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MONITORING AND ASSESSMENT OF THE OFFSHORE FISHERY IN SRI LANKA

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ABSTRACT

The present study evaluates the trends in offshore fishing activities and reviews the fisheries data collection programme in Sri Lanka from 1994 to 2004. The analysis is based on data from a large pelagic database (*PELAGOS*) of the National Aquatic Resources Research and Development Agency (NARA). The study reveals a continuous increasing trend of total offshore fishery production in Sri Lanka. Total annual production has decreased from 54,440 to 51,790 tons in the period 1994-1996 while it has increased up to 127,089 tons in 2004. Further total effort and catch per day (CPUE) increased gradually throughout the period considered. The increased landings are largely due to increased tuna catches but continuously increasing billfish landings are also evident. The shark catches show a clear declining trend in the western zone after 1998 and in both the western and southern zones after 2001. Longline and gillnets are the more frequently used gear types of the fleets that were studied. Due to lack of information on effort or catches by gear type, it is difficult to interpret the relative changes in CPUE based on effort or gear type. Length frequency analysis indicates that the dominant length classes of skipjack tuna and yellow fin tuna in the commercial catches lie in the region of 60.0 – 65.0 cm and 50.0 – 55.0 respectively. The analysis performed shows that the current data collection programme is inadequate for assessment purposes. The study attempts to identify some limitations of the sampling programme and comes up with suggestions for further improvements. Introduction of captain's logbooks, expansion of the biological sampling coverage and training for the data collectors are some major points highlighted in this study.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLE

1 INTRODUCTION

Marine fisheries in Sri Lanka can be broadly categorised into coastal and offshore fisheries. The coastal fisheries can be further divided into pelagic and demersal fisheries. Coastal fisheries still account for about 67% of the marine fishes caught, but there are some uncertainties regarding further expansion of coastal fishing activities (Wijayaratne 2001). Since it became clear that the coastal sector had limited capacity for further expansion, many attempts were made to expand the fishing more towards the offshore areas (Maldeniya 1998). The most effective phase of development began in the early 1980s partly due to government efforts to promote the offshore fisheries by introducing 80 9.8 m boats to conduct multi-day fishing operations in offshore waters. Since then multi-day offshore fishing has developed rapidly and this had caused a substantial increase in marine fish production in Sri Lanka (Maldeniya and Amarasooriya 1998, Samaraweera and Amarasiri 2004).

Fish is a renewable natural resource and proper management is required for its sustainable utilisation (Paul *et al*. 2002). According to the definition developed by Cocharne (2002), fisheries management is “the integrated process of information gathering, analysis, planning, consultation, decision-making, allocation of resources and formulation and implementation, with enforcement as necessary, of regulations or rules which govern fisheries activities in order to ensure the continued productivity of the resources and the accomplishment of other fisheries objectives”. Fisheries management involves a complex and wide-ranging set of tasks. The underlying goal is to achieve optimum benefits from the resources in a sustainable manner. The objectives of fisheries resource management are often of social, economic, institutional and/or political origins. Therefore, the primary concerns of fisheries management should address the relationship of fisheries resources to human welfare and the conservation of the resources for use by future generations (Cocharne 2002).

Management of fisheries cannot be effective without the availability of reliable fisheries statistics. This information is needed to monitor the social, economical, biological and environmental performance of the fishery (FAO 1999, Paul *et al*. 2002). The information needs for fisheries management are both short-term and long-term. Short-term information is needed for decision-making while long-term biological information is needed to differentiate between natural and human induced changes in fish stocks and ecosystems (Wolf *et al*. 1987). In many parts of the world, the main supply of such information is through monitoring of fisheries input (fishing effort) and output (catch), i.e. through fishery-dependent monitoring. Fishery-independent monitoring through experimental surveys is difficult to maintain by developing nations, as they are expensive and often they cannot generate the amount of data needed in order to evaluate the status of the resources or changes, especially not in highly diverse tropical marine coastal environments. Therefore, long-term monitoring of fish stocks is necessary for proper fisheries management (Paul *et al*. 2002). The aim of a fishery-dependent monitoring system is to collect at least three essential parameters in fisheries statistics, catch (C), fishing effort (f) and catch-rate (C/f). Catch and effort data collection systems maintained to address information needs for fisheries management vary in their degree of administrative and statistical sophistication (FAO 1999).

Over the past few decades, the methodological way of fisheries monitoring programmes, sampling strategies, data collection, data storage and also data handling has been consistently addressed by developing nations to build capacity in fisheries management (Paul *et al*. 2002). However, Paul *et al.* (2002) indicated the required precision of existing data collection systems in many developing countries show inefficiencies , which lead to poor quality of sampling data. The answer to such inefficiencies may not be just to gather more data. Instead, the answer may lie in the development of management practices that maximise the use of the existing data, information and knowledge on catch and fishing effort and in the improvement of the existing data collection programmes (Paul *et al*. 2002).

1.1 Status of fisheries statistics collection programme in Sri Lanka

In Sri Lanka, a wide fishery statistics collection programme was put in place by the Department of Fisheries and Aquatic Resources (DFAR) in the late 1940s, with the deployment of 12 permanent fisheries inspectors in 20 fishery districts. Since then this programme has been subject to several modifications. The present system of stratified sampling of landings was designed by FAO in the early 1970s (Banerji 1976) when the fishing industry was simpler and barely extended beyond the continental shelf. Since then the fisheries have expanded and undergone large changes especially with the introduction of offshore fishing activities in the 1980s (Maldeniya 1998). Over 28,000 fishing crafts are now operating, including multi-day boats that remain at sea sometimes for 20-25 days (NARA 2003). But the sampling system has not kept pace with changes in the fishery and estimates are based on limited samples. Furthermore, data collection is considered a minor task among the many responsibilities of the field officers. Under the present DFAR sampling scheme, data collection covers some tuna boats but there is no comprehensive data collection on tuna fisheries. Catch statistics by species are provided only for the coastal fishery. Except for yellowfin and skipjack tuna, catches of all other tuna varieties and billfish are grouped together as “other blood fish”. Catch data by type of vessel or gear are not available (Maldeniya 1996).

After the inception of the National Aquatic Resources Research and Development Agency (NARA) in 1981, research staff of the Marine Biological Resources Division (MBRD) of NARA have started a fisheries data collection programme paying special attention to tuna catch and effort statistics. But the sampling programme was limited to a few landing centres in the northwest, west, southwest and southern areas. In 1987, NARA was able to establish a comprehensive sampling programme with technical and financial assistance from the Indo Pacific Tuna Programme (Forster 1987). In 1994, this sampling programme was further strengthened and expanded to the east coast (Williams 1995). Twelve samplers were placed at major fish landing centres in the west, southwest, south, southeast, east and northeast to collect data on catch, effort by craft/gear combination and length measurements for all tuna species, billfish and seer fish in the large pelagic catch. The programme provided a database and a reporting system (Maldeniya 1998).

Updating the existing sampling programme began in late 2004 with technical and financial assistance from the Indian Ocean Tuna Commission (IOTC) and the Overseas Fishery Cooperation Foundation of Japan (OFCF). The objective of this collaborative project involving NARA, IOTC and OFCF is to strengthen data collection and processing systems on Sri Lankan billfish and tuna fisheries and thereby produce more accurate effort and catch estimates (e.g. by area and species) and increase the amount and quality of size frequency data for these species (IOTC 2005b).

1.1.1 Structure of the existing data collection programme

The concept of sample based estimation is the base for the existing sampling programme, which was started in 1994. It was basically designed to cover the large pelagic fish species especially coming from offshore multi-day boats and in a few cases coastal day boats are also targeted (Williams 1995). Data are collected according to stratified random sampling. Sampling stratification mainly consists of spatial strata (landing sites), technical strata (vessel categories and gear types) and temporal strata (months). A recent modification made by the IOTC / OFCF programme is that in a few cases time within the day is used to record the fishing strategy, morning or evening.

Spatial strata:

The coastline is divided into seven statistical zones (Appendix 1). In each zone major and minor landing sites have been identified and complete sampling is carried out in the major landing sites, while effort data is collected in the minor sites on a regular basis.

Technical strata:

(a) Vessel types
Vessel type is determined on the basis of the size and construction of the vessel. At present six boat types are operating in the large pelagic fishery (Appendix 2). Two boat categories (UN1 and UN2B) are used for coastal fishing activities and the other categories are considered to be involved in offshore fishing activities.

(b) Gear types
A range of fishing gears is used in the large pelagic fishing activities in Sri Lanka (Appendix 3). But gillnet or gillnet cum longline are the most widely used gears in the offshore fishing activities.

Temporal strata:

Data are collected on a daily basis and estimates are carried out on a monthly basis.

- Human resources

A team of 12 data collectors were recruited at the beginning of the sampling programme in 1994 and assigned in pairs to the major landing centres in the west, southwest, south, southeast, east and northeast statistical zones. Under the IOTC/OFCF project another six data collectors were recruited in late December 2004. Two were assigned to the northwestern statistical zone, which had not been covered previously, and the others were assigned to the west and southwest statistical zones in pairs.

All the data collectors live inside their corresponding statistical zone. The data collectors work every day except on weekends and national holidays according to a timetable provided at the beginning of each month. Apart from the data collectors, three research officers and two data entry operators are presently working under this sampling programme. Research officers monitor samplers, prepare their time schedule and screen the data before it is entered into the computer database and prepare the time schedule for the samplers.

- Allocation of sampling sites and days

The selection of landing sites for sampling is done randomly. At the beginning of each month, the responsible research officer prepares the timetable for sampling. Sites are visited on a rotational basis according to the timetable. Sometimes adjustments will be made in the timetable due to the seasonality of the fishing. The number of days allocated for landing sites may vary from one month to another.

- Data collected

Data collectors are supposed to collect following data at the landing sites:

1. Daily effort
Record the total number of landings as well as the total number of sampled crafts according to boat categories. According to recent modifications made by the IOTC /OFCF programme, samplers are supposed to record the boats' names and registration numbers. Data are recorded in a daily effort sheet (Appendix 4).

2. Catch data
The total catch of each species is recorded either by weight or numbers including unloaded fish. At the same time skippers are also interviewed to gather information about the type of fishing gears used during the trip. Catch and effort data sheets (Appendix 5) are used to record the data

3. Length weight data
Length and weight measurements are collected from the catches in the sampling boats as well as non sampling boats (biological sampling). The data are recorded on a length weight frequency data sheet (Appendix 7). Measuring tapes are used for length while weight is recorded individually or group wise depending on the field situation. According to the recently implemented programme (IOTC /OFCF), samplers should record the type

of weight and length according to a pre-defined code (e.g. lower jaw-fork length –LJFLT, gutted weight – GGT).

- Data storage

The framework of the large pelagic database (*PELAGOS*) (ACCESS 2.0) developed by (Williams 1994), is still used to store the raw data. This database was upgraded to ACCESS 2003 in 2005 under the IOTC/OFCF programme and is still being modified to fit with the updated sampling scheme and sampling forms.

Though large amounts of data have been collected, utilisation of these data for the purpose of fisheries management has been limited. The data are submitted to the IOTC which is an intergovernmental organisation mandated to manage tuna and tuna-like species in the Indian Ocean and adjacent seas. The main objective of data submission is to get advice to ensure appropriate management, conservation and optimum utilisation of stocks and sustainable development of fisheries based on such stocks (Sydnes and Normann 2003).

The data collection system in the Department of Fisheries has not been updated to reflect the changes that have occurred in fishing activities and estimates have been made with limited samples (Maldeniya 1998). Despite its limitations, the PELAGOS database maintained by NARA contains the best available information relating to offshore fishing activities in Sri Lanka.

1.2 Objective of the study

The main objective of the current study is to use the existing database (*PELAGOS*) to evaluate the status of the offshore fishery. Attempts are made to estimate total landings, catch per unit effort (CPUE), which can be considered as an indication of the status of the stocks utilised in the Sri Lankan Fishery. At the same time the limitations of the data will be discussed and suggestions made to improve it.

2 FISHERIES IN SRI LANKA

Sri Lanka is an island in the Indian Ocean southeast of the Indian sub-continent between 6-10° N latitudes and 80-82° E longitudes (Wijerathne 2001). The coastline of Sri Lanka is about 1770 km long and contains several bays and shallow inlets. Since declaration of a 200 mile Exclusive Economic Zone (EEZ) in 1978, Sri Lanka has had sovereign rights over about 500,000 km^2 of the ocean. Fishing takes place all around the coast, but primarily within the continental shelf which has a width rarely extending beyond 40 km and averaging 25 km, with a total area of about 30,000 km^2. This is around 6% of the total area of the EEZ (Figure 1, Joseph 1999).

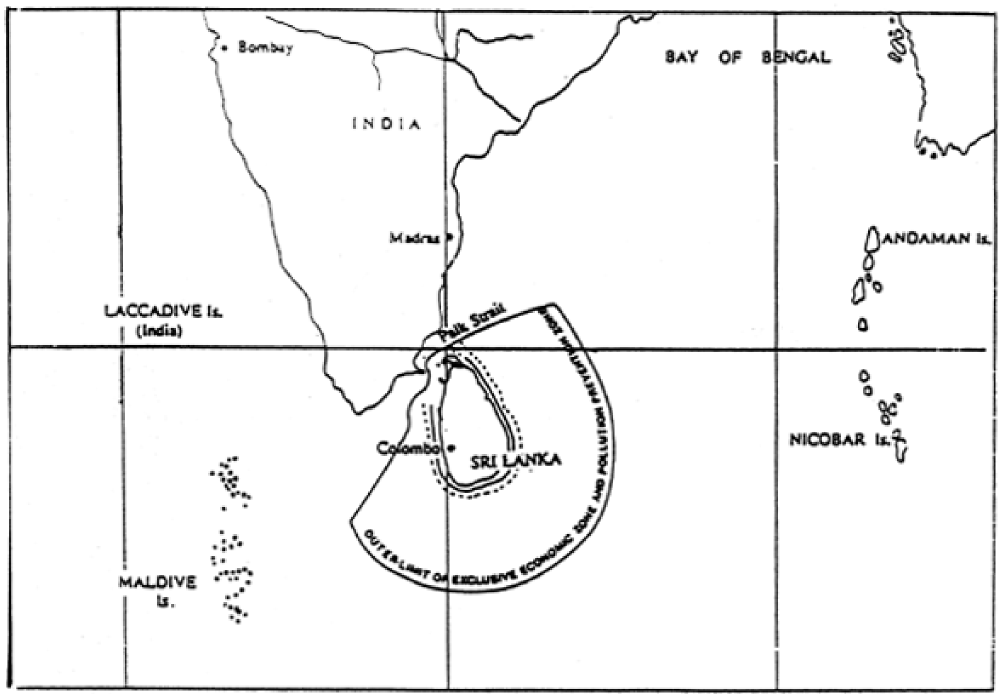


Figure 1: Sri Lankan territory and Exclusive Economic Zone (Survey Department of Sri Lanka 1988)

The climate is affected by the country’s insularity, proximity to the equator and the Indian Ocean. The rains are determined by monsoons and fishing seasons are generally associated with the two monsoons, the southwest monsoon from June to September and the northeast monsoon from November to March (Joseph 1999). The large-scale oceanic currents related to regional oceanic circulation dominate waters beyond the continental shelf. Winds and temperature differences control the currents and their general pattern changes seasonally. Off the east coast, currents are strongest during the northeast monsoon when they show an easterly trend while off the west coast they are strongest during the southwest monsoon and exhibit a westerly trend (FAO 1984a).

Though Sri Lanka is a tropical country with a high diversity of species, the narrowness of the continental shelf and the absence of up-welling limits the abundance and fisheries potential of marine fish species (Sydnes and Normann 2003). Marine fisheries in Sri Lanka are still conducted under an open access, common property regime and there is no active management in any sector of the fisheries (Joseph 1999).

1.1 Role of the fisheries sector

The fisheries sector in Sri Lanka is important in terms of income generation, employment, foreign exchange earnings and the provision of animal protein for the population (Sydnes and Normann 2003, Sugunan 1997). In 2004, fisheries accounted for 2.8% of the GDP and 2.6% of the GNP (MOF 2005). Estimates of employment in the fisheries sector are incomplete and vary depending on the sources. However, a reasonable estimate seems to be about 150,000 individuals engaged in fisheries including aquaculture and about 30,000 employed in related activities. In total, at least 700,000 individuals may depend on fisheries for their livelihood. However, during the past 10 years, the introduction of offshore boats has contributed to a substantial increase of employment in the fisheries sector (FAO 2005).

Export earnings in the fisheries sector have grown during the past few years, although the contribution of this sector to external trade still remains about 2%. The country exports mainly shrimps (40%), lobsters, crabs, bêche-de-mer, shark fins and frozen fish. The main markets are Japan, USA, Singapore and Hong Kong. The value of exports has increased from US$ 16 million in 1990 to US$ 94 million in 2004 (MOF 2005). The quantity exported increased from 3,162 tons in 1990 to 13,881 tons in 2004 (MOF 2005) including ornamental fish.

Fish also plays an important part of the diet among the Sri Lankans. According to Sydnes and Normann (2003), fish accounts for 65% of the animal protein consumed in the country. Due to increased production from offshore fishing, the annual per capita consumption has also risen in recent years and was 20.2 kg per person per year in 2002 (NARA 2003).

The fisheries sector is considered to be one of the major fields with potential for economic expansion (Sydnes and Normann 2003). The government has tried to further encourage growth by providing fiscal incentives such as duty concessions on raw materials, manufacturing fishing boats, and engines (FAO 2003a).

1.2 Marine fisheries

About 90% of total fish production in Sri Lanka comes from marine fisheries while the rest (10%) is from inland fisheries (Wijayaratne 2001). Finfish, shell fish, cuttle fish, sea cucumber, sea pens and sea weeds are the major fishery resources harvested from Sri Lankan waters. It has been estimated that the present level of fish production is around 300,000 Mt while the potential is around 500,000 Mt annually (FAO 2003a, FAO 1984b). Since the 1970s, marine fisheries in Sri Lanka have shown a drastic shift in the exploitation of the available fishery resources. Motorisation of craft, introduction of synthetic fishing gear, the establishment of the 200 mile EEZ, export demand, the economy of the country and civil disturbances have influenced most aspects of this industry. Three decades ago, demersal fisheries were the major fishing activity, and fishing was primarily by gillnets made of natural fiber, hand lines and beach seines. After that, pelagic fisheries became dominant with synthetic gillnets, longlines and purse seines (Dayaratne and Sivakumaran 1994)

1.2.1 The coastal fishery

The coastal fishery is the backbone of the marine fishery sector in Sri Lanka and it is mainly confined to the waters of the relatively narrow continental shelf area. Within the coastal waters, fisheries vary according to their distance from shore. In the inshore areas (up to 5 km) there are concentrations of small size pelagics, small demersals and non fin fish marine resources such as lobsters, crabs, shrimps and sea cucumbers. Sardinella and anchovies are dominant among the small size pelagics while pony fish and snappers are dominant among the small demersals found in this area. Medium size pelagics and large demersals are caught beyond the inshore area (Sydnes and Normann 2003).

Of the variety of gear used, small-mesh gillnets and beach seins are the main gear types used to exploit the coastal fish resources of the Island. Gillnets contributed over 80% of the landings while beach seines account for the rest (Wijayaratne 2001).

Approximately 28,000 fishing crafts are operating in Sri Lanka. Out of this, 87% of crafts are operated in the coastal fishery. Normally all the coastal fishing vessels are day boats and can be categorised into two major groups:

1. Traditional non-motorised crafts**:** This consists of outrigger canoes and wooden dug outs called orus and log rafts of different designs such as wallam, theppam and kattumarans. It has been estimated that 55% of all vessels belong to this category or about 15,600 boats.

2. Fiberglass reinforced plastic boats (FRP)**:** Most of the FRP boats are 18 feet and powered by an outboard engine. But there are some boats from 28 to 32 feet made of timber or fiberglass and powered by inboard engines. This category represents 32% (9,000 of boats) of all vessels in the inshore fishery (Wijayaratne 2001).

The coastal fishery sector was severely affected by the tsunami disaster on 26 December 2004. Due to this incident 16,101 coastal fishing crafts were destroyed, 7,105 vessels were damaged and 9,207 engines destroyed. Fishing gears of all the affected fishing crafts were also destroyed (MOF 2005).

The contribution of the coastal fishery was around 64% (163,850 tons) to the total fishery in year 2003 (MOF 2005). The coastal sector has contributed over 89% to the total fish production of the country during the early 1980s. The prolonged civil war situation in the northeast part of the country has adversely affected the coastal sector contribution to the total production (Wijayaratne 2001). According to a survey conducted in 1978-1980, the potential yield from coastal fish resources has been estimated at 250,000 tons per year with 170,000 tons (per year) from coastal pelagic species and 80,000 tons from demersal species (Blindheim and Foyn 1980).

1.2.2 The offshore fishery

Several attempts have been made to expand the fishing more towards the offshore areas since the 1960s (Maldeniya 1998). The most effective phase of development began in the early 1980s with the introduction of 80 9.8 m boats to conduct multi-day fishing operations in offshore waters. The success of the offshore fishing led to the conversion of many coastal day boats (8.8 m) into offshore multi-day boats, and the construction of new 10–11 m multi-day boats in the mid 1980s. Larger boats of 11.6–12.3 m also joined the offshore fishing fleet in late 1980s (Joseph 1999). At present all these types are actively engaged in offshore fishing activities in Sri Lanka.

Various types of fishing gears are used in the offshore fishery. Drift gillnets or drift net cum longline combinations became popular and well established in late 1980s (Joseph *et al.* 1985) This combination has contributed more than 95% of the fishing effort during that period (Maldeniya 1998). At the same time, fishermen on the southwest coast of Sri Lanka started to use purse seines and this also became popular very rapidly (Dayaratne and Sivakumaran 1994) by giving relatively higher effort contributions specially to the offshore fishing activities in the southern coast (Maldeniya *et al*. 1996). However, gillnets still remain the dominant fishing gear in the offshore fishery, while longline is carried out in most cases with the combination with gillnets. In gillnet operations, the number of net pieces per operation may vary from 100 - 150 with 5” to 6” mesh size and the number of hooks may be up to 700 but these numbers depend on the craft type. The troll lines, hand lines and purse seines are the other gear combinations, which are frequently carried out with, gillnets cum longline operations (Samaraweera and Amarasiri 2004).

With the development of multi-day crafts and gears, offshore fishing has expanded rapidly with a substantial increase of marine fish production in the country, especially since the 1980s (Maldeniya and Amarasooriya 1998). At present 35% of the total marine production is from offshore fisheries (MOF 2005). The offshore fishery mainly targets a large number of highly migratory species such as tunas, sharks and bill fishes (Joseph and Moyiadeen 1986). The tuna fisheries are dominated by the highly migratory skipjack and yellowfin tunas.

- Tuna fishery

Sri Lanka is one of the oldest and most important tuna producing island nations in the Indian Ocean (FAO 1985). Over the past years, tuna fishing has undergone many changes. The tuna fishing activities are carried out both in coastal and offshore ranges. It has been reported that a fleet of around 3,100 inboard motor (IBM) vessels in the size range of 8.8 – 18.3 m, some 300 to 400 5.5 - 7.2 m boats with outboard motors (OBM) and a few mechanised traditional vessels are engaged in tuna fishing operations (Maldeniya and Amarasooriya 1998, Maldeniya *et al*. 1987).

Tuna and tuna-like species are a major component of the large pelagic fisheries in the country. According to Campbell *et al*. (1998) Sri Lanka has a well-established offshore/oceanic tuna fishery, with a fleet of locally designed and constructed, multi-day boats sailing up to or even beyond the EEZ. Further surveys and exploratory fishing (Bay of Bengal Programme of the FAO and NARA) have shown a high density of tuna aggregation in the coastal and offshore waters around the Sri Lanka (Sydnes and Normann 2003, Maldeniya and Suraweera 1991).

Exploration and exploitation of the fishery resources in the Indian Ocean area over the past three decades have shown that the tuna resources in Sri Lanka consist of several species. They are yellowfin tuna (*Thunnus albacares*), big eye tuna (*Thunnus obsesus*), skipjack tuna (*Katsuwonus pelamis*), kawakawa (*Enthynnus affinis*), frigate tuna (*Auxis thazard*) and bullet tuna (*Auxis rochei*) (Joseph *et al*. 1985, Samaraweera and Amarasiri 2004) The latter three species are generally considered to be insular and with localised migratory habits. The first three species are known to be widely distributed in other parts of the Indian ocean and the limits of distribution of the stocks of these oceanic species are not clearly understood (Sivasubramaniam 1985). Among tuna species, skipjack is dominant in offshore areas, followed by yellowfin (Maldeniya and Amarasooriya 1998).

Gillnets alone or in combination with other gears, are the main fishing gear used in tuna fisheries and contribute more than 95 % to the total fishing effort. In the south, southeast and east gillnets have been used alone, while in the west and the southwest they are used in combination with longlines (Maldeniya and Amarasooriya 1998). Leonard (2003) also mentioned that 95% of Sri Lankan-owned vessels used gillnets to catch tuna and also that they don’t have the technology to catch fish in deep waters. According to him this causes a severe decrease of tuna catches during the monsoon periods. However, exports of chilled large tunas, such as yellowfin and bigeye, have become an attractive venture in recent years. The quality of fish especially proper handling and storing are important factors to get a high price on the export market. As a result, longlining for tuna is becoming popular in Sri Lanka because it seems that the quality of fish caught by the longline is much higher than of fish caught in gillnets (Maldeniya 1996, Leonard 2003).

According to Subasinghe (2004), tuna accounts for nearly 9% in value of the global trade in fish and fishery products and tunas are also becoming a species of special economic interest to many countries bordering the Western Indian Ocean. Tunas enjoy a very good export market as sashimi or loins. As the production of Sri Lanka is not enough to cater to the growing market for quality tuna abroad, fresh tuna is imported from the Maldives and re-exported (Subasinghe 2004).

- Shark fishery

Sharks have traditionally contributed to the marine catch in Sri Lanka. Originally the fishery focused on demersal species with localised distribution. With the expanding offshore fishery in 1980s there were increased landings of pelagic sharks (Joseph 1999). The fishery of pelagic sharks extends well beyond the EEZ, particularly off the western and southern coasts. Offshore multi-day boats operating in these areas undertake fishing trips lasting 10 to 15 days and venture well outside the EEZ. Some of the larger boats make only one trip per month (25 to 30 days fishing trip). These boats mainly target pelagic sharks, using drift longlines (Joseph 1999, Amarasooriya, 2001).

A total of 46 species of pelagic and demersal sharks have been identified from commercial landings (Amarasooriya 2001). The total number of shark species recorded from Sri Lanka is 60 but only about 12 species are of commercial importance (Joseph 1999). Of these, silky shark (*Carcharhinus falciformis*) may account for more than 50% of the landings by weight and this species is abundant in coastal as well as offshore areas (Amarasooriya 2001). Oceanic whitetip shark (*Carcharhinus longimanus*) and hammerhead shark (*Sphyrna spp*) are the next two dominant species and seem to be more abundant in offshore areas. The rest of the species such as blue shark (*Isurus oxyrinchus*), shortfin mako (*Isurus oxyrinchus*) and the thresher shark (*Alopias spp*) are more mainly found in sub-surface waters (Joseph 1999).

- Billfish fishery

The group of billfishes (family Istiophoridae) includes marlins, sailfishes and swordfishes. Five species of billfishes have been identified in local commercial landings, black marlin (*Makaira indica*), blue marlin (*Makaira nigricans*), striped marlin (*Tetrapturus audax*), sailfish (*Istiophorus platypterus*) and swordfish (*Xiphias gladius)* (Joseph *et al*. 1985, Samaraweera and Amarasiri 2004). The occurrence of another billfish species named as shortbill spearfish (*Tetrapturus angustirostris*) has also been reported in the commercial catches (Joseph and Amarasiri 1986, Maldeniya *et al*. 1987, Foster 1987) but does not appear to be common on the other studies (Maldeniya *et al*. 1996, Samaraweera and Amarasiri 2004).

The catch of billfish in the offshore fishery is generally considered as secondary to the tunas or as by-catch (Anon 1997). Prior to the development of the offshore fishery, studies on billfish and their fisheries around Sri Lanka were limited and mainly based on the landings made from coastal waters (Maladeniya *et al*. 1996). With the expansion of the fishing range of the large pelagic fishing fleet in the early 1980s, billfish catches increased from 4,000 tons in 1984 to 11,000 tons in 1993 (Maldeniya *et al*. 1996). At present, the contribution of billfish to the fishery is significant, and the catch has increased considerably over the years highlighting their importance in the large pelagic/offshore fishery in Sri Lanka (Samaraweera and Amarasiri 2004). Japanese and Taiwanese distant water fishing fleets are the main contributors of billfish catches in the Indian Ocean. However, Sri Lanka contributed substantially high production to the total Indian Ocean production compared with the other countries, which exploited billfish resources in the Indian Ocean (Samaraweera and Amarasiri 2004). The catch of billfish is often poorly recorded, being lumped together into a single category, misidentified or the fish is discarded (Campbell *et al*. 1998). Knowledge of Indian Ocean billfish biology and fisheries, the status of billfish species remains unclear due to lack of a targeted fishery on these stocks and uncertainties in the data available. The annual production of billfish in the Indian Ocean has been estimated to be in the region of 50 – 55,000 MT and the contribution of Sri Lankan bill fish is considered around 32% (Campbell *et al*. 1998).

3 METHODOLOGY

3.1 Collection of catch and effort data

In Sri Lanka, fisheries statistics are collected by random port sampling. Sampling stratification mainly consists of spatial strata (landing sites), technical information (vessel categories and gear types) and temporal information (months). The coastline is divided into seven statistical zones (Appendix 1) and 12 permanent data collectors have been assigned to cover these zones. Total sampling is carried out in the major landing sites, while effort data is collected at the minor sites on a regular basis. Data are collected mainly according to the vessel types and are supposed to consider the gear type whenever possible. Vessel type is determined on the basis of the size and construction of the vessel and there are three major fleet groups operating in offshore fishing activities (Appendix 2). A range of gears are also used in the offshore fishing activities and these are summarised in Appendix 3. Data are collected by random sampling of boats in each landing site. Table 1 shows the set of data collected at the landing site and the data sheets, which are used to record the data.

Table 1 : Type of data recorded in the sampling programme.

Type of data	Remarks	Data sheet
Daily effort	Record the total number of landed boats and sampled boats on each category in a particular sampling site on a particular sampling day.	Daily effort form (A) (Appendix 5)
Catch and effort data	Collect information on: • The species composition of the catch in number and /or weight • Interviews are supposed to be carried out to collect a) The fishing techniques (gear) used in the trip b) Number of crew members c) Gear information (no. of hooks, net pieces) d) Information about bait	Catch and effort form (B) (Appendix 6)
Biological data	Record the individual fish length both from sampled and non sampled boats. Weight of fish is recorded either individually or group wise depending on the field situation	Length weight frequency form (C) (Appendix 7)

3.2 Status of the available data

All the data mentioned above have been stored in the *PELAGOS* database maintained by the NARA. In this study, data from 1994 to 2004 were used to determine trends in the offshore fishery. In each year of the time period, 550 to 650 catch records (data sheets) were entered into the database and each record has represented the catch details of 5-10 offshore boats. The data are recorded into eight categories of fish some of which are highly migratory. These categories are tuna (skipjack tuna, yellowfin tuna, bigeye tuna, frigate tuna, bullet tuna and kawakawa), marlins (black marlin, blue marlin, striped marlin and shortbill spearfish), seer fish (Narrowbarred and Wahoo), swordfish, sailfish, sharks (silky shark, blue shark, white tip shark, spot tail shark, thresher shark and hammerhead shark), rays (manta ray, devil ray, eagle ray and guitar fish) and other bony fish.

3.3 Data analysis

In the present analysis, the total catch of a boat during one fishing trip is considered as a sampling unit. The following steps were carried out to obtain the total offshore production.

3.3.1 Estimate of the total annual production

Step 1 - Estimate the mean landing (average weight of landed catch) by class of vessel of one species in one zone during month

$$\overline{L}_{svmz} = \frac{\sum_{b=1-n_{vmz}} L_{sbmz}}{n_{vmz}} \qquad [1]$$

Where,

$\overline{L}_{svmz}$ = mean landing size of species (s) in month (m) by vessels of class (v) in zone (z)

L_{sbmz} = landing size of species (s) in month (m) by boat (b) in zone (z)

n_{vmz} = number of vessels of class (v) sampled in month (m) in zone (z)

Step 2 - Estimate the number of landings by a class of vessels in a zone during month

$$\overline{Q}_{vmz} = \frac{\sum_{b=1-n} Q_{bmz}}{n_{vmz}} \qquad [2]$$

Where,

$\overline{Q}_{vmz}$ = mean number of landings in month (m) by vessels of class (v) in zone (z)

$\overline{Q}_{bmz}$ = number of landings in month (m) by boat (b) from zone (z)

n_{vmz} = number of vessels of class (v) sampled in month (m) in zone (z)

Step 3 - Estimate monthly production of one species from zone

$$P_{smz} = \sum (\overline{L}_{svmz} . \overline{Q}_{vmz} . N_{vmz}) \qquad [3]$$

In here v - UN2B, UN3A, UN3B

Where,
P_{smz} = production of species (s) in month (m) from zone (z)
N_{vmz} = number of vessels of class (v) actively fishing in the fishery in zone(z) during month (m)

From 1994 to 1999 N_{vmz} were based on the survey done by the Ministry of Fisheries and Aquatic Resources in 1994. Under the guidance of the IOTC / OFCF programme, NARA carried out a boat census in 2004 and these data were used to back calculate the N_{vmz} to 1999 by assuming a constant rate of decrease year according to boat categories and zones. As the N_{vmz} was not updated on a monthly basis, it was considered as constant in all months within a year.

Step 4 – Annual production of a species within a zone

$$S_z = \sum_{m=1-12} P_{smz} \qquad [4]$$

Where
S_z = production of species in zone (z)

Step 5 – Total offshore production

Total offshore production is estimated by summing the annual offshore production in zones.

3.3.2 Estimate of the fishing effort

As there is no information regarding types of gear used and their frequency during a fishing trip the number of fishing days were considered to be a means of estimating fishing effort.

$$E_m = D_{fm} \cdot N_v \qquad [5]$$

Where
E_m = Total monthly fishing effort (Days)
D_{fm} = Total number of fishing days (f) during month (m)
N_v = Total number of vessels actively engaged in a fishery during the month

Annual Fishing Effort (E_z) was estimated by summing monthly effort

$$E_z = \sum_{n=1-12} E_{mn} \qquad [6]$$

Due to lack of information on effort by gear type, no attempt was made to calculate total effort according to different gears.

3.3.3 Estimate of the catch per unit effort

Catch per unit effort (CPUE) was estimated in the following way.

CPUE (Catch per day in kg) = Total annual production /E_z [7]

In order to estimate the catch per boat per day (kg) for three different boat categories one has to consider the total catch per trip and average fishing days for a fishing trip. Then the catch per boat per day in each year was compared.

Data were analysed by each statistical zone such as northwest, west, southwest, south, southeast, east and northeast (Appendix 1). The contribution from the northeast zone to the total offshore fishery production was negligible and there was no offshore fishing activity in the east zone at all. Therefore southern (combination of southwest, south and southeast) and western (northwest and west) zones were considered as the two major zones in the analysis. The total catch, effort and catch per day in kg were compared according to the two major zones. Data were analysed according to the major group of fish.

3.3.4 The offshore tuna fishery

The annual offshore tuna production and catch per day (CPUE) were analysed according to the two major statistical zones. The following analysis was carried out to compare the two major species of tuna targeted in the offshore fishing.

1. Estimate and plot the total annual production of skipjack tuna and yellowfin tuna from 1994 to 2004.
2. Estimate the catch ratio of yellowfin tuna to skipjack tuna.
3. Determine the total catch of yellowfin tuna and skipjack tuna according to the two major zones.
4. Estimate and plot the total production on a monthly basis from 2000 to 2004 to determine if there is seasonality in the production.
5. Examine length frequency distributions of yellowfin and skipjack tunas from 1994 to 2004.

3.3.5 The offshore shark fishery

Due to the limitation of available data, analysis of this fishery was restricted. The total production and CPUE of sharks were analysed according to the two major zones. The variation of annual total catch of silky shark, blue shark and oceanic whitetip shark were compared from 1994 to 2004.

3.3.6 The offshore billfish fishery

Analysis of this fishery was also restricted due to limited availability of data. Total production of billfish and CPUE were compared in the southern and western zones. The annual production of marlin, sailfish and swordfish were compared from 1994 to 2004.

3.4 Review of the data collection programme in Sri Lanka

In this part an overview of the current data collection programme in Sri Lanka is given. The weak points are summarised and some suggestions for future improvements are given. At the beginning of 2005, some steps were taken to improve the data collection programme with the financial and technical assistance of IOTC and OFCF. These improvements are also discussed whenever possible.

4 RESULTS

4.1 Variation of total catch and effort

The fishing effort was stable from 1994 to 1996 but thereafter it increased gradually (Figure 2). Total production increased from 54,000 tons to 127,000 tons during the period considered. CPUE (catch per day) nearly doubled from 1995 to 1999 but has remained at about 300 kg per day since then except in 2002 (Figure 3). Both the total production and CPUE show the same trend.

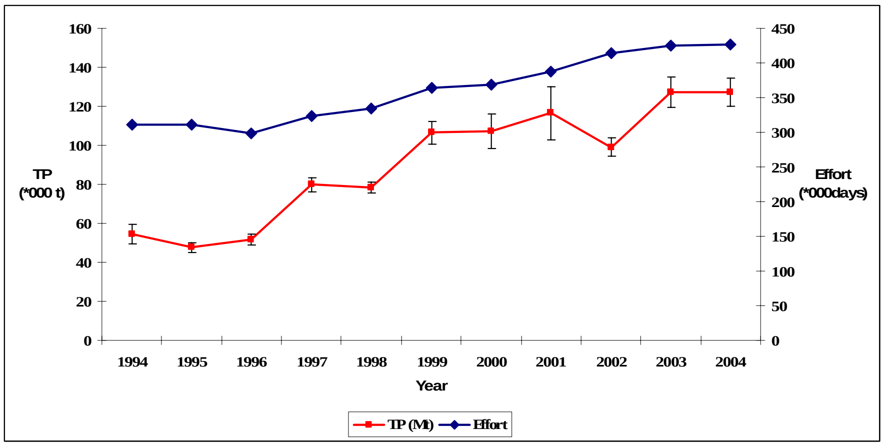


Figure 2: Total offshore fishery production (Mt) and fishing effort (number of fishing days) from 1994 to 2004.

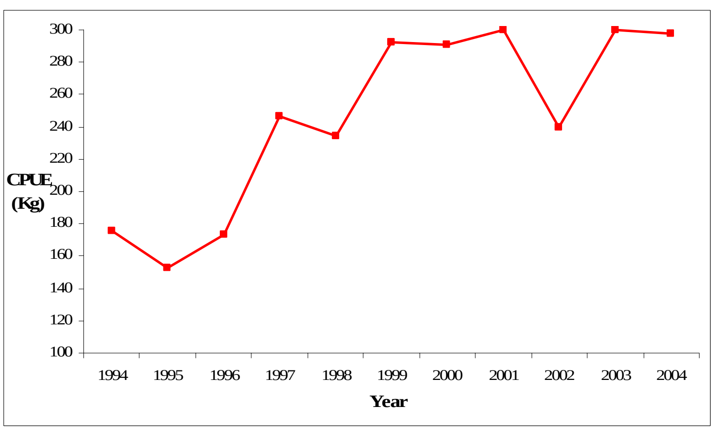


Figure 3: Average annual CPUE (catch per day in kg) from 1994 to 2004.

The observed catch per trip in UN2B was lower than the other two categories during the period considered (Table 2). The catch per trip in the UN2B boats gradually increased until 1999. After showing the maximum catch per boat in 1999 the catches declined gradually and ended up at 925 kg in 2004. In the UN3A boats, catches increased from 1326 kg to 4017 kg during the period of 1994 to 1998. After that catches declined gradually but stayed between 2000 and 3000 kg for the rest of the period. The catches from UN3B boats were always higher than the other two categories ranging from 2500 kg to 6000 kg per trip. The maximum and minimum catch per boat per trip was reported in 1998 and 1994 respectively. However it is impossible to see any clear trend in the UN3B boat categories. Catch and standard error fluctuate in a wider range compared to the other two categories.

Table 2: Catch per boat per trip according to three boat categories from 1994 to 2004.

Year	**Boat categories**					
	UN2B (8.8 - 9.8 m)		UN3A (9.8 – 12.2m)		UN3B (12.2 – 15.2 m)	
	Catch (kg)	± SE	Catch (kg)	± SE	Catch (kg)	± SE
1994	865	216	1326	307	3803	1351
1995	812	220	1471	371	2586	1480
1996	793	238	1355	434	2669	2422
1997	1107	427	2269	1086	5482	4091
1998	1905	664	4017	1500	6123	2221
1999	1289	434	3884	2409	4684	2634
2000	1156	208	2658	625	3936	2236
2001	953	122	2756	427	5399	1015
2002	568	210	2213	386	3497	1823
2003	929	61	2932	262	5759	1032
2004	925	150	3610	809	5518	1194

The number of the smaller boats (UN2B) has increased from 323 to 731 while the number of larger boats (UN3B) has decreased from 173 to 91 (Table 3). The change in the composition of boats has occurred after the 1998 especially in the UN2B and UN3B categories. The UN3A boats were the dominant category throughout the period considered and the number of boats increased gradually from 1994 to 2004.

Table 3: Variation in the number of boats in each category and their percentage of the total from 1994 to 2004.

Year	**Boat categories**					
	UN2B (8.8 - 9.8 m)		UN3A (9.8 – 12.2m)		UN3B (12.2 – 15.2 m)	
	No of boat	%	No of boat	%	No of boat	%
1994	323	27	691	58	173	15
1995	332	27	712	58	178	15
1996	342	27	734	58	184	15
1997	352	27	755	58	189	15
1998	363	27	778	58	195	15
1999	576	42	707	52	85	6
2000	605	42	753	52	87	6
2001	634	42	797	52	89	6
2002	664	42	847	52	90	6
2003	697	42	899	53	90	5
2004	731	42	955	54	91	5

There was a gradual increasing trend of total production in southern area except in 1998 and 2001 (Figure 4). The observed catches in the western zone increased gradually until 2001 except for the year 2000. After showing decreased catches in 2002, they increased again gradually until 2003. There was no significant difference between the mean productions reported from the two zones during the time period considered (paired t-test, t = 1.35; p = 0.207; df = 10).

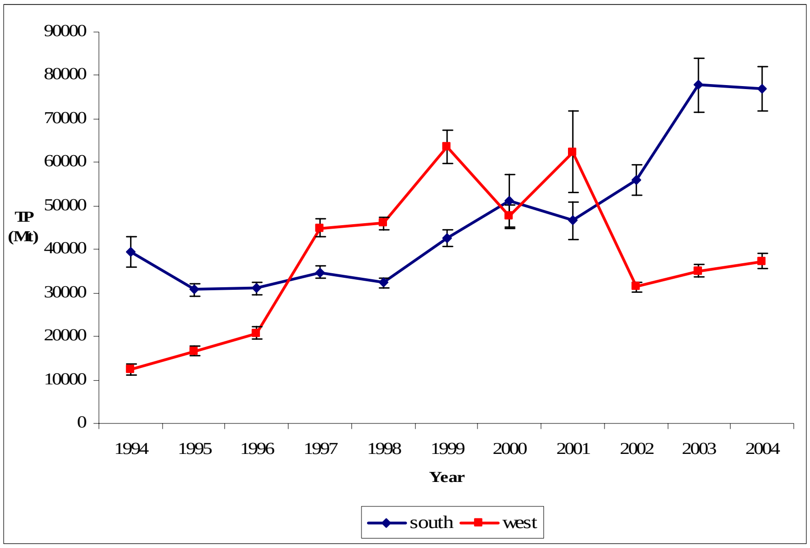
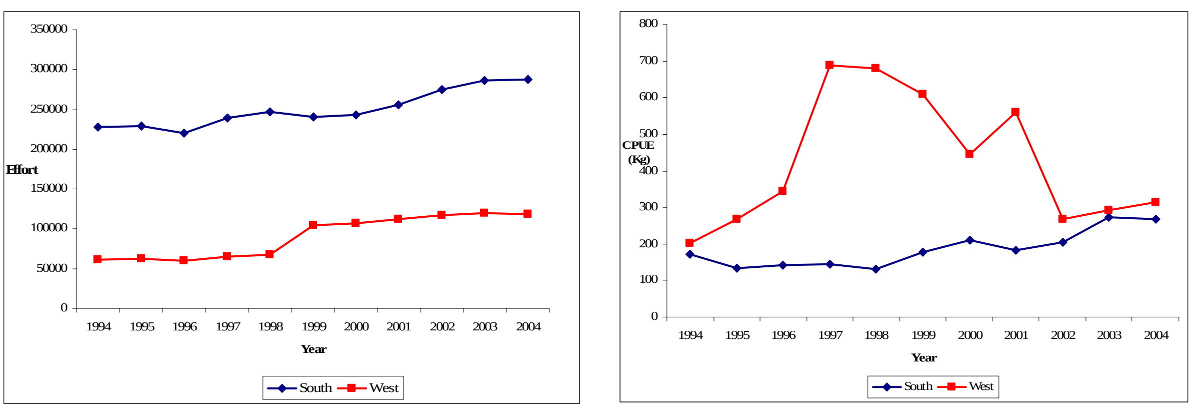


Figure 4: Variation of total production (Mt) in the southern and western zones from 1994 to 2004.

Total fishing effort (number of fishing days) and CPUE were compared for each of the two major statistical zones (Figure 5). Effort increased in both the zones during the period of study. In the western zone the effort doubled from around 50,000 boat days in 1994 to over 120,000 in 2004. Most of the increase occurred in one year from 1998 to 1999. Effort is much larger in southern zone and it increased continuously from 220,000 boat days in 1994 to 280,000 in 2004. The CPUE in the southern zone has shown a gradual increasing trend while in the western zone it increased very rapidly from 1994 to 1997, then it decreased continuously until 2004 with the exception of 2001. Furthermore, the mean daily catch per boat in the western zone is significantly higher than in the southern zone during the considered period (paired t-test, t = 3.87, df = 10, p = 0.003).



a b

Figure 5: Comparison of fishing effort (a) (boat days) and CPUE (b) (kg/boat day) in the southern and western zones from 1994 to 2004.

Thirty-six species belonging to six different groups are targeted in the offshore fisheries (Appendix 5). In 1994-2004 more than half of the offshore production came from tuna (56.3%) followed by shark (23.2%) and billfish (11.5%) (Figure 6).

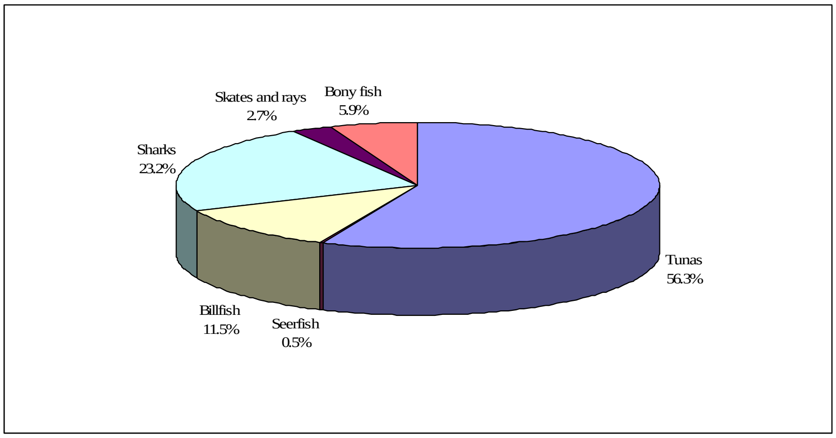


Figure 6: Percentage contribution of major species to the total offshore production in 1994 – 2004.

The total production of tuna and billfish have increased gradually while the shark catches declined after 2001. Significantly higher tuna production than either shark or billfish was obvious after 1996 (Figure 7) (ANOVA; P< 0.001; df = 2).

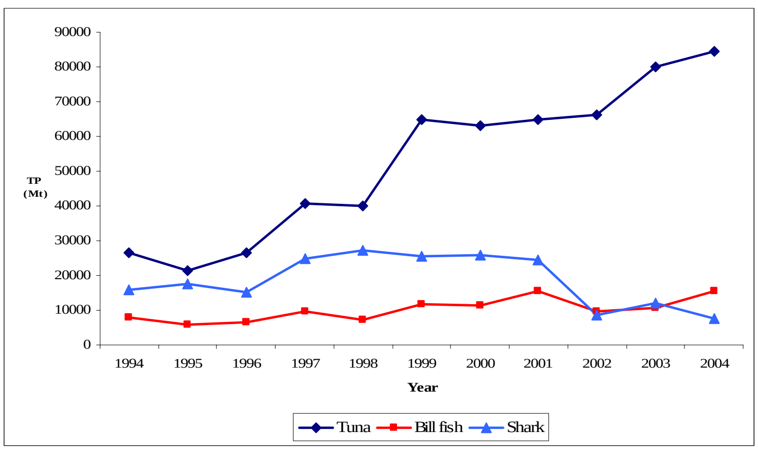
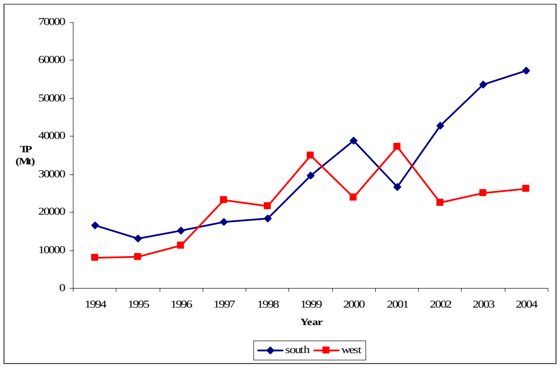


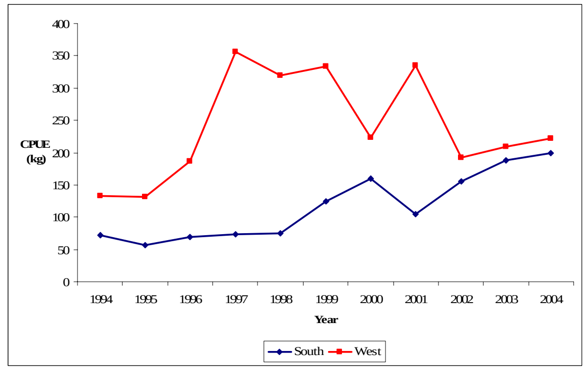
Figure 7: Variation of total island production of tuna, billfish and shark from 1994 to 2004.

4.2 The offshore tuna fishery

A continuous increase of total tuna production and CPUE was observed in the southern zone except in 2001 (Figure 8). The total production and CPUE from the western zone increased gradually up to 1997 when it reached 23,000 tons. Then it fluctuated until 2002 where it started to increase again. The mean CPUE in the western zone shows significantly higher levels than that from the southern zone ($t = 3.87$; $p < 0.001$; $df = 10$).



a



b

Figure 8: Total tuna production (a) and CPUE (b) for the tuna fishery in the southern and western zones from 1994 to 2004.

The annual total production of skipjack tuna has been higher than that of yellowfin tuna throughout the period (Figure 9). The mean production of skipjack tuna is significantly higher than yellowfin tuna ($t = 8.01$; $p < 0.001$, $df = 10$).

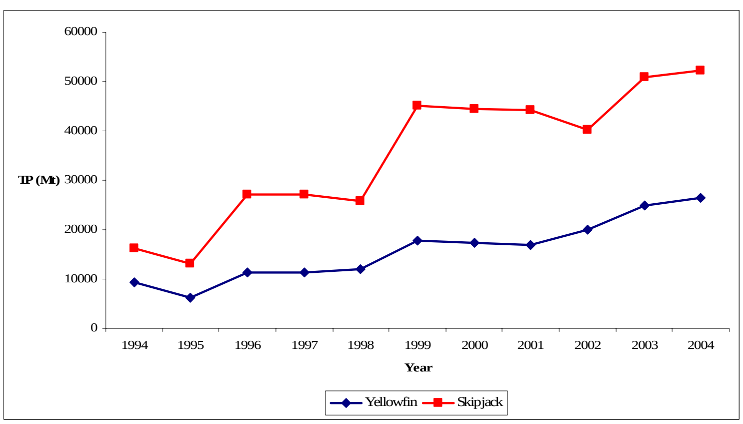


Figure 9: Annual total production of skipjack tuna and yellowfin tuna from 1994 to 2004.

The catch ratio between the yellowfin tuna and skipjack tuna remained more or less steady during the period investigated (Figure 10).

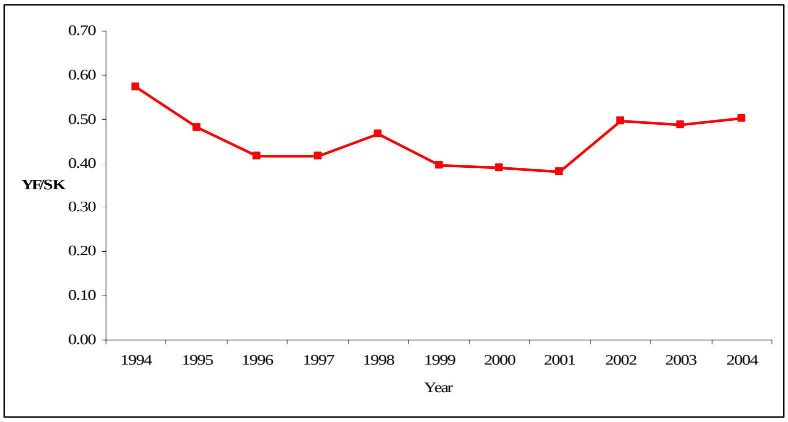
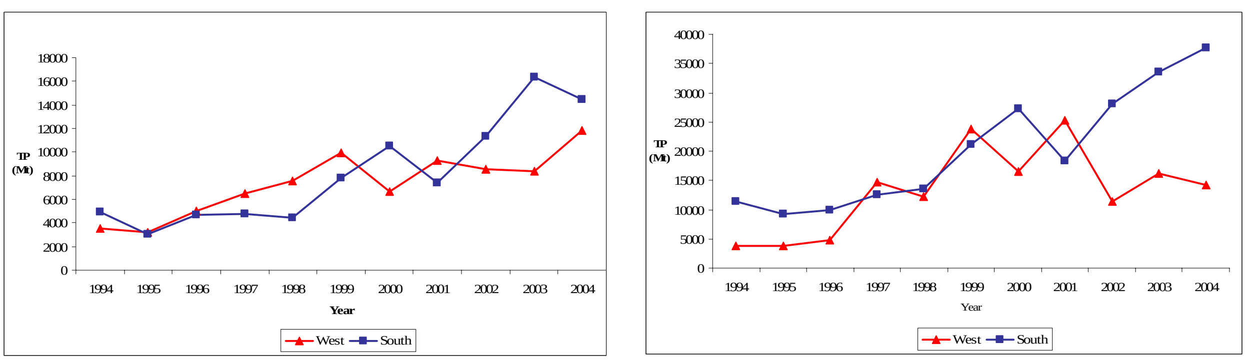


Figure 10: Ratio of yellowfin to skipjack tuna from 1994 to 2004.

Yellowfin catches were more predominant in the western area than in the southern area from 1995 to 1999 but after that catches coming from southern area became dominated except in 2001 by having lower catches compared to the previous year (Figure 11a). There was a gradual increasing trend of total production in both areas with some exceptions in 2000 and 2003 in the western area and 1995, 1998 and 2001 in the southern area. The mean catches reported from the two areas were not significantly different during the period considered ($t = 0.85$; $df = 11$; $p > 0.05$).

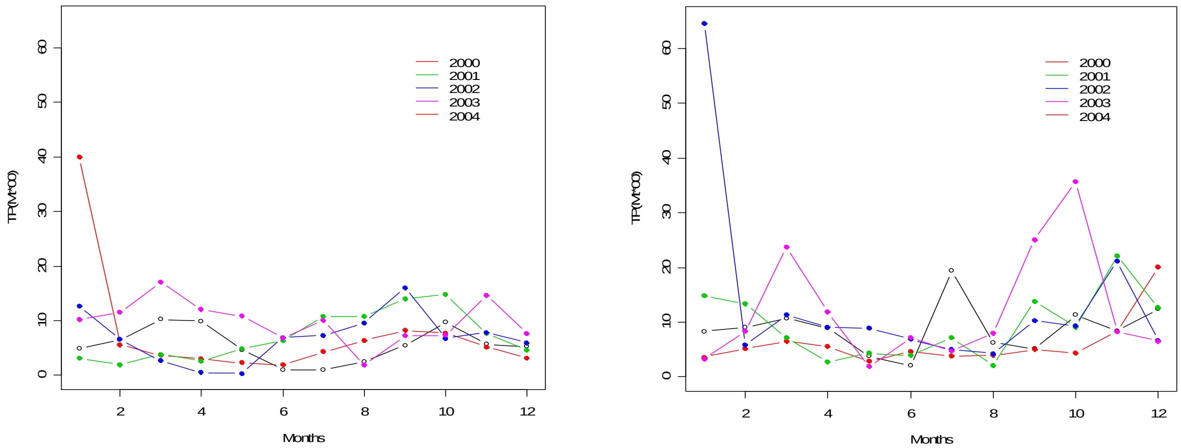
Production of skipjack tuna increased in the southern area from 11,000 tons to 37,000 tons at the end of the period (Figure 11b). The production in the western zone increased gradually from 1994 to 1997 but thereafter it fluctuated from 12,000 tons to 14,000 tons within the period from 1998 to 2004. A significantly higher mean catch has been reported from the southern area than the western area during the considered time period ($t = 2.42$, $df = 11$; $p < 0.05$)



a b

Figure 11: Total production of yellowfin (a) and skipjack tuna (b) catches in western and southern area from 1994 to 2004.

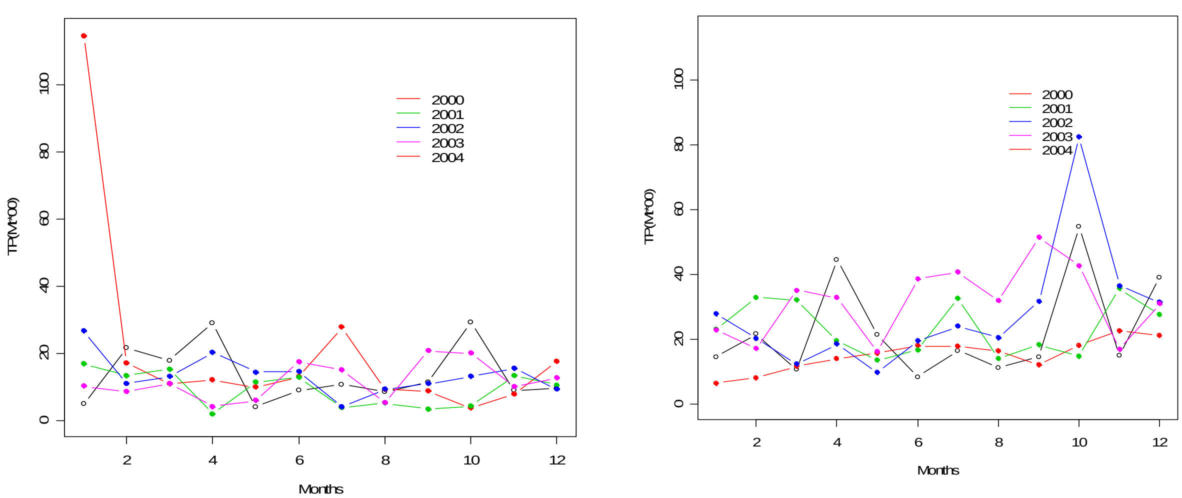
Monthly production of yellowfin tuna seems rather stable throughout the year both in the southern and western zones (Figure 12).



a B

Figure 12: Monthly catches of yellowfin tuna total production in the western (a) and southern (b) zones.

Though there were some fluctuations, monthly production of skipjack tuna has remained more or less steady throughout the year in both the areas except in unusual observation in January 2001 in the western area (Figure 14a and b).



a B

Figure 13: Monthly catches of skipjack tuna total production in the western (a) and southern (b) zones from 1994 to 2004.

The length of skipjack tuna ranges from 20 cm to 100 cm but most of the catch is between 40 - 70 cm in length (Figure 15). Two peaks are dominant throughout the period. A dominant peak is at of 60.0 – 65.0 cm followed by a secondary peak at 50.0 - 55.0 cm. Therefore, there are no obvious cohorts that can be followed.

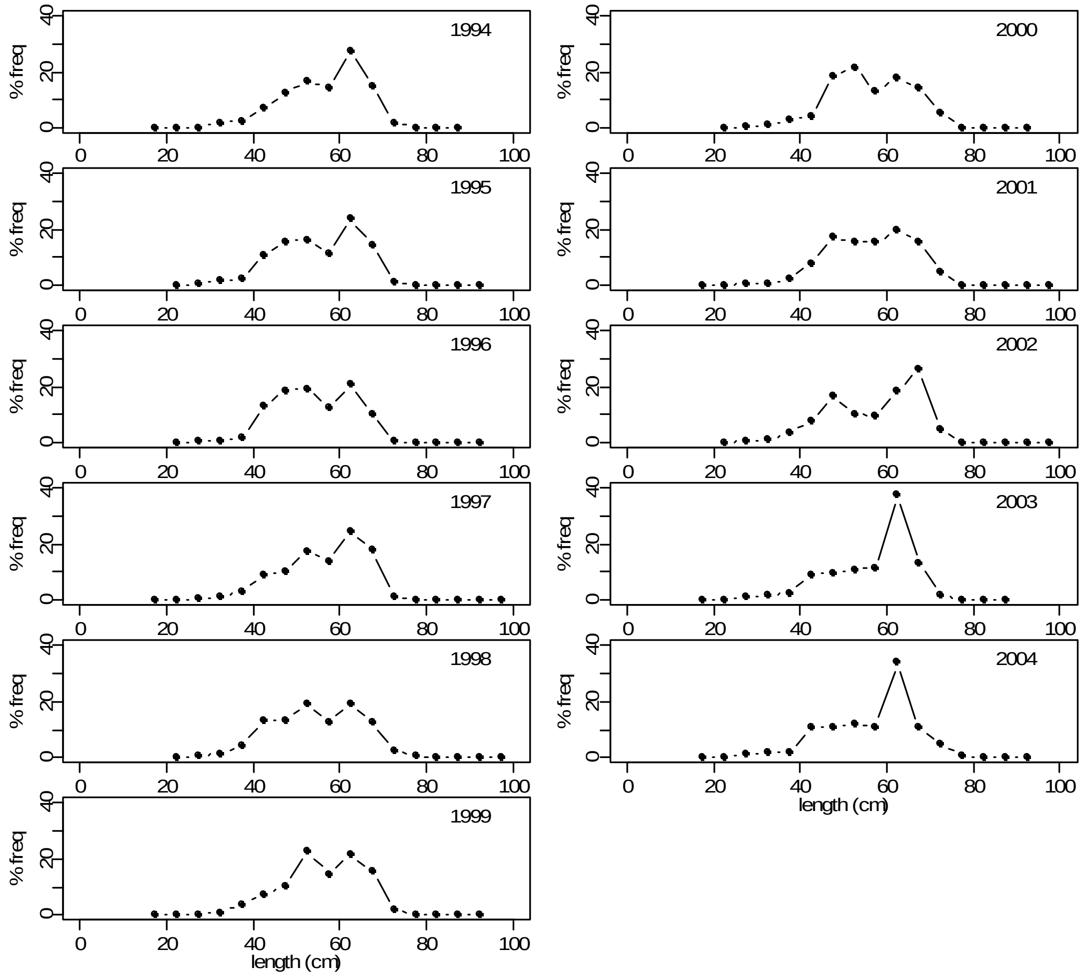


Figure 14: Length frequency distribution of skipjack tuna (targeted by offshore fishing activities) from 1994 to 2004.

The length distribution of yellowfin tuna ranges from 20.0 cm – 150.0 cm (Figure 16). The highest percentage frequency is observed between 50.0 – 55.0 cm in all the years except for 1994 and 1995. For these two years the highest frequency is observed in the 60.0 - 65.0 cm length range. Though there is a peak in this length class up to 1999 it is not a dominant peak as in the 50-55 cm length class in other years. After 2000 another peak can be seen in the range of 80-85 cm instead of 60-65 cm as observed prior to 2000. In 2003, a weak signal of a peak is observed in the length group of 125-130 cm and this became further dominant in 2004.

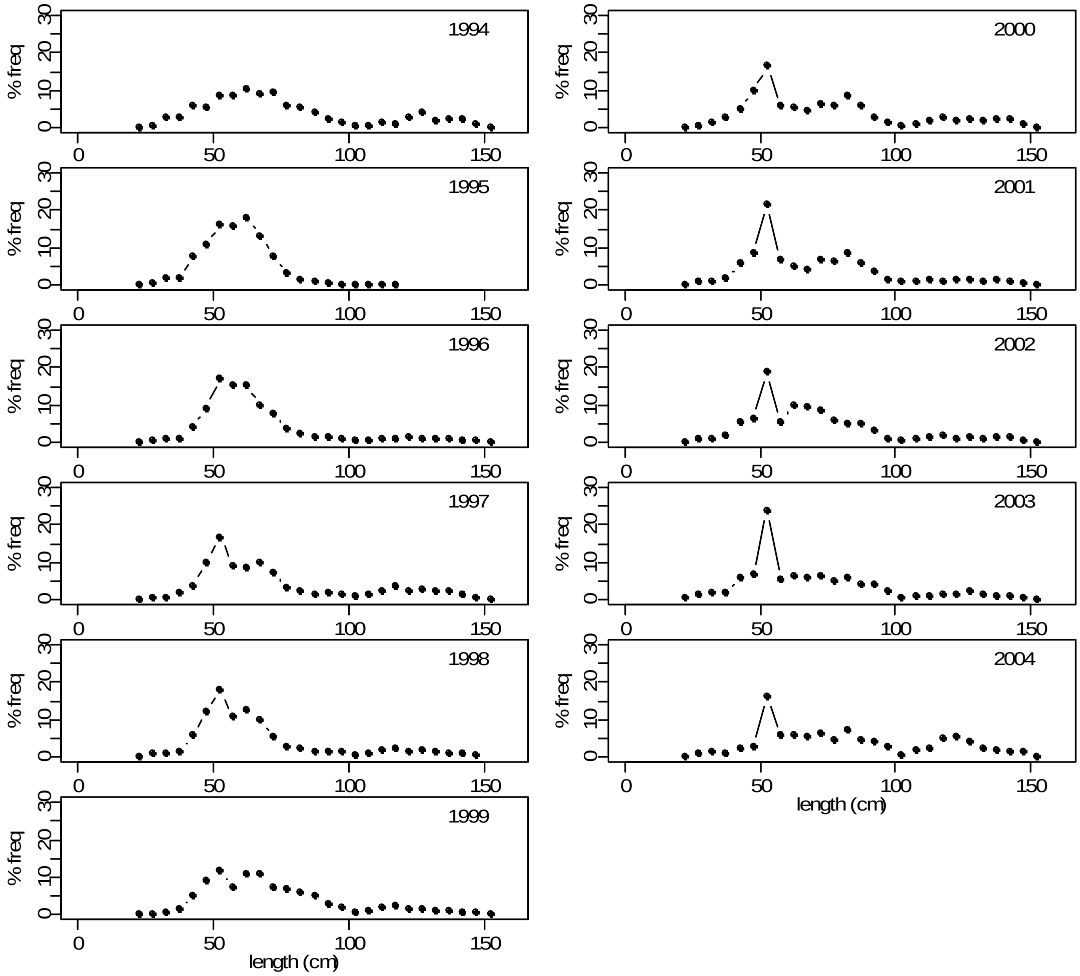
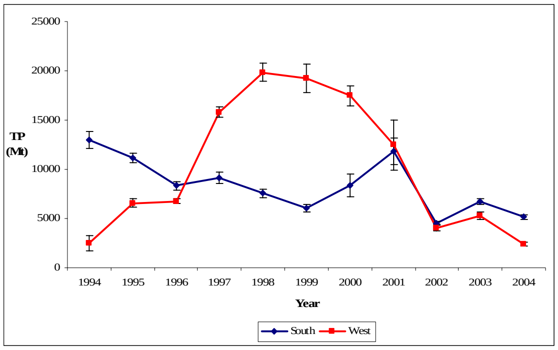
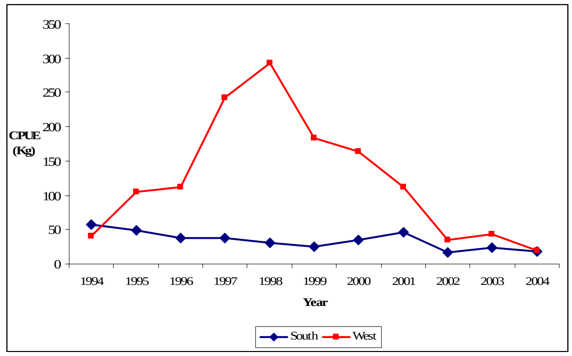


Figure 15: Length frequency distribution of yellowfin tuna (targeted by offshore fishing activities) from 1994 to 2004.

4.3 The offshore shark fishery

Shark contributes around 23% to the total offshore fishery production (Figure 6). The total shark production and CPUE in the western zone increased gradually up to 1998 and thereafter it decreased continuously until 2004. The shark catches from the southern zone decreased from 13,000 Mt in 1994 to 6000 Mt in 1999. Then they increased again in 2000-2001 but after that catches decreased reporting the minimum catch in 2002 (Figure 16a). The CPUE in the southern area remains more or less stable throughout the period considered (Figure 16b). From 1995 to 2003, both total catch and CPUE in the western area remained at higher levels than in the southern area but at the end of 2004 it became similar in both the zones.





A B

Figure 16: Total shark production (a) and CPUE (b) in the southern and western zones from 1994 to 2004.

The variation of total offshore production of silky shark, blue shark and oceanic whitetip shark species targeted in offshore fishing activities were compared (Figure 17). Silky shark production increased in the early part of the period with reaching its maximum production in 1998. Thereafter it decreased rapidly again from 18,000 Mt to 3000 Mt in 2004. The production of blue shark and oceanic whitetip shark has remained more stable than that of silky shark but it has nevertheless decreased in recent years, compared with the beginning of the period (Figure 17).

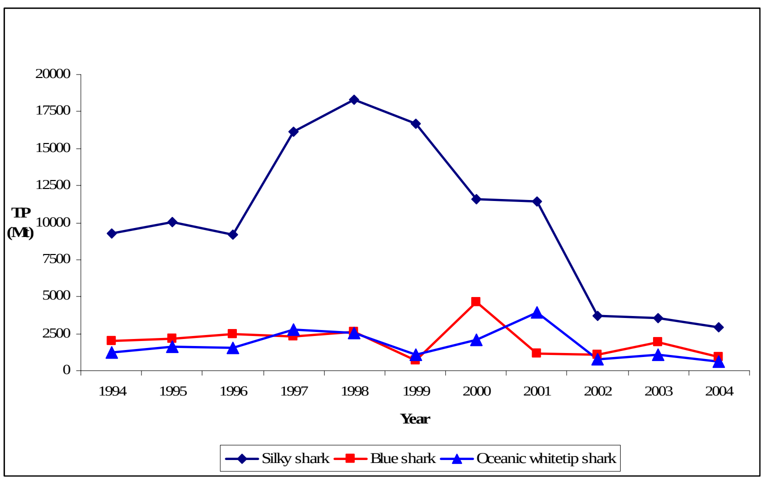
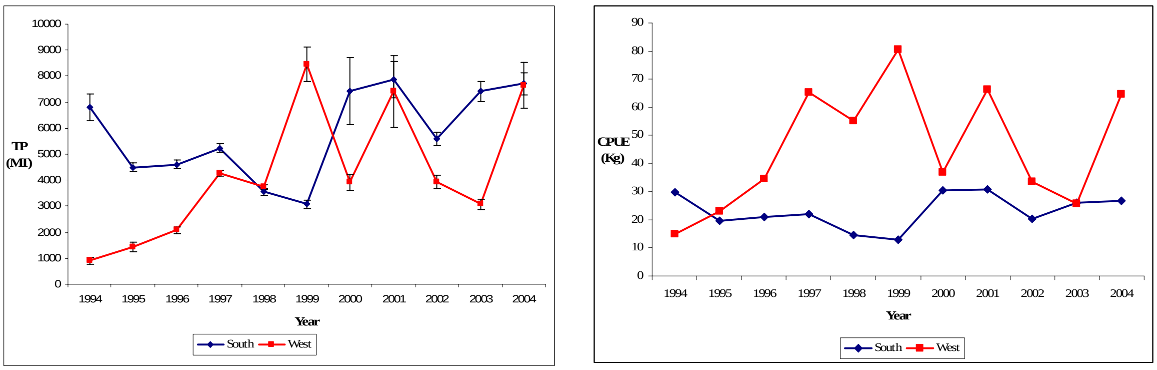


Figure 17: Total production of silky shark, blue shark and oceanic whitetip shark targeted in offshore fishing from 1994 to 2004.

4.4 The offshore billfish fishery

Billfish production in the western zone increased from 900 Mt in 1994 to 4200 Mt in 1997. Since then production has shown large fluctuations (Figure 18a) which appear to be dominant by variation in CPUE (Figure 18b). In the southern area, catches decreased gradually after 1994 and the fishery reported its lowest production in 1999. Then it shows an increasing trend and ends up with more or less similar catches to 1994. Both the total production and CPUE followed the same trend in the southern area (Figure 18).



a b

Figure 18: Variation of total billfish production (a) and CPUE (b) in the southern and western zones from 1994 to 2004.

The comparison of marlin, sailfish and swordfish total production targeted in the offshore fishing activities indicate a strong increase in sailfish catches from 1994 to 2004. Though there is a fluctuation in marlin and swordfish catches, there is not a directional change (Figure 19). From 1994 to 1998, marlins were dominant in the offshore billfish catches and had a gradual increasing trend. Marlin had its maximum and minimum production in year 2000 and 2001 respectively. The swordfish catches increased gradually until2000, and then remained more or less steady during the rest of the period.

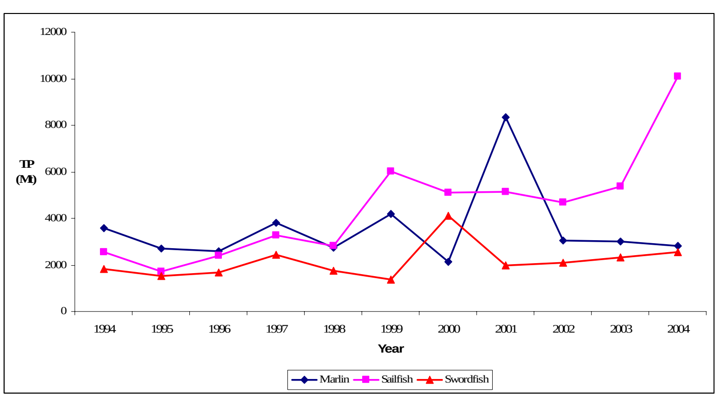


Figure 19: Variation of total production of marlin, sailfish and swordfish targeted in the offshore fishery from 1994 to 2004.

5 DISCUSSION

5.1 Status of the offshore fishery

5.1.1 Total offshore production and CPUE

The present study reveals a continuous increase in the offshore fishery production from 54,000 Mt to 127,000 Mt during the period 1994 to 2004. The available production estimates in the Ministry of fisheries also supported this finding though the estimates are much lower (around 30-40%) than the present study indicates, especially after 1999 (MOF 2005). FAO estimated the large pelagic fishery production at 75,000 Mt in 1994, but this included large pelagic fish targeted by both the coastal and offshore fisheries (Williams 1995). The survey carried out in 1978 estimated that the potential yield from coastal large pelagic fishes such as tunas, tuna-like fishes, king mackerels, billfishes and pelagic sharks may be around 30,000 Mt/annum (BOBP 1984). Furthermore, the coastal large pelagic production has ranged from 20,000 to 30, 000 Mt during the period from 1994 to 1996 by giving more than 75% of tuna (Maldeniya 1998). When considering this information, it seems the production estimates of the present study may be in the reasonable range though much literature is not available for comparison.

The continuous increase in offshore effort may be one of the reasons for the increase in offshore production and this has been mentioned in several reports. Sydnes and Normann (2003) indicated that the number of offshore boats had increased gradually from 1025 to 1614 during the period 1992-2002 while Joseph (1999) mentioned that the number of offshore boats increased from the early 1990s at average of 150 boats/year. But the general production trend deviated in the year 2002 by reporting decreased production though effort maintained the increasing trend. Leonard (2003) has mentioned lower fish production in 2002. According to Leonard (2003) the biggest imports of offshore large pelagic fish occurred in 2002 due to lower production in the country. The lower availability of fish species such as shark, billfish to the fishing gears may be the reason for lower production.

The present study indicates that catch per day (in kg) ranges from 180 kg to 280 kg within the period considered. During early 1980s the offshore catch rates fluctuated around 180 kg/day (Sivasubramaniam 1985). However, it was not able to focus the CPUE analysis based on the gear types due to unavailability of such information in the database. Therefore it is probably not possible to use these CPUE data to describe the actual trends of the stocks. It is obvious that there will be significantly higher catches in the UN3A and UN3B boat categories compared with UN2B. The former two categories spend longer periods at sea than the UN2B boats and the increased catch per day may be due to the use of a higher number of net pieces, hooks and new technology to detect schools of fish. Due to lack of information regarding the gear, it is not possible to compare the catch per boat according to gear type. The unusual observation from 1994 to 1997 in the UN3B boat category in Figure 13 may be due to misidentification of boat categories during the sampling.

Continuous increased production in the southern and western zones can be explained by having increased total production throughout the period. Due to continuous civil disturbances in the east and northeast parts of the country, fishing activities have been abandoned several times in these areas especially during the late 1990s. With that situation fishermen tend to migrate more towards the western and northwestern areas and this may be a possible reason for the unusual increase in fishing effort in the western zone in 1999. On the other hand, lack of updated effort information each year may also be the cause of this unusual observation. With the increasing effort, the offshore catches from the southern area also increased by maintaining the CPUE at a constant level. But the total catch and CPUE decreased in the western zone though there was a continuous increasing trend in fishing effort. The drastic decrease in shark and billfish catches may be a possible reason for this observation. The decreasing trend of shark catches has also been mentioned by the statistical unit of Ministry of Fisheries (MOF 2005).

5.1.2 The offshore tuna fishery

The present analysis indicates that tuna species contribute around 56.3% to the total offshore production followed by sharks, billfish and bony fish. Sydnes and Normann (2003) have mentioned that the offshore large pelagic consisted of 50% tuna, 35% sharks and 10% billfish. The present estimate for tuna is higher than the value reported by Sydnes and Normann (2003) while it is lower for shark. The estimates made by the IOTC from 1993 to 2002 also indicated the gradual increasing trend in tuna production in Sri Lanka similar to the present study (IOTC 2005a). As the estimates made by IOTC include both coastal and offshore tuna it is not possible to make a direct comparison with their figures to the present analysis. The predominant contribution of skipjack tuna and yellowfin tuna to the total production has been mentioned by several studies (Sivasubramanium 1971, 1985; Joseph *et al*. 1985 and Maldeniya 1996). The present analysis also indicated that the major portion of tuna production is from skipjack tuna followed by yellowfin tuna. Skipjack, yellowfin and bigeye tuna are the most common fish species group in the Indian Ocean and the highest catches may be attributed with the high abundance of these species (IOTC 2004). The reduction in skipjack tuna catches in 1995, 1998 and 2002, may be due to poor recruitment during those years. A continuous increase in yellowfin tuna catches is indicated in the present study and IOTC also reported the same observation. The continuous increase in yellowfin catches has been explained in several ways by IOTC and these reasons could be used to explain the increased catches in Sri Lanka. Due to some unexplained environmental conditions, yellowfin tuna aggregated over a relatively small area, so that it became easier to catch them in large quantities. The higher concentrations of the crustacean *Natosquilla investigatoris*, reported to have occurred in large quantities in various locations of the Indian Ocean has been cited as possible a reason for the unusual concentrations of yellowfin tuna. Use of high technology could be another reason because this enables vessels to find schools that were not previously detected. The other hypothesis is that large recruitments to the population in the period 1998-1999 may be responsible for the large increase in yellowfin catches in recent years. In 1998-1999 an oceanographic event occurred in the Indian Ocean, creating favourable environmental conditions for good recruitment (IOTC 2004).

The high catches in the southern zone for both skipjack and yellowfin tuna can be associated with both high fishing effort in this zone and the high density of species. A previous study revealed that the best average catch was in the southwest for both skipjack and yeltowfin tuna, followed by areas off the west and east coasts of Sri Lanka. Furthermore, it has been mentioned that the relative density of these two species appears to be greater in the oceanic ranges south and west of Sri Lanka than on the eastern side (Sivasubramaniam 1985).

It is not possible to identify any seasonality in the yellowfin and skipjack tuna fisheries in either the southern or western zones. Previous studies have shown a peak in the skipjack tuna drift gillnet fishery in the south in January but for other gears the peak was in May and declined gradually until August. The peak was in September in the west, October in the north and August on the eastern side. The yellowfin peak season has begun with the southwest monsoon in the southern area and then shifted to the west (Sivasubramaniam 1970, 1971, 1985). Due to constraints in the available data, it is not possible to draw any conclusions about the peak production season of tuna based on the gears. The high catches in January 2001 for both the tuna species in the western zone and in January 2003 for yellowfin tuna catches in the southern zone may be due to errors in the sampling.

The approximate size of tuna caught varies according to the depth of the water where fishing is carried out. By considering the depth of fishing the tuna fisheries have been classified into three groups: (a) surface fisheries (pole and line, troll, and purse seines), (b) sub-surface fisheries (gillnet or gillnet-based combined gears), and (c) mid-water fisheries (longline and handline) (Nishida 1996). In Sri Lanka the offshore fishery is mainly based on either gillnet or gillnet cum longline operations, which come under the sub-surface fishery and mid-water fishery. Unfortunately due to scarcity of length information relating to gears, it was not possible to carry out length frequency analysis according to the gears.

Available information revealed that size ranges of skipjack tuna in the Indian waters ranged from 31-80 cm (Kaewnuratchadasorn *et al*. 2003). Sivasubramanium (1985) has shown that, the size range of the exploited population of skipjack tuna varied in the range of 30-78 cm around Sri Lanka and the present study reveals the length range to be from 20 -100 cm. Sivasubramanium (1985) has discussed five modes in the length frequency distribution: 34, 43, 52, 63 and 71 cm. But the present study indicates two dominant peaks at 52.5 cm and 62.5 cm which are much more similar to the third and fourth mode obtained by the previous study. As this study mainly focuses on skipjack tuna targeted in offshore fishing activities, the absence of first two peaks can be explained. The modal length of 52, 63 and 71 cm are associated with the drift gillnet catches (Sivasubramanium 1985) and this may be the reason for the observed peaks in the present study. According to his explanation, the lengths of skipjack tuna targeted from longline are frequently found beyond these modal lengths. So the observed frequencies between 80 and 100 cm may be due to catches from longline.

The present study indicates that length distribution of yellowfin tuna varied from 20 – 150 cm, which is similar to the findings of Sivasubramanium (1985) who found that the length of yellowfin tuna caught around the Sri Lanka ranges from 20 to 145 cm. The length of yellowfin tuna targeted by longline can be extended up to 174 cm FL (Chantawong1 1998). According to the present study, the major proportion of yellowfin tuna catches are within the range of 50-100 cm and this has also been found in previous studies (Sivasubramanium 1971, 1972, Joseph *et al*. 1985). Joseph *et al.* (1985) have observed the occurrence of distinct modes in the length of 48 to 50 cm and 70 cm. But the observed modes in the present study are in the length ranges of 50-55 cm and 60-65 cm and a weak signal also appears in the range of 125-130 cm. As skipjack and yellowfin tuna have similar body shapes and are caught with the same gear with the same specification, the occurrence of modal lengths within similar ranges may be due to gear selectivity. Previous studies on recruitment indicate that the 0 and I age groups remain in the insular surface fishery at least for one year and these are targeted by the drift gillnet fishery. After one year, yellowfin tuna tend to shift northwards of the island and on reaching age group II they commence to spread into the deep swimming layer. This process is accomplished by the time they reach the end of the age group III having the size range of 50-80 cm and they are available to the longline fishery (Joseph *et al*. 1985). So the observed length class beyond 70 cm may be due to the deep-sea yellowfin tuna targeted by the longline. Maldeniya (1996) has also supported this statement by mentioning the length distribution of yellowfin tuna taken in the longline fishery has ranged 71-176 cm fork length. The occurrence of new peaks around 117 and 127.5 cm may be due to large recruitments to the population in 1998-1999 (fish around 120-140 cm FL) as mentioned by the IOTC (IOTC 2004). According to the IOTC, exceptionally high catches of 120-140 cm FL yellowfin tuna have been observed not only in Sri Lanka but also in the commercial and artesian fisheries of Yemen, Oman and the Maldives.

5.1.3 The offshore shark fishery

The decreasing trend in shark catches found in this study has also been reported by the statistical unit of Ministry of Fisheries (MOF 2005). The present study reveals that shark catches in the western zone declined considerably after 1998 while the catches reported from the southern area remained more or less steady until 2001. The possible reasons for the lower catches in these areas may be either depletion of the major shark species targeted in this zone or lower effort to catch shark due to economic reasons. Silky shark catches have especially decreased which has caused severe decreases of shark catches in the western zone. Most of the shark species are commonly taken as by-catch of the tuna fisheries. Shark species are usually finned and discarded due to the low value of their meat. The reason for discarding shark is its high urea content which confers a strong taste and odour of ammonia to the flesh. If their carcasses are put on the boats near other more valuable species of fish, such as tuna and swordfish, there is a risk of contaminating them (FAO 2003b).

5.1.4 The offshore billfish fishery

Billfish is also caught as the by-catch of tuna fishery (Samaraweera and Amarasiri 2004, Campbell *et al.* 1998). Increasing trends in billfish catches have also been reported by the study made by Samarawera and Amarasiri (2004). According to them the increasing trend could be due to several reasons such as increased use of combination of gears, expansion of the fishing range towards offshore and deep-sea, under-reporting, increased quality of statistical records, improving market or reduced levels of discards. However the species composition of billfish has changed dramatically over a short period. Marlins dominated the billfish landings in the early 1990s and after 1998 sailfish became more dominant. According to previous reports this could be due to either over-exploitation of marlins or increased abundance of sailfish for gears used (Samaraweera and Amarasiri 2004). Incomplete data, improved statistical recordings, species misidentification, rather than a change in the fishing strategy, may explain some of the changes. Due to lack of studies based on offshore billfish catches, it is not easy to make any comparisons especially according to catches from different zones.

5.2 Status of the fisheries data collection programme

There are some obvious drawbacks of the current data collection programme which caused difficulties in using the data for assessing the status of the fishery in terms of gears used as well as the status of individual species of stocks caught by different fleets. Some drawbacks of the database have been summarised and try to give some suggestions for further strengthening the existing programme.

5.2.1 Catch information

The major concern of the existing system is to collect the total catch by species, according to the boat categories when it is unloaded. Normally skippers are supposed to be interviewed to get information about fishing days, crew members and fishing gears. But when considering the available data from 1994 to 2004; it seems that there are a lot of gaps in the reported information. Furthermore, the reliability of the available information is questionable because it is impossible to obtain detailed information from the skippers after having a long fishing trip.

Another weak point is that in most of the instances the actual catch of the trip is not represented when it is unloaded at the landing site. This may be for several reasons.

1. Part of the catch is used as the bait: This situation is very common among the boats, which are operated in offshore fishing activities especially by targeting highly migratory carnivorous species such as tuna and sharks. In some instances fishermen use small mesh gillnets with 1.25” to 2” mesh sizes to catch flying fish species for bait. But according to De Croos (2003) flying fish is a highly seasonal fishery and it can only be operated from September to April. For the rest of the period, fishermen tend to use small size skipjack and frigate tunas which have been caught in the same fishing trip as bait to catch more valuable tuna species like yellowfin tuna, bigeye tuna and some shark species.

2. On board processing: In most of the cases skipjack tuna are processed on board as dry fish. Evidence suggests that there is transhipment of the catch at sea. Further the landing of fresh fish and dry fish are not carried out at the same time and sometimes the location of landings may also differ even from the same boat. This situation is highly variable with the availability of transport facilities and market demand.

3. Discard of catch: In some cases a considerable amount of processed shark fins are unloaded from the boats but no information is available about the catches. After removing the fins, shark carcasses are discarded because the long-term cold storage of shark is not beneficial in an economic point of view.

Another major drawback of this system is lack of information about the daily catch. So final estimates are based on the total catch per trip which may cause some errors especially when both gillnets and longlines are used in different proportions during the same trip and this may also vary from trip to trip

5.2.2 Effort information

The main focus of the existing system is to record the information about types of gear used and gear specification but data collectors are supposed to be collecting information on gear setting time (day/night) and the number of sets per day. All this information is collected through interviews and the reliability of this information is questionable because the information source is interviews with people after long fishing trips. On the other hand, no information was available about the frequency of each gear used (alone and/or in combination) and true fishing times during the period from 1994 to 2004. Information about the horsepower of the engine may be a useful area to be considered together with the crew members to get an accurate picture of the fishing effort.

5.2.3 Information about the fishing position

At present, no information is available about the fishing position. Many attempts were made to get the information about the fishing position by interviewing the fishermen and skippers, but these attempts have always failed. This is another weak point in the existing sampling programme.

As it is not easy to make any arrangements for the above mentioned weak points under the current sampling programme, it may be useful to implement a logbook system at least to cover 10% of the offshore boats including different boat categories from different statistical zones. As we are targeting fishermen as the data collectors in the logbook system, data sheets should be informative as well as simple. Suitable data sheets for logbook surveys for the large pelagic offshore fishery have been designed in this study and attached (see Appendix 7).

5.2.4 Biological information

The special target of the present sampling scheme is to cover the length measurements but rarely observers are focused on weight measurements too. Corresponding length weight measurements of the same individuals were very rarely available in the period considered for analysis. It seems that the biological information relating to some groups such as sharks and billfish is very limited though there is considerable coverage of tuna species. Even with tuna, available biological information is not related with the gear used for fishing so it is not easy to draw any realistic conclusion about the migratory stock. Limited biological information is collected on the sampling programme and needs further improvements.

It is necessary to increase biological sampling coverage of the sampling programme. In this case it is advisable to give equal attempts to cover at least major species of tuna, billfish and shark. Weight measurements and maturity stages should be recorded together with length measurements. It is necessary to relate these biological measurements with the gear type used whenever it is possible. Though offshore fishery seems to be multi-gear, some vessels operate a single gear. These vessels ought to be targeted specially for biological sampling coverage. On the other hand some species of tuna (yellowfin tuna) and billfish (swordfish and marlin) are caught by targeting the export market. In this case longlines are very frequently used as the gear because quality is considered as the major factor. As the catch is directly sent to the processing factories, it may be useful to cover processing factories on a random basis to get biological information. Further, it may be useful to consider the economic information such as fixed cost per fishing unit, variable cost per fishing unit (cost of man power, cost of fuel, cost of labour, depreciation cost), revenue (income per fishing unit), profitability of each fleet, other sectors (processing, wholesalers) depending on the fishery, infrastructure cost and enforcement cost together with biological information. Because both biological as well as economical information will provide the basis for suggesting fisheries management strategies which leads to proper fisheries management.

5.2.5 Seasonality in the fisheries

Fishing activities are associated with the monsoon pattern of the country. The southwest monsoon exists from June to September and the northeast monsoon from November to March. During the southwest monsoon periods, the boats in the southern and western coasts migrate to eastern part of the country and vice versa. As there is no proper ID system for boats, which creates difficulties in identification of these migratory boats when sampling is carried out. The number of boats (landings) in each area is very important in production estimates because estimates are based on a raising factor. The presently used raising factor is mainly based on the number of registered boats in each area and this was considered as constant throughout the year for estimates. Neglecting the boat migration may lead to errors in production estimates

There is a need to establish a proper ID system especially for offshore multi-day boats. It has been planned to carry out a sticker programme as an ID system for multi-day boats under the technical and financial support from the IOTC/OFCF project and most probably this will be implemented in 2006. Furthermore, it is necessary to update the total number of boats landing at least on a monthly basis rather than using a constant number throughout the year. A complete boat census should be carried out at least once a year because new boats are coming very rapidly to the industry due to its open access nature, but in some cases boats are not registered. The other option is to try to collect the information on new boat from the boat yards.

Furthermore, it may be useful to carry out workshops and seminars targeting fishermen or fishermen co-operative societies to explain the importance of fisheries statistics for fisheries management. Community participation in data collection is a very important concept , which requires some sort of training for fishermen especially if a logbook system will be implemented in the near future. Though the quality of data gathered by the fishermen may not be of a high level, their involvement may result in gathering large quantities of reasonably reliable data. FAO (1999) also mentioned that it is possible to obtain large quantities of reliable data in a relatively cheap manner through the involvement of local fishermen. When fishermen realise that they are getting benefits through this programme, automatically they tend to give their support and this may lead to better quality data being collected than at present.

It is necessary to conduct a training programme by targeting data collectors and research officers involved in the sampling programme. Data collectors must have a clear idea about the importance of the sampling programme because they are responsible for its implementation. Frequent discussion about the status of the fishery based on the sampling, weak points and solutions should be carried out. Data collectors should always have a good understanding of the status of the fishery in their statistical zone because they are responsible for communication with the fishermen. So research officers have the responsibility to analyse the data on time and should give the output to the data collectors.

It is a crucial requirement to strengthen the monitoring programme. It seems to be a requirement to prepare a time schedule (by mentioning the time that data collectors should stay in the field) together with the field schedule for the data collectors. Requirements of a time schedule for data collectors has also been mentioned in the IOTC /OFCF field manual (draft) prepared in 2005 but it has not yet been implemented. So a time schedule coupled with a field schedule is an urgent requirement to have morning as well as afternoon landing coverage.

6 CONCLUSION AND RECOMENDATIONS

This study evaluates the trends in offshore fishing activities and the fisheries data collection programme in Sri Lanka. It is probably the only analysis done on the offshore fishery in the past few years and gives rough indications on the status of the most important stocks caught in this fishery though there are many gaps in the sampling data. As discussed in chapter 5, improvement of the data collection programme is recommended and suggestions for further improvements are summarised below:.

- Implementation of a logbook system to the multi-day boats is suggested in order to improve the quality of the data especially true fishing time, fishing position, fishing gears, catch related to each gear and daily catch information.

- It is recommended to expand the coverage of biological information including length, weight and maturity stages.

- It is important to highlight the requirements of training for the data collecting staff as well as data entry staff.

- More collaborative research activities on the life history parameters of migratory species are needed. Without these data the status of the stocks in the region will remain uncertain and it will not be possible to identify the most appropriate management options for these stocks.

- Since some schools are overexploited both in the coastal and offshore fisheries there is a need to establish a centralised data system rather than having limited and often incompatible information in different places.

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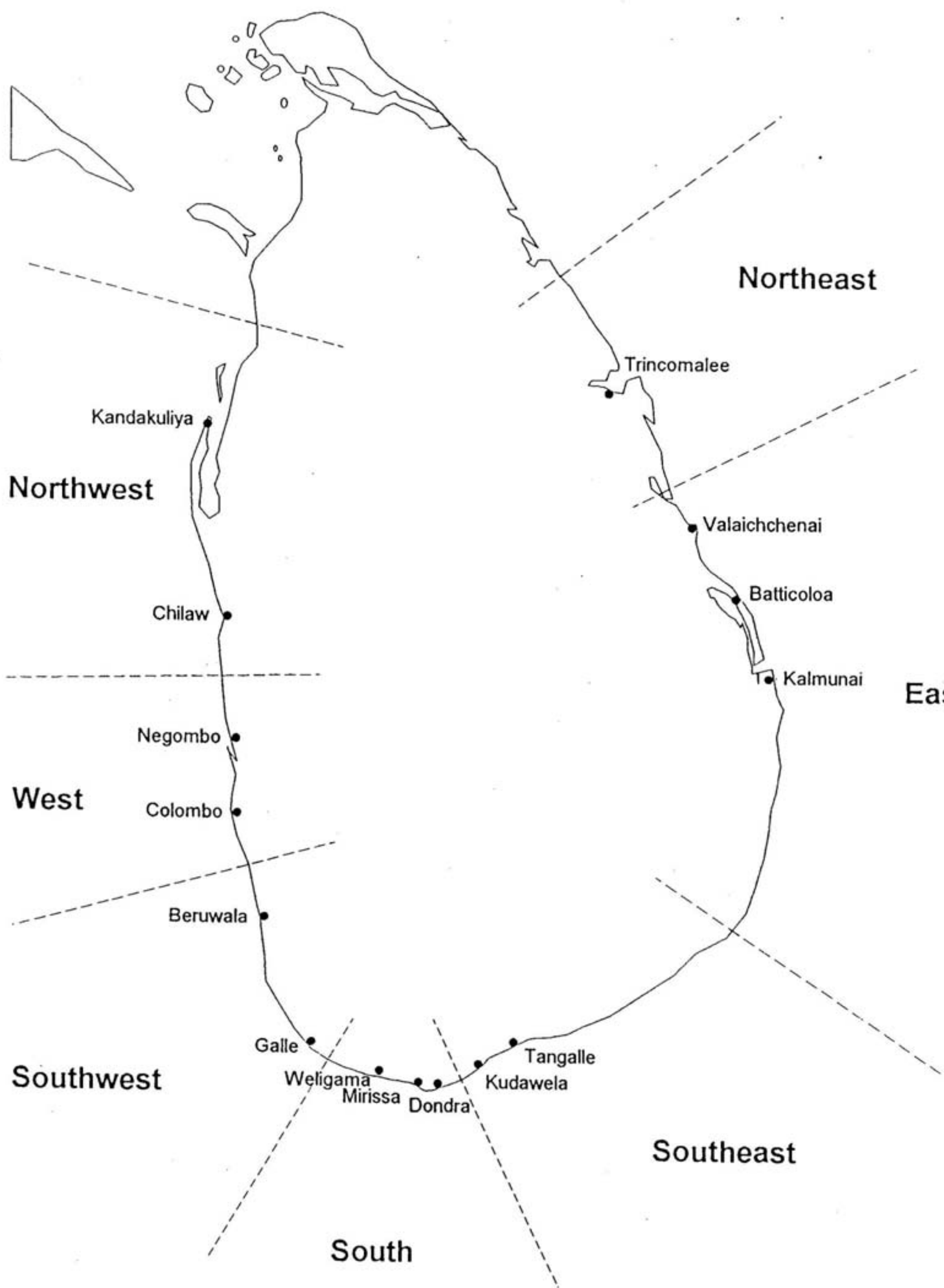
APPENDICES

Appendix 1: Principal statistical zones and major landing centers used in estimating offshore fish production in Sri Lanka.



Appendix 2: Type of boats operating in the marine fisheries in Sri Lanka

Number	Boat category	Boat Descriptions
1	UN1	5.5 - 7.2 m (17' - 21') FRP dinghy Outboard engine - 8-40 HP (usually 15 - 25 HP) Operate in coastal waters
2	UN2A	8.8 - 9.8 m (28' - 34'). FRP or wooden. Inboard engine (single) - 40 HP No ice box or insulated fish hold, no gear hauler, navigational or acoustic equipments. Operate in coastal waters
3	UN2B	8.8 - 9.8 m (28' - 34'). FRP wooden. Inboard engine (single) - 40 HP Insulated fish hold - no gear hauler, may have GSP/sounder/fish finder Operate in offshore waters
4	UN3A	9.8 - 12.2 m (34' - 40'). FRP wooden. Inboard engine (single) - 60 HP - (includes Abu Dhabi vessels) Insulated fish hold and may have gear Hauler/GSP/sounder/fish finder Operate in offshore waters
5	UN3B	12.2 m – 15.2 m (40' - 50'). FRP or wooden Inboard engine (single) - 60 + HP Insulated fish hold and may have freezer facilities. Gear Hauler/GSP/sounder/fish finder Operate in offshore waters
6	UN4	Reserved for vessel category e.g. 15.2 - 18.3 m (50' - 60') Few in numbers Operate in offshore waters

Appendix 3 : Major gear types used in offshore fisheries

Gear code	Gear
BB	Pole and line
GN	Gillnet
LG	Combination tuna Longline and Gillnet
LH	Combination Long line and hand line
LL	Longline (tuna)
OT	Other
PS	Purse seine
RN	Ring net
SG	Combination shark Longline and Gillnet
TH	Combination Troll and handline
TL	Troll line
UN	Unknown

Appendix 4: Daily effort form – Form A

Daily effort form	craft enumeration				
DATE		LOCATION	PAGE		
FLEET DETAILS	UN1	UN2A	UN2B	UN3A	UN3B
Number operated					
BOATS INFORMATION					

Boat Type	Boat's Name	Sampled(Y/N)	Registration Number

Appendix 5: Catch and effort form - Form B

Catch & Effort Form																
DATE		LOCATION							PAGE							
FLEET DETAILS		UN1			UN2A			UN2B			UN3A			UN3B		
Number operated																
Number sampled																
BOAT & FISHING TECHNIQUES																
boat number																
Boat Type																
Boat's Name																
Boat registration no																
Target species																
Days fished																
Gear Type																
Hook number																
Pieces of net																
bait type (LL)																
Gear setting time (night/day)																
How many set per day																
transfer at sea (yes/no)																
CATCH		No	Weight	Type	No	Weight	Type	No	Weight	Type	No	Weight	Type	No	Weight	Type
	YFS															
Yellowfin	YFM															
	YFL															
	SKS															
Skipjack	SKM															
	SKL															
Skipjack dry	SKD															
Kawakawa	KAW															
Frigate	FRI															
Bullet	BLT															
Bigeye	BET															
Other tuna	TUX															
Narrow barred	COM															
Wahoo	WAH															
Other seer	KGX															
Black marlin	BLM															
Blue marlin	BUM															
Striped marlin	MLS															
Sailfish	SFA															
Shortbill spearfish	SSP															
Swordfish	SWO															
Marlin	MAR															
Other bony fish	MZZ															
Dolphin fish	DOF															
Carangid sp.	CAR															
Silky shark	FAL															
Blue shark	BSH															
White tip	OWT															
Spot tail	SPT															
Longfin mako	LFM															
Shortfin mako	SFM															
Bigeye thresher	BTH															
Pelagic thresher	PTH															
Scallop hammerhead	SCH															
Smooth hammerhead	SMH															
Great hammerhead	GRH															
Other sharks	SKH															
Manta ray	MAR															
Devil ray	DER															
Eagle ray	EGR															
Guitar fish	GUF															
Other skates	SKA															
COMMENTS : Name and registration numbers of boats at landing site																

Appendix 6: Length and weight frequency form

Length & Weight frequency Form													
							Biological sampling						
DATE			LOCATION					PAGE			OF		
		WEIGHT						LENGTH					
Boat No	Species	No fish	Weight	Type	Gear	Label	Sex	Length	Type1	Length2	Type2	Length3	Type3
COMMENTS													

Page 1