workers who made detailed studies on different families and genera. For example, according to Munro there are only three species of *Scomberomorus*, but subsequent studies by Jinadasa (1984) and Dayaratne (1989 c) has shown that *S. quttatus* and *S. koreanus* too exist in the coastal waters of Sri Lanka. These species have been reported to the Indian Ocean in 1983 (Collette and Nauen, 1983). Similarly, studies on the flying fishes were very incomplete. Munro (1955) has reported only three species of flying fishes. Later de Silva (1956) has reported five more species. Subsequently Jinadasa, (1971) made a detailed study covering the entire shores of Sri Lanka for a period of 3 years and found that Sri Lanka has a total of 15 species of flying fishes. *Leiognathidae* on the other hand was reported to be represented by only 11 species in Sri Lanka. However, detailed studies by Jayanth (1989) found two more species over that of Munro (1955). Similarly, de Silva (1986) reported 20 species of commercially important sharks, some of which had not been reported by Munro. Sivasubramaniam (1965 a, 1969 a, 1964) during his studies on tuna long line catches had reported the occurrence of predatory sharks in the tuna fishing grounds. Canagaratnam (1965) and Gunawardene (1971) highlighted some species of sharks, skates and their production. The taxonomy of Carangids ('parau'), which are very popular among Sri Lankans are poorly known. Therefore, a complete taxonomic review of marine species is vitally important. Similarly the phylogenetic relationships among fishes around Sri Lanka or even in the Indian Ocean have not been worked out except for the work done on Scienids (Dharmarajan 1971, Trewavas, 1962). Therefore, studies on the Ichthyology of all the species recorded for the seas round Sri Lanka or even of some selected commercially important species is a needed, as taxonomy and Ichthyalogy are continuing processes.

5. Food and Feeding

The food habit studies of fishes are very important not only to decide upon their capture methods and ecological habitats, but it also brings about the whereabouts of prey and predators. For example, by studying the food habits of fishes on the continental shelf, it is possible to understand the species composition of penaeid prawns, crabs etc. that live there (Collette and Nauen 1983, Groot, 1971). Although it is fairly easy to carry out such studies they have been more or less neglected by most fishery scientists, except such studies on sharks and tuna (Sivasubramaniam, 1965 b, 1969 c) flying fishes (Jinadasa, 1971), bill fishes (Forster, 1989), and pony fishes (Jayanth, 1989).

The above information reveal that food habit studies of fish in the waters around Sri Lanka and their habitats are very poorly known compared to that of the Irish or North Seas. (Groot, 1971; Roigers and Jinadasa 1988).

6. Distribution

In the study of the distribution and resource analysis of tuna around Sri Lanka, Sivasubramaniam, (1971 d) had used aerial survey techniques. Although his findings were based on five days of flying, covering the entire coastal waters and a little beyond, his work not only highlighted the location of tuna schools, plankton patches, but she light on schools of dolphins and porpoises off the coast of Trincomalee.

The distribution of tuna in the entire Indian Ocean have been very well documented by Sivasubramaniam (1965 a, b, c, 1969 c). He has used the hooked rate of tuna caught east to west and north to south of the Indian Ocean to arrive at his conclusions. From his findings it is clear that tuna fishing had shifted from the east to the west and the heaviest fishing was reported from off Somali, off East Africa to about the middle of the Indian Ocean (70 E), just south of the equator.

He has also proved that tuna species are distributed in association with equatorial currents and with the disappearance of the north equatorial and the equatorial counter currents during the southwest monsoon with tuna moving northwards from the equator. As a result heavy tuna catches have been made in Sri Lanka. Similar distributions of marlins, spearfish and sharks with the Indian Ocean currents have also been observed by him (Sivasubramaniam, 1965, a, b, c, 1971 a). He had further highlighted the density of distribution of albacore tuna in the Indian Ocean, using the hooked rate over a long period of time. If the catch per unit effort is monitored for a long period of time, it clearly indicates the density and nature of a fishery (Ricker, 1975; Gulland, 1975). Therefore, Sivasubramaniam's work on the above aspects of tuna has shed a wealth of information on the tunas and the nature of their resources in the Indian Ocean in general. This is further supported by Joseph (1984) and Maldeniya and Joseph (1988).

The boundaries of the fishing grounds of migratory species are difficult to ascertain, but the best area for exploitation could be forecast. This has been done for tuna, spanish mackerel (Sivasubramaniam, 1965, a, b, c,; Amarasiri et al., 1986, Jinadasa. 1984, 1985, Dayaratne, 1989, e). For most resident species however, such boundaries could be fairly easily monitored using standard techniques. For example for the areas of the Pedro Bank, and the Wadge Bank, the species composition and potentials have been worked out (Sivalingam and Medcof, 1955, 1963; Mendis, 1965, a, b; Munasinghe, 1969, 1970; Sivalingam, 1966).

All of them have divided the fishing ground into sectors and trawling has been done at random stations in each of the sectors. This is the best known technique to ascertain the demersal fish resources. Of the small pelagic fishes, the extent of the fishing ground has been worked out for flying fish (*H. coromendelensis*) by Jinadasa (1972, 1985). He had used the exploratory fishing technique off the north and east of Point Pedro, the east and south of Trincomalee and the east of Vakerei and thus has demarcated the fishing ground (Jinadasa, 1972). From the above account it is evident that further studies on the distribition of the commercially important fish species are essential.

7. Wadge Bank and Pedro Bank

Sri Lanka is fortunate to have two demersal fishing grounds in her coastal waters. The larger of the two is the Wadge Bank, which is situated at the southern tip of India (Sivalingam and Medcof, 1955, 1957; Sivalingam, 1964, 1966, 1969; Munasinghe, 1969; Mendis, 1965, a, b). It is 182km from Colombo and its area has been worked out as 9600 sq. km by most of the above workers. Most of them have divided the entire Wadge Bank into 15sq. miles sectors to estimate the total area. Therefore, their methodology is correct. Joseph (1984) on the other hand does not mention the methodology used nor given any references. Whatever methodology is used, there is a 25% discrepancy in his estimate with that of others. No two estimates are equal, therefore, all estimates could be accepted. The depth of the fishing ground and the nature of the bottom have been documented. The total number of demersal species of fish have been studied by experimental fishing. According to Sivalingam and Medcof (1956), there are 128 species of demersal fish. The most valuable commercial species belong to the groups: lutianids, lithrinids, carangids small and large epinephalids, red mullets, sharks and skates. The above species composition has been agreed upon by most of the workers in the Wadge Bank. Munasinghe (1969) who analysed the catch composition in detail had shown that small and large 'paraw' (carangids) varies from 3-50% of the total catch and according to Mendis (1968) it varied from about 3-63%. However, from both estimates it is clear that carangids are the most common fish in the Wadge Bank, although there is a certain amount of discrepancy between the two estimates. By the use of seasonal occurrence, Munasinghe (1967) and Sivalingam, (1957) have shown that some species are migratory, specially the Carangids, and are most abundant in October. According to him they migrate out during the rest of the year. The explanation given to prove that migration takes place is the complete absence of such species during certain months, which is a reasonable assumption and can be accepted as being true. The total production of demersal fish from the Wadge Bank has also been estimated by experimental trawling. Munasinghe (1970) had trawled at randomly selected stations in 15 sectors of the fishing ground. This is the most acceptable method of population estimation in trawling grounds as stated by Gulland (1975), Ricker, (1975). Such estimations can be made using the following equation as given by them.

$$\text{Total potential} = \frac{W}{a} \times A$$

Where a = total area trawled.

W = total weight of fish caught in area 'a'

A = total area of the fishing ground (9,600 sq. km)

The above equation shows the method of calculating the total catch in a trawl fishery, and it is accepted all over the world. According to Munasinghe (1970) the total production is about 4, 475, 720 lbs or about 2,200mt., with an optimum economic effort of 1000 trawling hours. Mendis (1965, a, b) had used a slightly different method. He had used the results of a commercial trawler maple leaf. He also made a similar estimation, but in his study the fishing ground was not divided into sectors, nor were the stations randomly selected for trawling. Usually a commercial trawler changes operation sites in order to get a better catch. Therefore, an over estimation could not be ruled out. Mendis (1965, a, b) estimated it as being about 6,730,000 kg or about 7,000mt, which is about 1.5 times the amount as estimated by Munasinghe (1970).

According to Munasinghe Pedro Bank has a potential fish production of 2,400mt, in other words, its area is about 1/3 of that the Wadge Bank and its production is also approximately 1/3 of the Wadge Bank which can be considered to be a theoretical estimate. According to most other eminent fishery biologists, like Sivasubramaniam (personal communication 1967). The Pedro Bank is a virgin fishing ground. Joseph (1984) has also indicated the same idea. Therefore, estimates of Mendis for Pedro Bank need further checking. On that basis, even the estimates made for Wadge Bank is questionable. According to Joseph (1984) the average production from the Wadge Bank was about 700mt by the state owned fishing fleet of six stern trawlers. But the details of the manner of operation of the six trawelers is not known. However, these were not operated at the same time. Therefore, Joseph's (1984) estimations cannot be accepted as the potential production from the Wadge Bank. If 700mt is the maximum sustainable yield, there should not be an increase in catch per unit effort with increase in effort (Ricker, 1975, Galland, 1975, Schaefer, 1968) Joseph has not documented the above. Now Sri Lanka has no access to this valuable fishing grounds. In 1980, according to the law of the sea convention, Sri Lanka unilaterally declared a 200 mile Exclusive Economic Zone (EEZ). As a results of this declaration Sri Lanka lost the entire Wadge Bank and the northern portion of the Pedro Bank, which means Sri Lanka lost between 2,200 and 7,000mt of valuable demersal fish like 'Parau'. At the same time, although we have ownership up to 200 miles from the shore can we ever police the area to prevent poaching? By the unilateral declaration of 200 miles EEZ, we lost the Wadge Bank and part of the Pedro Bank with hardly any gain. Further, Sivasubramaniam and Maldeniya (1985) had reviewed the demersal fisheries of Sri Lanka. From which the depth of the most productive areas, species composition, potential production catch rates and drospects for improvemens have been high lighted.

8. Growth Parameters

The management of fish stock is brought about according to the fisheries principles formulated by Beverton and Holt (1957), Galland (1975), Ricker (1975) and Pauly and David (1981). All of these principles utilize the age of fish, age structure of the fish population, and the calculated growth parameters. In the event that age structure of a particular stock declines in successive years, correspondingly, the calculated growth parameters would change. If $L\infty$ declines over the years, then the fishery may be declining too (Gulland, 1975). Similarly, using K, $L\infty$ and T according to Pauly (1980), it is possible to calculate M (natural mortality) and F (fishing mortality), which are useful parameters in managing a fishery. In Sri Lanka, small pelagic fishes form about 60-70% of the total fish catch, (Dayaratne, 1984, 1985) of which clupeids form the majority. The age and length at each age of four species of culpeids have been highlighted (Dayaratne, 1989). Further the maximum age, length at each age, and age at maturity have been documented (Dayaratne and Gjosaeters, 1986) for *Sardinella albella*, *S. gibbosa*, *S. longiceps* and *S. sirm* Similar growth studies have been made for *A. sirm* (Karunasinghe, 1990). Based on the growth parameters and yield per recruit the present level of exploitation have been calculated (Dayaratne, 1989). *Stelephorus heterolobus* is widely exploited using gill nets and beach seines all along the south and south-west coast of Sri Lanka. Its growth parameters obtained using otolith readings is estimated as $K=4.02$. $L\infty=8.62$ (Dayaratne, 1989). Further, Dayarathe (1989) has also estimated the growth of the fish per day as being O.81mm. One weakness in her studies is that she had not validated the growth marks. According to Taubert and Coble, (1977), formation of daily growth rings do not hold for fishes older than a few months. Therefore, extrapolation of the number of daily growth bands laid down at the initial stages up to old age could not be correct. It is that growth bands with different thicknesses could be formed due to changes in environmental factors such as salinity and rain fall (Paunella, 1971, 1974). But such bands have to be validated taking samples at different times of the day and the year. These problems have to be resolved if otolith readings are to be satisfactorily used for the detection of the age of tropical fish.

The age structure and its corresponding lenght s for the exploited stock of skip-jack tuna of the southwest coast of Sri Lanka have been demonstrated using length frequency data (Sivasubramaniam, 1972). According to him the exploited skipjack (*Katsuwonus pelamis*) fall into V year classes, ranging from 1 to V years. He had utilized the principle of model lengths to separate one year class from the other. When his data was analysed using polymodal frequency analysis, (Cassie, 1954) they gave results very close to that of Sivasubramaniam. Therefore, his results could be effectively used to calculate mortalities, yield per recruit, exploitation rate etc. as suggested by Pauly and David (1981) or Gulland (1975).

Age determination of flying fish has been attempted (Jinadasa, 1972). According to him the whole of the spawning flying fish stock of the east coast is two years old. Jinadasa had used conventional methods as well as polymodal frequency analyses in his studies. According to his results, the SL of both one year and two year old fish ranged from 18-25cm, and 20-25cm which means that 0 year old fish ie, within the first year, fish grows up to 18cm in length. This however, needs further verification.

The age determination of mackerel tuna caught in Sri Lanka had not been carried out. Therefore, Sivasubramaniam (1970) used the findings for Seychelles in his studies to assess the degree of maturity of the fish caught in Sri Lanka. He found that 0 to II year old fish caught by trolling, are sexually immature and III to V year old fish which are caught in gill nets are mature. Although his findings indicated the age structure of the fish caught by the two gears in Sri Lanka, their validity is questionable, as stocks caught in Sri Lanka and in Seychelles could be from two different populations, migrating from different places. Studies on the growth parameters of *A. sirm* has also been made by Karunasinghe (1990). She had used the ELEFAN method and described the state of the fishery as being heavily exploited. The best method suitable to assess over epxloitation is to find the catch per unit effort data, (CPUE) coupled with $L\infty$ If $L\infty$ and CPUE decline over a period of years then only small fish remain in the stock which is an indication of over exploitation (Gulland, 1975). According to Ricker (1975) and Gulland (1975), it is dangerous to use (CPUE) data gathered over a short period of time to assess the status of a fishery.

Studies on the growth parameters of large fishes such as spanish mackerel and bill fisher are very sparse. The age structure of *Scomberomorus commersoni*, which is the most common of the spanish mackerels and which is mostrelished in Sri Lanka, has been worked out using length frequency, otolith and polymodel frequency analysis methods. (Boughlet, 1985; Devaraj, 1983; Jinadasa, 1984). The results obtained by them are similar. Subsequent studies by Dayaratne (1989, a, c) using some of the above methods has highlighted mortality rates and rates of exploitation and other such parameters for the stocks in Sri Lanka. One major weakness in her studies is that the sampling war confined to just one station for a period of just over one year. There is a danger involved in calculating the rate of exploitation and other parameters using data collected over a short period of time.

For large pelagic species such as bill fishes, the growth parameters, mortalities and exploitation rates have not been worked out in detail. Here too Sivasubramaniam (1965, a,) had initiated the studies. Later, their species and eatch composition, (Jinadasa, 1985; Forster, 1988; Joseph and Amarasiri, 1986) have been studied for fish caught in the west coast. All the above workers have completely neglected the east coast. Therefore, the nature of the fishery, the stock size, rate of exploitation and management plans of these fishes for the native Island are far from complete. From the above account on age parameters, mortalities, exploitation rates abundance, it would be clear that only a fraction of the commercially important species such as tuna and small tuna, (6 species), spanish mackerel (one species), bill fish (five species), sardines (six species) have been studied and even that only very superficially. Other commercially important species such as carangids, mullets, sciaenids, sharks rays dolphine fishes and lithrinids have not been paid any attention at all.

The population dynamics of even the most common and commercially important species is virtually unknown. However, the changes in length frequency of skip jack (*K. pelamis*) and tuna like fishes have been studied (Amarasiri and Joseph, 1985; Sivasubramaniam, 1972, 1965, a). Special emphasis have been made by Sivasubramaniam (1965 a, 1971, 1964) on yellowfin tuna, (*Thunnus albacares*), mackerel tuna (*Euthunnus affinus*) and frigate mackerel (*A, thazard*). He had shown that there are size differences within the same species depending upon the type of gear used and method of exploitation. He had pointed out that greater number of young immature fish are caught by trolling and lesser numbers are caught in long lines and gill nets. These conclusions of his have been arrived at after sampling almost all stores, including the east coast of Sri Lanka, for a considerable length of time. Similarly, the areas of abundance for some of the above species have been estimated. However, information obtained so far as very small when compared to the lack of information on a number of species present around the Island.

9. Population Dynamics

The study on the population dynamics of exploited fish stock of Sri Lanka is in its infant stage. Although nothing of the quality of work of Baronov (1926), Ricker (1975), Shaefer (1954) Schaefer and Bevorton (1963) or Cushing (1968) has emerged. The work of Sivasubramaniam is worth commenting upon. He (1971) has analysed the monthly length frequency data of *E. affinis* collected using different gear. From his data he had pointed out what component of the population is exploited by each of the gears. He had confined sampling only to the west coast and ignored the rest of the country, which is a weak point in his work. Tunas are extremely migratory species, and therefore, it is necessary to look at the Indian Ocean as a whole to understand whether the fishery is in a steady state according to the principles of Baranov (as quoted by Ricker, 1975). Similarly, Sivasubramaniam's work (1972) on *K. pelamis*. lacked data for the whole Island. Sivasubramaniam (1966) had formulated a common equation to express length and weight relationship for tuna and tuna-like species. This attempt is a very important one, as there are well over six species of tuna and tuna-like species and separate equations cannot be used for obtaining definite conclusions, because, in the equation $W=aL^3$, a slight error in length would reflect a three fold error in weight. Further-more, he had not taken samples from all the shores of Sri Lanka for this study which is a weak point in his work as tuna are migratory species. Similarly, population changes have been highlighted for *Sarda orientalis* Sivasubramaniam (1969, b). Dynamics of the exploited *K. pelamis* have also been studied by Amarasiri and Joseph (1985) using the ELEFAN program. These authors have obtaned total mortality (M), fishing mortality (F), exploitation rate and compared $L\infty$ that they obtained with that of others. But they have failed to highlight that the increase in $L\infty$ is an indication of under exploitation of the stock according to Ricker, (1975 p. 259). These authors also did not attempt to extend their study to the east and north coasts of Sri Lanka. Similarly studies carried out for *S. commersoni* off Negombo and Chilaw (Dayaratna, 1989 a) have limitations. Dayaratne had gone further than the earlier workers and compared the growth rates of *S. commersoni* in Sri Lanka with that of Oman and has expressed the view that the *S. commersoni* population in Sri Lanka is been actively exploited, The changes in the population structure of small pelagics like *Amblygaster sirm* caught with gill nets have also been discussed (Dayaratne, 1988, Siddeek et al., 1985). Here too sampling has been confined to Negombo. Other than the above mentioned elementary studies on fish population dynamics detailed studies using mathematical models are very scarce. Similarly, mathematical models for fish resource management have never been attempted. This is partly because, the fisheries biologists in Sri Lanka do not have a sufficient mathematical background and partly because, mathematical modelling in fisheries biology itself is a relatively young science. The very first workshop to teach mathematical modelling in Fisheries Biology was held in 1982 in Trieste, organized by the University of Texas, and Princeton, USA.

10. Fishing Gear

The primary fishing gear that are used in Sri Lanka are gill nets of different mesh sizes catch, small medium and large pelagics. (Dayaratne, 1985, a, b, 1988; Sivasubramaniam, 1978). Long lines, troll lines and their performances, types of commercially important fish, their biology, primarily the age structure, and sizes have been very well documented. They are especially documented for tuna, tuna like fishes and sharks Sivasubramaniam, 1965 a, b, 1969 a, b, 1971 a, b, c, 1972, 1975; Joseph, 1984; Amarasiri and Joseph, 1985). The work of Sivasubramaniam in most cases was extended to the west and east coasts of Sri Lanka, whereas the other workers had concentrated their effort only to a part of the west coast. Therefore, their results have to be accepted with that limitation. Similarly, experiments with purse seines have brought in satisfactory tesults for small pelagics. Here too the studies have been restricted to the southwest coast (Dayaratne, 1988; Joseph, 1977; Joseph, 1975, 1974). However, attempts with purse seines in Sri Lanka was pioneered by Joseph (1974). In most cases, these operations have been restricted to findings a bait fish for the pole and line fishery.

Apart from the above gear, experimental and commercial trawling have been carried out in the two demersal fishing grounds, namely, the Wadge and Pedro Banks. These have brought in encouraging results (Munasinghe, 1977; Weerasooriya, 1977; Mendis, 1965, or b; Sivalingam and Medcof, 1955; Sivalingam, 1966; Jean, 1955). As a result of the above experimental operations the Ceylon Fisheries Corporation introduced six 250 GT trawlers to the Wadge Bank. These brought in 700 MT for each year. But with the loss of the Wadge Bank to India, these trawlers also ceased to operate (Joseph, 1984). Similarly, as a result of the extensive work of Sivasubramaniam on tuna longlines (1965-1968), the Ceylon Fisheries Corporation introduced a number of tuna clippers, which were expected to stay for about 3 months at a time out at sea. However, as this sort of fishery usually separates families of fishermen for long periods of time (this fishery is usually called "widow fishery") the Sri Lankan fishermen did not like to stay out at sea for such long periods of time (Sivasubramaniam, personal communication 1968-70). Further more there were shortages of bait (Jinadasa, 1984). All these contributed to loss in revenue from the clippers. Therefore, they had to be abandoned by the state. However, tuna long lines are regularly operated by private fishermen with relatively short lines with about 60-100 baskets in each line (300-500 hooks). The research by Sivasubramaniam (1965, a, b, c, 1978), Joseph (1974, 1975, 1977, 1984), Dayaratne (1988), Sivalingam (1964, 1966,) Munasinghe (1970) Suraweera and Maldeniya (1990) and Karunasinghe and Wijeratne (1990) have shed light on the most common commercial fishery gears of Sri Lanka. However, less important gear, such as hand lines, traps lift nets pole fishing have not been paid sufficient attention so far. At least the species composition of the catch from such gear is not fully known. Studies on beach seine fishery is limited, although it had contributed very largely to our fish production up to 1958 (Weerakoon, 1965). It is mostly popular to catch Engraulids, which formed about 33.9% of the catch. *Sardinella* spp. have been among the major varieties too (Canagaratnam, 1965). There are about 62 registered fishermen in the south-west region alone. However, no innovations or research done on this inexpensive fishing gear. Therefore, initiation of studies on the above gear is warranted.

11. Bait Fish

Fish resources of Sri Lanka waters is exploited using many types of gear, of which drift nets (gill nets) troll lines, long lines (or floating long lines) and pole and lines are the most popular among fishermen. Except drift nets, all the other gear require either a bait or a jig. According to Sivasubramaniam, (1975), who had done extensive research on local and Japan tuna long-lines

(1965, a, b, c) the tuna catch in Sri Lanka is proportional to the bait catch. long lines and troll lines can use dead baits, sometimes troll lines could also be operated using jigs. Pole and line method of fishing is quite different to the above and it requires a live bait (red bait). This method of fishing is very popular among the fishermen of the south and east coast of Sri Lanka (migrant fishermen from the south) Sivasubramaniam (1965 a, 1975). The red bait required for this fishery is caught from the near-by coastal waters. The species that are suitable to use as red bait and their fishing grounds are not fully explored. But the bait is so important that the seasonal nature of the Pole and line fishery is due to the seasonal availability of red bait *Dipterygonatus, lencogramicus*). Work by Joseph (1977) had shown that a large number of species which could be used as red bait is available off the southwest coast ranging from Mabole to Udappuwa. He had reported 9 such species, out of which sardines form the most dominant consisting of about 79 of the total catch and the rest was red bait (*D. leucogramicus*), which is about 21%. According to him, they are very hardy. Therefore, they could stand the crude conditions of the cane baskets in which they are taken to the fishing grounds alive and are kept for a long period before use. They are ideally suited as a bait fish for pole and line fishery. Sivasubramaniam (1975) had experimented with six different species of live baits in pole and line fishery and found that red bait had the lowest mortality. Therefore, he had worked further afield and explored bait grounds of the coasts of Chilaw, Trincomalee, Colombo and Galle. Joseph (1975) by conducting similar studies found that of eight species of live bait caught experimentally in five different regions of the coastal waters, the abundance of red bait was second only to sardines. According to him the size of the red bait caught ranged from 5-9cm, which is the ideal size for pole and line fishery. Jinadasa (1971 unpublished data) also conducted exploratory fishing for red bait off the northern tip of Back Bay, Trincomalee, and found that the coastal area north of Back Bay up to Uppuweli has rich bait grounds and the catch per unit effort is about 16-20kg/hr. This area is widely exploited by the southern migrant fishermen. From the above account on red bait, it is evident that so far it is the best for pole and line fishery. However, more fishing grounds for live bait have to be explored.

Long-line fishery on the other hand utilizes dead bait. In Sri Lanka species such as chub mackerel, flying fish, squids, meat of dolphins (Forster, 1988, 1989) etc. are used as bait. The Ceylon Fisheries Corporation up to 1970 imported Saury (*Cololabes saira*) from Penang, Malasia, to use as tuna long-line bait. The cost of the bait per trip of tuna long liner at that time was about Rs. 45,000/- (in foreign exchange with FEECS). In order to save the above sum of money spent on bait, Jinadasa, (1971) under the supervision of Sivasubramaniam made arrangements to use flying fish and Saury in alternate-baskets in tuna long lines. His results gave significant results. The local flying fish was in fact found to be better than the imported saury as a tuna long line bait fish. Further, it cost only Rs. 10,000- per trip without any foreign exchange being involved thereby saving as much as Rs. 35,000!- per trip in the form of foreign exchange. Sivasubramaniam (1965, a,) and Jinadasa (1972) had also systematically estimated the total flying fish catch in Sri Lanka as about 300 tons per year. However, the total number of long-line fishermen in the country is difficult to estimate as most fishermen operate more than one gear simultaneously. Further, the number of hooks used in a long line varies from about 65 hooks to 500 as opposed to 2000 hooks on a traditional long line and which is about 20 miles long. There are no records of experiments done on hand-line except the one done by Jinadasa (1985). His work on live flying-fishes as hand-line bait fish had shown that flying fish can live long, even as long as 6 to 8 hrs when hooked mid-dorsally. However, this sort of operation is possible only at the flying fish fishing grounds off Trincomalee. Therefore, it has its limitations. However, these sorts of operations are very common among flying fish fishermen of Trincomalee.

From the above account it is evident that a fair amount of work on bait has been carried out and what is needed is to expand the search for bait grounds.

12. Bio-economics of Fisheries

Bio Ecconomics modelling in Fisheries Biology is almost unheard of in Sri Lanka. However, an elementary model on beach seine has been produced by Perera and Jinadasa (1981) where they have analysed the Biology of anchovy, the amount harvested, production costs, break-even catch, marginal cost and the life span of the beach seine. Afterwards Dayaratne (1989, personal communication) had worked on the bio-economics of small pelagics for a number of years. Similarly, marine resources economics is a relatively young field of study. Even in developed countries like the USA, there are only a very few universities and professors who work on marine resources economic But as pointed out by Cope (1970 using the backward bending supply curve. Some fisheries have been become completely extinct due to high demand. In Sri Lanka there is a very high demand for prawns, lobsters and crabs, where demand exceeds the supply, a case very much similar to the one explained by Cope (1970). Therefore, studies on marine resources economics together with socio-economic aspects could shed new light on our marine resources and help in a better sustainable level of fisheries productivity in Sri Lanka.

13. Acknowledgements

I wish to thank Professor W. E. Ratnayake for inviting me to write a review paper on the marine fisheries research in Sri Lanka and for correcting the manuscript, and Sriyani Hewaratne for typing the manuscript. I also greatly appreciate the criticisms and subsequent information provided to improve the manuscript by Mr. B. D. L. Joseph of BOBP.

References

Administrative Report 1940-50. Director of Fisheries, Dept. of Fisheries.

Amarasiri, C. and B. D. L. Joseph 1985. An analysis of length frequency data of Skipjack tuna (*Katsuwonus pelamis*) from gill net fishery using LEFAN Programme. J. Nat. qA. Res. Agency **32: 1 / 2.**

Andrews, T. J. 1978. Personal Communication

Baranov, V. 1926, On the question of the dynamics of the fishing industry. Byull. Rybn. Khoz. **8:** 7-11.

Baughlet, M. 1985, Stock assessment of the king fish *S. commersoni* inhabititg the coastal waters of Djbauti Republic and state of the fish stocks. UNDP. FAO Project Report. FI. RAB/83/P23/INT/18.

Canagaratnam, P. 1965, Coastal Fisheries. Bull. Fish. Res. Stn. **18 (2)**: 53-57.

Collette, B. B. and 1978, Personal Communication.

Cassie, R. M. 1954, Some uses of probability paper in the an alysis of size frequency distri bution. New Zealeand. J. of Fish. **1954:** 513-521

Collette, B. B. and L. . Nauen, 1983, FAO species catalogue Scombrids of the world. FAO Fish. Synopsis (125) **Vol. 2** 137p.

Cope, P. 1970, The backward bending supply curve of the fishery industry. Scotish. J. of Politieal Economy. **32** No. (10): 69-70.

Currey, J. R. 1984, Is it mid plate platelet. J. Nat. Aq. Res. Agency **31:** 31-51.

Cushing, D. H. 1968, Fisheries Biology. A study in the population dynamics. Uni. Wisconsin Press, Madison. Wis. 200p.

Dajoz, R. 1971, Intriduction to Ecology. Hodder and Stoughton, London, 415p.

Dayaratne, P. 1985 a, Status of the Sardine stocks on the west coast of Sri Lanka. J. Nat. Aq. Res. Res. Agency **32,** Nos. 1 & 2.

——do——1985 b, Some observations on small meshed gill nets fishery in Negombo and Chilaw, J. Nat. Aq. Res· Agency **32.** Nos. 1 & 2: 66-82.

Dayaratbe, P. 1988, Gill net selectivity of *Amblygaster sirum* Asian. Fish. Sci. **2:** 71-82.

——do——1989 a, Age, Growth and Mortality stimates of *Scomberomorus commersoni* from the west coast of Sri Lanka. Report of the workshop on Tuna and Seerfishes in the northern Arabian Sea Region. **IPTP/89/Gen/16:** 72-82.

——do——1989 b, Age and Growth Estimation of *Stolephorus heterolobus* from daily growth rings in otoliths. Asian Fisheries Forum **2:** 417-420.

de Silva R. I. 1986, The Natural History of Sharks of Sri Lanka. Loris. **XVII** No. 4: 151-164

de Zylva, E. R. A. 1950, Administrative Report (part 1, 1940-47). Acting Director of Fisheries Govt. Press, available, NARA library.

——do—, 1952, Administrative report (part II, 1948-50). Acting Director of Fisheries Govt. Press, available, NARA library.

——do——1953. Adm. Report part IV of Asst. Director of Fisheries.

Dharmaranjan, 1971. The anatomy of *Otolithus ruber* (Bi and scha). Part I. The endo skeleton. J. Res. Asiatic Soc. Bengal. Sci. **2 (1)** : 1-72.

Evans, W. E. 1982. Distribution and differentiation of stocks of *Delphinus delphls* in the Norther eastern Pacific mammals in the seas. **Vol. IV.** Small Catacens FAO Fish. Series. No. 5.

Forster, R. 1988. A sampling program conducted by IPTP in Sri Lanka Report on work shop on small tuna, etc. **IPTP/87/Gen/13.** Colombo.

——do——1989, A preliminary analysis of the Billfish landings observed on the west coast of Sri Lanka. Report of workshop on small Tuna, Seerfish and Billfishes in the Indian ocean. **IATP/87/Gen/13/3/4.8.**

Gross, M. G. 1972, Oceanography—a view of the earth. Printice-Hall. Inc. NJ. USA.

Groot, S. J. de 1971, On the interrelationships between morphology of alimentory tract food and feeding behaviour in flat fishes. Netherland J. of Sea Research **5** (**2**): 121-196.

Gulland, J. A. 1975, Manual of methods for fish stock Assessment. Part. a. Fish population Analysis. FAO. Manual in fish. science. **No. 4 FRS/M4.**

Gunawardhana, T. P. 1971, The Hammerhead Sharks of Ceylon seas (Family sphyrnidae). Bull. Fish Res, Stn. **22.** Nos. 1 & 2: 1-4.

Illangakoon, A. 1990, Manuscript Report. Marine Mammal section. NARA Colombo 15.

Jayanth, H. D. S. 1989, Biology and Fishery of Pony Fishes in the Bolgoda Lagoon, Sri Lanka. M. S. Thesis, 200p. U.S.J.P. Library.

Jean, Y. 1955, Exploratory bottom trawling along with northeast coast of Ceylon during south west monsoon Fish. Res, Stn. Progress Report 1955-56 1 & 2:11-17.

Jinadasa, J. 1971, Taxonomic Notes on a Collection of flying fishes from Ceylon waters. Bull. Fish. Res. Stn. **21:1**

——do——1972, Bionomics of the flying fish *Hirundichthys coromandelensis* Hornell. M. S. Thesis. 151p. U.S.J.P. Library.

——do——1984, The age structure maturity fishery and the resources of seer (*Scomberomorus sp*) in waters north of Negombo, Sri Lanka proceedings Sri Lanka Association for Advancement of Sci. **40:55-5.**

——do——1985 a, Species composition, Size ranges and Abundance of sail fish and marlins caught in the waters of Negombo. Sri Lanka Association for the Advancement of Sci. Ann. Sess. **41** (i):80

——do——1985 b, The predators of the flying fish (*H. coromandelensis*) and its suitability as a tuna long line bait fish Vidya. J. of Arts. Sci. and Letter. Jubilee Issue.

Joseph, B. D. L. 1974, Preliminary report on fishing with purse seine and lampara nets for smaller pelagics around Sri Lanka. Bull. Fish· Res. Stn. **25.** Nos. 1 & 2.

——do——1975, Purse seines for small pelagics around Sri Lanka. Bull Fish. Res. Stn. **26** No. 1 & 2: 31-43.

——do——1977, Red Bait (*Dipterygonatus leucogrammicus*. Bleeker). Resources in the western coastal waters (7-8N) of Sri Lanka. Bull. Fish. Res. Stn **27**: 1 & 2, 1-9.

——do——1984, 200 mile exclusive economic zone and fishery development in Sri Lanka. J. Net. Aq. Res. Agency **31**:52-57.

——do——1984, Review of tuna fishery in Sri Lanka. **IPTP/84/WP/10.**

——do——and C. Amarasiri, 1987, Preliminary study on bill fish from Sri Lanka. Paper presented at the Export Consultation on stock Assessment, Colombo, Sri Lanka, **TWS/86**

Karunasinghe, W. P. N. 1990, Some aspects of biology and fishery of Trenched sardine *Amblygaster sirum* (Piscess: Clupeidae) from the coastal waters around Negombo Sri Lanka. Thesis submitted for M. Phil. Degree U. of Kelaniya

——do——and M. S. J. Wijeyaratne, 1990, Selectivity estimates for *Ambligaster sirm* (Clupeidae) in the small meshed gill net fishery on the west coast of Sri Lanka. Fisherics Research **8** : 1-7.

Maldeniya, R. and B. D. L. Joseph, 1988, Recruitment and migratory behaviour of yellow fin tuna (*T. albacaris*) from the western and southern coast of Sri Lanka. *I*P**TP/88/WP/17**

Mendis, A. S. 1965a, The Trawler fishery. Bull. Fish. Res. Stn. **17.** No. 2: 268-274.

——do——1965b, Resiurces of Pedro and Wadge Bank. Bnll Fish. Res. Stn. **18** (**2**): 47 51.

——do——1968, Stern Trawling on the Wagde Bank with 235 ton. Trawlers. Proceedings. 13th session. **IPFC/C68/Sym 34.**

Munasinghe, N. L. R. 1967, Seasonal variation in the distribution and availability of Carangids ('Paraw' & 'Parati') in the Wadge Bank. Bull. Fise. Res. Stn. **20.** No. 2:91-200

——do——1970, Evaluation of stern trawler operation in the Wadge Bank for economic Exploitation of its Demersal fish resources. Bull. Fish Res. Stn. **Vol. 21.** No. 2:97-111.

——do——1972, The influence of light on diurnal behaviour of Carangids in the Wadge Bank Bull. Fish Res. Stn. **23.** No. 1.

——do—1977, A description of some dee0 sea fishes from the gulf of Mannar and adjacent waters. Bull. Fish. Res. Stn. **27. Nos. 1 / 2:** 55-81.

Munro, I. S. R. 1955, Marine and Freshwater Fishes of Ceylon. Dept. of External Affairs, Canberra.

Nielson, S. and E. A. Jensen, 1957, Primarly orgatic production. The autotrophic production of organic matter in the ocean. Galathea. Repti. **1**:49-136.

Odum, E. P. 1959, Fundamentals of Ecology, 2nd Edition Sounden, London.

Paunella, G. 1971, The Otoliths Daily growth layers and periodical patterns. Science **173:** 1124-1127.

——do——1974, Otolity Growth Patterns: an aid in age determination in temperate and tropical waters. In. T.B. Bagenal (Editor). The aging of fish. Unwin old working. England.: 28-39.

Pauly, D. and David. 1981, ELEFAN Ia. BASIC program for the objective extraction of growth parameters from length frequency data. Marine Rcsearch **28** (4):205-211.

Perera, K. M. L. and J. Jinadasa. 1981, A Bio-economic model of the exploited stock of the Anchovy resource of the southwest coast of Sri Lanka. SLAAS. ANN. Sessions. (Apbstract) 37(i): 44-45.

Perera, W. V. J. 1987, The productivity of Bolgoda Lake. M.Sc. Thesis, U. of S. J. P. Library, 250p.

Prasad, R. R. and V. K. Nair, 1960, A preliminary account of primary production in relation to Fisheries of the inshore waters of the Gulf of Mannar. Indian J. of Fisheries **7:** 165-8.

——do—1963, Studies on organic production. I. Gulf of Mannar. J. Mar. Bio. Ass. India. **5** (i): 1-26.

Raymont, J. G. 1943, Plankton and productivity in the oceans Macmillan, Pargamon press. N.Y. 265p.

Rhyther, J. H. 1969, Photosynthesis and fish produc'ion in the sea. Science. **166:** 72-76.

Ricker, W. 1975, Dorporation and Interpretation of Biological statistics of Fish Population Dynamics. Fish. Rcs. Bull. Canada. 191p.

Roigers, S and J. Jinadasa 1988. Prey partioning among juvenile flatfish ICES 1988, Poster 54.

Schaefer, M. B. 1954, Some aspects of the dynamics of populations important to the management of the commercial marine fishes. Bull. Inter American Tropical. Tuna Com. **1** (2)

1 No. 2.

Schaefer, M. B. and R. J. H. Beverton, 1963, Fishery dynamics their analysis and interpretation. The sea. Vol. 2. NY.

Siddeek, M. S. M., Joseph, L., Jayasooriya, P. M. A., W. P. N. Karunasinghe,)1985), A preliminary analysis of length frequency data of *Amblygaster sirm* frpm Negombo, Sri Lanka using ELEFAN program J. Nat. Aq. Res. Agency **32** (**1** / **2**): 46-57.

Sivalingam, S. and Medcof, 1955, Study of Wadge Bank Trawl Fish. Res. Stn. Progress Report No. 1 & 2: 10-24.

——do——1957, General features and productivity of the Wadge bank trawler fishery. Bull. Fish. Res. Stn. Ceylon. **6:** 1-23.

Sivalingam, S. 1964, Assessment and possible development of the fishery resources of Pedro Bank. Bull. Fish. Res. Stn. **17** (**1**): 33:148.

——do——1966, Wadge Bank Trawl Fishery studies. Part I Bull. Fish. Res. Stn. **19** (**1** / **2**): 9-13.

——do——1966. Wadge Bank Trawl Fishery studies Part II. Bull. Fish. Res. Stn. **19** (**1** / **2**): 19-23.

——do——1969, Wadge Bank Trawl fishery studies. Part III. Rull. Fish. Res. Stn. **20** (**1 / 2**): 27-39.

Sivasubramaniam, K. 1964, Predation of tuna long line catches in the Indian ocean by killer shark. Bull. Fish. **17** No. 2: 221-236.

——do——K, 1964, Predation of tuna long line catches in the Indian Ocean by killer whales and sharks. Bull. Fish. Res. Stn. **17** (**2**): 225-236.

——do——1965 a, Exploitation of Tuna in Ceylon coastal waters Bull. Fish. Res. Stn. **18** No. 2: 59-75.

——do——1965 b, A review of Ja ans Long line Fishery in the Indian ocean. Bull. Fish. Res. Stn. **17** (**2**): 274-

——do——1965 c, Off Shore znd Deep Sea Fishery for large Scombroids in the Indian ocean. Bull. Fish. Res. Stn. **17**:**2**: 283-287.

——do——1966, Distribution and length weights relationships of tuna and tuna like fishes around Ceylon. Bull. Fish. Res. Stn. **19** (**1 / 2**) 27-47.

——do——1969 a, New evidence on the distribution of predatory pelagic sharks in the tuna grounds if the Indian Ocean. Bull. Fish. Res. Sṭn **20** (**1**): 65-72.

——do——1969 b, Occurences of oriental Bonito (*S. orientalis*) in the inshore waters of Ceylon Bull. Fish. Res. Stn. **20** (**1**): 73-79.

——do——1969 c, New evidence on the distribution of predatory pelagic sharks in the tuna grounds of the Indian Ocean. Bull. Fish. Res. Stn. Cey. 20:1.

——do——1971 a, Surface and subsurface fisheries for young and immature yellow find tuna around Ceylon. Bull. Fish. Res. Stn. **22**: 1

——do——1971 b, Apparent abundance of yellow fin and big eye tuna in the inshore and near oceanic ranges ground Ceylon. Bull. Fish. Res. Stn. **22** (**1 / 2**): 23:38.

——do——1971 c, Ceylon's tuna long line fishing effort and catch distrifution in the Indian ocean. Bull. Fish. Res. Stn. Col. **22** (**1 / 2**) :39-46.

——do——1971 d, An areal survey for surface tuna reslurces around Ceylon. Bull. Fish. Res. Stn. **22** (**1 / 2**): 17-23.

——do——1972, Skipjack tuna (*K. pelamis*) in the sea around Ceylon, Bull. Fish. Res. Stn. **23** (**1 / 2**): 14-29.

——do——1975, Analysis of the xpt. Pole and line fishery conducted around Sri Lanka by Nidiro Fishing Company of Japan. Bull. Fish. Res. Stn. **26** (**1 / 2**): 61-82.

——do——1978, Palagic fish resources of Sri Lanka and its present level of exploitation with special reference to off shore and deep sea waters. **Bull. Fish. Res. Stn. 28**: 54-59.

——do——and R. Maldeniya, 1985, The demersal fisheries of Sri Lanka. **BOBP/WP/41.**

Suraweera, S. L. and R. Maldeniya, 1990, Exploratory fishing for large pelagic species in Sri Lanka. **BOBP/REP/47/19p**.

Taubert, B.D. and D.W. Coble. 1977, daily rings in otoliths of three species of Lepoanis and *Tilapia mossambica*. Fish. Res. Bull. Canada **34**: 332-340.

Tennent, E. 1861. Sketches of Natural History of Ceylon, London.

Trewavas, E. 1962. A basis for classifying the Sciaenid fishes of Tropical west Africa Ann. Mag. Nat. List. Ser.

Weerakoon, A. C. J. 1965. Ceylon Fisheries: Past and Future Bull. Fish. Res. Stn. **17** No. 2.

Weerasooriya, K. T. 1977, Trawl nets presently used in the coastal waters of Sri Lanka. Bull. Fish. Res. Stn. **27** (**1 / 2**): 19-29.