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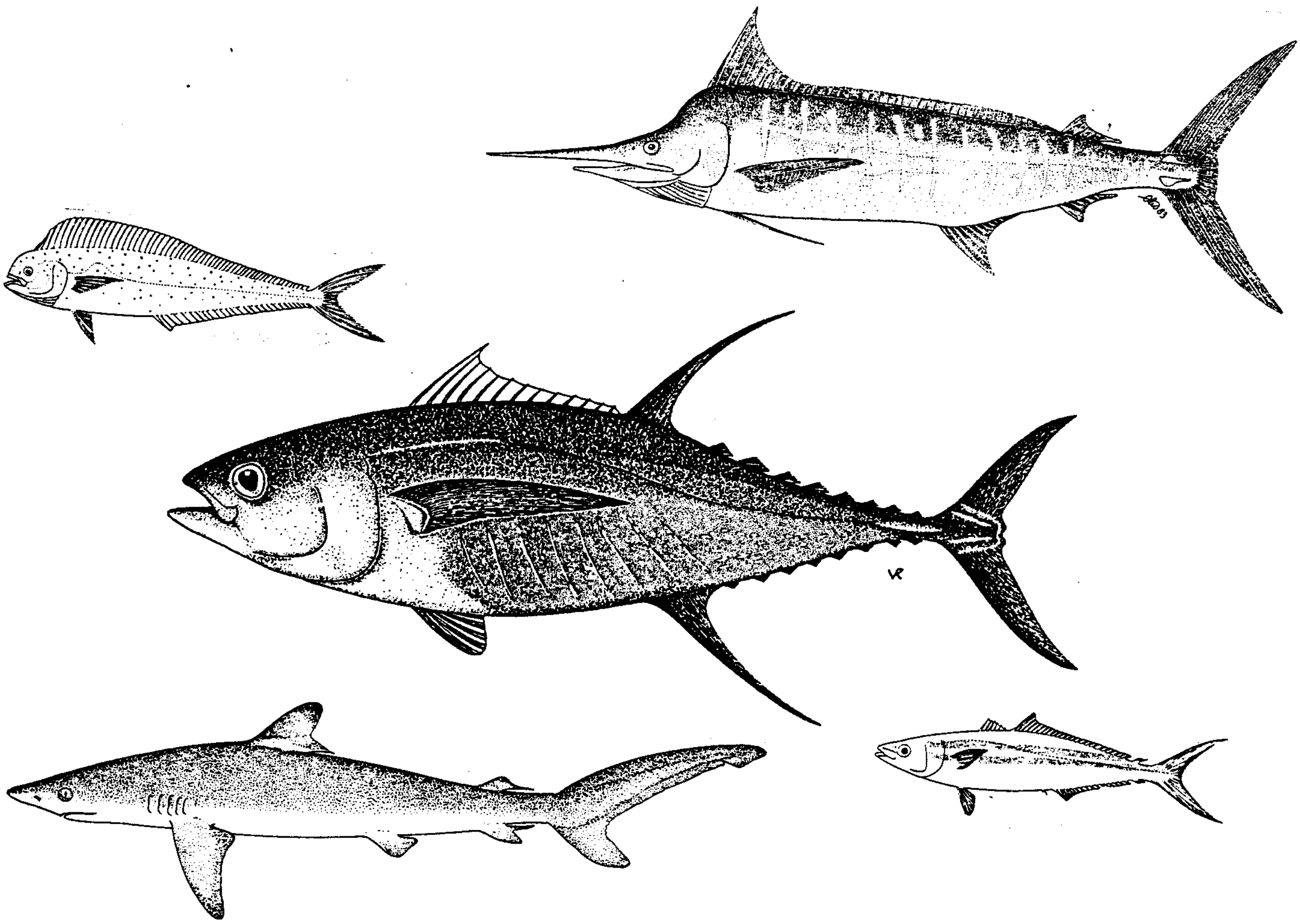
BY-CATCH AND DISCARDS IN WESTERN PACIFIC TUNA FISHERIES: A REVIEW OF SPC DATA HOLDINGS AND LITERATURE



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Tuna and Billfish Assessment Programme
South Pacific Commission
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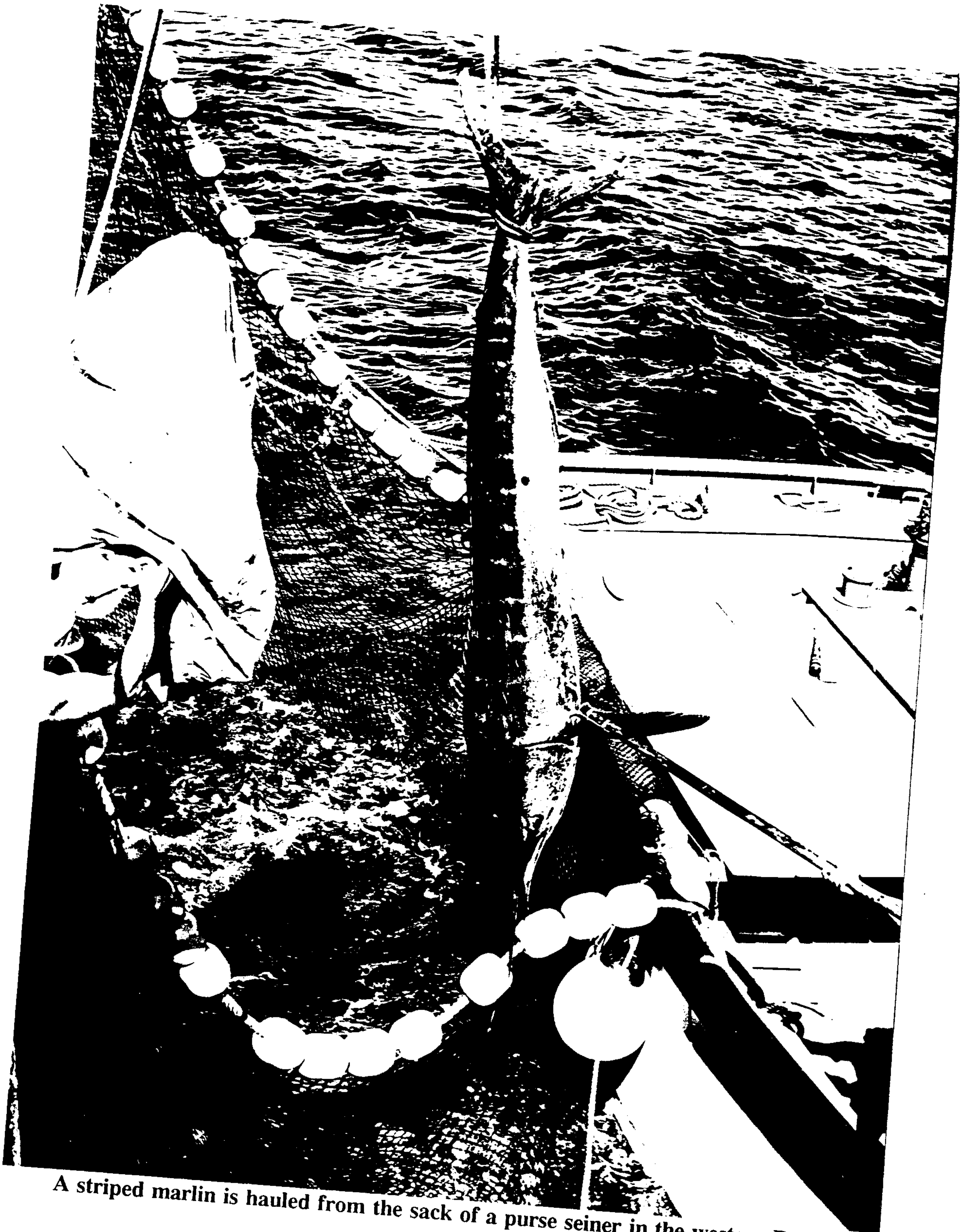

A striped marlin is hauled from the sack of a purse seiner in the western Pacific

1. INTRODUCTION

The western Pacific Ocean currently supports the largest industrial tuna fishery in the world, with an estimated catch in 1990 of 863,000 mt and over 1 million mt in 1991 (Lawson 1992a). Skipjack is the most important of the four major tuna species in the fishery, accounting for 74 per cent of the catch by weight in 1991, followed by yellowfin (20%), bigeye (4%) and albacore (2%). Purse seine gear was responsible for 78 per cent of the total catch, with pole-and-line gear accounting for 12 per cent, longline gear 9 per cent and troll gear 1 per cent. A small catch was also taken by driftnets.

All of these fisheries invariably have some level of catch of non-target species, that are hooked or netted with the targeted tuna. A portion of this by-catch is discarded because it has little or no economic value, and if retained would take up storage capacity best used for the more valuable tuna species. A portion of the target catch is also often discarded for economic reasons, or because it is damaged, physically too small for processing, or lost because of gear failures during fishing operations.

Recently, widespread attention has fallen on the large-mesh driftnet fishery operating in the South Pacific and its alleged high levels of by-catch of dolphins and numerous species of fish, as well as its effect on the stock size of the target species, albacore. This attention, most obviously seen in emotive and misleading statements in the media about the 'wall of death', has resulted in a world-wide moratorium on using large-mesh driftnets, even though experiments with nets suspended below the sea surface have reduced the by-catch substantially. The moratorium is one product of a growing perception amongst government agencies and environmental interest groups of the potential waste in the world's fisheries. A second example is the recent decision by US canneries not to purchase, process or sell any tuna caught in association with dolphins. This decision, made under mounting pressure from environmental groups, has had far reaching repercussions in the tuna industry, the least of which has been a displacement of US purse seiners to the western Pacific (e.g. Kronman 1990).

As attention will almost certainly fall on the industrial tuna fisheries in the western Pacific, it is timely that an objective review of their levels of by-catch and discards be undertaken. Thus, the Fourth Standing Committee on Tuna and Billfish requested the South Pacific Commission to 'evaluate and report available information on by-catch and discards in western Pacific tuna and billfish fisheries and advise on the need for further action' (SPC 1991). The Fifth Standing Committee on Tuna and Billfish considered the preliminary report and directed the draft to be formally presented to the Sixth Standing Committee on Tuna and Billfish. The Tuna and Billfish Assessment Programme of the SPC is well placed to carry out such a review as it maintains a database of daily catch and effort logsheet data from the major tuna fisheries in the region, and has in its employ fisheries scientists with considerable practical experience in these fisheries.

2. OBJECTIVES AND DEFINITIONS

The main objective of this report is to carry out a review of the by-catch and discard practices of the industrial tuna fisheries operating in the western Pacific, using logsheet data provided to the member countries of SPC, observer information, and published and unpublished reports. As stated above, the second objective is to advise the Standing Committee on Tuna and Billfish (STCB) on the need for further action regarding by-catch and discard practices.

The following definitions, based on those determined by the Fourth Standing Committee on Tuna and Billfish, are used throughout this report:

Target catch: Catch of target species, ie. skipjack, yellowfin, bigeye, albacore and southern bluefin tuna, and, in some instances, billfish. The actual target species vary depending on the gear used and the location. A fishing operation need not be restricted to a single target species, although one might be preferred over others (e.g. bigeye tuna preferred to yellowfin in longline operations).

By-catch: Any catch of species (fish, sharks, marine mammals, turtles, seabirds, etc) other than the target species. 'Incidental catch' can be regarded as synonymous.

Total catch: Sum of target catch and by-catch.

Discards: The portion of the total catch that is discarded. This includes discards of target species ('Tuna discards') and 'By-catch discards'.

Tuna discards include catches that are deliberately discarded because the fish are too small or damaged to be retained, are excess to storage capacity, and catches that are unintentionally discarded through gear failure (e.g. ripped purse seine sacks, driftnet drop-out, trolling drop-off, refrigeration failures). By-catch discards usually consist of species that have little or no economic value and are deliberately discarded.

The western Pacific is defined as the SPC statistical area, shown in Figure 1, that is covered by the South Pacific Commission/Forum Fisheries Agency Regional Tuna Fisheries Database (RTFD). The approximate boundaries of this area are the 25°N and 45°S lines of latitude, and the 125°E and 120°W lines of longitude, reflecting the 200 mile limits of the SPC member countries. For convenience, the statistical area is called the western Pacific Ocean (WPO) in this report and subdivided, because of the various fisheries involved, into the western tropical Pacific (WTP, 10°N—10°S), the western subtropical Pacific (WSP, 10°S—35°S, and the area to the north of 15°N designated WSPn) and the western temperate Pacific (WTeP, 35°—45°S). The new fisheries statistical area proposed by FAO to cover the main fishing grounds in the western Pacific (area 74) extends from 130°E to 120°W and 20°N to 30°S, and encompasses much of the WTP and WSP areas used here.

The industrial fisheries covered include six gear types, namely the purse seine, longline, pole-and-line, troll line, handline and driftnet. All of these gears, except for the driftnet, are currently in use. Table 1 summarises the various tuna (and billfish) fisheries in the WPO that are reviewed in this report. Artisanal fisheries, although widespread in the Pacific and incorporating varying degrees of commercial enterprise, are not reviewed because few data are available. The six gear types are covered in individual sections, with each section including an overview of the fishery or fisheries involved, a description of data sources used and gross levels of by-catch, by-catch discards and tuna discards from the data, followed by specific discussion of species and quantities involved and special attributes of the fisheries that influence by-catch and discards. Particular attention is placed on species of by-catch that may or are perceived to be under threat, e.g. billfish, seabirds, marine reptiles, particularly sea turtles, and marine mammals. Estimates of by-catch and discards are made when considered realistic with the available data. Brief comparisons of by-catch and discard levels are made with similar fisheries in other oceans. Each section ends with a summary of the essential by-catch and discard aspects of the specific fisheries. The final section in the report attempts to synthesise this information and present it in a realistic frame of reference; recommendations for further action are made where appropriate.

Recognised common names of species are used throughout the text; species names are only mentioned if they have not been included in the tables of by-catch provided for each fishery.

3. PURSE SEINE FISHERIES

3.1 Overview of western Pacific purse seine fisheries

3.1.1 Summary of the fishery

The purse seine fisheries in the WPO can be divided into two main components: a tropical component, that operates throughout the year in calm equatorial waters and provides the bulk of the tuna catch, made up of skipjack and a substantial proportion of yellowfin, and, to a lesser extent, bigeye; and a subtropical component that yields much smaller catches, is highly seasonal and consists almost entirely of skipjack. The tropical component, or WTP fishery, is mainly located in the area bounded by the 10°N and 10°S lines of latitude between eastern Indonesia (about 120°E) and the Phoenix and Line Islands of Kiribati (170°W—150°W). The subtropical component consists of the waters of eastern Australia, northern New Zealand and Fiji. Part of this component extends into the temperate waters of eastern Australia, targeting skipjack at present and southern bluefin prior to 1983. A large fleet of Japanese seiners targeting northern bluefin and skipjack to the north of the statistical area is not covered in this report. The WTP component is dominated by US-style single purse seine vessels with a smaller number of group seiners working in the region. Most of the WTP seiners utilize boom mounted power blocks with a small number of vessels using deck-mounted hauling gear, while the WSP and WTeP components have a greater mix of the two hauling systems. Itano (1990) summarises the development of purse seine activity in the WTP and details the gear and fishing techniques by school type utilised by the various fleets.

In 1990, the WPO purse seine fishery yielded an estimated 670,017 mt of skipjack and yellowfin (the latter including up to 10% bigeye, by weight), taken by 189 seiners from ten countries, including Australia, Indonesia, Japan, Korea, New Zealand, Philippines, Russia, Solomon Islands, Taiwan and USA. By 1991, the catch had risen to an estimated 848,907 mt. Most of these catches came from the WTP, and primarily from the large fleets operated by Japan, Korea, Taiwan and USA. A detailed breakdown of catches by the individual fleets is given in Lawson (1992a). Much of the following discussion centers on the fishery in the WTP.

3.1.2 Fishing method by school association

Purse seiners set on a variety of school types or 'associations,' ranging from schools associated with floating objects, such as logs and other naturally occurring debris, man-made Fish Aggregation Devices (FADs), and dead whales, to schools swimming with live animals such as whales and whale sharks. Sets are also made on tuna schools not associated with floating objects or other animals; these may be unassociated or free swimming schools that are usually feeding on baitfish or schools associated with geographic features such as seamounts and islands, or with oceanographic features such as current interfaces and areas of upwelling. Such sets are collectively termed school sets. Hampton and Bailey (1993) provide a detailed description of the principal school associations encountered in the WPO purse seine fishery. A summary of this description is given below because the associations largely determine the quantity and kinds of by-catch and discards in the fishery.

Logs and other floating debris are found throughout the WPO, often concentrating along productive interfaces between currents and water masses. Schools of tuna aggregate around them for a variety of possible reasons (e.g. feeding, shelter, orientation) and a viable purse seine fishery in the WTP was initially based on seining tuna schools associated with drifting objects (Doulman 1987). This fishing technique accounts for a significant portion of the purse seine catch (56% of the 1975-1990 catch from 49% of the sets on the RTFD). Logs can consist of sections of trunk, groups of branches or entire trees. Other debris includes almost any floating object that is washed or drifts out to sea or is jettisoned from ships, e.g. canoes and boats, drums, cable spools, polystyrene floats, discarded mooring lines, and wooden pallets. Most occurrences within this association type are, however, of logs. Log sets are usually made immediately before dawn, at a time when tuna are most vulnerable to purse seining as they are concentrated close to the log and can not see and avoid the encircling net.

FADs in the WPO appear to operate very much like logs in terms of fish aggregation, how the tuna behave in their vicinity, and the general strategies used by seiners to set on them. Two basic types of FAD association are recognised; the first involving FADs that are anchored in place, usually within a network of similar units, and the second involving FADs that have broken loose from their mooring lines and drifted away or have been deliberately deployed without mooring lines. Within the second category, the Japanese appear to include associations with logs and debris that have been roped together (Tanaka, 1989). The Japanese are also known to anchor FADs near small islands and release them to drift after a suitable 'ageing' period has resulted in the accumulation of encrusting life and a population of baitfish (D.G. Itano pers. comm.). A large volume of literature exists on the types and designs of FADs in use in the WPO (e.g. Preston 1982; SPC 1989; Malig et al. 1991). Anchored and drifting FAD sets make up 3 per cent and 2 per cent of the sets recorded on the RTFD, respectively.

Apart from tuna, logs and FADs aggregate a considerable number of other fish species, ranging from typically reef associated species such as the sergeant major, rainbow runner and barracuda, to the truly pelagic species such as the ocean triggerfish, oceanic whitetip shark and blue marlin. Some of these species, particularly the small schooling pelagics such as the rainbow runner, mackerel scad, frigate tuna and kawakawa, can occur in quantity, often in terms of tonnes. To US purse seine fishermen, these species are collectively known as 'bait fish', although they may variously compete with or prey on tuna.

There is strong evidence of stratification of the bait fish and tuna species beneath logs, with many of the small or typically reef associated species (eg. ocean triggerfish, drummer, jacks and sergeant major) maintaining a close relationship with the object while the larger, species (eg. rainbow runner, wahoo, mahimahi, mackerel scad) ranging further away. The bait fish generally stay in the upper part of the water column with the tuna species aggregated below. Skipjack tend to aggregate in the upper 20-40 m, with yellowfin further below and bigeye the down below 100 m.
Seiners often use the rise of these schools in the early morning as a signal to begin setting. The latter species also appears to form the strongest association, as schools of bigeye are apparent underneath logs throughout the day and night while skipjack and yellowfin tend to forage away from the log during daylight hours.

Animal associations commonly consist of two distinct association types; tuna aggregating and feeding with sei whales (*Balaenoptera borealis*) and, to a lesser extent, minke whales (*B. acutorostrata*), and schools associated with the slow moving whale shark. Tuna schools found with live whales do not appear to form long-term associations with the whales; they seem only to come together to feed on pelagic baitfish schools and separate once the feeding activity is finished. In this sense, these schools are similar to the unassociated schools described below, and are set on in the same way. The seiner will, however, attempt to encircle the whale during the setting operation, as the tuna will tend to remain close to the whale thus improving the chance for a successful set. Once pursed, the whale escapes by punching a hole through the net.

Whale shark associations appear to be intermediate between live whales and logs in that the shark and tuna often come together to feed on anchovy but can maintain the association for some time in the absence of feeding behaviour, much like tuna aggregating under a slow moving log. There have even been records of tuna schools travelling with slow moving sailing craft (Oceans mag?). Whale sharks are set on during the day, as it is impractical to mark them with buoys and therefore difficult to locate in the dark. The amount of bycatch associated with these categories is typically low.

In comparison, schools found associated with floating whale carcasses are similar to log associations, with large attendant schools of bait fish species. Dead whales are rarely encountered but when so, are treated like logs, marked with radio and light buoys for tracking and set on before dawn. Animal sets make up 2 per cent of the sets on the database.

In the eastern Pacific, a large proportion of purse sets are made on tuna associated with porpoise. This association is extremely rare in the western Pacific, presumably because of the low abundance of large schools of porpoise in the main fishing grounds and oceanographic conditions that differ markedly from the eastern Pacific. In addition, successful purse seining on porpoise associated schools is a technically complicated procedure that requires a crew experienced with this type of fishing and a modified net.

Consequently, there is no evidence of purse seiners deliberately setting on dolphin-associated tuna schools in the western Pacific.

Unassociated schools are typically surface schools that range in activity from fast moving 'breezers' that appear like a breeze blowing across the sea surface to stationary 'boilers' and 'foamers' consisting of tuna churning the surface into a white froth while feeding on pelagic bait fish and other forage. The latter types of schools are most preferred for seinging as the tuna are distracted by their feeding frenzy and easier to encircle with the seine. In comparison, breezing schools are more erratic in behaviour and are often moving at speed, making them difficult to encircle and catch. School fishing in the WTP has required that nets be lengthened to effectively encircle the fast-moving schools and deepened to extend below the depth of the WTP thermocline. A typical U.S. net currently measures in excess of 1,500 m long by 220 m deep. Along with these developments, there have been increases in mesh size and recuctions in twine size to allow the net to sink faster with reduced water resistance during pursing and net retreival and increases in purse winch power that allows net pursing to be conducted in less than 15 minutes. Unassociated sets make up 34 per cent of the sets on the RTFD.

3.2 Sources and coverage of data

Catch and effort log sheet data from foreign purse seiners operating in the Exclusive Economic Zones of SPC member countries are provided to those countries as part of the reporting requirements of access agreements. Data from domestic seiners are also provided. These data are forwarded to FFA and SPC for computer storage and, in the case of SPC, used for reporting back to the countries on the condition of the tuna stocks in their waters and the WPO as a whole. Table 2 details the fleets and periods for which catch and effort data are stored in the RTFD and used in this review; for the WTP fishery, the data cover the period from 1979 to the end of 1991. The various access agreements in effect between member countries and purse seine operators or associations require that log sheets be completed, and instructions are provided with the forms to assist the vessel captains. While by-catch and discards are usually defined in the instructions, there are no legal obligations to include this information and no penalties are imposed on non-reporters. Thus, the information at hand is extremely patchy and largely unvalidated. In most cases, however, it is the best information available at present.

Coverage of individual fleets in the RTFD is extremely variable, eg. the catches of Korean and Taiwanese vessels are estimated to be under-reported by a factor of three for the period 1980—1989 and by a factor of five in 1990 (Lawson 1992b). The estimated levels of non-reporting of catch (and by inference, sets) for the two fleets in 1990 are quite different, 75 per cent for the Korean fleet and 5 per cent for the Taiwanese fleet. Coverage of the U.S. fleet is poor for most years up until mid-June 1988, when the Treaty on Fisheries Between the Governments of Certain Pacific Island States and the Government of the United States of America came into affect and all U.S. flag tuna vessels were required to provide catch data within a large treaty area stretching from the Line Islands of Kiribati to Palau. The coverage of the Japanese fleet is good for most of the period (70% for 1980-1989), while the smaller fleets are of variable and often unknown coverage. The estimates of 1990 by-catch levels presented in this study are based on the following levels of reporting of sets:

Australia	100%	(Unknown but assumed)
Indonesia	100%	(Unknown but assumed)
Japan	70%	
Korea	25%	
Philippines	100%	(Unknown but assumed)
Solomon Islands	100%	
Taiwan	95%	
U.S.A.	100%	

Various log sheet forms have been used by the purse seine fleets for the recording of catch and effort data, and although the information on the forms had been largely standardised by the mid-1980's, many forms used in the early years of the fishery by Japanese and Solomon Islands vessels had no provision for the recording of by-catch and/or discards. The small percentage of records from such forms do not affect the conclusions and estimates presented here. New forms to be used by FFA observers on US purse seiners operating under provisions of the US Multi-lateral Treaty on fisheries were designed to obtain more accurate catch, effort, by-catch and discard information.

As there are a limited number of set types identified on most catch forms used on seiners, it is not possible in the present analysis to divide the data into the variety of associations described in the previous section. Thus, sets made on live and dead whales and whale sharks, all of which are different in terms of setting strategy, by-catch species, and often the target species, have been combined into a single category, the animal set. Similarly, it is not possible to determine what proportion of school sets are made on geographic or oceanographic features. As a number of these features tend to concentrate logs and other floating debris, it is probable that data on log sets include sets made on schools that have formed a geographic or oceanographic association.

In the database there are two further categories of set type, 'Other' and 'Unspecified', The former involves such set types as boat-associated schools (Itano 1991; Suzuki 1992), early morning sets on schools that have temporarily moved away from logs, and subsurface schools set on with sonar, and are difficult to assign to specific set types, and the latter includes all records where no set type was recorded. These two set types both comprise 5 per cent of the data on the RTFD.

As the Philippine fleet deploys the largest number of FADs in the WPO, it is likely that many of the drifting FAD sets recorded in the database for this fleet are in fact on FADs or their underwater appendages that have been disconnected from their mooring lines rather than having broken loose naturally. Thus many of these sets should be considered as anchored FAD sets, but cannot be easily separated in the database. Similarly, drifting FAD sets made by New Zealand vessels operating in Fiji waters were probably all on anchored FAD rafts that were deliberately unhooked prior to setting and then rehooked after the set (G. Preston pers. comm.)

A number of limitations exist in the structure of the RTFD, the most relevant to this study is that entry of by-catch species is limited to one entry per set (or record), even though the log sheet may include more than one by-catch species per set. To rectify this would involve re-writing existing programmes and re-entry of data, a task which is of low priority, considering the low level of reporting of by-catch species and limited personnel. Also, and not surprisingly, less care has been taken in the recording of by-catch and discard than with target catch. Practical experience in the fishery and common sense has meant that glaring errors in data entry have been located and corrected (eg. 590 mt of rainbow runner in five log sets changed to 590 kg.) Error checks now built into the entry routines currently prevent such discrepancies from arising in the future.

Data from the SPC Regional Tuna Tagging Project (RTTP) and Philippines Tuna Research Project (PTRP) have also been used. Although these projects employed a pole-and-line vessel as the principal fishing and tagging platform, the vessel has concentrated its efforts in the main purse seine area in the WTP and fished on essentially the same surface and subsurface schools available to seiners. This has been borne out by the high proportion of recoveries of tagged fish from the purse seine vessels.

The available literature on the fishery is sparse, and the present review relies heavily on a series of SPC reports describing observer trips on Japanese, U.S. and New Zealand seiners from 1984 to 1990, and Pacific Tuna Development Foundation (PTDF) reports generated from exploratory fishing by U.S. seiners in the WPO between 1976 and 1983. The South Pacific Forum Fisheries Agency observer programme on U.S. vessels has also provided a limited amount of data, although the programme is primarily aimed at compliance and enforcement of the Multilateral Treaty rather than scientific data collection.

The experiences and private log books of two SPC staff members (D.G. Itano and K. Bailey), who have worked on U.S. seiners in the WTP and New Zealand fisheries for a number of years, have also been incorporated in this report.

3.3 By-catch and discards of by-catch

3.3.1 Gross levels of by-catch and reporting
(a) General

During the period 1975 to 1991, data stored on the RTFD account for 2.2 million mt of fish caught by purse seiners operating in the WPO. Of this reported catch, 99.79 per cent consisted of target catch, ie. skipjack, yellowfin and bigeye tuna (and a small percentage of southern bluefin tuna in eastern Australia), while only 0.21 per cent consisted of by-catch (Table 2). This reported by-catch represents 4,703 mt of fish.

For the main fishery in the WTP, the levels of by-catch reported by the fleets varies by one or two orders of magnitude. Although some of this variation can be explained by the types of schools that are targeted by various fleets (eg. Philippine and Solomon Islands vessels concentrate on FAD-associated schools, which would expect to result in relatively high levels of by-catch), it appears from this gross view of the available data that there is considerable non-reporting of by-catch. This is particularly apparent amongst the main fleets of Japan, Korea, Taiwan and U.S. which fish the same areas and use the same basic strategies and gear yet have levels of by-catch that vary by an order of magnitude.

The geographical distributions of reported purse seine effort and by-catch (mt) are shown in Figure 2. By-catch is almost entirely concentrated in the equatorial WTP between 5°N and 5°S, particularly to the south of the Equator. Large by-catch levels were reported to the northeast of the Solomon Islands and in the Solomon Sea, in areas of relatively low effort. The area immediately to the north of Papua New Guinea also yielded high by-catch, but as a result of high effort.

3.3.2 Species and levels of by-catch by school association

An indication of the various levels of by-catch resulting from fishing on different types of schools, and by inference the extent of non-reporting amongst the fleets, is given in Table 3. The bottom of the table lists descriptive statistics for all school types, i.e. mean, standard deviation, median, mode, geometric mean. The reported by-catch in metric tonnes per set is generally less than two tonnes, with most reported by-catch by school association having a mode of 1.0 mt per set. Figure 7 (a)-(e) indicates the frequency of reported by-catch by school association, and clearly illustrates the skewed distribution with most values falling below two or three tonnes and a long tail extending along the X axis which represents a few sets with large quantities of bycatch. An abnormal frequency distribution of this kind is not well represented by an arithmetic mean, and median values for by-catch per set were substituted in Table 3.

For example, the mean by-catch value for all reported school sets (n = 71) is 3.8 mt/set. This value seems far too high in relation to the frequency distribution depicted in Figure 8 and observer reports and practical experience in the fishery. In addition, this mean value is higher than mean by-catch for log and FAD sets which is counter to general knowledge that associated sets contain higher quantities of by-catch. The value is unnaturally elevated by a single set with 90.0 mt of reported by-catch. The actual mode for all school sets is only 0.1 mt/set, with a median and geometric mean of 0.5 and 0.6 mt per set respectively. These values are far more reasonable by-catch estimates for unassociated sets that have some by-catch according to what is known of the fishery.

The median values for log, drifting FAD and anchored FAD associated sets are 1.0, 1.0 and 1.2 mt per set respectively. These values may be too conservative, as WTP drifting logs and FADs are known to hold large populations of some by-catch species. However, it is considerably higher when compared to useful observer data (81 sets) which yields an average of only 0.3 mt per set. The mean values for these associated school types are 3.3, 1.9 and 2.9 mt respectively. The geometric means fall between mean and median values at 1.1, 1.3 and 1.6 mt per set which appear to be reasonable estimates of 'average' by-catch from log and FAD associated purse seine sets.

No matter what value is used to describe by-catch quantities, it is clear that the level of by-catch reporting is extremely low, with for instance only 0.2 per cent of the 28,791 school sets and 1.5 per cent of the 41,524 log sets on the database reporting by-catch. In comparison, observer reports show that most if not all log and FAD sets and a considerable proportion of school sets have some level of by-catch. The highest level of by-catch reporting occurs in anchored FAD sets, at 14.4 per cent of sets.

In terms of individual fleets, the Philippines and Solomon Islands fleets provide the highest level of by-catch reporting, ranging from 14.5—16.3 per cent of anchored FAD sets and 19.2—50.0 per cent of log sets (Table 3). Both fleets are based on fishing on anchored FADs. Reporting levels from the Philippine fleet are known to be relatively good and the Solomon Islands purse seine fishery is regularly monitored by a domestic observer programme which improves reporting considerably. The lowest levels of reporting are seen in the Japanese, Korean and Taiwanese fleets, most of which are not subject to regular observer programmes and seldom enter regional ports. The U.S. reporting level for school sets is comparable to the above three fleets but an order of magnitude higher than either Japan or Taiwan for log sets. This discrepancy is compounded by the fact that Japanese and Taiwanese log sets recorded on the database out-number those of the U.S. by a factor of seven. Reporting on US boats may be better due to the presence of FFA observers on many of the vessels.

In a number of the cases, it appears that by-catch may only be reported when it is unusually high and particularly noticeable. Reported by-catch for school sets is very low at 0.2% of all school sets. However, observer reports show that school sets often have some degree of by-catch (12.9% of 287 sets for Bailey and Souter 1982; Gillett 1986a,b; Itano 1991; FFA observer programme), but the by-catch is usually limited to a small number of apex predators taken per set. Common by-catch species from school sets include blue marlin, black marlin, and silky and oceanic whitetip sharks (Table 4) that may approach 0.2-0.5 mt per set. On rare occasions, sets may be made on schools, particularly those near reefs or seamounts, where rainbow runner, mackerel or small tunas (frigate, bullet, kawakawa) are common, and such sets may produce relatively large amounts of by-catch (Table 5). In addition, unsuccessful school sets ('skunks') often result in catches of sharks and billfish, although such catches are unlikely to be recorded unless an observer is on board.

It is difficult to estimate the amount of by-catch from school sets using the data from the RTFD because of both the questionable catch rates and proportions of sets with by-catch. Much of the data pertaining to the 287 sets mentioned above only include numbers of fish as by-catch. However, rough estimates can be made assuming that 12.9 per cent of school sets have some by-catch at approximately 0.5 mt per set.

Both the literature and RTFD data show that most of the by-catch in school sets is discarded, primarily because the species caught have a much lower value compared to the target species when stored using the technology employed by most WTP purse seiners. For the U.S. fleet, with the largest number of reported by-catch sets, over 90 per cent of the by-catch is discarded. On most seiners, sharks fins are retained for sale in landing ports and the carcasses are discarded. Occasionally, the teeth or jaws are retained for souveniers or sale. Billfish are a special case, and depending on the amount of catch and school activity, are either discarded, retained for consumption or occasionally stored for sale. Billfish by-catch is discussed in section 3.3.4 (a).

Log schools produce an overall median of 1.0 mt per set from the 682 sets in which by-catch is declared, with a range of 0.5 to 5.0 mt per set reported from the fleets (Table 3). For anyone who has witnessed WTP log associated sets, this level of catch is not surprising. Not only do most logs have a large attendant population of fish (at lease a possible 45 species, as listed in Table 4, also Table 5), dominated by rainbow runner, mahimahi, ocean triggerfish, mackerel scad, and silky shark, but the purse seine operation does not allow for an easy escape for most species. Earnest attempts are made to reduce by-catch levels because of the extra work involved in cleaning the net of 'gillers' and sorting the catch during brailing in the limited time available before the tuna begin to spoil in the tropical climate. Most fishermen also believe that removing the 'bait' species from a log will detract from its productivity, e.g. ability to aggregate tuna schools. Thus, when pursing is complete and before net hauling commences, the main boom is lowered on the net side so that a gap forms between the vessel and the end of the net through which the log can be slowly towed allowing the bait to escape. While this operation can be successful, most log sets end with the species that swim furthest from the log turning back into the net and becoming mixed with the catch that is brailed aboard.

As with school set by-catch, much of the by-catch from log sets is of low economic value and is discarded at sea. This is particularly apparent for U.S. and Korean vessels which discard 86.6 and 84.4 per cent of their respective by-catches. Discarding usually takes place on the working deck after the catch is brailed to a sorting receiver or 'hopper'. Some of the hardier species, such as rainbow runner and ocean triggerfish are known to survive this ordeal, but the majority of purse seine by-catch is discarded dead or mortally wounded (Itano, pers. obs). On most vessels, small quantities of mahimahi, wahoo and other edible species are kept for crew consumption and barter or gifts in port.

The Philippines fleet exhibits the lowest by-catch discard rate (16.9% for the fleet), primarily because one of the companies involved (Company 2 in Table 6) retains and processes both tuna and by-catch species for sale. The high by-catch and proportion of recorded sets for the company (4.4 mt per set, 24.8% of sets) may also relate in part to this retention. In comparison, Company 1, which fishes in a similar fashion to Company 2, records extremely low levels of by-catch and discards. According to an executive of Company 1, its vessels keep by-catch and catch of small tuna (and hence, tuna discards) to a minimum by:

(a) Using a mesh size of 12" (30 cm) in the main body of the seine net, through which they claim bait fish can swim without becoming entangled. In comparison, U.S. and Japanese nets typically have a mesh size of 4—6" (10—15 cm) and 4—9" (10—23 cm), respectively. The mesh size in Company 2 nets measures about 1—2"(2.5—5 cm) for obvious reasons. The mesh size in the sack of Company 1 nets is similar to other fleets, averaging 3.5" (9 cm), but the company is considering increasing this to 6" to reduce gilling of small tuna and mackerel scad.

(b) Careful gauging of the size of the tuna around the FADs. If all fish signs on the sonar are within 15 m of the surface, the FAD is usually not set on as the tuna are thought to be too small for canning (for this company, < 1.2 kg). This is verified by observing surface activity. If large tuna are mixed with the spot, however, they are usually seen jumping, and in this case a set is made. If there is a separate sonar target below the bait and small tuna, then a set is also made.

(c) Pursing at maximum speed so that bait fish can escape over the corkline as it sinks, although this can result in tuna escaping as well.

While these practices would certainly reduce the amount of by-catch, it is difficult to believe the reduction would be as substantial as that shown in the logsheets provided by Company 1. Point (b), for example, is a routine method used by most fleets to determine whether logs or FADs are chosen for a set. The large mesh size in the Company 1 nets and the possibility of increasing the mesh size in the sack are innovations that may be worth investigating if there is a movement towards reducing or controlling by-catch in the fishery.

It is interesting to note the relatively low discard rate on Japanese vessels (24.5%), which might suggest that much of the by-catch is retained. Observer reports tend to refute this (eg. Gillett, 1986b; Itano, 1991), although Itano notes that on one group seiner a small amount of by-catch was retained for crew consumption and Gillett mentions that one Japanese single seiner retained marlin for sale in Japan. Such retention is unlikely to account for the reported discard rate, as crew consumption is minimal and marlins mostly occur in small numbers around individual logs. As most of the logsheet forms supplied to Japanese vessels have columns for discards, the high retention rate is probably not due to unintentional non-reporting. One possibility is that the Japanese (and perhaps some of the other Asian fleets) are unclear in their understanding of the difference between 'Other catch' (ie. retained by-catch) and 'Other discards' (discarded by-catch), as defined on the logsheets, and therefore record most by-catch in the Other catch column when in fact a large proportion is discarded. This bears further investigation, and if it proves to be the case may require changes to form layout and definitions.

Reported FAD by-catch ranges from medians of 3.0 mt per set for Solomon Islands anchord FADs (171 sets with declared by-catch) to 1.0 mt for Philippine anchored FADs (210 sets)(Table 3). It is possible that the higher reporting rate for Solomon Islands seiners may due to better reporting on those vessels that is encouraged by an active domestic observer programme conducted by the Solomon Islands Fisheries Division.

FADs produce a similar range of by-catch species to logs, dominated by the same five or six species (Table 4) and drifting FADs are essentially identical to logs. The slightly higher by-catch rates between anchored FADs and logs indicated in Table 3 is possibly related to the fact that FADs are usually anchored near islands and land masses where by-catch species may be more abundant. Also, FADs are usually set in a network allowing a seiner to set on a different FAD every day, thus allowing the associated tuna (and by-catch) populations to rebuild between visits. In contrast, logs are often set repeatedly or within a short time period until they become unproductive which does not allow time for by-catch to recruit to the log.

Two medium sized New Zealand purse seiners operated in Fiji from 1981 to 1985, fishing almost exclusively on a large network of anchored FADs. During the 1984-1985 season, one of these vessels recorded a bycatch of 1.7 mt per set for one year of operation (62 mt in 103 sets) (Itano 1989). Most of the catch consisted of rainbow runner, but mahimahi and kawakawa were other common by-catch species. Farman (1984) notes that all by-catch from FAD sets made by the New Zealand vessels in Fiji were sold locally, except for sharks, where only the fins were marketed. All proceeds of these sales went to the crew. It also appears that a large part of the by-catch in the Solomon Islands is retained, most of which probably goes for local sale and consumption. Sale of by-catch (and tuna discards) has lead to intense conflict between seiner crews and local fisherman in the Solomons and Fiji (A.D. Lewis, pers. comm.) The same is true in American Samoa, where inexpensive and readily available purse seine and longline by-catch has long been a constraint on the development of local artisanal fisheries (Itano, 1991).

By-catch information on animal sets from the RTFD is limited to two sets made by Korean seiners that produced an average of 1.0 mt of by-catch per set; as live whale sets produce a similar range of species to school sets it is possible that the two Korean sets were of this type.

Dead whale sets are similar to log and FAD sets, with the same predominant species, possibly in greater quantities. Sharks are very abundant around floating whale carcasses, probably in higher densities compared to logs or FADs. Information on the species taken in dead whale sets is limited, with only nine species recorded (Table 4). It is probable that most of the species found with logs and FADs also occur with this association type. There is also little information for whale shark sets; RTTP records list three species but it is almost certain that many of the species found with schools and logs (eg. silky sharks, rainbow runner, mahimahi) are common with whale sharks. For the purposes of estimating by-catch, all animal sets have been considered as school sets.

Other and Unspecified set types produce a variety of by-catch species (Table 5) and quantities that suggest that many of these sets are made on floating objects. For the sets with by-catch, 60.3 per cent of Other sets and 95.3 per cent of Unspecified sets were made before 0600 hours, at a time when most floating object sets are made in the WTP (Hampton and Bailey 1993). The respective percentages for all sets within these categories made before 0600 are 26.3 per cent and 67.4 per cent.

The seasonal New Zealand purse seine fishery of the WTeP is based entirely on setting on unassociated schools of skipjack. However, the seasonality of the fishery, its proximity to a large land mass and extensive continental shelf and location in temperate seas results in an unique mix of by-catch species, including pelagic and benthic resident species, tropical migrants and species found in all oceans. Habib et al. (1982; unpublished) provide a detailed list of the 68 species of sharks, rays and bony fishes that have been recorded by MAF observers during the period from 1975 to 1982 when U.S. super seiners dominated the fishery. However, because of the inconsistent nature of these recordings, it is not possible to use this information to determine the relative occurrence of species in the by-catch. A subset of the data, using records of observers who consistently reported by-catch, is presented in Table 7. A total of 904 sets by U.S. and New Zealand super seiners was examined; 47.9 per cent of these sets contained some by-catch. Of the 46 species of sharks, rays and fish listed, the most common species were the sunfish (15.5% of all sets), manta ray (8.2%), albacore (7.3%), and porcupine fish (5.8%). Although it is not possible to convert these occurrences to weights, observer records and personal experience indicate that the by-catch of this fishery rarely exceeded 0.5-1 mt per set. In terms of the limited data held on the RTFD for the New Zealand fishery, it appears that U.S. vessels have completely ignored by-catch in their reporting. For the period 1976 to 1983, super seiners made a total of 2,924 sets in the fishery (West 1991); assuming that about half of these sets had by-catch, and that the by-catch attained a level of 0.5-1 mt/set, then an estimate of overall by-catch would be 578-1,147 mt.

Most of this by-catch was discarded because of its low economic value; a small but unquantifiable amount was retained for crew consumption, particularly the marlins, albacore and yellowfin tuna (K. Bailey pers. obs.).

Apart from a single super seiner operating from 1976 to 1982, New Zealand flag vessels are small (23-36 m LOA, carrying capacity 90-350 mt) and unable to effectively compete with the larger and faster U.S.-style seiners. Thus, much of their effort has been limited to continental shelf waters, particularly in the Bay of Plenty, and their by-catch has differed accordingly, with a higher percentage of coastal species. Unfortunately, observer activity on these vessels was limited and no useful information is readily available. The RTFD has records of 1,829 sets by these vessels, resulting in the capture of 2,170 individual by-catch fish. As by-catch is provided in numbers, the data are of limited use. An unusual feature of this fishery is the high percentage of mako shark in the by-catch (73.7 per cent of records) and high numbers in individual sets (averaging 33 sharks per set catching mako), which suggests that by-catch is only reported when numbers are substantial.

No information is available on the by-catch of the purse seine fisheries in eastern Australian waters. Similarly, there is very little data available on the by-catch of the small number of sets made in New Caledonian waters by U.S. seiners. Hoffschir (1981) reported the presence of considerable numbers of sharks taken as bycatch during three school fish sets near the Chesterfield Reefs during an observer trip on one U.S. vessel.

(b) Billfish

Six species of billfish are known to occur as by-catch of the purse seine fishery in the WTP (Table 4). Billfish by-catch data on the RTFD is very sparse and therefore of little value (Table 5), apart from highlighting the extent of non-reporting. The introduction of a new log form to the U.S. fleet in mid-1991 that includes a column specifically for billfish catch has only slightly improved the quantity of data. In comparison, observer reports, summarised in Table 9, show that billfish are a common by-catch item in log sets (41.7% of 103 sets) and to a lesser extent in school sets (9.4% of 159 sets). Marlin species dominate this by-catch, particularly the blue marlin which occurs in at least 72.1 per cent and 33.3 per cent of those observed log and school sets, respectively, with billfish catch.

An extrapolation from the figures in Table 9 gives an estimated catch of 27,686 billfish over the period 1982-1991 (3,068 from school sets, 24,618 from log sets), and 6,959 in 1990 (1,012 from school sets, 5,947 from log sets) after scaling the set number for coverage. Taking an average weight of 66 kg per billfish (Ref.), the estimated catch in 1990 may represent 459 mt of billfish. Japanese participants at Billfish Symposium II mentioned that Japanese seiners operating in the WTP caught between 114 and 139 mt of marlin per year over the period 1985 to 1987 (Bailey 1988), which suggests that the estimate for 1990 is of the correct order of magnitude.

As the fishery has developed, there has been a gradual shift amongst the larger and more technologically advanced fleets from fishing on logs to setting on free schools. As the proportion of school sets with accompanying marlin is substantially less than with log sets, this shift has possibly resulted in a decrease in marlin by-catch, offset to an unknown degree, however, by fleet expansion.

In the New Zealand skipjack fishery, the billfish by-catch is dominated by striped marlin in terms of numbers

(Habib et al. 1982) and occurrence in sets (Table 7), followed by the blue marlin and black marlin. Swordfish occur in relatively small numbers. The predominance of striped marlin in the catch is not surprising considering that the species prefers subtropical and temperate waters (Nakamura 1985) and supports a world-famous big game sport fishery along the northeast coast of New Zealand.

The proportion of billfish by-catch that is discarded is not known, although from observer reports and personal experience, it is probably high. Billfish are normally discarded from U.S. seiners when they hinder the sacking-up and brailing processes, but are brought on board for crew consumption if time permits and the catch of tuna in the particular set is small (Bailey, pers. obs.). Special efforts are made to retain swordfish on the rare occasions they are caught, because of their superior eating quality. On Japanese vessels, billfish are also usually discarded, although Gillett (1986b) reports that one single seiner retained billfish for sale in Japan. It is not known how widespread this practice is, although it is probably dependent on current prices on the Japanese market and the species involved.

Amongst the remaining fleets, billfish are probably retained for consumption whenever practical, and for sale in some instances (eg, Philippines vessels, and New Zealand vessels operating in Fiji waters (Farman 1984)).

(c) Seabirds

There are no records in either the RTFD or in the literature of seabirds occurring as by-catch of purse seiners operating in the WPO.

(d) Marine reptiles

There are no data on the by-catch of marine reptiles in the RTFD. SPC staff have noted the occurrence of three species of turtle and a single species of sea snake in the vicinity of logs and FADs and in purse seine sets on logs. Of the 116 logs investigated by the RTTP in 1991, individual turtles were associated with six (5.2%). Taking this percentage as a rough estimate of turtle occurrence around logs in the WTP, it is possible that some 2,100 turtles have been caught in logs sets over the period investigated, with about 384 in 1991 alone. The fate of turtle by-catch is unknown, although on many vessels they are probably retained as food for the crew, and in the case of at least the Philippine and Indonesian seiners are probably retained for sale as ornaments. One US seiner, owned and operated by Americans of Japanese descent, is known to release any turtles caught because it is considered bad luck to hurt them. It is not known, however, whether turtles are also released by Japanese flag vessels, although it is possible that vessels operated by some of the older Japanese fishermen may follow this belief.

There are no records of turtles being caught in other set types, although they are known to occur in association with drifting and anchored FADs and current lines of floating debris.

(e) Marine mammals

There is no evidence to suggest that purse seiners make dolphin-associated sets in the WPO. The dolphin species that form associations with large yellowfin tuna in the eastern Pacific, primarily the spotted dolphin (*Stenella attenuata*) and to a lesser extent the spinner (*S. longirostris*) and common (*Delphinus delphis*) dolphins (Wild 1991), are present in the WPO, but appear to be rare in the main area of purse seine activity and do not form large aggregations similar to those found in the ETP. In a series of exploratory charters between 1974 and 1984, ten U.S. seiners experienced in tuna/porpoise fishing recorded 190 dolphin pods over a period of 772 searching/fishing days, of which 61 were of the preferred three species (PTDF 1977, 1978; Souter and Broadhead 1978; Burns and Souter 1980; Salomons and Souter 1980; Souter and Salomons 1980a,b; Bailey and Souter 1982; Lambert 1984). In two instances dolphin-tuna associations were encountered but not set on (PTDF 1977). More recent reports on Japanese and U.S. vessels support this evidence, with none of the authors recording dolphin sets (Gillett 1986a,b; Farman 1987; Tanaka 1989; Itano 1991; Suzuki 1992). In addition, of the 1,794 tuna schools sighted and fished by the SPC tagging vessel, *Te Tautai*, in the WPO (excluding Indonesia and the Philippines) over the last two years only one school, found in northern Papua New Guinea waters, was associated with dolphins. These dolphins were tentatively identified as spinners. This vessel has, however, fished on six dolphin associated tuna schools (out of 264 schools) in the archipelagic waters of Indonesia and the Philippines, suggesting that the association is more common in these areas. It should be noted that none of these associations involved the large yellowfin typical of the eastern Pacific association but involved either skipjack or mixed schools of skipjack and small to medium-sized yellowfin. The tightness of this association was also unknown.

In addition to the differences in dolphin abundance, it appears that the oceanographic and biological conditions in the eastern Pacific that may promote the association between dolphin and yellowfin (e.g. shallow thermocline, abundance of ommastrephid squid) are not usually present in the WPO.

The only recorded instances of dolphin by-catch in the WPO come from the seasonal purse seine fishery for skipjack in northern New Zealand waters. This fishery was routinely monitored by a MAF Fisheries scientific observer programme that recorded catch and by-catch. Of the 2,924 sets made in the fishery between 1976 and 1983, only two are known to have resulted in the capture of dolphin (MAF Fisheries records). One set, made at dusk, resulted in the drowning of 11 common dolphin, while the second set resulted in the capture of 15 common dolphin, of which 13 were released alive. In both instances, the catch was purely accidental as dolphin do not form an association with skipjack in New Zealand waters. The first author was an observer on the vessel that made the dusk set, and noticed a group of dolphin riding on the bow wave on the port side of the vessel. By the time the circle was complete it was dark, the dolphin were unable to evade the net or dive under it, and it was impossible to rescue them. Near the end of retrieval, the net 'collapsed' and the dolphin were caught in the webbing and drowned. The second set was made in mid-afternoon, and there was sufficient time for a 'backing-down' operation and the release of most of the trapped dolphin. It is worth noting that the common dolphin is abundant in New Zealand waters and not shy of approaching fishing vessels (Gaskin 1972); the low incidence of their capture noted here therefore suggests that in most cases they are capable of evading purse seine nets.

Pilot whales (*Globicephala* spp.), or 'blackfish' as they are known to U.S. fishermen, are often seen in the vicinity of logs. These whales are readily observed in the early hours of the morning because they produce a characteristic signal on the sonar equipment that is used to check the logs for tuna. Their presence tends to disrupt the usual aggregation pattern at this time of day, resulting in the tuna schools dispersing rather than forming fishable concentrations. Because of this, few if any sets are made on logs with pilot whales in attendance and no records in the RTFD or literature exist of these whales being caught.

Baleen whales, most commonly the sei whale, are occasionally encircled during purse seine operations on tuna schools that are usually feeding on pelagic baitfish. These animals generally punch through the net, usually close to the surface or are aided in their release by submerging a portion of the corkline. In some cases, whales have been observed to return to feeding after being set on (D.G. Itano, pers. obs.), which suggests that their encounters with the purse seine operation are not overly traumatic.

3.3.3 Seasonality of by-catch

The seasonal distributions of by-catch CPUE (mt/set with declared by-catch) for each school association are shown in Figure 4. All of these distributions show some degree of seasonality, particularly the school and log set distributions which exhibit marked peaks in CPUE in March and July, and June and December, respectively. It is possible that these peaks represent biannual recruitment pulses that are influenced by the seasonal changes in current and weather patterns in the WTP. This environment-influenced recruitment pattern appears to be a common feature of tropical marine fishes (see eg. Navaluna and Pauly 1986, on monsoon influences on Philippine fish recruitment). With anchored FADs, the peaks are not as readily apparent, and in fact there appears to be a plateau of high CPUE in the first 6 months of the year that may relate to higher and more prolonged productivity in the archipelagic waters where much of the FAD fishing occurs.

Seasonal patterns in by-catch in the WSP are more distinct, with well defined Trade Wind seasons and pronounced fluctuations in sea surface temperatures. The New Zealand purse seiners operating in Fiji during the early 1980s noted definite seasonal fluctuations in FAD associated by-catch. The occurance of mahimahi and rainbow runner increased noticeably during the winter months and mahimahi disappeared completely during the summer (Itano 1989).

Micronesian Maritime Authority observers have recorded 39 whale associated purse seine sets on DWFN purse seine vessels in Micronesian waters between 1984 and 1993. Thirty-four of the 39 sets were made during February, March and April, agreeing with anecdotal accounts that indicate that the Japanese purse seine fleet operates on whale associated schools mostly during the first quarter of the year. The position, school type and catch of every set (n = 92) made by one Japanese group seine vessel during its 1991 season was recorded by Itano (1991). Four whale associated sets were made, all of them during March and April.

3.3.4 Estimates of by-catch

A summary of the estimates of by-catch for 1991 by fleet and school association is presented in Table 8. Estimates were developed from the number of actual sets by fleet and school type on the RTFD raised to reflect the estimated reporting level of each fleet then multiplied by the figures for geometric mean of by-catch (mt/set) from Table 3. The total estimated by-catch of 20239 mt represents 2.4 per cent of the total estimated catch by WPO purse seiners of 848,907 mt from Lawson (1991). In comparison, the actual level of by-catch reporting on the RTFD amounted to only 426 mt, or 0.05% per cent of the total catch.

During 1991, almost half (49.0%) of the estimated by-catch from Table 8 came from log, drifting FAD and anchored FAD sets, even though these set types accounted for only 36.2% of the estimated effort. The reported by-catch data on the RTFD for 1991 indicates that 65.0% comes from log and FAD sets and 27.9% from school fish sets.

The Australian, Korean and Taiwanese fleets reported significant catch and effort during 1991 but zero by-catch, yet these fleets probably made over 4500 log and FAD sets during the year and are estimated to have contributed over 38.4 per cent of the total by-catch estimate. The remaining four fleets appear to have low levels of reporting, ranging from 0.6 per cent of the fleet by-catch estimate for Japan to 15.9 per cent for the Philippines. The Philippine fleet actually declared almost sixty per cent of the reported by-catch, followed by the US and the Solomon Islands; the Japanese fleet declared only 0.6 per cent of estimated by-catch figures.

3.4 Tuna discards

3.4.1 Gross levels of tuna discards

During the period 1975—1991, the RTFD shows that 0.24 per cent of the total catch of the purse seine fishery consisted of tuna discards. This percentage amounts to 5,594 mt of tuna. As with by-catch, the reporting of tuna discards by the various fleets can vary by one or two orders of magnitude, e.g. Japan and Korea reported tuna discards of 0.01 and 0.29 per cent of their total catches in the WTP, respectively. The highest levels of tuna discards are seen in the FAD-based fisheries of the Solomon Islands and Philippines fleets (3.31% and 1.05%, respectively). The Australian, Mexican, Russian and Taiwanese fleets did not report tuna discards for the period, and neither did the US fleet operating outside the WTP nor the New Zealand fleet working in its home waters.

The distribution of tuna discards (mt) for the period is shown in Figure 2. As with by-catch, almost all discards occur in the WTP between 5°N and 10°S. The highest level occurs in the FAD-based Solomon Islands fishery, followed by the Solomon Sea and the area between the Equator and 5°S.

3.4.2 Tuna discard levels by school association and reasons for discarding

Tuna discard levels recorded on the RTFD, and by observers and in the literature are summarised in Tables 10 and 11, respectively. Considerable variation is apparent in this information, particularly in the proportions of each type of set that have tuna discards and the quantities discarded.

One trend apparent in the data is that tuna discards are more common in sets on floating objects than on unassociated schools. For the RTFD data, 1.5 per cent of log sets and 20.0 per cent of anchored FAD sets had tuna discards, compared with 0.3 per cent of school sets. Similarly, at least 23.2 per cent of log sets in observer and literature records had tuna discards compared with 5.4 per cent of school sets. The volumes of discards per set, however, are similar, with median values of 1.8 mt for school and log sets and 2.0 mt for anchored FAD and unspecified sets (Table 10). The frequency distributions of tuna discards are shown in Figure 8.

An examination of the reasons given on logsheets for discarding tuna provides a clearer picture of the nature of tuna discards and of the apparent trends. A summary of these reasons is given in Table 12, while Table 13 and Figure 5 show the RTFD discard data subdivided by reason. Tuna can be discarded accidentally through gear failure, such as a ripped sack during sacking-up or brailing, or storage problems that affect the quality of the catch and may result in the loss of a well of fish or the entire load. Tuna can also be discarded deliberately because the fish are too small for canning (typically < 3—4 lb or < 1.4—1.8 kg), are soft or smashed, or the vessel is fully loaded. The RTFD also includes discards of undesirable tuna species, presumably of frigate tuna and kawakawa, that should in fact be considered as by-catch.

Seventy per cent of all reported tuna discards were discarded because they were too small for canning (Table 13). Most of the discards in this category occurred in log and anchored FAD sets (31.2% and 46.7%, respectively, of all small tuna discards, and 63.8% and 90.6% of tuna discards by association (Figure x)), presumably because the associations tend to aggregate a wide size range of tuna that often includes a large proportion of small fish (e.g. Hampton and Bailey 1993). As these sets are made before dawn, there is little chance of avoiding the small tuna if they are present. Some vessels, particularly in the US fleet, attempt to reduce this incidence by trolling around the floating object during the day in order to determine what size of tuna is present and whether a set is worthwhile. Vessels in the Philippine fleet take this one step further by often setting only when the tuna school is clearly separated vertically from the bait under the log or FAD, in the belief that small tuna are usually mixed with the bait (see section 3.3.2). In comparison, unassociated schools largely consist of uniformly sized fish. As school sets are made during the day on visible schools, experienced fishermen are usually able to judge tuna size and avoid setting if they appear too small. As a result, a smaller volume of tuna in school sets is discarded because of size (7.6% of all small tuna discards, 30.0% by association). It should be noted, however, that this is still the principal reason for discarding tuna in the association, both in terms of weight and occurrence (47.3% of school sets with tuna discards). This suggests that it is not necessarily an easy task to judge fish size or that care is always taken to do so.

On a fleet basis, both the Korean and US fleets discarded greater quantities of small tuna in log sets than in school sets, while the Japanese fleet reported no small tuna discards in either set type. This category accounts for all reported tuna discards in the Solomon Islands FAD-based fishery, and the largest part of the discards in the Philippines fleet. The latter fleet reported no small tuna discards from the 72 school sets or 2,444 drifting FAD sets made. The New Zealand fishery is dominated by medium-sized skipjack (Habib et al, 1981), so that discards of small tuna are unknown.

Soft and smashed tuna are discarded because they are too damaged for processing at the cannery. Tuna in this category have either been crushed by the power block after becoming entangled in the net or have been at the bottom of the sack for too long during sacking-up and brailing, have consequently softened because of high temperature and been crushed against the webbing by the weight of the tuna above. In the logsheets used by the fleets, this category has to be entered under 'Other reason' and the reason specified by the person filling in the form (Appendix 2). Only US vessels have recorded soft and smashed discards, and this is reflected in Table 13. Not surprisingly, this category is most common in sets with catches in excess of 100 mt (xx of 33 school sets, 3 of 5 log sets), where sacking-up can take 1-2 hours and brailing a similar period. However, the actual volume of discards is not positively correlated with catch, and in most cases is either 0.9 or 1.8 mt (1 or 2 short tons), irrespective of the catch. The regularity of these values is suspicious. One school set of 200 mt resulted in 59 mt of discards, probably because of mechanical problems (e.g. burst hydraulic line, damaged brailer or burnt-out winch motor) that prolonged the sacking-up and brailing times.

It is likely that most sets in the WTP that yield over 100 mt have some volume of soft and smashed tuna discards. The RTFD records a total of 2,970 such sets, which is an indication of the occurrence of this discard type. The large quantity of tuna discards under the 'Other' category of Philippine log sets (292.8 mt) came from sets with catches below 100 mt, which suggests that most of these discards were not soft or smashed.

It should be noted that this discard category is really a function of the high water temperature experienced in the WTP, and that similar problems do not exist in the New Zealand fishery, where catches often exceed 100 mt per set but temperatures are typically 10°C lower.

Tuna become entangled in the net in most sets, irrespective of association, but usually in low numbers. In most cases, the fish can be shaken out of the net and back into the water inside the encircling net by momentarily changing the direction of pull of the power block. Most seiners in the fishery use boom-mounted power blocks and are able to shake 'gillers' out of the net. Those vessels with deck mounted net haulers (7 Japanese group seiners, 1 Australian single seiner, and possibly 1 Japanese single seiner) are unable to do this, and as a consequence all gillers are dragged through the hauler, then the power block, and are crushed. Itano (1991), for instance, notes that one Japanese group seiner discarded 3 mt of smashed tuna during the course of 15 sets. The relatively small number of these vessels, however, means that such discards are probably very low. Occasionally, a large part of the catch may become entangled if the net collapses because of strong currents, poor setting practice, or mechanical problems that delay net retrieval. Japanese vessels are best suited to counter this because they utilise two or three small towboats to keep the net 'open'; US-style seiners typically employ one towboat, making the task more difficult.

Gillers often occur in school sets that are made in the late afternoon or early evening, simply because the fish blunder into the net in the encroaching dark. While the power block operator will usually try to shake the gillers out of at least the first half of the net, much time is lost and a point reached where this is detrimental to the condition of the remaining catch. Thus, net retrieval may proceed at full speed, and all remaining gillers run through the power block and crushed. The actual quantity of these discards is impossible to estimate because they are controlled by the practices of individual fishing masters, conditions at the time of each set and the amount of catch. However, an indication of their occurrence can be seen in the number of successful school sets that began after 1700 hours. For the RTFD, this figure is *x,xxx* sets. It is possible to reduce the incidence of gillers during night sets by shining a spotlight into the center of the net, in the hope that the tuna will be attracted to the light and away from the net.

Fishing gear failure that results in tuna discards usually occurs as a result of a ripped sack, which usually occur with large catches (>100 mt) that prove too heavy for the webbing. This occurs because of worn webbing, burrs or sharp edges on the stern or hull of the vessel that rip the net during setting or sacking-up, or because of improper sacking-up technique. In the later case, if the netting is not retrieved evenly, pockets can develop in the sack that are not supported by the vessel and the catch can suddenly shift into such a pocket and cause the net to rip. The rip can occur during sacking-up and result in the loss of the entire catch or during brailing so that at least part of the catch may have already been lifted aboard. Ripped sacks appear to be a rare event in the fishery because of the care usually taken in sacking-up and in maintainance of the webbing. There are only two such events recorded in the RTFD, namely a school set that resulted in the loss of an estimated 227 mt after 110 mt was successfully brailed on board and a log set that lost 9.1 mt (Table 13). The observer data and literature list three school sets that resulted in losses of 150, 200 and 272 mt. The first two losses occurred during an early PTDF exploratory charter to the WTP using a modified eastern Pacific-style purse seine net and relatively old vessel (Souter and Broadhead 1978). Since that time, net and hauling technology has improved considerably. The third loss was reported by a FFA observer but neither the set nor the loss was recorded on the logsheet for the vessel (MV *Margaret Z*, 6 May 1991, set started at 1930 hours). It is therefore likely that ripped sacks occur more often than reported. An indication of the possible extent of this problem can be seen in the numbers of sets, particularly those on schools and logs, that catch over 100 mt (3.8% of school sets (1,475), 2.7% of log sets (1,255)).

Tuna discarded because the seiner has filled all her wells but caught in excess of requirements on the last set appears to be a relatively common occurrence in the fishery, although largely uncontrollable. The 'Vessel loaded' category on the standard Catch Report Form is reported in four of the six fleets declaring tuna discards and makes up 7.0 per cent of discards by weight. School sets appear to have larger volumes of discards than log sets (Table 13, Figure x), although this is biased by the large volume of discards in the US fleet, that concentrates largely on school fish. The actual discard volume is impossible to determine because it depends on how much tuna is on board when the set is made and the size of the school set on. If a vessel is close to loaded and encounters a group of schools, the fishing master may select a school that is sufficient to fill the remaining capacity and avoid those that are too large. However, his decision will probably be driven more by which school appears to be the most catchable, and this may prove to be far in excess of what is required. If another seiner is nearby, transhipment of the excess may occur, as happened with 59 mt from a school set in the US fleet. Once again this is an unpredictable feature of the fishery, as seiners often fish in groups, particularly when areas of school fish or logs have been located, but also operate alone, so that there is little chance of transhipping excess catch. Japanese, Korean and US seiners are known to operate in groups, searching areas en masse and passing on daily intelligence to members of the group by coded radio messages (hence the term 'code group'). It is unlikely, however, that transhipment will occur between vessels belonging to different fleets or different code groups of vessels within a fleet. The transhipment mentioned above, for example, was made between two US vessels belonging to the same code group (and owned by the same company).

Another problem with transhipping excess catch is that it is a difficult and time-consuming operation with US-style single seiners. The catch has to be brailed onto the vessel that originally caught the fish and transferred by shutes to a net belonging to the second vessel. Then it is a matter of either lifting this net or brailing the fish on to the second vessel. Thus, there is a good chance that much of the excess catch will be too damaged or soft to be retained. Transhipment of excess catch is a common practice with group seiners because they regularly operate with two or more carrier vessels and are configured to brail directly to the carrier.

Group seine vessels have the advantage of calling in another carrier if the catch is excess to the capacity of one ship. On one Japanese group seiner, Itano (1991) reported that a 60 mt catch was kept alive in the net for several hours until a second carrier vessel arrrived on the scene and brailing commenced. Fifteen tonnes were required to fill the first carrier after which she exchanged places with the second vessel which took the remaining 45 tonnes.

However, approximately three tonnes of skipjack were discarded on the first carrier one day after the holds were filled as the fish had expanded during freezing to over-fill the holds. This is probably a standard practice on some carrier vessels that assures that the carrier is completely filled with high quality catch that is not crushed or smashed during freezing.

Storage problems relate to the refrigeration and storage of the catch. One problem that occurs at sea, albeit rarely, is the contamination of a well of fish because of burst ammonia coils. There are no observer or literature records covering such an incident, and only one record on the RTFD, resulting in the loss of 54 mt (Table 13). Wells of tuna or entire catches of a vessel have been known to be rejected at the canneries in Pago Pago, American Samoa, if fish quality is poor, e.g. not frozen properly, high histamine or salt levels, or 'honeycombing' of the meat. Burns (1985) reviews outlines procedures for the handling and refrigeration of tuna on U.S. purse seiners and lists causes of quality loss. There are no records of such events in the literature or on the RTFD, not surprisingly. The authors know of one occasion in 1982 when an entire catch of a US vessel, amounting to about 850 mt, was rejected because of excessive salt levels. This particular vessel was the oldest in the fleet and was modified for seining rather than being purpose built. It has since left the western Pacific fishery. Smaller amounts of tuna are routinely discarded at canneries during unloading of seiners because the fish have been crushed at the bottom of the wells before they have had time to freeze, were damaged during unloading or are too small for canning but have slipped past the at-sea discard process. The extent of these discards at canneries is unknown, although they probably vary between canneries because of differing quality control practices.

The species composition of the tuna discards is not recorded on the RTFD but it is possible to determine a rough composition by considering the target species caught for each set with declared discards. As shown in Table 14, mixes of skipjack and yellowfin (and some bigeye) made up the majority of tuna discards in log, drifting FAD and anchored FAD sets (62.9%, 100.0% and 88.1% by weight, respectively) while single species catches dominated the school sets (44.6% skipjack, 41.1% yellowfin) and half of the animal sets. Discards in the Other and Unspecified associations were dominated by mixed catches, which suggests that most of these sets were made on floating objects.

3.4.3 Seasonality of tuna discards

The seasonal patterns of tuna discard CPUE (mt/set with declared discards) shown in Figure 6 (left) exhibit similar patterns to those seen with by-catch, with marked biannual peaks for school and log discards and a plateau of high CPUE for anchored FAD discards. An interesting pattern emerges when considering discards of tuna too small for canning (Figure 6, right); school recruitment peaks in March-April and October-November, followed one or two months later by peaks in recruitment to logs. As school and log sets are largely made in the same area, this pattern may show the time lag between recruitment to schools and recruitment to logs, assuming that most juvenile tuna recruit to schools first. In this respect, the small peak in April for log sets could represent tuna that recruit immediately to logs. The high incidence of small tuna around anchored FADs from December to June is a regular feature in both the purse seine and pole-and-line fisheries in the Solomon Islands and provides a good indicator of the turnover of the tuna population in the area.

3.4.4 Estimates of tuna discards

Due to the irregular nature of tuna discards in purse seine fisheries, an estimate of the extent of such discards in a similar fashion to the by-catch estimate is neither possible nor realistic with the available information.

3.5 Comparisons with other purse seine fisheries

As many of the by-catch species found in the various school associations in the WPO are cosmopolitan and occur in similar associations throughout the world's oceans (e.g. Arenas et al., 1992, for eastern Pacific), it is likely that they, or related species, also occur as purse seine by-catch. This is particularly so for the most abundant species encountered around logs and FADs, notably the rainbow runner, silky shark, mackerel scad, ocean triggerfish and mahimahi. Little published information is available, however, on the actual levels of by-catch and discards in other purse seine fisheries. Au (1991) presents detailed information on the proportions of by-catch species in school, log and porpoise associated schools in the eastern Pacific fishery. Although there are differences between the two areas (e.g. billfish occurrence was similar for all set types in the EPO, with sailfish and striped marlin the predominant species c.f. blue and black marlin in the WPO), the essential point remains that most by-catch occurs with log sets. Hallier and Parajua (1992) make a similar point with the Indian Ocean purse seine fishery, where 87 per cent of by-catch observations came from log schools.

By-catch levels of US purse seiners operating in the eastern tropical Atlantic from 1967—1975 are summarised by Sakagawa (1976). Reported by-catch consisted entirely of scombrids (albacore, little tunny (*Euthynnus alleteratus*) and frigate and bullet tunas (*Auxis thazard* and *A. rochei* respectively)) and were usually recorded when 'about a ton or more' were caught in a set. Albacore were usually retained beause of their high value; catch levels of the less valuable species (little tunny, *Auxis* spp.) were considered to be underestimates because of non-reporting of discards. Rainbow runner were rarely caught and never reported. No break-down of by-catch by school type is provided, although length frequency information for little tunny and bigeye is given.

3.6 Conclusions

The main conclusions and recommendations to come out of this investigation of purse seine by-catch and discard practices are as follows:

(a) A summary of data held on RTFD and in reports of observers trips, private log books and personal experience of the purse seine fishery in the WPO indicates that there is an extremely high incidence of non-reporting of by-catch and discards of by-catch and target catch. For the period from 1975 to 1991, the data stored in the RTFD covers purse seine catch exceeded 2.2 million mt, of which 0.21 per cent was listed as by-catch, 0.06 per cent as discarded by-catch and 0.24 per cent as tuna discards.

(b) Coarse estimates of by-catch in the purse seine fishery are derived for the period investigated and for 1991, based on figures of median by-catch per set type and the proportions of different set types that yielded by-catch, raised by the number of each set type on the data base. In 1991, where coverage is good for some fleets and can be estimated for others with a degree of accuracy, the raised estimate of total by-catch in the WTP is 20239 mt, which represents 2.4 per cent of the total estimated catch. By using the discard rates in the RTFD, it is possible that 40 per cent of this by-catch was discarded. While these estimates need to be treated with caution, the 1991 figure is probably a good reflection of the order of magnitude of by-catch in the fishery.

(c) In terms of set types, floating object sets produce the largest volumes, highest incidences and greatest variety of fish and other species. Log sets accounted for 40.0 per cent of the estimated by-catch in 1991 from 30 per cent of the estimated sets. The most common species in these sets are the silky shark, mackerel scad, rainbow runner, mahimahi, and ocean triggerfish. In contrast, school sets produced 40.8 per cent of the estimated by-catch from 57.5 per cent of the estimated sets. There is a trend in the larger and more technologically advanced fleets to move away from log sets and concentrate on school fish. As the by-catch of such schools is less, it is likely that by-catch levels may have decreased over the last 3—4 years and will continue to decrease in the future.

(d) There is no evidence to suggest that dolphins are deliberately set on or caught by the purse seine fishery in the WTP. The occurrence of dolphins in the by-catch of the seasonal New Zealand skipjack fishery is shown to be extremely rare and purely accidental. Large baleen whales are occasionally set on in the WTP, but are easily able to escape alive. There is no evidence of seabirds being taken in purse seines. Marine turtles are occasionally caught in log sets, and there is some evidence that numbers are released alive by U.S. and Japanese vessels. Marlin are uncommon in school sets but relatively common in log sets. However, this catch is minor compared to the marlin catch of longliners operating in the same area.

(e) Tuna discards are an irregular and unpredictable feature of the fishery, the levels of which are often dependent on setting practices of individual fishing masters, size of the catch, conditions during the set and condition of fishing gear. Thus an estimate of such discards for the period investigated or for 1991 is not possible. However, it is obvious that considerable non-reporting occurs. Three-quarters of tuna discards were made because the tuna were too small (< 3-4 lb) for canning. Similarly, 76 per cent of tuna discards came from log and FAD sets.

(f) At present, it would not appear to be possible to collect reliable information on by-catch and discards from unverified logbook records. As with many fisheries, the only practical solution is to mount a scientific observer programme aimed at collecting accurate and representative data from all fleets involved. Only with this information will it be possible to determine the true extent of the occurrence. The observer programme currently administered by the FFA is not able to collect the required information as it is restricted to a single fleet.

(g) By-catch and discards could be utilised to a far greater degree than current levels, eg. seiners could dedicate one or two fish wells to the storage of this catch, regardless of species or size. Such a scheme would have economic repercussions on the viability of seiners and would almost certainly cause intense conflict between crew and local fishermen supplying fish to the same market. Alternative refigeraton systems and markets could be developed for the storage and sale of high quality by-catch that would not compete with artisanal fishermen and open up new markets. If fully developed, this approach may improve the economic viability of industrial purse seining in the region but a great deal of development work would be necessary at high risk.

(h) The by-catch and discard information stored in the RTFD is representative of the relevant data recorded on the daily logsheets, although some information pertaining to by-catch species and reasons or discarding have not been entered. Because of the low levels of reporting, however, it is not worthwhile to either check or re-enter historical data. Minor improvements to the database can be made, however, to ensure that future data are entered fully and analysis made more efficient.

4. LONGLINE FISHERIES

4.1 Overview of the western Pacific Ocean longline fisheries

4.1.1 Summary of the fishery

For 1991, the RTFD contains daily fishing information for a total of 722 longline vessels from 10 countries (Australia, Peoples Republic of China, FSM, Fiji, Japan, Korea, New Caledonia, New Zealand, Taiwan and Tonga), with a total declared catch of 36,374 mt in the WPO. Due mainly to the unavailability of data for vessels fishing in international waters, the actual number of vessels and total catch for the longline fishery in the WPO is not known, although a catch of 92,245 metric tonnes for the three target tuna species (albacore, bigeye and yellowfin) has been estimated by Lawson (1992a) for the area. Using this value, the estimated coverage for the WPO longline fishery in the RTFD is well below 50%. A detailed breakdown of catches and levels of RTFD coverage by the individual fleets is given in Lawson (1992a). A crude estimate for annual longline effort in the WPO of 200,000,000 hooks was derived for this report from the expected coverage the RTFD provides.

There are basically two categories of longline vessel fishing in the WPO. The first category contains the large distant-water vessels (typically > 150 GT) from Japan, Korea and Taiwan; these vessels are capable of fishing far from their home ports, with trips usually ranging from about one month to, at times, more than one year. The second category consists of vessels that are generally smaller and used specifically for shorter fishing trips, basing themselves in proximity to the fishing areas, with trips from less than one week to normally around two weeks or more in duration. These vessels have established home ports in SPC member countries and territories (e.g. FSM, Guam, Marshall Islands, Palau) and fish under the nationalities of Japan, Taiwan, Korea or the country where fishing activity takes place (i.e. domestic fleets). The trend of the decline in the large distant-water vessels and the increase in activities involving the establishment of smaller vessels out of SPC member countries in the past 10-15 years is seen primarily as a reaction to the increased operating costs in the fishery.

The following is a brief description of the geographical distribution of longline fisheries throughout the WPO by area, based on data available in the RTFD for 1991. Maps showing longline effort by fleet for 1991 are described in Lawson (1992a) and for combined fleet effort in the Fourth Quarter SPC Regional Tuna Bulletin (1992). Figure 8(a) shows the distribution of longline effort in the WPO for the years 1978 - 1991 combined, and the distribution of seasonal effort for this period is described in Figure 9. Figure 10 shows annual trends in longline effort by fleet for the WPO, based on data available in the RTFD.

Longline activity in the Western Temperate Pacific (WTeP) occurs primarily in the waters around south eastern Australia and southern waters of New Zealand. While very little RTFD daily fishing information exists for Taiwanese and Korean vessels fishing in the WTeP, there are considerably more aggregated data available from statistical bulletins published by these nations which detail effort in the WTeP for years prior to 1990. It is evident that fishing by these fleets, primarily in the Subtropical Convergence Zone (STCZ), is strictly seasonal and has been treated as an extension of their Western Subtropical Pacific (WSP) activities in this report.

Between 10° and 35°S, in the area defined in this report as the Western Subtropical Pacific (WSP), longline activity is not as confined as in the WTeP. Daily information for 1991 is available for fishing off the east coast of Australia, the northern waters of New Zealand, New Caledonia, Fiji, Tonga, Cook Islands, French Polynesia and in the international waters bordering these areas. As would be expected, seasonality in operations in the WSP longline fisheries are not as pronounced as in the WTeP. It should be noted that the choice of the 35°S line to divide the WSP and WTeP is purely for convenience; in fact, the WSP and WTeP longline fisheries of New Zealand and Australia, as defined in this report, do extend above and below this line depending on season. As with the WTeP, there are very little RTFD daily fishing information for Taiwanese and Korean vessels fishing in parts of the WSP and the best indication of the amount and distribution of activity is provided in the statistical bulletins published by these nations.

The tropical waters of the WPO north of 10°S, the Western Tropical Pacific (WTP), contain the majority of longline activity, even though activity has been almost completely absent from Papua New Guinea (PNG) since Japanese vessels last fished there in 1987. In the warm waters of the WTP, there are not as pronounced seasonal changes in the fishery as in the more temperate waters, and the target species are almost exclusively yellowfin and bigeye tuna. In 1991, distant-water Japanese vessels were active in FSM, Solomon Islands, Marshall Islands, Kiribati and the northern waters of French Polynesia, while distant-water Korean vessel effort was concentrated in and around the ecomonic zones of the three island groups of Kiribati, and to a lesser extent, in French Polynesia. The vessels that operated out of SPC member countries unloaded at ports in FSM, Guam and Palau; an unloading facility began operations in the Marshall Islands in December, 1991.

There are virtually no data in the RTFD for the area north of the WTP (the WPO north of 15°N, called the WTPN), as it constitutes mostly international waters; reference to the WTPN in this report has been largely omitted.

While the area covered by this report includes part of the southern bluefin longline fishery in Australia and New Zealand, for which there is a substantial amount of information available, more emphasis is given to the WTP and WSP fisheries, where possible, as these are of primary interest to the mandate of the TBAP.

Even though some billfish (e.g. swordfish and striped marlin) are among the target species of some longline vessels in parts of WSP waters, all billfish catches have been included as by-catch in this report. In the tabulated data presented in this report, target species for each area have been defined as the tuna species of prime commercial interest in that area (Table 1).

4.1.2 Targetting by variations in gear depth

(● This section needs to be expanded ....)

In the three areas of the WPO, there are a number of considerations in the fishing strategy when attempting to attain the optimum catch level of target species : the depth of the gear in relation to knowledge of the temperature stratification of the water column (i.e. depth of the thermocline), real-time information from other vessels in the vicinity (group fishing), types of bait used, time of setting/hauling and any other oceanographic (e.g. current, ocean floor topography) and environmental factors that might effect the fishing conditions. Clearly, the horizontal and vertical attributes of the gear used by longline vessels are prime reasons for a much broader species range in the catch than the surface fisheries (purse seine and pole-and-line) in this area. Variations in some factors of the fishing strategy may exist between areas; this occurs, for example, in the comparison of the seasonal fluctuations in the thermocline structure in more temperate waters of the WPO, to the more permanent nature of the thermocline structure in tropical waters. Some factors are more important than others, for example, the proportion of bigeye is generally higher when setting deeper gear in the WTP (Suzuki, 1988). As data on these factors are limited or non-existent in the RTFD, this report attempts to deal only with the effect that ranges of gear depth have on by-catch from longline vessels.

Suzuki (1988) provides a time-series breakdown of the deep versus conventional gear distribution, based on the number of hooks per basket, for Japanese longline vessels in the areas of the Pacific, highlighting trends in gear development for the years 1975-1985. Figures 11(a) and (b) present a time-series of the frequency of hooks per basket used by longline vessels fishing in the WTP and WSP respectively for the years 1981-1991, based on data held in the RTFD. In both areas, there are distinct groups which represent conventional gear utilisation (WTP : 3-6 hooks per basket; WSP : 5-8 hooks per basket) and deep gear utilisation (WTP and WSP : >= 10 hooks per basket), with very little activity coming from the intermediate group (WTP : 7-9 hooks per basket; WSP : 9 hooks per basket). Provided with this breakdown, Figures 12(a) and (b) describe the annual trends in gear depth range utilisation for the WTP and WSP, respectively. It is evident that the trend for recent years has been towards nearly 100% of the effort in the WTP for deep geared vessels and thus some preference for targeting bigeye tuna. In contrast, there are no obvious trends between the utilisation of conventional and deep gear in the WSP. This is probably due to the need to alter gear configuration to cater for more pronounced seasonal and areal fluctuations in the water column throughout this broad area.

4.2 Sources and coverage of data

Table 15 summarises by fleet, the daily longline catch and effort data available from the RTFD for the period 1978 to the end of 1991; as indicated for the purse seine fishery, data for 1992 were not considered because they were incomplete at the time of writing. Numbers of fish, instead of weight, were used throughout as the average weight of the 11 most common species of the catch on logsheet forms in the WPO (yellowfin, bigeye, albacore, southern bluefin, skipjack, striped marlin, black marlin, blue marlin, swordfish, sailfish and shark) vary markedly, sometimes by a factor of 10, and thus using total weights by species would tend to give a misleading impression in comparisons of catch levels. Catch and effort data in aggregated form that have been made available to SPC by DWFNs (Japan, Taiwan and Korea) were used in this report only when comparing annual trends in the CPUE of certain species of by-catch and in an attempt to estimate total catches of the billfish species in the WPO.

The main source of longline daily catch data in the RTFD are logsheet forms completed by longline vessels as a requirement for fishing in the economic zones of SPC member countries. Since the inception of data processing, 21 different form types have been received, in addition to data provided on magnetic media from Australia and New Zealand. As the prime aim of the logsheet (and hence the RTFD) is to obtain catch levels of the commercially important species of the longline fishery, quite often the lesser important by-catch and discarded species were ignored. This was the case not only in the design of the various logsheets used and in the subsequent design of the RTFD, but also in the recording of the catch, even though provision for this breakdown may have existed both on the logsheet and in the RTFD. Michael et al. (1989) found that in comparisons between observer and logsheet data, the level of under-reporting increased when relative importance of species decreased.

In reviewing the levels of by-catch and discards in the WPO from data held in the RTFD, the following inconsistencies were encountered due to the variation in format of the data available:

(a) some forms have provision for recording numbers only;
(b) some forms omit or group certain by-catch species (for example, some forms provide a column for 'Billfish' instead of the individual billfish species);
(c) some forms have no provision for recording discard information (this was also the case with the New Zealand magnetic media data);
(d) some forms require discards to be entered in numbers only, some as weights only;
(e) no forms provide an identification or breakdown of the tuna or other species discarded;
(f) no forms provide reasons for discarding;
(g) though not strictly important to this report, information on the structure of the gear and bait used were often lacking or incorrectly recorded and time of set is provided for on less than 0.01% of longline vessel logsheet trips and thus not catered for in the RTFD.

The extent to which logsheet data entered into the RTFD have provision to record by-catch and discards is shown in Tables 16 and 17, respectively. As the amount of discards reported in the RTFD was clearly either not available or grossly under-reported, specific information on discards is restricted to average values of discards and their percentages of the total catch, only for records where discards were recorded.

Due to this paucity of data for discards (and to a lesser extent some by-catch species) in the RTFD, reference to observer reports made available from programmes operating out of Australia, FSM, Kiribati, New Zealand and SPC, were relied upon to give a more representative composition of the lesser important by-catch species of the longline catch. An attempt has been made in this report to highlight the quantity of non- and under-reporting of by-catch and discards, by comparing RTFD data with percentage target, by-catch and discard of the total catch from the observer reports available. As there were very few observer reports available for this review and, as it appears there are many variables that determine this breakdown, estimates are restricted to the percentages of target, by-catch and discards by area presented in Table 18. It is hoped, however, that further data from the observer reports will provide an better indication of the levels and breakdown of longline catch and further highlight discrepancies in what is reported by the logsheet data (RTFD).

There are a number of publications that specifically review aspects of the more common by-catch (i.e. billfish) of longline vessels, the main sources being Nakamura (1985) and the proceedings from various international billfish symposiums, the last held in 1988 (Stroud ed., 1990). The latest works found to review species of marlin stocks in the area of interest were by Suzuki (1977) and Sakagawa (1987); nothing was available in the literature to specifically review stocks of any of the other by-catch species mentioned for this area except the non-target tuna species, for example skipjack which are target species of surface fisheries in the WPO. No literature specifically addressing discards from the longline fishery were found, however, several observer reports give descriptive accounts of methods and reasons for discards, which are useful in comparison to what can be discerned about the WPO longline fishery from the RTFD.

4.3 By-catch and discards of by-catch

4.3.1 Gross levels of by-catch and reporting

Table 15 shows levels of by-catch by fleet and area for longline vessels fishing in the WPO, as reported by the RTFD. For comparison, Table 18 provides a breakdown of total catch into target and by-catch for data available in observer reports; it should be noted that due to the few data available from observer cruises at this stage, the approach taken in summarising this information is simply to give an indication of the possible non- and under-reporting of the RTFD data. Several observations can be drawn from these data. In the RTFD, there is a distinct trend in the proportion of target to by-catch between the three areas of interest (target:bycatch; WTP - 93.5% : 6.5%; WSP - 87% : 13%; WTeP - 49% : 51%). This trend is also evident when considering the few observer data available, although it is apparent that the catch composition from individual trips can vary markedly. It is interesting to note that this trend is not so apparent for tuna discarded from longline vessels (Figure 8(b)). The variation in catch composition between fleets in the RTFD and the observer data is also noticeable. For example, the Japanese fleet appear to have a better ability to target than the other fleets in the WTP, although it is evident that the proportion of by-catch in the overall catch as reported in the logsheets is lower than that reported by observers, indicating some degree of under-reporting.

The most noteworthy comparison between levels of by-catch reported by logsheets (RTFD) and observer data is the degree of non- and under-reporting of the discards of by-catch species. Considering the information presented in Table 17, it is apparent that the problem is more one of non-reporting than under-reporting, as the proportion of discard for days when there were discard reported on the logsheet is in the order of that reported by observers. The notable exception is that the level of by-catch discarded in the WTeP as reported by observers is far greater than the level determined from the logsheet data (RTFD). Figure 8(c) describes the distribution of the discards of by-catch in the WPO. This distribution clearly does not correspond to that of effort for the area, as would be expected, and perhaps merely indicates the operating locations of vessels which reliably report discards.

Table 19 describes the species composition of the most common by-catch by fleet and area for the WPO. Basically, by-catch from the longline fishery of the WPO can be divided into 6 categories,

(a) The non-target tuna species that are sometimes of no commercial interest to the vessel; these are primarily skipjack (*K. pelamis*), however, may consist of species which are not strictly targeted in that area, yet are commercially exploited in other areas, for example, albacore (*T. alalunga*) in the WTP.

(b) The billfish, which are normally retained and in some rare instances considered as the target species, for example, Striped Marlin (*T. audax*) have been the target species for some Japanese longline vessels fishing in north-eastern Australian and New Caledonia waters.

(c) The various shark species taken by the longline fishery; a common practice with certain species of these fish is to remove the fins for sale on return to port and discard the trunk at sea.

(d) By-catch species other than tunas, billfish and shark, that are retained; for example *Lampris* spp.

(e) By-catch species other than tunas, billfish and shark that are considered worthless and are normally discarded, for example, the snake mackerels.

(f) By-catch species other than tunas, billfish and shark that are protected and landing is prohibited. It other areas, turtles fall into this category.

While billfish form the most recognised part of the by-catch of longline vessels in the WPO, it is not the intention of this report to give an in-depth review of the exploitation of billfish stocks in the WPO. The information compiled from the logsheet data (RTFD) provides some insights into the distribution and relative abundance of the individual billfish species in the WPO, however, further information and analyses would be required to ascertain the impact of longlining on individual stocks, for example.

No provision has been made to account for the following factors in the presentation of nominal catch rates for billfish throughout this report. These factors, while not catered for quantitatively, should be considered in light of the information that follows.

(a) The seasonal patterns in longline fishing effort in Australia and New Zealand;
(b) The legislative actions by the local governing bodies to prohibit the catch of billfish, as was the case in New Zealand with the establishment of a billfish moratorium in the northern fishery since 1988 (Murray, 1992), in order to prevent competition with growing recreational fisheries;
(c) The seasonal closure of an area off the north coast of New South Wales (N.S.W.) where domestic fishermen were prohibited to land live striped marlin (*T. audax*). This practice was also adopted by Japanese longliners fishing in this area. (Ward, pers. comm.).
(d) The agreement by Japanese vessels, licensed to fish in the AFZ, to release all black (*M. indica*) and blue marlin (*M. mazara*) that were alive at the time of landing. This agreement was voluntary on behalf of the Japanese who recognised the importance of the developing recreational fishery for marlins off the east Australian coast. These practices have occured since 1986/87 and apply to all areas of the AFZ. (Ward, pers. comm.).
(e) The agreement by Australian domestic vessels in 1987 to release all black and blue marlin, whether alive or dead. Striped marlin can be retained for export, however it is prohibited to land and sell any marlin and swordfish in N.S.W. (Ward, pers. comm.).
(f) Area closures (since 1980/81 : the AFZ 12°S—18°43'16"S; since 1990/91 : the AFZ 12°S—20°28'49"S) off the north-east coast of Australia, prohibiting foreign longline fishing in order to reduce competition with the recreational fishery for black marlin and sailfish. (Ward, pers. comm.)

4.3.2 Species and levels of by-catch

- Billfish sections need to be completed ...

4.3.2.1 Striped Marlin

Striped Marlin are taken by longline vessels throughout the WPO, however the catch is greater in the WSP (Figure 13(a) and Figure 14(a)). The occurrence of striped marlin in the WTeP is attributed to the seasonal extension of their WSP activities into this area, for example, the warm waters of the East Australian Current push further south in the austral summer months, suggesting an extension of the striped marlin habitat during this period. The seasonal pattern of catch rates in the WSP is primarily attributed to feeding behaviour associated with the period of spawning in this area. The near absence of striped marlin in the catch of deep geared vessels in the WSP, as measured by CPUE (Figure 15(a);Figure 16(b)), suggests a preference for a temperature range, which is normally between the 20° and 25° isotherms (Nakamura, 1985), found in the shallower waters of this area. Similar conclusions on the preferred depth range of striped marlin in the EPO have been made via observations on vertical movement patterns from tracking experiments (Holland et al., 1990) and experiments using time-depth recorders (Boggs, 1992).

Striped marlin have been one of the target species for some Japanese longliners fishing in and around the waters of north east Australia, New Caledonia and the northern waters of New Zealand, although in the latter case, the retention of billfish caught by foreign longline vessels has been prohibited since 1987.

Suzuki (1977) refers to two different stocks of striped marlin for the Pacific Ocean, with the majority of the WPO caught striped marlin taken from the hypothetical southern stock. The occurrence of generally smaller striped marlin in the WTP (Figure 17(a); Table 21), an area thought to be part of the major spawning grounds, corresponds to the hypothesis that these fish may stay in the warmer waters as juveniles and only move to higher latitudes after maturity. Examination of gonad indices of striped marlin caught in the Coral Sea (WSP) indicate a primary spawning season in the months of November and December (Hanamoto, 1977). The feeding behaviour associated with spawning corresponds well with the seasonality of catch rates by conventional geared vessels in the WSP as reported by the RTFD (Figure 15(a)). This is also demonstrated by the fact that over 30% of the longline sets where striped marlin were taken for this season in the WSP, contained 6 or more individuals; this compares to less than half this percentage for any other season, for catches of 6 or more individuals.

Striped Marlin, with swordfish, appear to be the hardier species of the billfish (Table 22).

In regards to the marketing, striped marlin as sashimi is considered the best among the billfish (Nakamura, 1985).

4.3.2.2 Black Marlin

Longline catches of black marlin are distributed throughout the WPO, although they are aligned more to coastal areas than the other two marlin species reviewed here and the catch is not as high. There has been some evidence that targetting of this species by Japanese longline vessels may have occurred off the north-east coast of Australia prior to the early 1980s (Ward, pers. comm.). This particular area has historically reported high catch rates as a result of seasonal spawning aggregations. Management measures have recently been introduced in order to restrict the catch of black marlin and thus possible competition with the world renowned sports fishery established there.

Black marlin catches have been recorded in the three areas of the WPO, with the highest catch rates occurring in the WSP areas off the north eastern coast of Australia and eastward, in and around the waters of New Caledonia, Fiji and Tonga (Figure 13(b)). Since 1976, catch rates in the WSP have stabilised somewhat to around 1-2 fish per 10,000 hooks (Figure 14(b)). In the WTP, annual catch rates rarely exceed 1 fish per 10,000 hooks, although, it is worth noting that the WTP CPUE was similar to the WSP level in 1989. Catches in the WTeP were practically non existent in comparison. A seasonal pattern for catch rates of black marlin exists in the WSP (Figure 15(b)). The increase in catch rates in certain areas of the WSP (Coral Sea) for the last quarter of the year (Figure 15(b)) could be attributed to denser distributions of spawning schools occuring in this area at the time (Nakamura, 1985). There is apparently little difference in the size composition of black marlin caught by longline vessels in the WTP and the WSP (Figure 18(b)), although there appears to be a higher tendency for larger fish to be taken in the WSP. Catch rates for deep geared vessels in the WSP and WTP generally match those of the conventional geared vessels for most of the year, although there are noted higher rates experienced for vessels setting fewer hooks per basket in the 4th quarter for the WSP and also a possible preference for deeper waters in the WTP; the changes in gear utilisation in the WTP during the last 10-15 years, however, should be taken into account when considering these data.

There has been some concern that marlin species misidentification occurs throughout the WPO longline fishery (Farman, 1986). The confusion may also stem from japanese names of marlin species, for example, Black marlin is refered to as "white" marlin and blue marlin as "black" marlin. The level to which misidentification occurs is currently unknown, although it should be noted that observer programmes offer a mechanism of determining this.

There is some information available on the movement patterns of this species from tagging conducted in Australia. Recaptures of tagged black marlin far from their position of release indicate that they are highly mobile fish, although it was noted that it appears there is a greater tendency for long distance travel for individuals less than 100 kg. (Ref.)

No evidence of black marlin discard was found in the data available and post harvest treatment of this species is primarily for the sashimi market; low quality black marlin are primarily used for fish sausage (Izumi, pers. comm.).

4.3.2.3 Blue Marlin

The distribution of catch rates for blue marlin (Figure 13(c)) shows the highest values in and around the northern waters of the Marshall Islands, although, given the distribution of effort in the WTP, the catch volume of blue marlin taken is fairly consistent throughout. Preference to the warmer offshore waters of the WTP and northern areas of the WSP is apparent, in contrary to the mainly WSP distribution exhibited by the striped marlin and to a lesser extent, the black marlin. Annual blue marlin CPUE has displayed no apparent trend of increase or decline in the years leading up to 1989, after a noticeable decline during the earlier to mid 1960's. The drop in CPUE in the WTP for 1989 and 1990, coincides with a higher than normal CPUE for the WSP, an interesting trend that is difficult to explain. It is believed that the variable nature of the blue marlin CPUE in the WTP (particularly for the period 1984-1989) may be related to migratory behaviour of males away from the equator (Ref.); when this occurs, good catch rates are experienced. Blue marlin CPUE for the WTP has generally fluctuated between 4 and 7 fish per 10,000 hooks since the early 1970's, while for the same period in the WSP, values of between 2 and 4 fish per 10,000 hooks existed; catch of blue marlin in the WTeP were practically non-existent.

The higher blue marlin catch rate for deep geared longline vessels in the WTP and the fluctuation for the depth ranges in the WSP (Figure 15(c)) highlights a different depth range preference for feeding than the other marlins. Evidence of feeding at greater depths is mentioned in Nakamura (1985), with the occurence of the deep-dwelling squirrel fish (*Holocentrus lacteoguttatus*) in the stomachs of this species. It is interesting to compare with the depth range preferences in observations on the short term vertical movement of sonic tagged blue marlin in the waters off Hawaii (Holland et al., 1990), and comparable data on blue marlin CPUE breakdown for these gear types, described in Suzuki (1977). There is a slight seasonal pattern for catch rates of blue marlin in the WTP, a more pronounced pattern appears for the WSP which is at a period that coincides with spawning in parts of this area. As with the other marlin species discussed in this report, there appear to be a greater proportion of larger blue marlin taken by longline vessels in the WSP than the WTP (Figures 19(a) and (b)). As mentioned previously, there has been some concerns relating to the misidentificatin of these species on some vessels.

It is generally considered that due to the historic pattern of effort, blue marlin stocks would be the most vulnerable to over-exploitation of the marlin species. The results from analyses of available longline data (1952-1975) on the catch of blue marlin in the Pacific by Yuen and Miyake (1980) indicated that the stock was probably over-exploited as catch rates diminshed and the catch level fell below the estimated maximum sustainable yield (MSY = 22,000 metric tonnes) even though fishing effort remained very high. Sakagawa (1987), however, suggested a reappraisal of this earlier work, as changes in gear depth utilisation since the late 1970's are believed to have effect on the vulnerability of blue marlin to longline gear.

It is not known whether blue marlin are targeted anywhere in the WPO, however, it is assumed they are generally retained and primarily processed for the sashimi market.

4.3.2.4 Swordfish

Swordfish are the target species for some Japanese and New Zealand longline vessels fishing in the waters off the east coast of Australia and in the waters of New Zealand; studies on the diel behaviour patterns of swordfish, and experience in the fishery have determined that the night is best time to catch this species using light sticks in the surface ocean layers. The lack of 'time of set' information in the RTFD, however, prevents a quantitative description of this fishing practice. This species of billfish is different from the others mentioned above in that fecundity is lower and longevity is higher, both important factors in management considerations.

The WSP produces the highest catch rates and catch volume in the WPO, according to the RTFD (Figure 13(d)). Annual values of CPUE show no trend in the overall catch rates levels for swordfish in the WSP and the WTeP; these areas, in reality, should be considered as one for this species. Since the late 1960s, CPUE for these areas has fluctuated generally between 5 and 12 fish per 10,000 hooks. CPUE for the WTP has remained somewhat constant over the 29 years, with a value of about 1-2 fish per 10,000 hooks. No definitive work was found on the status of swordfish stocks in the WPO and recent interest in targetting this species in parts of the WPO, may warrant further management attention in the future. In view of what may be possible in areas of the WPO, 61,000 swordfish were taken by the longline target fishery in Hawaii during 1991 at an average CPUE of 5.0 fish per 1,000 hooks (NMFS, 1992).

A strong seasonal pattern exists for swordfish CPUE in the WSP for conventional geared vessels which is in contrast to the marlins. It shows an increase in CPUE for the months leading up to the austral winter, a sharp decline during winter and another slight increase towards the beginning of spring. Observations elsewhere (Atlantic Ocean : Carey and Robinson, 1981), have shown swordfish making ventures into colder deeper water than marlin and they are also known to favour surface waters at night when the temperature is of the range of 18° to 22° C. It is interesting to compare these findings with the fact that that deep geared vessels in this area consistently catch less than 1 fish per 10,000 hooks, and this no doubt highlights the methods used in targetting this species. Desurmont (pers. comm.) mentioned that when targetting swordfish in New Caledonia, the gear of the first set of a trip was structured in a way to find the prefered depth (and thus temperature) range for swordfish in that area; catch rates, stratified by hook number, identified this depth range to be very narrow.

At the moment, the marketing of swordfish in Australia is restricted by regulations prohibiting the sale of this species where greater than 0.5 ppm mercury content is encountered, however, there has been recent efforts to try and have this minimum level increased, which may lead to an increase in interest for this species in the future. Similar regulations exist in the U.S. and Japan.

From a marketing standpoint, in Japan, swordfish are primarily sold as steaks in the preparation of *Teriyaki* (Nakamura, 1985), however, it is known to be available for sashimi as well. In the U.S., swordfish is popular and normally grilled/broiled using BBQs.

4.3.2.5 Sailfish

Figure 13(e) shows that sailfish catch rates are the highest in the areas off the north east coast of Australia, in the waters around New Guinea, Solomon Islands and New Caledonia. While the distribution of this species is widespread, higher levels of catch are known to occur in coastal waters, close to islands and reefs. Historical catch rates for sailfish are limited to the RTFD since the historic Japanese data for sailfish is not available. Figure 14(e) shows annual sailfish CPUE, highlighting a decline in the late 1970's - early 1980's for the WSP and an increase in the years leading up to 1990. CPUE was generally between 1-2 fish per 10,000 hooks in the WSP, compared to a level never exceeding 1 fish per 10,000 hooks in the WTP. Sailfish catch rates in the WSP show a slight seasonal pattern. Sailfish tend to remain in one area more so than the marlin species and they are known to form feeding aggregations, which is not as evident with the other billfish. There have been observer reports of relative high species composition of saifish for some longline sets in the WTP (Heberer, 1993) and this is also demonstrated by the high percentage of total catch exhibited in the WTP for days where sailfish catch were encountered (Figure 16(j))). This is also supported by the fact that more than 7% of trips where sailfish were encountered in the WTP contained 6 or more individuals; this compares with approximately 4% of the trips where 6 or more blue marlin were taken, even though this species is considered the more abundant billfish species overall in this area.

It is not expected that sailfish would be included in the target species of any longline vessel fishing in the WPO and it is more likely that under-reporting of this species would occur due to its relative importance when compared to the other billfish (the tendency to group this species with short-billed spearfish is an example : Farman, 1988). No information of stock status was found or is suggested, however, some action may be necessary to improve coverage and distinction in the the catch with short-billed spearfish.

Sailfish are retained catch, although not as highly valued as the other billfish; increasing utilization of sailfish as sashimi have been mentioned (ADL, pers. comm.).

4.3.2.6 Shark by-catch

- (comparison of biology of shark, tunas and billfish ...to be completed)

The proportion of the shark by-catch to total catch taken by longline vessels in the WPO is the highest of the gear types reviewed in this report and the highest by-catch group for longline.

Various species of shark are taken throughout the WPO (Figure 13(f)). Table 21 describes the species of shark caught and their broad distribution in the WPO based primarily on observer data; detailed descriptions of the biology and geographic distribution can be found in Compagno (1984). Very little information is available on the exploitation levels of the individual species of shark in the WPO, the most relevant literature reference being a review of the Japanese longline catch of Blue (*P. Glauca*) and Mako (*I. oxyrinchus*) sharks off south-eastern Australia (Stevens, 1992). Observer data collected by some SPC member countries provide the only means of distinguishing, to a very minor extent, the exploitation levels of the individual species of shark, as logsheets (RTFD) do not provide for a breakdown of shark species (Tables 21 and 24). There has been some effort in Australia to gain more information through the recent introduction of a shark logbook supplement for the Japanese longline fleet (P. Ward, pers. comm.), requiring the breakdown of shark by-catch into numbers/weight/discard of the most important species in their zone, that is, Blue shark (*P. Glauca*), Mako (*I. oxyrinchus*), Porbeagle (*Lamna nasus*) and Bronze whaler (*C. brachyurus*).

One of the predominant species taken throughout the WPO appear to be the Blue Shark or Blue Whaler Shark (*P. Glauca*), although significant catches of Mako (*I. oxyrinchus*), Thresher (*Alopias* sp.) and *Carcharhinus* species) have been observed in the WPO. While there is not enough quantitative data for the WPO, Sivasubramaniam (1964) described the shift in a higher species composition from Blue Shark to *Carcharhinus* species as one moved from temperate to tropical waters in the Indian Ocean. Stevens (1992) estimated that average Japanese catch rates for landed Blue Shark taken off south-eastern Australia is around 1-2 fish per 100 hooks, however, noted that there were considerable variations in catch levels experienced between periods of sampling. In comparison, he describes Japanese catch rates for the New Zealand longline fisheries which, after raising to account for under-reporting, are estimated to be in the range 1-4 fish per 100 hooks for the period from 1980 to 1989; catch rates (1.0 and 0.9) calculated from data collected on two observer trips (Michael et al., 1989) on Japanese vessels in New Zealand waters tend to agree with the lower bound of this range is level. The main concern with the level of catch of this species in the south-eastern Australian longline fishery was the high incidence of immature and adolecent females in the catch. Few data were found on the catch of this species in the WTP and no information was available to test the hypothesis that greater catches of Blue Shark were taken by deep-geared longline vessels in tropical waters.

Blue Shark are not a valued by-catch and in most cases only the fins are retained for additional crew revenue, with the remaining trunk usually discarded. In contrast, the other more common shark by-catch species (Mako Shark, for example) tend to be retained in entirety, although it appears that practices in retaining the trunks of shark may vary between vessel nationalities, for example the Taiwanese seem to catch

and retain more shark that the other fleets (Table 24; Heberer, 1993); the levels to which this occurs can only be validated by further observer data collection and analyses. Due to concerns relating to the practice on foreign longline vessels of removing the fins from shark (primarily Blue Shark) and discarding the trunk, Australia recently (1991/92) introduced regulations to prohibit this type of processing (Ward, pers. comm.). While there are obvious problems in enforcing this requirement, it has been nonetheless reported that the market for Blue Shark trunks has improved. The high rate of survival of shark species taken by this gear (Table 23) suggests that this may be a viable management option for other countries where this is seen to be a problem.
In the WTP, levels of shark by-catch based on information contained in the RTFD are seriously under-reported. As an indication, the average species composition of shark reported in the RTFD between 1985 and 1990 for Taiwanese vessels fishing in one area of the WTP was 25%; this compares to 0.09% for the same period and area for Japanese vessels. For this period, a subset of 60 trips by Taiwanese vessels had over 50% of the total recorded catch (in numbers) as shark, compared to none by the Japanese (although, prior to 1985 there were 4 Japanese trips where shark by-catch exceeded 50% of the total catch, perhaps highlighting the decline in shark by-catch reporting in recent years). The species composition of shark in the catch by Taiwanese vessels in the WTP from logsheet data is in the same order of magnitude as that reported by observers in this area and maybe indicative of the real catch of the other fleets operating in the area, however, it is difficult to accept this broad assumption without taking into account the range of activities of all fleets. While shark by-catch by Japanese vessels in the WTP appear to be under-reported, it is interesting to note the contrast in the apparent consistent reporting level of shark by-catch by Japanese vessels in the WTeP (Table 19), possibly highlighting more interest placed on some shark species in this area. It is hard to imagine these differences are valid and more likely occur because the various vessels/fleets have a tendency not to report catch of no commercial value or they are not obliged to do so. The fact that Taiwanese vessels in the WTP appear to provide much shark by-catch reporting may be related to their interest in this catch, for example, some vessels purposely set their gear shallower in order to target shark towards the end of a trip when suitable transportation back to Taiwan is available (Heberer, pers. comm.).
In regards to shark by-catch in related fisheries, the Hawaiin longline fishery reported a catch of 71,000 sharks during 1991 at a catch rate of about 6.0 per 1,000 hooks, although only 4,500 (6%) were retained (NMFS, 1992).

Due to the degree of non- and under-reporting of shark catch by longline vessels in the WPO, particularly in the WTP, it is difficult to estimate the exploitation levels. It would be of some concern if the overall shark catch rate in the WTP is anything close to that reported for the WTeP, although it is more likely to be closer to the level reported by the Taiwanese for this area. If it was considered necessary to introduce species-specific recording on catch logsheets, one of the problems envisaged would be correct species identification. In addition to ensuring reliable catch data is collected, some knowledge of fecundity, natural mortality and longevity of the species of shark in question would be required in order to review the status of individual species stocks for the areas of interest.

4.3.2.7 Non-target tuna species

Skipjack (*Katsuwonus pelamis*) are considered by-catch for the longline fishery in the WPO, as there is no documented evidence of any targeting in the areas of interest. The distribution of skipjack vulnerable to the longline gear is widespread and extends beyond the main areas of activity of the surface fishery fleets, which is primarily the WTP. An indication of the exploitation levels by longline vessels in the WTP is difficult due to inconsistent reporting from longline vessels of catch of this species (Table 16), and it is expected that the species composition (Table 19: 0.03% in the WTP), even after raising to account for non-provision on logsheets (Table 16 : logsheet coverage 23%), is below the real level. Data available in observer reports from the WTP indicate that 14 out of 21 trips reviewed had some skipjack catch (species composition ranging to 5% for one trip, averaging about 1%), most of which were discarded (Heberer, 1993). This proportion is far above what has been reported on logsheets but also differs considerably with the proportion of trips where other discards were reported in the RTFD (Table 17 : 0.57%), assuming the normal practise is to discard this species in this area. In the WSP, there is also evidence of some degree of under-reporting of skipjack catch, as 2% of the catch (by weight) unloaded in 1990 from longline vessels in Fiji were skipjack (Fiji, 1991); this highlights the fact that there are some areas where this species is always retained and thus, it would be difficult to provide broad indications of the fate of this species.

It is apparent that when there is sufficient freezer space and/or vessels make short trips from SPC-member country ports, skipjack are sometimes retained and then sold or given away on return to port; in some instances skipjack have been also retained for on-board crew consumption. The levels of under-reporting seem to stem primarily from the fact that skipjack are of lesser importance in the catch of these vessels and very rarely, if at all, contribute to the commercial catch.

Table 25 indicates the seasonal distribution of skipjack catch by longline vessels in the areas of the WPO, based on data held in the RTFD. It appears that more skipjack are taken during the third quarter of the year in the WTP and WSP, although it would be difficult to conclude that this is typical due to the degree of under-reporting and the fact that most skipjack are presumed to be discarded and not subsequently recorded on the catch logsheet. A more accurate indication of the seasonality of skipjack catch from longline vessels could be obtained from observer reports, provided there was sufficient coverage to represent the fishing activity for the given time/areas of interest.

The longline fishery operating in the equatorial regions in the Indian Ocean have reported consistently high hooking rates (> 2 per 1,000 hooks) for skipjack; it is also evident that the skipjack taken by this gear are generally larger than those taken by the surface fisheries in that area (Marcille, 1974), a fact also prevalent in the WTP. From the few data in the RTFD where vessel trips recorded skipjack catch the following average CPUE values are available for the period 1978-1991 where the frequency of trips is greater than 10 : Japanese vessels fishing in Australia (0.4 fish per 1000 hooks; 399 trips), Korean vessels in Cook Islands (1.1; 22 trips), Taiwanese in Fiji (0.7; 41 trips), Japanese in FSM (0.2; 13 trips), Koreans in Kiribati (0.4; 23 trips, Japanese in the Marshall Islands (0.7; 17 trips), Japanese in Papua New Guinea (0.4; 13 trips), Japanese in Solomon Islands (0.3; 49 trips) and the domestic Tongan longliner (0.7 for 49 trips). It is assumed that these were retained catches and it is unknown whether there were further discards of skipjack not included in these reports.

There have been only two skipjack releases reported as longline recoveries, one skipjack released during the Skipjack Survey and Assessment Programme (SSAP) conducted by SPC from 1977 to 1981 and one release from the Regional Tuna Tagging Project (RTTP), conducted by TBAP from 1988 to 1992.

Albacore (*Thunnus alalunga*) are usually the target species for longline vessels operating in the WSP, although there are also incidental catches taken by longline vessels in the WTP; the fate of this by-catch is largely unknown, but considered to be kept for crew consumption or gifts on return to port. No albacore catch occured from any of the WTP observer trips that have been made available for this report. Albacore longline catch data are available in the RTFD for activities in the WTP waters of FSM (where CPUE have ranged from about 0.1 to 1 fish per 10,000 hooks annually by the Japanese fleet since 1982 and a range from 1.7 to 2.4 fish per 1000 hooks annually by the Tawianese fleet during 1987-1989), Kiribati (0.2 to 1.1 fish per 1000 hooks by the Japanese fleet since 1981; 0.1 to 1.5 per 1000 hooks annually for Korean fleet since 1985), the Marshall Islands (CPUE range from about 0.1 to 2 fish per 10,000 hooks for the Japanese fleet since 1982), Papua New Guinea (1 to 7 fish per 10,000 hooks annually for the Japanese during 1980 to 1987), Palau (1 to 12 fish per 10,000 hooks annually for the Japanese since 1980) and the Solomon Islands (0.2 to 5.1 fish per 1,000 hooks annually for the Japanese since 1978). The average weight of albacore taken in the WTP tend to be larger than that of the more temperate waters, with very few records of individuals less than 15 kilograms appearing in the RTFD.

Bluefin (*Thunnus thynnus*) and **Southern Bluefin** (*Thunnus maccoyii*) are the valuable target species of longline fisheries bordering parts of the northern and southern areas of the WPO, respectively. Incidental catches of bluefin in the WTP are available in the RTFD, although, some uncertainty surrounds the exact species identification and the assumption that they are *T. thynnus* has been made based upon the proximity to this species target fishery. Examples of outstanding catches in the WTP are (i) during 1991-1992, 9 individuals averaging over 200 kilograms were taken by Taiwanese longline vessels in FSM waters (ii) during 1990-1991, 4 individuals averaging over 250 kilograms each were taken by mainland Chinese vessels fishing in Palau waters (iii) 3 individuals, each weighing over 100 kilograms, were taken by Japanese vessels fishing in Solomon Island waters north of 10°S during 1985 to 1990 and (iv) several individuals taken in Fijian waters weighing over 150 kilograms. None of the available observer data contains occurences of Bluefin catch of either species in the WTP.

4.3.3.8 By-catch of other species

For reasons described in the sources and coverage of data section above, information on the by-catch of the 'other' species contained in the RTFD are lacking. Tabulated data are provided in an attempt to give some representation of the levels of by-catch in the WPO; the seasonal catch for each retained species reported on logsheets is shown in Table 25, and Table 21 describes the species that have been caught by longline vessels in the WPO according to observations. Table 20 gives some indication of the broad distribution and size composition of the some of the individual 'other' species by-catch. There was no attempt to show annual CPUE trends by species, detailed geographic distribution nor quantitative estimates of other species by-catch for the WPO due to the paucity and inconsistent reporting in data available.

Domestic fleets operating in the WTP and WSP generally retain more by-catch species than the DWFN fleets; by-catch from locally based vessels are usually sold in local markets or retained by crew for personal consumption or gifts to family and friends, although, in Fiji for example, up to 90% of the retained by-catch is exported and it has been reported that when appropriate, some by-catch unloaded at ports in FSM by Taiwanese vessels are shipped back to Taiwan.

Of the species catch contained in the RTFD, only moonfish (*Lampris sp.*) have been reported regularly in the three areas of the WPO. Considered a delicacy, the fate of these fish seem to vary, some are exclusively kept for crew consumption, whether on-board or return to port, while there are other reports of the commercial sale of this fish; for example, moonfish have been exported from Fiji (Viala, pers. comm.).

In areas of the WTP and the WSP, Wahoo (*A. solandri*) and Mahi mahi (*Coryphaenus* sp.) are the common by-catch of longline vessels. Catch of these species is more seasonal in the WSP and they are not normally discarded as they are generally considered for crew consumption or commercially imported enough to provide local markets, although this may not be the case for vessels making long trips where freezer space is at a premium. The RTFD contains catch data for Wahoo from Fiji (vessel trip CPUE ranging from 1-2 fish per trip to 0.4 per 1000 hooks for the trip), New Caledonia (CPUE ranging to 0.9 fish per 1000 hooks for the trip) and PNG (CPUE ranging to 0.3 fish per 1000 hooks for the trip); consistent Wahoo catch has been reported by observers on foreign longline vessels fishing in FSM waters (vessel trip CPUE ranging to 1.4 fish per 1000 hooks; Heberer, 1993). The catch of Mahi Mahi has been reported in the RTFD from Fiji (vessel trip CPUE ranging to 0.8 fish per 1000 hooks), FSM (to 13.3 fish per 1000 hooks), Marshall Islands (to 4.7 fish per 1000 hooks), PNG (to 0.03 fish per 1000 hooks) and Tonga (to 0.2 fish per 1000 hooks); FSM observer data also reveal consistent catches for Mahi mahi, with CPUEs ranging to 2.7 fish per 1000 hooks for the observed trips. The Hawaian longline fishery reported an average catch rate for Mahi mahi of 3.1 per 1,000 hooks during 1991. Some of the logsheets received by SPC contain specific columns for each of these species, indicating their importance in the catch of those areas (for example, New Caledonia). The importance of these species as part of overall longline catch is highlighted also in the actions taken by the Western Pacific Regional Fisheries Management Council's (WPRFMC) to specifically include them in their Pelagics Fisheries Management Plan (FMP) for the longline fisheries of their area of jurisdiction (some of which includes areas of the WPO, for example Guam). The FMP, also contains summarised information on the biology and geographic distribution of these species in the Pacific Ocean, which is useful in reference to our area of interest. No indication of overall levels of exploitation for the WPO are suggested or were found due to the paucity of data.

There are some by-catch species which are very seldom considered commercially valuable nor kept for crew consumption. The most common of these species are the Oilfish (*Ruvettus pretiosus*), Snake Mackerel/Escolar (Gempylidae), Lancet fish (Alepisauridae) and the Barracudas (Sphyraenidae). As an example, there was only one trip out of 21 reviewed by Heberer (1993) where any of these species were retained, eventhough there were reasonable catches observed (at least 75% of trips contained by-catch of this nature). According to observers on foreign longline vessels in Australian waters, less than 1% of the observed catch of these species was retained. In regards to the ability of these species surviving after discard, the Oilfish (81% encountered alive on landing) and Snake Mackerel (78%) appear to be the hardier species (AFZ observer data; Ward, pers. comm.).

Of the species not already mentioned, little information was available on the exploitation levels of Sunfish (*Mola* sp.) and Bramids (Bramidae) by the longline fisheries in the WPO, although it appears they are regular by-catch of longline vessels and, thus should warrant further attention.

4.3.3.9 By-catch of non-fish species of particular interest

No RTFD record of seabird, turtle or marine mammal capture by the longline vessels in the WPO exist. The following describes what exist in observer reports and the literature on these animals.

(a) Seabirds

Due to the nature of baiting and setting longline gear, seabirds have for some time caused a problem for longline vessels in some areas. When baited hooks are flung from the vessel, birds in the vicinity of the vessel will try and take the bait before there is time for the line to sink; there have also been reports of birds taking baits in the hauling process, although the frequency of birds caught in this manner is nowhere near that of bird catch during the setting process. The catch rates of bird are typically at their highest in the WSP and WTeP where vessels are in proximity to the major land masses of Australia and New Zealand. The genera mostly taken in these areas are *Diomedea spp.* (albatrosses) and *Procellaria spp.* (petrels). Up until recently, catch rates of 0.9 birds per 1000 hooks for the southern bluefin longline fishery in New Zealand (Murray, 1992) and 0.41 birds per 1000 hooks in the Australian southern bluefin fishery (Brothers, 1991) have been recorded by observers. Concern related to the decline in the population of these birds, in particular the albatross species, prompted initiatives on both sides of the Tasman Sea to try and reduce this catch. There was also keen interest from the fishermen, as bait loss from birds (one estimate of 5 baits lost per hooked bird; Murray, 1992) meant the reduced efficiency of their gear. The implementation of what is referred to as a tori (bird) pole, consisting of a boom and trailing streamer line, has seen a substantial reduction in the bird catch rate of 88% to previous years when this device was not used (AFS, 1991; Brothers, 1991). Other mechanisms that have been suggested are
(i) the possibility of setting longlines at night when bird activity is at a minimum; and (ii) the closure of areas known to be localities where birds frequent and are likely to be a problem to the longline vessel (Murray, 1992). (iii) A mechanical bait-throwing device to reduce slack in the branch line and speed bait sinking is also showing promising results.

No references to the catch of birds by longline vessels in the WTP, where a large proportion of the effort occurs, were found. As the populations of the above-mentioned genera are prevalent in the higher latitudes, the problems encountered in the WTeP would not be expected to occur in the WTP.

(b) Marine reptiles

There are references to the catch of some turtle species by longline vessels in the WPO from observers (Table 21), and in nearly all cases, they were released alive. While there are no records of turtle catch in the RTFD, observer reports suggest that turtles caught by longline vessels in the WTP (and WSP) may be common. From the observer reports available, there were no mention of commercial interest in turtles nor of retaining for consumption on-board or on return to port; this practice, however, may vary from vessel to vessel and fleet to fleet. Not enough information was found to ascertain the overall exploitation levels of turtle by longline vessels in the WPO.

The incidental catch of turtle in areas other that the WPO have been documented. Witzell (1984) calculated a CPUE of 0.073 turtles per 10,000 hooks for Japanese longline vessels fishing in US waters in the Atlantic Ocean and 0.18 per 10,000 hooks in the Gulf of Mexico. The percentage of turtles (leatherback, Green, Kemp's ridley and loggerhead) released alive were 70.4% and 93.3% for two areas respectively, suggesting a good survival rate which could be applied to WPO occurences.

If one considers that available space on-board is valuable, consumption of this animal is usually not preferred (the Japanese have certain superstitions involving turtles; reference to this is made in the Purse Seine section of this report) and the fact that it is expected that they are alive when retrieved (and presumably released), it can be concluded that the longline fishery in the WPO does not pose a serious threat to the turtle population. This hypothesis can only be validated by further specific data collection via logsheet or observers and, perhaps, relevant interviews with captain and crew of these vessels.

(c) Marine mammals

There was only one account found where two common dolphins (*Delphinus delphis*) were accidently caught by a foreign longline vessel (Michael et al., 1987) and one account of the hooking of a porpoise (species not known) in New Zealand waters; both occurences were reported by observers. Evidence of the capture of a killer whale (*Orcinus orca*) by a longline vessel in New Caledonian waters was witnessed by one of the authors and there is a report of the same species being taken in the southern waters of New Zealand by a Japanese longliner.

Due to the somewhat frequent accounts of tuna damaged by killer whale, false killer whale (*Pseudorca crassidens*) and pilot whale (*Globicephala* spp.) occurring in the longline fishery by fishermen and observers, it is possible that there may be occasional hook-ups or tangles as a result these species 'playing' with or attacking tuna already on the line. However, reported instances of their catch is very rare and as they are regarded as a serious 'pest', fishermen endeavour to avoid operations in areas where they may occur in order to reduce major catch losses. Normally, these species will leave only the head or lips of the catch and the frequency of damage in the total catch is almost always far greater than that of shark. As an example, there were two days out of 9 observed where at least half of the target catch from a Japanese longline vessel fishing in the north-eastern AFZ were damaged by false killer whales (Staisch, 1993) and it was necessary to shift operations on the days subsequent to avoid such incidents; false killer whale-damaged tuna were observed on three other days of this observation period, but not to the same extent as mentioned above. Table 18 provides some further indication of the level of damage caused by these species in the WPO.

Observers in New Zealand have reported the incidental catch of seal (Pinnipedia) by Japanese longline fishing vessels targetting Southern Bluefin tuna, however, further information on their fate and the frequency of this type of catch were not available. As the WPO longline area has little overlap with areas where seal populations are abundant, it is perceived that this by-catch is extremely low in comparison to the overall effort.

4.3.3.10 Discards of by-catch

Discards of by-catch in the WPO fall into the 6 following categories :

(a) **Undesirable species.** This is probably the most common reason for the discard of by-catch as the species in question has no commercial value. These fish may be discarded after landing or if they are identified before landing, they may be struck off (flicked off) the line by the crew before the gear reaches the vessel. The latter method of discarding has caused some observers concern when trying to monitor the entire catch composition of a set or a continuous hauling period of a set, as they are usually not in a good position to observe these occurences. As mentioned already, Oilfish, Snake Mackerel, Lancet fish and Barracudas are the most common in this category. The species of by-catch that are normally discarded are considered nuisance as they lower the effective fishing power, i.e. the number of available hooks. No strategy to counter the hooking of these undesirable species, other than the sea birds, was found in the literature, and it seems likely that the economics of investigations and subsequent implementation of such strategies far outweigh the simple discarding practises now performed.

Non-target tuna species of no commercial value to the longline vessel may be discarded if there is no interest in on-board consumption or the lack of freezer space means that they can not be retained for consumption on return to port. The most common species that fall into this category are Skipjack (*K. pelamis*). While specific references were not found, it is also likely species that are target in other parts of the WPO, for example albacore (*T. alalunga*) are target in areas of the WSP, may be discarded in areas where they are not considered for personal consumption or as part of commercial catch.

(b) **No available space.** The species of by-catch is normally retained, however, when freezer space is limited due to success in taking target catch, these fish, for example Mahi mahi and Wahoo, are discarded. These occurences are more likely to occur on the larger longline vessels making longer trips further away from offloading ports than the vessels that operate out of SPC member country ports. It is possible that these species may be retained during the early part of a trip and discarded later as the more valuable species are taken and freezer space becomes limited.

(c) **Damaged by-catch.** The by-catch species is normally retained, however, have been mauled by killer whale, false killer whale or shark and are not worth retaining (billfish would normally fall into this category). If the damage has been caused by a marine mammal, then normally only the head is left remaining.

(d) **Shark Fins.** For certain species of shark (primarily the Blue shark (*P. glauca*), the dorsal, ventral, tail, and pectoral fins are removed and the remainder of the carcass discarded. A common practise throughout the WPO, efforts have been made recently in Australia to try and reduce the incidence of this type of discard.

(e) **Difficult to land.** There have been instances reported by observers where very large fish (e.g. shark) have been difficult to process or land, and discarding was necessary (Ward, pers.comm.).

(f) **Protected species.** There are requirements in certain areas of the WPO that billfish that are still alive at the time of landing must be released. The fate of these species after the enduring the stress of hooking is unknown, although, sonic tagging experiments on billfish that have undergone similar stress levels (Holland et al., 1990) and observer reported survival rates provide encouraging findings. Billfish tagged on longline vessels and the discarding of turtles would also fall into this category.

Discarding practises may vary from fleet to fleet and often from vessel to vessel within a fleet. The determinants for retaining or discarding fish sometimes come down to the captain/fishing master's personal preferences. Table 18 gives the best available indication of the variablility of levels of by-catch discarded in areas of the WPO. The amount of by-catch taken has some relationship with the amount that is considered for discard, although it is apparent that by-catch alone can not be used as an indicator to subsequent levels of discard, as some fleets (and vessels) tend to retain by-catch more than others.

Very little information on by-catch discarded is available from the RTFD as no species indentification nor reason for discard is provided for on logsheets. This is compounded by the inconsistencies in by-catch discard reporting throughout the WPO.

An important aspect of discard important in conservation issues, is the number of species that are likely to be alive at the time of landing. Some data have been collected by observers and other sources indicating the survival rates of some by-catch species from longline vessels (Tables 22 and 23) and it would be expected that data of this type would be important in discussions and implementations of future management plans in this fishery. No information was found on the survival rates of by-catch tuna species, although with knowledge of the biology of these species, it is expected that high mortality would occur, especially for skipjack.

4.3.3 Estimates of by-catch

Table 21 provides a broad indication of the likely frequency of incidental by-catch species appearing in the catch of longline vessels, based on observer accounts. The only other indication provided are the catch rates of species observed in only certain areas of the WPO.

An attempt has been made to estimate the catch of billfish species by longline vessels operating in the WPO (Table 26). The trend in the reduction of overall catch for most of the billfish species is difficult to explain, however, it is thought that differences in the level in effort between years and fleets and the changes in areas fished by some fleets (for example, the Japanese fleet have not fished in PNG waters since 1987) have some effect. It is believed also that the recent introduction of regulations prohibiting the landing of certain species of billfish in areas of the WPO may have some bearing for some of these species. While it is not in the scope of this report, it may be necessary to look further into the exploitation levels of billfish species, particularly Blue marlin, in order to determine current stock status. It is worth noting the points raised by Farman (1988), who warns about using solely catch and effort statistics in reviewing stock status of billfish without taking into consideration other forms of data, such as size composition data.

The Blue Shark catch by longline vessels occurs throughout the WPO (Compagno, 1984). Assuming a very crude estimate for the catch rate of blue shark to be 1 per 1,000 hooks (Stevens, 1992; available observer data) and annual effort of around 200,000,000 hooks, a very crude estimate for the total annual catch would be around 200,000 fish or 6,000 metric tonnes (assuming an average weight of 30 kgs; Stevens, 1992).

The catch rates available from observer and logbook data for Wahoo and Mahi Mahi could be used to derive estimates (albeit very crude) of total catch, although one would have to take into account the variation in the distribution and the seasonality of catch of these species throughout the WPO.

4.4 Target tuna discards

4.4.1 Gross levels of target tuna discards

Table 15 shows levels of tuna discard by fleet and area for longline vessels fishing in the WPO and Figure 8(b) shows the distribution of tuna discards, both sourced from data available in the RTFD. Table 18 shows the proportion of target tuna discarded from the total catch as reported by observers.

Unfortunately, as tuna discarding reported in the RTFD is inconsistent, Figure 8(b) showing distribution of tuna discarded can only be seen to represent where reliable reporting has occurred. The small amount of information available from observers suggests that, due to the higher frequency of marine mammal and shark damage occurrences in the lower latitudes (i.e. WTP and WSP) and that smaller species of target tuna are more likely to appear in these areas, and the fact that a large amount of the WPO effort occurs in the WTP, it is believed that most of the tuna discards should occur in this area.

The best available indication to the levels of discard is provided in Table 17. It is interesting to note the comparison between the average proportion of tuna discard for days where it was reported in the RTFD (cumulative : 9.4% for WTP; 4% for WSP) and the proportion of total catch reported discarded as reported by observers (11.3% for WTP; 0-5% for WSP). This is stark contrast to the value of less than 0.2% reported for the WTP and WSP for all RTFD data where there was provision for entering tuna discard information.

4.4.2 Reasons for target tuna discards

The following are, in no particular order, the reasons why target tuna species are discarded in the WPO.

(a) **Target species that are too small.** In the WTP, there have been reports from observers where the standard practice on some vessels is to discard target species that are smaller than a size considered marketable (this has been reported by some observers to be 15 kilograms for some vessels, 95 cm on others). The minimum size limit appears to differ from vessel to vessel and fleet to fleet and seems to vary depending on whether the trip is long or short (and thus freezer space being a constraint). There are also reports of certain preferences for target species below the minimum size for crew consumption, for example, Heberer (1993) mentions, in his review of one observer trip, that small bigeye were prefered for crew consumption/gifts to small yellowfin, which were mostly discarded. Towards the end of a successful trip, discarding of the target catch of a higher than standard minimum weight may also occur if freezer space is limited. No information was available to indicate whether foreign vessels that are based out of SPC member country ports show a lesser tendency to discard in this manner than the distant-water/larger longline vessels.

This practise should be particularly noted in analyses of length and weight data collected at ports of unloading to obtain a representative size composition of the catch. With the knowledge that landed tuna in this category have a relatively poor survival rate, it is of some importance to gain further information on the levels of discarding of this kind and then ascertain if management measures should then be introduced, although consideration should also be given to the levels of natural mortality and discard of these species by surface fisheries.

b) **Shark or marine mammal damaged target species.** The incidences of shark and killer whale damaged tuna appear to be one of the most common reasons for target species of tuna to be discarded. Of the 9 observer trips in the WTP where target tuna damage information are available, there are 6 trips where tuna damage accounts for approximately 50% or more of the number of target tuna discarded. Hooked tuna become easy prey for shark and killer whale/false killer whale/pilot whale, although, the latter are considered the more dangerous to the commercial catch as it will work along the line once it has encountered its first prey. There are numerous accounts of hauling a line littered with bodiless heads of tunas after attacks by these species of marine mammals. Shark damage, in contrast, is usually restricted to isolated attacks per shark. The undamaged sections of the tuna are sometimes retained for crew consumption (in some instances even the heads), with the remainder discarded. Sivasubramaniam (1964) estimated an average of 11% of tuna catches may be susceptible to shark damage in the Indian Ocean and that attacks were more frequent in warmer waters in areas where *C. longimanus* and *C. brachyurus* are abundant; this level appears to be in the order of that experienced during observer trips in the WTP. No reports of billfish damaged tuna were found.

The high incidence of damaged target tuna in the WTP is evident in the proportion of the total catch that falls into this category as reported by observers (Table 18), although few data of this nature exist at this point and it is hoped more accurate levels will be known as a result of appropriate changes to logsheet and observer data collection procedures.

There are also observer reports of slight damage of target tuna by the Cookie cutter shark (*Isistius brasiliensis*) and, in the instances where this was reported, did not result in spoiling the fish. This is in contrast to a report by an observer (Staisch, 1993), where tuna with minor puncture marks, caused by the teeth of false killer whales 'playing' with its prey, were apparently discarded as it was thought the bacteria from the predator's teeth had contaminated the flesh of the tuna and thus would soon make it unfit for human consumption.

(c) **Target of poor quality.** On some vessels it is a requirement that the target tuna are landed alive and tuna maybe discarded when they have been on the line too long and hence are not of the quality suitable enough for the sashimi market. Discard may also occur due to the failure of the freezing equipment on-board, as fish thawing to a level beyond the optimum range for storage, become unsuitable for sale.

(d) **No available space on-board.** Discarding practices for target species may occur towards the end of a successful trip when freezer storage capacity has been reached.

4.4.3 Estimates of target tuna discard

Due to the irregular nature of target tuna discard in the longline fisheries, an estimate of the extent of such discards is neither possible nor realistic with the available information.

4.5 Conclusions and recommendations

The main conclusions and recommendations to come out of this investigation of longline by-catch and discard practises are as follows :

(a) For the period 1978 to 1991, the RTFD contains total WPO catch for the longline fishery of over 20,000,000 fish, of which 12.6% was listed as by-catch, less than 0.2% as discarded by-catch and less than 0.1% target tuna discard.

(b) No attempt has been made in this report to estimate the amount of total by-catch and discard of by-catch and target tuna. Instead, reference is made to available observer data (Table 18) to give some indication of the degree of non- and under-reporting that exist in the RTFD and, thus, the likely levels of by-catch and discard. For the by-catch species where some information is available, that is the billfish species (Table 26) and possibly also the Blue Shark (*P. glauca*), estimates of total catch have been suggested. For some other species, ranges in CPUE, for the vessels and observers that have reported the catch of that species, is the best indication that is currently available.

(c) The most important concerns related to the exploitation of billfish by the longline fishery in the WPO are the interactions with recreational fisheries in the WPO and the possible over-exploitation of Blue Marlin in the WTP. No recent scientific evidence on the latter was found for this report, however, its importance may necessitate further specific investigations.

Management measures in releasing live billfish in order to restrict the foreign catch of billfish in Australia and New Zealand have been in force since the early 1980s. Data on survival rates of marlin taken by longline vessels suggest that releasing live billfish is a viable option for other countries where interaction between recreational and longline fisheries is perceived to be a potential problem, although, there is still some concern in regards to the enforcement of this practice. The collection of finer detail on the survival rates of billfish taken by longline vessels (the AFZ observer programme have introduced a scale of life status on landing, rather than just dead/alive) and some more knowledge on the degree of interaction between recreational and longline fisheries would no doubt benefit decisions to be made in the future.

(d) Little information is available in the RTFD on the by-catch of shark in the WPO. The few observer data available provide a better indication of species breakdown, however, coverage of the WPO is low at this stage.

The catch of shark in the WPO appears to constitute a large proportion of the total catch but very rarely is part of the commercial catch and, hence, are rarely recorded on the logsheets. In order to get some idea of the exploitation levels of these species, efforts should be made to ensure accurate data is collected. This has in some way been addressed already by the increase in observer activities on longline vessels in the WSP and efforts in Australia in providing a shark logsheet supplement to foreign fishing vessels which is an implementation that could be applied to other areas of the WPO. The observed high survival rates of shark is encouraging and management measures involving the discard of these species maybe the most effective way of dealing with a potential problem, although, as in live billfish discard, there may be problems with enforcing this practice.

Without adequate data, it is impossible to determine stock status. The Blue Shark appear to constitute a large proportion of the shark catch in the WPO and a very crude estimate of 6,000 metric tonnes per year has been suggested. At this stage, however, there is no information available to indicate what affect this level of catch has on the stock of this species.

(e) There are incidental catches of skipjack and other non-target tuna species throughout the WPO. Discarding of these species vary somewhat between area and fleet, however, the level of this by-catch is not of the order to be detrimental to their stocks nor provide competition with the surface fisheries.

Little is known about the exploitation levels of by-catch of species other than billfish, shark and non-target tuna species. It appears that the best mechanism for obtaining more definite species-specific data is observer programmes, although, the reporting of catch of the more commercially important species, such as Wahoo and Mahi mahi could be improved by suitable changes in the format of catch logsheets.

(f) As in the purse seine fishery, target tuna discards are an irregular and unpredictable feature of the longline fishery. The two major reasons for tuna discard are due to size and damage by shark or marine mammal. As target species have been discarded in both cases, it is important to know the degree of this practise in order to obtain true CPUE values. The damage by large predators is unavoidable and should not normally present the fishermen with any reason for not providing accurate data.

There is evidence of the discarding of small target species, although it is not perceived to exist at the levels encountered in the surface fisheries. The recording of discards due to size may be more difficult to enforce than the damaged target species, although it should be strongly considered if the size measurements taken at unloading time are to be representative of the population that is vulnerable to this fishing gear.

It would be difficult to determine the incidence of target tuna damage in the WPO from data collected by observers due to the variable nature of these occurences, and proposed coverage of observer activities would need to be carefully designed in order to obtain representative indications. On the other hand, improvements to catch logsheets to include specific columns for the number of target species damaged by shark/marine mammal could provide a means for obtaining a better overall indication.

The presumably low survival rates of small tuna species mean that the possiblity of discarding these species alive is not viable.

(g) The sheer diversity of by-catch species caught by longline vessels in the WPO should encourage some form of monitoring. At least all catch that have commercial value should be recorded on the catch logsheet. The suitability of the RTFD to give indications of by-catch and discard levels for the longline fishery in the WPO can only be applied to the reporting of billfish catch. It is apparent, for a number of reasons, that the by-catch of shark and the less important species and discards of tuna and by-catch as reported by the RTFD are lacking. It is more difficult, however, to enforce the recording of (i) the by-catch retained for purposes other than the commercial exploitation, (ii) the by-catch discarded and (iii) the target tuna discarded, as no comparison to a verifying document (for example, unloading data) can be made.

(h) Observer reports provide both quantitative and qualitative information on the levels of by-catch and discards of by-catch and target catch for individual vessels. At this stage, while there are established observer programmes in Australia, New Zealand and Federated States of Micronesia, the coverage of observer data for the whole WPO is inadequate and increasing activities in this area would go a long way to providing more information on the levels of by-catch and discarding practises. It should be noted that the experiences dealt with by the abovementioned observer programmes would be invaluable to the implementation of well designed and efficient regional observer programme.

(i) In summary, better indications of by-catch and discard of by-catch and target tuna in the WPO longline fishery could be obtained by the allowing for the following important data collection implementations :

By-catch and discard of by-catch. Observer data collection should provide for the recording of catch of **all** species, the landed status (e.g. discarded or not), the condition on landing (life status/damage), and processing status.

Target tuna discards. Catch logsheets should provide for the recording of damaged tuna that necessitates discarding, stratified by predator and prey species. It is more difficult to ensure that the discard of small target species is recorded on the logsheets and, for this reason, the degree to which this occurs would be better identified from data collected by observers.

(j) Lastly, methods of dealing with nuisance by-catch and subsequent discard may need to be explored, as exemplified in the method for the reduction of albatross by-catch. The local sale of by-catch is not seen as a viable option in all cases as it competes with local fisheries and may be uneconomical for the vessel to waste the time and operating costs to do this. Rather, there may be techniques in the fishery that can be used to reduce the incidence of nuisance by-catch. This is of importance to the fishermen, as each hook taken by nuisance species is one less available for their targets.

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Table 1: Industrial tuna and billfish fisheries operating in the South Pacific Commission statistical area of the western Pacific Ocean

Gear	Target species (secondary target)	Area	Season	Countries involved
Purse seine	Skipjack, Yellowfin (Bigeye)	WTP	All year	Australia, Federated States of Micronesia, Indonesia, Japan, Korea, Marshall Is, Mexico, Philippines, Russia, Solomon Is, Taiwan, USA
	Skipjack	WSP	Oct.-Jun.	Australia, New Zealand, Philippines, Philippines, U.S.A.
	Southern bluefin, skipjack	WTeP	Oct.-Apr.	Australia
Longline	Yellowfin, Bigeye (Albacore, billfish)	WTP	All year	China, FSM, Marshall Is, Japan, Korea, Solomon Is,Taiwan
	Yellowfin, Bigeye, Albacore (Swordfish, Striped marlin)	WSP	All year	Australia, Fiji, French Polynesia, Korea, Japan, New Caledonia, Taiwan, Tonga (Korea and Taiwan extend into WTeP from Mar.-Jun.)
	Southern bluefin, Yellowfin (Albacore, Bigeye, Swordfish)	WTeP	All year	Australia, Japan, New Zealand
Pole-and-line	Skipjack (Yellowfin, Bigeye)	WTP	All year	Japan, Kiribati, Palau, Papua New Guinea, Solomon Is, Tuvalu
	Skipjack (Yellowfin)	WSP	Nov.-Aug. Dec.-Mar.	Fiji Australia
	Skipjack (Yellowfin)	WSP	All year	French Polynesia
Troll	Albacore	WTeP	Nov.-Apr.	Australia, Canada, Fiji, French Polynesia, New Zealand, U.S.A.
Handline	Yellowfin, Bigeye	WSP	Oct.-Nov.	Australia, Japan
	Southern bluefin	WTeP	May-Aug.	Australia, New Zealand
Driftnet	Albacore (Skipjack)	WTeP	Nov.-Apr.	Japan, Taiwan, (Korea)

Table 2: By-catch and discards as a percentage of the total catch of purse seine fleets operating in the WPO, based on logbook data held on the SPC Regional Tuna Fisheries Database, 1975-1991. (% Target catch includes tuna catches retained and discarded; % By-catch includes by-catch retained and discarded; the sum of these two percentages equals 100%. New Zealand by-catch in NZ waters has been provided in numbers.)

Fleet	Area	Period	Total sets	Total catch	% Target catch	% By-catch	% Tuna discards	% other discards
Australia	WTP	1988-1991	584	10117.0	100.00	0.00	0.00	0.00
	WSP/WTeP	1975-1990	424	8850.8	100.00	0.00	0.00	0.00
FSM	WTP	1991	105	627.0	100.00	0.00	0.00	0.00
Indonesia	WTP	1986-1990	433	11471.0	99.98	0.02	0.39	0.00
Japan	WTP	1979-1991	45823	1039476.1	99.93	0.07	0.01	0.01
Korea	WTP	1980-1991	7877	153306.9	99.93	0.07	0.29	0.06
Mexico	WTP	1984	164	3191.0	100.00	0.00	0.00	0.00
New Zealand	WSP	1983-1985	165	1935.9	96.34	3.66	0.36	0.10
	WSP (NZ)	1983-1988	1829	22612.0	100.00	(2170)	0.00	0.00
Philippines	WTP	1982-1991	6454	105876.2	98.24	1.76	1.05	0.38
	WSP	1989	20	292.0	98.63	1.37	0.00	0.00
Russia	WTP	1985-1986	529	5539.0	99.49	0.51	0.00	0.00
Solomon Islands	WTP	1984-1991	1750	56105.0	98.38	1.62	3.31	0.00
Taiwan	WTP	1983-1991	10311	155639.5	99.98	0.02	0.00	0.00
USA	WTP	1983-1991	27058	659790.0	99.86	0.14	0.27	0.11
	WSP	1984-1991	234	4928.8	100.00	0.00	0.00	0.00
Totals	WTP	1979-1991	101088	2201138.7	99.79	0.21	0.24	0.06
	WSP/WTeP	1975-1990	424	8850.8	100.00	0.00	0.00	0.00
	WSP	1983-1991	419	7156.7	98.95	1.05	0.10	0.03
	WSP (NZ)	1983-1988	1829	22612.0	100.00	(2170)	0.00	0.00
Grand total	All areas	1975-1991	103760	2239758.2	99.79	0.21	0.24	0.06

Table 3: Median by-catch per set (mt) by school association for purse seine fleets operating in the WTP, 1975-1991 with descriptive statistics for all fleets combined. Figures are median tonnes of by-catch per set for sets on the SPC Regional Tuna Fisheries Database that contain records of by-catch, number of sets with by-catch, the percentage of by-catch sets against all sets for each association type, and the percentage of by-catch that was discarded. (+ = < 0.1%)

Fleet		School	Log	Drifting FAD	Anchored FAD	Animal	Other	Unspec.
Indonesia	By-catch/set	-	1.0	-	-	-	-	-
	No. by-catch sets	-	2	-	-	-	-	-
	% by-catch sets	-	0.6	-	-	-	-	-
	% by-catch discarded	-	0.0	-	-	-	-	-
Japan	By-catch/set	2.0	2.0	0.1	2.0	-	2.0	1.0
	No. by-catch sets	3	89	2	1	-	133	4
	% by-catch sets	+	0.3	1.0	0.8	-	3.6	0.9
	% by-catch discarded	11.1	24.3	100.0	0.0	-	0.0	0.0
Korea	By-catch/set	1.0	1.0	-	-	1.0	-	3.0
	No. by-catch sets	6	37	-	-	2	-	1
	% by-catch sets	0.2	0.9	-	-	0.6	-	0.3
	% by-catch discarded	100.0	84.2	-	-	100.0	-	100.0
Philippines	By-catch/set	1.8	1.1	1.0	1.0	-	2.0	1.0
	No. by-catch sets	4	286	14	210	-	46	52
	% by-catch sets	5.6	19.1	0.6	14.5	-	7.8	13.0
	% by-catch discarded	100.0	21.9	0.0	37.2	-	0.0	0.1
Russia	By-catch/set	9.5	4.5	-	-	-	-	-
	No. by-catch sets	2	2	-	-	-	-	-
	% by-catch sets	0.4	9.1	-	-	-	-	-
	% by-catch discarded	0.0	0.0	-	-	-	-	-
Solomon Islands	By-catch/set	-	3.0	-	3.0	-	3.0	1.0
	No. by-catch sets	-	11	-	171	-	5	30
	% by-catch sets	-	50.0	-	16.3	-	4.0	5.5
	% by-catch discarded	-	0.0	-	0.0	-	0.0	0.0
Taiwan	By-catch/set	10.0	5.0	-	-	-	-	10.0
	No. by-catch sets	1	3	-	-	-	-	1
	% by-catch sets	0.2	+	-	-	-	-	0.1
	% by-catch discarded	0.0	0.0	-	-	-	-	0.0
USA	By-catch/set	0.2	0.5	-	-	-	-	0.2
	No. by-catch sets	55	252	-	-	-	-	3
	% by-catch sets	0.3	5.0	-	-	-	-	0.8
	% by-catch discarded	36.5	88.9	-	-	-	-	8.2
Totals	Median By-catch/set	0.5	1.0	1.0	1.2	1.0	2.0	1.0
	No. by-catch sets	71	682	16	382	2	184	91
	% by-catch sets	0.2	1.5	0.6	14.4	0.1	3.8	3.1
	% by-catch discarded	40.8	44.8	0.8	12.8	100.0	0.0	1.5
Descriptive statistics	Minimum	0.1	0.1	0.1	0.1	1.0	1.0	0.1
	Maximum	90.7	64.0	7.0	55.0	1.0	46.0	18.0
	Mean	3.8	3.3	1.9	2.9	1.0	3.2	2.4
	Standard deviation	11.8	6.5	1.8	4.7	0	5.1	3.0
	Median	0.5	1.0	1.0	1.2	1.0	2.0	1.0
	Mode	0.1	1.0	1.0	1.0	1.0	1.0	1.0
	Geometric mean	0.6	1.1	1.3	1.6	1.0	2.0	1.0

Table 4: By-catch species from purse seine sets on different school associations. (R – rare, <1/set; S – common in small numbers, 1–10/set; M – common in moderate numbers, 10–100/set; L – common in large numbers, >100/set; - not present)

Species	School	Log	Drifting FAD	Anchored FAD	Animal associations: Live whales	Dead whales	Whale shark
Sharks and rays							
Blue shark (*Prionace glauca*)	-	R	-	-	-	-	-
Oceanic whitetip (*Carcharhinus longimanus*)	S	S	S	S	S	S	-
Silky shark (*C. falciformis*)	S	M	M	M	M	M	-
Tiger shark (*Galeocerdo cuvier*)	-	R	-	-	-	-	-
Whale shark (*Rhincodon typus*)	-	R	-	-	R	-	S
Manta ray (*Mobula japanica, Manta* spp.)	S	S	-	-	S	-	-
Stingray (*Dasyatis* sp.)	-	R	-	-	-	-	-
Scombrids							
Frigate tuna (*Auxis thazard*)	S	S	S	S	-	-	-
Kawakawa (*Euthynnus affinis*)	S	S	S	S	-	-	-
Wahoo (*Acanthocybium solandri*)	S	M	M	M	-	-	-
Billfish							
Black marlin (*Makaira indica*)	R	R	R	R	-	-	-
Blue marlin (*M. mazara*)	S	S	S	S	-	-	-
Broadbill swordfish (*Xiphias gladius*)	-	R	-	-	-	-	-
Sailfish (*Istiophorus platypterus*)	R	R	-	R	-	-	-
Shortbill spearfish (*Tetrapturus angustirostris*)	-	-	-	R	-	-	-
Striped marlin (*T. audax*)	R	-	-	-	-	-	-
Carangids							
Amberjack (*Seriola rivoliana*)	-	L	L	L	-	-	-
Bar jack (*Carangoides ferdau*)	-	R	-	-	-	-	-
Bigeye trevally (*Caranx sexfasciatus*)	-	M	M	M	-	-	-
Bigeye scad (*Selar crumenophthalmus*)	-	-	-	L	-	-	-
Caranx spp. (*ignobilis, lugubris, melampygus*)	-	R	R	R	-	-	-
Golden trevally (*Gnathanodon speciosus*)	-	S	-	-	-	-	-
Greater amberjack (*Seriola dumerili*)	-	S	S	S	-	-	-
Mackerel scad (*Decapterus macarellus*)	-	L	L	L	-	-	-
Pilotfish (*Naucrates ductor*)	S	S	S	S	S	S	S
Rainbow runner (*Elagatis bipinnulata*)	S	L	L	L	-	L	-
Other fish							
Batfish (*Platax teira*)	-	S	S	S	-	-	-
Bramid (*Brama* sp.)	-	R	-	-	-	-	-
Drummer (*Kyphosus cinerascens*)	-	L	L	L	-	L	-
Filefish (*Aluterus monoceros*)	-	M	M	M	-	-	-
Filefish (*A. scriptus*)	-	S	-	-	-	-	-
Flutemouth (*Fistularia* sp.)	-	R	-	-	-	-	-
Great barracuda (*Sphyraena barracuda*)	-	S	S	S	-	-	-
Mahimahi (*Coryphaena hippurus*)	S	L	L	L	-	L	-
Man-o-war fish (*Psenes cyanophrys*)	-	M	M	M	-	-	-
Ocean anchovy (*Stolephorus punctifer*)	L	-	-	-	L	-	L
Ocean triggerfish (*Canthidermis maculatus*)	-	L	L	L	-	L	-
Porcupine fish (*Diodon hystrix*)	-	R	-	-	-	-	-
Porcupine fish (*Cyclichthys echinatus*)	-	R	-	-	-	-	-
Sargeant major (*Abudefduf saxatilis*)	-	M	M	M	-	-	-
Sea bream (*Rhabdosargus sarba*)	-	R	-	-	-	-	-
Seahorse (*Hippocampus* sp.)	-	R	-	-	-	-	-
Sharksucker (*Remora remora*)	S	S	S	S	S	S	S
Therapon perch (*Therapon* sp.)	-	R	-	-	-	-	-
Tripletail (*Lobotes surinamensis*)	-	S	S	S	-	S	-
Marine reptiles							
Green turtle (*Chelonia mydas*)	-	R	R	R	-	-	-
Hawksbill turtle (*Eretmochelys imbricata*)	-	R	R	R	-	-	-
Olive ridley turtle (*Lepidochelys olivacea*)	-	R	-	-	-	-	-
Sea snake (*Pelamis platurus*)	-	R	-	-	-	-	-

Sources: Bailey and Souter 1982; Farman 1987; Gillett 1986a,b; Itano 1991, pers. obs.; Itano and Buckley 1988; A.D. Lewis, pers. obs.; Preston 1982; SPC RTTP records; Wankowski and Witcombe, no date; K. Bailey, pers. obs.

Table 5: Purse seine catches of by-catch species (mt per set, number of sets) recorded in the RTFD, 1975-1990

Fleet	By-catch species	School		Log		Drifting FAD		Anchored FAD		Other		Unspec.	
Japan	Blue marlin	-	-	1.0	1	-	-	-	-	-	-	-	-
	Frigate tuna	-	-	6.5	2	-	-	-	-	-	-	-	-
	Mahimahi	15.0	1	-	-	-	-	-	-	-	-	-	-
	Ocean triggerfish	-	-	-	-	-	-	-	-	1.8	26	-	-
	Rainbow runner	-	-	3.0	3	-	-	-	-	1.2	22	-	-
	Tuna - mixed	-	-	-	-	-	-	-	-	4.8	56	-	-
New Zealand	Broadbill swordfish	-	-	-	-	1.0	1	-	-	-	-	-	-
	Mahimahi	-	-	-	-	-	-	-	-	-	-	1.0	3
	Mako shark	(2170)	(xx)	-	-	-	-	-	-	-	-	-	-
	Rainbow runner	-	-	-	-	3.0	2	-	-	-	-	1.8	15
Philippines	Albacore	-	-	-	-	-	-	-	-	-	-	1.0	1
	Blue marlin	-	-	7.5	2	-	-	2.0	1	-	-	-	-
	Kawakawa	-	-	-	-	1.7	10	-	-	2.8	40	-	-
	Mackerel	-	-	1.8	23	-	-	1.5	12	-	-	-	-
	Rainbow runner	-	-	5.7	54	1.0	1	1.6	41	1.0	1	1.0	1
	Tuna - mixed	-	-	1.6	29	-	-	0.8	20	27.0	1	3.0	1
	Tuna - unspec.	-	-	1.4	5	-	-	1.5	14	-	-	-	-
Russia	Mackerel	10.0	1	4.5	2	-	-	-	-	-	-	-	-
Solomon Is	Rainbow runner	-	-	-	-	-	-	1.7	3	1.0	1	1.2	20
	Tuna - mixed	-	-	-	-	-	-	-	-	5.0	2	-	-
USA	Billfish - unspec.	-	-	0.9	1	-	-	-	-	-	-	-	-
	Marlin - unspec.	0.1	1	-	-	-	-	-	-	-	-	-	-
	Ocean triggerfish	-	-	0.05	2	-	-	-	-	-	-	-	-
	Rainbow runner	-	-	1.4	37	-	-	-	-	-	-	-	-
	Shark - unspec.	0.06	5	0.2	2	-	-	-	-	-	-	-	-
Totals	Blue marlin	-	-	5.3	3	-	-	2.0	1	-	-	-	-
	Billfish - unspec.	-	-	0.9	1	-	-	-	-	-	-	-	-
	Broadbill swordfish	-	-	-	-	1.0	1	-	-	-	-	-	-
	Marlin - unspec.	0.1	1	-	-	-	-	-	-	-	-	-	-
	Albacore	-	-	-	-	-	-	-	-	-	-	1.0	1
	Frigate tuna	-	-	6.5	2	-	-	-	-	-	-	-	-
	Kawakawa	-	-	-	-	1.7	10	-	-	2.8	40	-	-
	Mackerel	10.0	1	2.0	25	-	-	1.5	12	-	-	-	-
	Tuna - mixed	-	-	1.6	29	-	-	0.8	20	5.2	59	3.0	1
	Tuna - unspec.	-	-	1.4	5	-	-	1.5	14	-	-	-	-
	Mahimahi	15.0	1	-	-	-	-	-	-	-	-	1.0	3
	Ocean triggerfish	-	-	0.05	2	-	-	-	-	1.8	26	-	-
	Rainbow runner	-	-	3.9	94	2.3	3	1.6	44	1.0	24	1.4	36
	Mako shark	(2170)	(xx)	-	-	-	-	-	-	-	-	-	-
	Shark - unspec.	0.06	5	0.2	2	-	-	-	-	-	-	-	-

Table 6: By-catch and discards (mt per set) of Philippine purse seiners operating in the WPO, 1982-1991

Philippine Company		School	Log	Drifting FAD	Anchored FAD	Animal	Other	Unspec
By-catch and discards								
Company 1	By-catch/set	0.0	14.0	1.6	1.0	0.0	2.8	1.0
	No. by-catch sets	0.0	1.0	12.0	1.0	0.0	45.0	4.0
	% by-catch sets	-	0.7	0.5	0.3	-	7.7	2.1
	% by-catch discarded	-	0.0	0.0	0.0	-	0.0	75.0
Company 2	By-catch/set	2.1	4.0	2.5	1.6	-	3.9	0.6
	No. by-catch sets	4.0	293.0	2.0	224.0	-	7.0	225.0
	% by-catch sets	7.5	21.7	1.5	20.8	-	14.3	20.9
	% by-catch discarded	100.0	22.3	0.0	37.8	-	0.0	0.0
Tuna discards								
Company 1	Tuna discards/set	-	-	-	-	-	-	-
Company 2	Tuna discards/set	10.6	1.5	-	2.3	-	-	-
	No. of tuna discard sets	-	187.0	-	126.0	-	-	-
	% tuna discard sets	-	19.7	-	15.9	-	-	8.1

Table 7: By-catch of US and New Zealand purse seiners operating in the New Zealand EEZ, 1976-1982, based on observer data supplied by the N.Z. Ministry of Agriculture and Fisheries. (Total number of observed sets = 904, number with by-catch = 433 (47.9%))

Species	Occurrence (No. of sets)	% occurrence	Average number per occurrence
Cephalopods			
Arrow squid (*Nototodarus sloanii*)	22	2.4	3.5
Octopus (*Octopus* sp.)	17	1.9	1.4
Paper nautilus (*Argonauta argo*)	7	0.8	1.2
Sharks and Rays			
Blue shark (*Prionace glauca*)	18	2.0	1.2
Bronzewhaler shark (*Carcharhinus brachyurus*)	4	0.4	1.8
Hammerhead shark (*Sphyrna zygaena*)	2	0.2	1.0
Mako shark (*Isurus oxyrinchus*)	17	1.9	1.1
Spiny dogfish (*Squalis acanthias*)	1	0.1	1.0
Thresher shark (*Alopias vulpinus*)	7	0.8	1.0
Unidentified sharks	7	0.8	1.7
Eagle ray (*Myliobatis tenuicaudatus*)	3	0.3	1.3
Electric ray (*Torpedo fairchildi*)	12	1.3	2.4
Long-tailed stingray (*Dasyatis thetidis*)	20	2.2	1.7
Manta ray (*Mobula japonica*)	74	8.2	2.2
Short-tailed stingray (*D. brevicaudatus*)	5	0.6	1.4
Unidentified stingray (*Dasyatis* spp.)	10	1.1	2.0
Scombrids			
Albacore (*Thunnus alalunga*)	66	7.3	8.9
Blue mackerel (*Scomber australasicus*)	18	2.0	28.8
Frigate tuna (*Auxis thazard*)	26	2.9	6.1
Slender tuna (*Allothunnus fallai*)	2	0.2	1.5
Yellowfin tuna (*T. albacares*)	12	1.3	1.8
Billfish			
Black marlin (*Makaira indica*)	10	1.1	1.5
Blue marlin (*M. mazara*)	11	1.2	1.1
Broadbill swordfish (*Xiphias gladius*)	3	0.3	1.0
Striped marlin (*Tetrapturus audax*)	16	1.8	1.1
Unidentified marlin	3	0.3	1.0
Other fish			
Blue maomao (*Scorpis violaceus*)	1	0.1	50.0
Blue warehou (*Seriolella brama*)	1	0.1	1.0
Dealfish (*Trachipterus trachypterus*)	3	0.3	1.0
Flying fish (*Cheilopogon melanocercus*)	35	3.9	1.4
Frostfish (*Lepidopus caudatus*)	8	0.9	6.5
Hapuku (*Polyprion oxygeneios*)	1	0.1	1.0
Jack mackerel (*Trachurus* spp.)	13	1.4	11.5
John dory (*Zeus faber*)	4	0.4	2.3
Lamprey (*Geotria australis*)	1	0.1	1.0
Monkfish (*Kathetostoma giganteum*)	1	0.1	1.0
Pilchard (*Sardinops neopilchardus*)	2	0.2	22.5
Pilotfish (*Naucrates ductor*)	20	2.2	2.9
Porcupine fish (*Allomycterus jaculiferus*)	52	5.8	125.9
Pufferfish (*Lagocephalus cheesemanii*)	1	0.1	1.0
Rays bream (*Brama brama*)	13	1.4	1.6
Red cod (*Pseudophycis bachus*)	1	0.1	1.0
Remora (*Remora remora, R. brachyptera*)	22	2.4	2.3
Rudderfish (*Centrolophus niger*)	3	0.3	1.0
Saury (*Scomberesox saurus*)	12	1.3	9.6
Silver dory (*Cyttus novaezelandiae*)	3	0.3	1.3
Starry toado (*Arothron firmamentum*)	35	3.9	16.8
Sunfish (*Mola mola*)	140	15.5	1.3
Tarakihi (*Nemadactylus macropterus*)	1	0.1	1.0
Witch (*Arnoglossus scapha*)	2	0.2	1.0
Yellowtail kingfish (*Seriola lalandi*)	1	0.1	1.0
Marine mammals			
common dolphin (*Delphinus delphis*)			

Table 8: Estimated and reported by-catch (mt) in the WTP purse seine fishery, 1991[1].

Fleet	Reporting of sets (%)	School association	No. of sets (on RTFD)	No. of sets (raised)	Estimated by-catch (mt)	Reported by-catch (mt)
Australia	100% (assumed)	School	46	46	27.6	0
		Log	176	176	193.6	0
		Drifting FAD	2	2	2.6	0
		Animal	3	3	3.0	0
		Unspecified	67	67	67.0	0
		Subtotals	294	294	293.8	0
Japan	70%	School	1811	2587	1552.2	0
		Log	1334	1906	2096.6	23.0
		Drifting FAD	30	43	55.9	0
		Animal	89	127	127.0	0
		Other	217	310	620.0	0
		Unspecified	36	51	51.0	0
		Subtotals	3517	5024	4502.7	23.0
Korea	25%	School	684	2736	1641.6	0
		Log	524	2096	2305.6	0
		Drifting FAD	29	116	150.8	0
		Anchored FAD	3	12	19.2	0
		Animal	19	76	76.0	0
		Other	36	144	288.0	0
		Unspecified	22	88	88.0	0
		Subtotals	1317	5268	4569.2	0
Philippines	100% (assumed)	School	40	40	24.0	8.2
		Log	406	406	446.6	122.4
		Drifting FAD	693	693	900.9	0
		Anchored FAD	285	285	456.0	93.5
		Animal	1	1	1.0	0
		Other	7	7	14.0	0
		Unspecified	124	124	124.0	30.1
		Subtotals	1556	1556	1966.5	254.2
Solomon Islands	100%	Anchored FAD	131	131	209.6	24.0
		Unspecified	124	124	124.0	0
		Subtotals	255	255	333.6	24.0
Taiwan	95%	School	80	84	50.4	0
		Log	1994	2099	2308.9	0
		Drifting FAD	4	4	5.2	0
		Anchored FAD	6	6	9.6	0
		Animal	12	13	13.0	0
		Other	49	52	104.0	0
		Unspecified	197	207	207.0	0
		Subtotals	2342	2465	2698.1	0
USA	100%	School	8267	8267	4960.2	110.7
		Log	692	692	761.2	13.8
		Animal	1	1	1.0	0
		Other	53	53	106.0	0
		Unspecified	47	47	47.0	0
		Subtotals	9060	9060	5875.4	124.5
Totals		School	10928	13760	8256.0	118.9
		Log	5126	7375	8112.5	159.2
		Drifting FAD	758	858	1115.4	0
		Anchored FAD	425	434	694.4	117.5
		Animal	125	221	221.0	0
		Other	362	566	1132.0	0
		Unspecified	617	708	708.0	30.1
Grand totals		All types	18341	23922	20239.3	425.7

[1] Estimates derived from number of sets raised to reflect reporting levels multiplied by values for geometric means of total bycatch by school association from Table 3.

Table 9: Observer and RTFD records of billfish catches of purse seiners operating in the WTP, 1982-1991. (Sch. = school sets)

Vessel flag and type	Period and area		No. of sets observed	No. of sets with billfish	Billfish species and No.s caught	Source
Observer records						
US single	Jan.–Apr. 1982 North PNG	Sch.	26	2	2 marlin	K. Bailey, pers. obs.
		Log	27	0	-	
US single	Jul.–Aug. 1982 FSM–Kiribati	Sch.	20	6	3 blue marlin, 3 marlin, 1 sailfish	Bailey & Souter, 1982
		Log	7	0	-	
Japan single	Jun.–Jul. 1982 FSM	Sch.	1	1	1 blue marlin	Gillett, 1986b
		Log	22	15	15 blue marlin, 1 black marlin	
Japan group	Feb. 1983 North-west PNG	Sch.	2	0	-	Gillett, 1986b
		Log	3	2	4 blue marlin	
Japan group	Apr. 1984 FSM	Sch.	7	0	-	Farman, 1987
		Log	7	7	8 billfish	
US single	Nov.–Dec. 1984 North-west PNG	Sch.	7	0	-	Gillett, 1986a
		Log	7	7	10 blue marlin	
US single	Jul.–Oct. 1988 North PNG, FSM	Log	7	1	2 black marlin	FFA observer programme
US single	Aug.–Oct. 1988 FSM	Sch.	13	2	2 marlin	FFA observer programme
		Log	9	5	9 blue marlin	
US single	Jan.–Mar. 1989 North PNG	Sch.	41	3	1 blue marlin, 2 marlin	FFA observer programme
		Log	9	5	4 blue marlin, 5 marlin, 1 sailfish	
Japan group	Apr. 1990 FSM	Sch.	10	0	-	Itano, 1991
		Log	5	1	2 blue marlin	
US single	Jul.–Aug. 1991 East of Kiribati	Sch.	32	1	2 marlin	FFA observer programme
Observer totals	1982–1991	Sch.	159	15	17 billfish (11 marlin, 5 blue marlin, 1 sailfish)	
		Log	103	43	61 billfish (8 billfish, 5 marlin, 44 blue marlin, 3 black marlin, 1 sailfish)	
RTFD records US single	Jun.–Dec. 1991 WTP, mostly east of 170°E	Sch.	5415	42	51 billfish (18 billfish, 26 black marlin, 6 blue marlin, 1 striped marlin)	
		Log	306	7	7 billfish (2 billfish, 4 black marlin, 1 striped marlin)	

Table 10: Median discards of tuna per set (mt) by school association for purse seine fleets operating in the WTP, 1979-1991. Figures are median tonnes per set for sets on the SPC Regional Tuna Fisheries Database that contain records of tuna discards, number of sets with tuna discards, and the percentage of tuna discard sets against all sets for each association type. (+ = < 0.1%)

Fleet		School	Log	Drifting FAD	Anchored FAD	Animal	Other	Unspec
Indonesia	Tuna discards/set	10.0	10.0	-	-	-	-	-
	No. of tuna discard sets	1	3	-	-	-	-	-
	% tuna discard sets	2.7	0.9	-	-	-	-	-
Japan	Tuna discards/set	2.0	3.0	-	-	-	-	1.0
	No. of tuna discard sets	1	11	-	-	-	-	15
	% tuna discard sets	+	+	-	-	-	-	3.2
Korea	Tuna discards/set	2.5	2.0	-	-	4.5	-	1.5
	No. of tuna discard sets	12	101	-	-	2	-	6
	% tuna discard sets	0.4	2.5	-	-	0.6	-	1.8
Philippines	Tuna discards/set	20.1	1.0	-	0.9	-	-	2.0
	No. of tuna discard sets	1	251	-	186	-	-	24
	% tuna discard sets	1.4	16.7	-	7.6	-	-	6.0
Solomon Islands	Tuna discards/set	-	-	-	3.0	-	-	3.0
	No. of tuna discard sets	-	-	-	340	-	-	87
	% tuna discard sets	-	-	-	32.4	-	-	15.9
USA	Tuna discards/set	1.8	2.0	1.4	-	-	1.8	28.4
	No. of tuna discard sets	95	206	2	-	-	3	2
	% tuna discard sets	0.4	4.1	7.4	-	-	1.4	0.5
Totals	Tuna discards/set	1.8	1.8	1.4	2.0	4.5	1.8	2.0
	No. of tuna discard sets	110	572	2	526	2	3	134
	% tuna discard sets	0.3	1.5	7.4	20.0	0.6	1.4	6.0

Table 11: Observer and literature records of tuna discards by purse seiners operating in the WTP, 1977-1991. (See Table 9 for sources)

Vessel flag and type	Period	No. of sets observed	Sets w. tuna discards	Mt of tuna discards	Discard reason
US single	Aug. 1977-Apr. 1978	Sch. 55	2	350.0	Sack ripped
		Log 59	1	4.0	Tuna too small (1.5 lb)
US single	Jan.-Apr. 1982	Sch. 26	1	0.25	Tuna damaged
		Log 27	0	-	-
	Jul.-Aug. 1982	Sch. 20	0	-	-
		Log 7	0	-	-
Japan single	Jun.-Jul. 1982	Sch. 1	0	-	-
		Log 22	?	80.2	0.2 mt too small or damaged, 80 mt 1 log set gear failure.
Japan group	Feb. 1983	Sch. 2	?	)1.5	Tuna too small or damaged.
		Log 3	?	)	
Japan group	Apr. 1984	Sch. 7	?	)0.5	Tuna too small.
		Log 7	?	)	
US single	Nov.-Dec. 1984	Sch. 7	0	-	-
		Log 7	7	37.0	Tuna too small.
US single	Jan.-Mar. 1989	Sch. 41	0	-	-
		Log 9	3	8.2	Tuna too small (< 4 lb)
Japan group	Apr. 1990	Sch. 10	?	)3.0	Tuna gilled and crushed by power block
		Log 5	?	)	
US single	Oct. 1990-Jan. 1991	Sch. 25	6	0.2	Tuna damaged, 0.02 mt too small, 0.04 mt no reason.
		Log 19	18	12.9	10.0 too small, 0.1 damaged, 1.4 undesirable, 1.4 no reason.
US single	Dec. 1990-Mar. 1991	Sch. 57	1	0.1	Tuna too small
		Log 7	0	-	-
US single	Apr.-May 1991	Sch. 4	0	-	-
		Log 11	6	10.5	Tuna too small, 1.9 mt no reason.
US single	Apr.-May 1991	Sch. 30	1	0.9	Tuna smashed.
		Log 8	2	10.9	Tuna too small (< 3 lb).
US single	May 1991	Sch. 24	1	272.4	Sack ripped
US single	Jun.-Jul. 1991	Sch. 21	2	0.1	Tuna too small or damaged
		Log 9	6	5.9	Tuna too small
US single	Jun.-Jul. 1991	Sch. 48	3	33.1	Vessel loaded, 1.3 damaged.
US single	Jun.-Jul. 1991	Sch. 67	6	4.3	Vessel loaded, 1.6 damaged.
Totals	1977-1991	Sch. 426	23	661.4	622.4 mt sack ripped, 34.5 vessel loaded, 4.2 damaged, 0.1 too small, 0.1 damaged or too small, 0.1 too small or no reason.
		Log 185	43 + ?	169.6	80.6 mt too small, 4.1 damaged, 0.2 too small or damaged, 80.0 gear failure, 1.4 undesirable, 3.3 no reason
		Log & Sch. 34	?	5.0	3.0 mt damaged, 1.5 too small or damaged, 0.5 too small.

Table 12: Reasons for discarding tuna in the WTP purse seine fishery

Discard	Reason	Comments	Occurrence
Accidental	Gear failure	Sack rips during sacking-up or brailing, part of or entire catch is lost.	Rare, occurs with large catches (>100 mt) if sack worn or sacking-up technique poor.
	Storage problem	Refrigeration problem, eg. ammonia coil rupture in fish well, catch contaminated.	Rare
		Poor quality product delivered to cannery because of inadequate freezing, high salt or histamine levels and 'honeycombing' in meat. Can result in rejection of well of fish or entire catch of vessel.	Unknown, but probably very rare. Unlikely to be recorded on log sheets. One occasion where 850 mt load of old US seiner rejected in 1982 because of high salt content.
Deliberate	Tuna too small	Tuna < 3-4 lb (1.4-1.8 kg), too small for most canneries	Common with log & FAD sets, less common with school sets as able to target on larger fish. Some discarding at canneries.
	Tuna soft or smashed	Tuna at bottom of sack and last to be brailed aboard are softened by weight of catch above and high sea temperature (commonly > 28°C). Also, tuna gilled in net and crushed as net is pulled through power block and haulers.	Common in large sets (> 100 mt) where sacking-up and brailing may take over 3–4 hours to complete. Gillers common in sets made on dusk and when breakdowns delay net retrieval. Also some discarding at canneries after being crushed in fish wells.
	Vessel loaded	Last set of trip exceeds carrying capacity, well coamings and food freezers also filled. Excess is transhipped to other seiners, if any are nearby.	Common
	Undesirable species	Tuna species of little or no economic value, such as frigate tuna and kawakawa.	Uncommon, mostly in log and FAD sets.

Table 13: Discards of tuna (mt) and numbers of tuna discard sets in the WTP purse seine fishery by school association and reason for discarding, 1979-1991

Fleet	Discard reason	School		Log		Drifting FAD		Anchored FAD		Animal		Other		Unspec.	
		mt	No.	mt	No.	mt	No.	mt	No.	mt	No.	mt	No.	mt	No.
Indonesia	Vessel loaded	10.0	1	35.0	3	-	-	-	-	-	-	-	-	-	-
Japan	Undesirable spp.	-	-	2.0	1	-	-	-	-	-	-	-	-	-	-
	Tuna too small	-	-	-	-	-	-	-	-	-	-	-	-	29.0	14
	Vessel loaded	2.0	1	25.0	3	-	-	-	-	-	-	-	-	10.0	1
	Other	-	-	15.0	4	-	-	-	-	-	-	-	-	-	-
	Unknown	-	-	5.0	3	-	-	-	-	-	-	-	-	-	-
Korea	Undesirable spp.	-	-	3.0	2	-	-	-	-	-	-	-	-	-	-
	Tuna too small	62.0	12	361.0	99	-	-	-	-	9.0	2	-	-	12.0	6
Philippines	Undesirable spp.	-	-	34.1	23	-	-	47.7	32	-	-	-	-	-	-
	Tuna too small	-	-	28.2	14	-	-	312.3	38	-	-	-	-	178.0	22
	Vessel loaded	-	-	3.9	2	-	-	-	-	-	-	-	-	-	-
	Other	-	-	292.8	124	-	-	92.5	39	-	-	-	-	-	-
	Unknown	20.1	1	49.6	88	-	-	50.6	77	-	-	-	-	0.3	2
Solomon Is	Tuna too small	-		-	-	-	-	1525.0	340	-	-	-	-	334.0	87
USA	Undesirable spp.	0.9	1	78.3	22	-	-	-	-	-	-	-	-	-	-
	Tuna too small	237.3	40	838.9	157	2.7	2	-	-	-	-	4.8	3	2.7	1
	Vessel loaded	202.5	11	104.8	9	-	-	-	-	-	-	-	-	-	-
	Tuna smashed	98.4	33	10.0	5	-	-	-	-	-	-	-	-	-	-
	Sack ripped	227.0	1	9.1	1	-	-	-	-	-	-	-	-	-	-
	Storage prob.	-	-	-	-	-	-	-	-	-	-	-	-	54.0	1
	Other	136.7	8	18.9	8	-	-	-	-	-	-	-	-	-	-
	Unknown	19.0		10.8	4	-	-	-	-	-	-	-	-	-	-
Totals	Undesirable spp.	0.9	1	117.4	48	-	-	47.7	32	-	-	-	-	-	-
	Tuna too small	299.3	52	1228.1	270	2.7	2	1837.3	378	9.0	2	4.8	3	555.7	130
	Vessel loaded	214.5	13	168.7	17	-	-	-	-	-	-	-	-	10.0	1
	Tuna smashed	98.4	33	10.0	5	-	-	-	-	-	-	-	-	-	-
	Sack ripped	227.0	1	9.1	1	-	-	-	-	-	-	-	-	-	-
	Storage prob.	-	-	-	-	-	-	-	-	-	-	-	-	54.0	1
	Other	136.7	8	326.7	136	-	-	92.5	39	-	-	-	-	-	-
	Unknown	20.6	2	65.4	95	-	-	50.6	77	-	-	-	-	0.3	2
Grand total	All reasons	997.4	110	1925.4	572	2.7	2	2028.1	526	9.0	2	4.8	3	620.0	134

Table 14: Species composition of tuna discards by school association, 1979-1991. (Undesirable species discards have been excluded.)

Association	Tuna discards (mt)	Skipjack (%)	Yellowfin (%)	Mixed (%)
School	997.1	32.0	2.0	66.0
Log	1915.3	2.8	<0.1	97.2
Drifting FAD	9.7	0.0	0.0	100.0
Anchored FAD	2029.6	0.0	0.3	99.7
Animal	9.0	0.0	0.0	100.0
Other	4.8	0.0	0.0	100.0
Unspecified	620.0	0.0	0.0	100.0
Totals	5585.6	6.7	0.6	92.7

Table 15: By-catch and discards of longline fleets operating in the WPO, based on logbook data held in the SPC Regional Tuna Fisheries Database, 1978-1991.

Fleet	Area	Period	Total catch (number)	%Target catch	% By-catch	% Tuna discards	%other discards
Australia	WSP	1986-1991	69,785	85.18	14.82	{ 0.08}	{ 0.05}
	WTeP	1985-1991	65,240	89.48	10.52	{ 0.05}	{ 0.05}
FSM	WTP	1991-1991	293	79.18	20.82	5.46	0.03
Fiji	WSP (Fiji)	1989-1991	1,570	77.07	22.93	0.00	0.00
Japan	WTP	1978-1991	11,790,100	94.12	5.88	{ 0.02}	{ 0.01}
	WSP	1978-1991	3,920,044	84.32	15.68	{ 0.09}	{ 0.02}
	WTeP	1979-1991	1,957,379	51.21	48.79	0.00	0.00
Korea	WTP	1978-1991	1,122,738	92.73	7.27	{ 0.48}	{ 0.13}
	WSP (and WTeP)	1980-1991	630,469	92.80	7.20	{ 2.97}	{ 1.23}
New Caledonia	WSP (N.C.)	1983-1991	224,099	85.22	14.78	{ 0.23}	{ 6.76}
New Zealand	WSP	1990-1991	1184	69.85	30.15	0.00	0.00
	WTeP	1980,89-91	35,384	21.66	78.34	0.00	0.00
China	WTP	1989-1991	34,720	78.87	21.13	0.11	3.30
Solomon Is	WTP (and WSP)	1981-1985	58,406	88.83	11.17	0.00	0.00
Taiwan	WTP	1980-1991	229,560	69.28	30.72	0.01	0.01
						{ 0.13}	{ 0.15}
	WSP (and WTeP)	1980-1991	672,102	97.00	3.00	0.03	0.17
						{ 0.06}	{ 0.42}
Tonga	WSP	1982-1991	123,054	74.62	25.38	1.19	8.29
						{ 0.69}	{ 0.02}
Totals	WTP	1978-1991	13,235,817	93.51	6.49	0.00	0.02
						{ 0.05}	{ 0.02}
	WSP	1978-1991	5,642,307	86.95	13.05	0.07	0.35
						{ 0.20}	{ 0.30}
	WTeP	1978-1991	2,058,003	49.09	50.91	{ 0.03}	{ 0.05}
Grand total	All areas	1978-1991	20,936,127	87.38	12.62	0.01	0.08
						{ 0.08}	{ 0.09}

NOTES

1. % Target catch includes tuna catches retained and discarded; % By-catch includes by-catch retained and discarded; the sum of target and by-catch equals 100%.
2. All calculations are based on numbers, except where weight of discards were available only. Where this occurs, the % discards represent the proportion of discard (in kilograms) to the total weight of catch in kilograms and have been bounded in brackets {}.
3. % tuna and other discards are for logsheet forms where there has been provision to record this information only.

Table 16: Coverage of by-catch species in the RTFD.

(This table describes the extent to which the data source logbooks contain provision for recording information on the species listed)

	WTP trips	WTP %	non-WTP[2] trips	non-WTP %
Total	17,166	100.00	8,312	100.00
Striped Marlin	15,157	88.30	8,258	99.35
Black Marlin	14,981	87.27	8,179	98.40
Blue Marlin	15,858	92.38	8,258	99.35
Swordfish	15,157	88.30	8,258	99.35
Sailfish	15,157	88.30	8,258	99.35
Shark	15,858	92.38	8,283	99.65
Skipjack	3,930	22.89	7,764	93.41
Provision for 'other' species identification	1,825	10.63	5,316	63.96
Billfish grouped (i.e. not specified)	873	5.09	133	1.60
Species columns on logsheet not covered by RTFD[3]	0	.00	93	1.12
Provision for Numbers of fish, only, on logsheet	3,345	19.49	40	0.48

NOTES

1. Details by species refers to the provision of the source data to contain a specific column for this field. For example, only 22.89% of longline trips had logsheets that contained a column for SKIPJACK catch.

2. 'non-WTP' refers to all other areas reported in the RTFD other than the WTP.

3. Species mentioned on some logsheet forms not covered by the RTFD are short-billed spearfish and wahoo; the data for these have been stored in 'other' species catch in the RTFD.

4. This table includes data sent to SPC in electronic form.

Table 17: **Coverage of Tuna and other species discards by the Regional Tuna Fisheries Database, 1978-1991.**

	Units	WTP	WSP	WTeP
Fishing Days with provision for recording discards	days	225,913	79,004	16,868
Trips with provision for recording discards	trips	11,587	4,973	2,413
Days with tuna discards recorded	days	443	1070	221
	%	0.19	1.35	1.25
Trips with tuna discard recorded	trips	74	214	133
	%	0.64	4.30	5.51
Days with other species discard recorded	days	640	2,648	275
	%	0.28	3.35	1.63
Trips with other species discard recorded	trips	97	248	1570
	%	0.57	5.00	65.06
Average tuna discard, where recorded	no./day	2.41	6.33	-
	(sd)[2]	(1.14)	(8.41)	-
	kgs/day	140.07	75.78	3.43
	(sd)	(444.28)	(329.3)	(3.61)
Average other species discard, where recorded	no./day	50.52	12.64	-
	(sd)	(60.47)	(19.36)	-
	kgs/day	70.09	65.68	2.95
	(sd)	(91.97)	(272.00)	(40.00)
Tuna discard as % of total catch, where recorded	%no.	3.5	6.84	-
	(sd)	(1.18)	(8.36)	-
	%kgs	9.43	3.94	1.05
	(sd)	(15.58)	(7.80)	(1.06)
Other discard as % of total catch, where recorded	%no.	54.05	13.13	-
	(sd)	(31.19)	(14.96)	-
	%kgs	9.28	5.11	1.45
	(sd)	(11.80)	(9.04)	(2.53)

NOTES

1. Some logsheet forms require discards to be recorded in numbers, others in kilograms; both have been calculated where relevant.

2. 'sd' - Standard deviation.

Table 18. Summary of longline observer data available to SPC.

Area	Year	Vessel Nation	Hooks	Total Catch (numbers)	Target %	By-catch %	Target Discards %	Target Damaged %	By-catch Discards %	Source
WTP	1980	Japan	49690	2240	76	24	32	10	22	PNG Observer report (Wright, 1980)
	1980	Japan	78000	2373+	84+	16-	N/A	N/A	11+	MMA Observer report (FSM)
	1985	Japan	60000	1125+	60-	40+	13	N/A	26+	MMA Observer report (FSM)
	1985	Japan	16770	379	76	24	4	4	20	Kiribati Fisheries report
	1985	Japan	58000	1142	73	27	6	N/A	23	MMA Observer report (FSM)
	1985	Japan	49500	823	78	22	34	27	18	MMA Observer report (FSM)
	1986	Japan	54000	1766	79	21	24	9	11+	MMA Observer report (FSM)
	1986	Japan	72500	1694	74	26	13	N/A	21	MMA Observer report (FSM)
	1986	Japan	56000	1960	88	12	14	7	3+	Kiribati Fisheries report
	1987	Japan	21600	341	73	17	9	4	5	MMA Observer report[1]
	1987	Japan	42000	1071	59	41	20	N/A	5	MMA Observer report[1]
	1987	Japan	70200	1213	96	4	4	N/A	3	MMA Observer report
	1988	Japan	70200	425	78	22	22	N/A	17	MMA Observer report
	1988	Japan	29900	802	89	11	8	N/A	9	MMA Observer report
	1988	Japan	40800	1048+	89-	11+	11	10	4	MMA Observer report
	1989	Japan	47500	1229+	96-	4+	17	11	4+	MMA Observer report
	1989	Japan	55200	1298	77	23	5	N/A	20	MMA Observer report
	1992	Taiwan	9600	218	44	56	6	N/A	48	MMA Observer report
	1992	Korea	22500	343	43	57	6	N/A	46	MMA Observer report
	1992	FSM	5400	72	10	90	4	N/A	75	MMA Observer report
	1992	Taiwan	7200	236	11	89	1	N/A	28	MMA Observer report
	1992	Taiwan	5600	314	16	84	4	N/A	45	MMA Observer report
	1992	Taiwan	4000	202	65	35	1	N/A	4	MMA Observer report[1]
	1992	Korea	18200	372	29	71	3	N/A	38	MMA Observer report
		Average			65.13	34.87	11.35	10.25	21.08	
		sd			25.59	25.59	9.27	6.81	17.81	
WSP	1986	Tonga	37488	1025	64	36	5+	+	+	SPC Observer report (Farman, 1986)
	1991	Japan	?	13239	65	35	2	N/A	20	Aust, observer data (pers. comm. Ward)[4]
	1992	New Caledonia	5758	136	58	42	1	1	9	SPC Observer report (Palu, 1992)
	1993	French Polynesia	4200	80	41	59	0	0	37	SPC Observer report (Labelle, 1993)
WTeP	1985	Japan	?	813	77	23	N/A	-	16	Australian observer report
	1985	Japan	?	98	83	17	N/A	-	11	Australian observer report
	1987	Japan	74784	1304	54	46	N/A	-	22	MAF report (Michael et al., 1987)[4]
	1988	Japan	116880	4128	28	72	N/A	N/A	55	MAF report (Michael et al., 1988?)[4]
	1989	Japan	39120	976	4	96	N/A	N/A	N/A	MAF observer programme (Burgess, pers. comm.)
	1989	Japan	57510	1786	2	98	N/A	N/A	N/A	MAF observer programme (Burgess, pers. comm.)
	1989	Japan	35634	968	5	95	N/A	N/A	N/A	MAF observer programme (Burgess, pers. comm.)
	1989	Japan	56280	646	10	90	N/A	N/A	N/A	MAF observer programme (Burgess, pers. comm.)
	1989	Japan	58008	893	10	90	N/A	N/A	N/A	MAF observer programme (Burgess, pers. comm.)
	1990	Japan	47892	578	31	69	N/A	N/A	N/A	MAF observer programme (Burgess, pers. comm.)
	1990	Japan	26350	557	6	94	N/A	N/A	N/A	MAF observer programme (Burgess, pers. comm.)
	1990	Japan	42240	683	11	89	N/A	N/A	N/A	MAF observer programme (Burgess, pers. comm.)
	1990	Japan	57330	1725	11	89	N/A	N/A	N/A	MAF observer programme (Burgess, pers. comm.)
	1990	Japan	168680	5627	7	93	N/A	N/A	N/A	MAF observer programme (Burgess, pers. comm.)
	1990	Japan	104962	2306	2	98	N/A	N/A	N/A	MAF observer programme (Burgess, pers. comm.)

1. Data from these observer trips have been raised from 4 x 100 hook samples.
2. All percentages are calculated from the total catch in numbers. 'Tuna damaged' represents tuna damaged by sharks or killer whale and is included in 'Tuna discards'.
3. '+' and '-' indicates where accurate quantities were not available.
4. Data are from more than one observer trip. Data from Australia includes some activity in WTeP. Data from New Zealand includes some activity in WSP.

Table 19: Species composition of by-catch taken by longline fleets in the WPO, based on logbook data held in the SPC Regional Tuna Fisheries Database, 1978-1991.

Fleet	Area		Striped Marlin	Blue Marlin	Black Marlin	Swordfish	Sailfish	Shark	Skipjack	Other
Australia	WSP	%	3.08	1.03	0.65	0.86	0.53	6.15	2.53	0.00
		no	2,132	716	453	594	367	4,263	1,755	0
	WTeP	%	0.42	0.03	0.03	1.95	0.02	6.71	1.40	0.00
		no	273	18	18	1274	12	4,375	913	0
FSM	WTP	%	0.34	9.56	0.00	0.34	1.37	5.46	0.00	3.75
		no	1	28	0	1	4	16	0	11
Fiji	WSP (Fiji)	%	1.46	1.27	2.04	1.53	2.87	2.29	0.00	11.46
		no	23	20	32	24	45	36	0	180
Japan	WTP	%	0.12	2.81	0.17	0.46	0.20	0.57	0.02	1.54
		no	13,617	330,789	20,533	54,419	23,845	67,053	1,846	181,731
	WSP	%	2.58	1.27	0.61	3.64	0.71	5.03	0.24	1.60
		no	100,284	49,576	26,553	141,736	27,809	195,683	9,431	62,177
	WTeP	%	0.41	0.01	0.00	3.03	0.01	35.00	0.00	10.33
		no	7,980	284	163	59,266	100	684,992	79	202,084
Korea	WTP	%	0.50	2.05	0.45	0.91	0.07	0.59	0.15	2.55
		no	5,593	23,027	5,013	10,262	772	6,631	1,629	28,654
	WSP/WTeP	%	0.49	0.86	0.26	0.34	0.07	2.92	0.11	2.16
		no	3,097	5,398	1,651	2,155	424	18,379	701	13,612
New Caledonia	WSP (N.C.)	%	3.41	0.53	1.84	0.51	0.80	1.68	0.00	6.01
		no	7,633	1,177	4,127	1,149	1,801	3,772	0	13,472
New Zealand	WSP	%	0.08	0	0	2.20	0	18.58	0	9.29
		no	1	0	0	26	0	220	0	110
	WTeP	%	0.03	0	0	1.39	0	58.44	0	18.47
		no	12	0	0	493	0	20,679	0	6,537
China	WTP	%	0.00	0.00	0.00	4.33	6.23	3.94	0.00	3.84
		no	0	0	1	1,453	2,088	1,320	0	1,287
Solomon Is	WTP/WSP	%	0.13	2.62	1.55	0.22	6.12	0.00	0.00	0.54
		no	74	1,529	906	126	3,576	0	0	315
Taiwan	WTP	%	0.48	1.09	7.68	2.86	0.88	16.28	0.19	1.24
		no	1,110	2,506	17,617	6,563	2,018	37,377	444	2,849
	WSP/WTeP	%	0.30	0.40	0.14	0.18	0.10	0.41	0.64	0.63
		no	2,035	2,708	912	1,198	692	2,741	4,280	4,192
Tonga	WSP	%	0.25	0.23	1.80	0.37	0.36	1.64	1.50	10.79
		no	278	252	1,994	409	393	1,808	1,655	11,929
Totals	WTP	%	0.15	2.70	0.33	0.55	0.24	0.85	0.03	1.62
		no	20,395	357,879	44,070	72,824	32,303	112,397	3,919	214,847
	WSP	%	2.06	1.07	0.65	2.63	0.56	4.05	0.32	1.89
		no	115,483	59,847	36,580	147,291	31,531	226,902	17,822	105,672
	WTeP	%	0.40	0.01	0.00	2.97	0.01	34.50	0.05	10.14
		no	8,265	302	181	61,033	112	710,046	992	208,621

NOTES

1. Percentages are the proportion of numbers to the total catch (described in table L1).

Table 20: Average weight and CPUE range data for by-catch species from longline vessels, based on data held in the RTFD from 1978-1991.

	Units	WTP	WSP	WTeP
Striped Marlin				
Average weight (weighted)	kgs	38.7	74	76.8
Maximum CPUE - daily	CPUE[1]	1.04	6.30	1.95
Maximum CPUE - month/5° square	CPUE	0.22	1.73	0.36
Black Marlin				
Average weight (weighted)	kgs	50.7	66.7	86.6
Maximum CPUE - daily	CPUE	2.83	3.33	0.23
Maximum CPUE - month/5° square	CPUE	1.55	1.18	0.02
Blue Marlin				
Average weight (weighted)	kgs	50.8	71.5	126.6
Maximum CPUE - daily	CPUE	3.00	1.78	0.80
Maximum CPUE - month/5° square	CPUE	1.26	0.64	0.21
Swordfish				
Average weight (weighted)	kgs	42.5	64.5	60.1
Maximum CPUE - daily	CPUE	5.63	7.41	4.17
Maximum CPUE - month/5° square	CPUE	0.67	0.92	1.30
Sailfish				
Average weight (weighted)	kgs	25.6	21.9	15.6
Maximum CPUE - daily	CPUE	4.10	1.29	0.67
Maximum CPUE - month/5° square	CPUE	1.46	0.44	0.04
Shark				
Average weight (weighted)	kgs	25.1	41.7	29.0
Maximum CPUE - daily	CPUE	13.29	20.00	40.79
Maximum CPUE - month/5° square	CPUE	4.43	4.62	15.65
Skipjack				
Average weight (weighted)	kgs	8.7	6.2	3.6
Maximum CPUE - daily	CPUE	3.57	14.29	10.37
Maximum CPUE - month/5° square	CPUE	1.43	1.56	0.50
Butterfly tuna				
Average weight (weighted)	kgs	-	35.3	32.9
Maximum CPUE - daily	CPUE	-	7.18	2.43
Maximum CPUE - month/5° square	CPUE	-	0.22	0.74
Mahi Mahi				
Average weight (weighted)	kgs	9.8	4	-
Maximum CPUE - daily	CPUE	2.53	1.43	-
Maximum CPUE - month/5° square	CPUE	0.44	0.08	-
Moonfish				
Average weight (weighted)	kgs	9.7	12.1	19.7
Maximum CPUE - daily	CPUE	1.62	1.67	7.00
Maximum CPUE - month/5° square	CPUE	0.09	0.20	0.44
Oilfish				
Average weight (weighted)	kgs	-	8.4	25.8
Maximum CPUE - daily	CPUE	-	2.46	5.43
Maximum CPUE - month/5° square	CPUE	-	0.48	0.73
Sunfish				
Average weight (weighted)	kgs	-	16	25.1
Maximum CPUE - daily	CPUE	-	3.01	5.09
Maximum CPUE - month/5° square	CPUE	-	0.49	0.64
Wahoo				
Average weight (weighted)	kgs	11.6	9.6	-
Maximum CPUE - daily	CPUE	2.81	0.88	-
Maximum CPUE - month/5° square	CPUE	0.28	0.30	-

[1] CPUE is numbers of fish per hundred hooks.

Table 21: **Target and by-catch species taken by longline vessels fishing in the WPO.**

Species	WTP	WSP	WTeP	Retained[1]
Sharks and Rays				
Silky shark (*Carcharhinus falciformis*)	S	R	-	Y
Tiger shark (*Galeocerdo cuvier*)	R	R	-	N
Great white shark (*Carcharodon carcharias*)	-	R	R	Y
Mako shark (*Isurus oxyrinchus*)	A	A	S	Y
Blue shark (*Prionace glauca*)	A	A	S	N
Porbeagle shark (*Lamna nasus*)	-	C	C	N
School shark (*Galeorhinus galeus*)	-	S	S	Y
Thresher shark (*Alopias* sp)	C	C	S	Y
Crocodile shark (*Pseudocarcharais kamoharai*)	R	R	-	N
Bronze whaler (*Carcharinus brachyurus*)	-	S	C	Y
Silvertip shark (*Carcharinus albimarginatus*)	R	R	-	Y
White-tip reef shark (*Triaenodon obesus*)	R?	-	-	-
Black-tip reef shark (*Carcharhinus melanopterus*)	R?	-	-	-
Black-tip shark (*Carcharhinus limbatus*)	R?	-	-	-
Grey reef shark (*Carcharhinus amblyrhynchos*)	M	C	-	Y
Oceanic white tip (*Carcharinus longimanus*)	A	C	-	Y
Hammerhead shark (*Sphyrinus* sp)	-	S	-	Y
Dogfish (*Symnodon* sp; Squalidae)	-	R	R	N
Smooth lanternshark (*Etmopterus pusillus*)	-	R	-	N
Manta rays (Mobulidae)	-	R	-	N
Stingray (*Dasyatis* sp)	S	S	-	N
Scombrids				
Skipjack tuna (*Katsuwonus pelamis*)	A	C	S	N
Bigeye tuna (*Thunnus obesus*)	T	T	S	Y
Yellowfin tuna (*Thunnus albacares*)	T	T	S	Y
Southern Bluefin tuna (*Thunnus maccoyii*)	-	S	T	Y
(Northern) Bluefin tuna (*Thunnus thynnus*)	R	R	S	Y
Albacore tuna (*Thunnus alalunga*)	S	T	T	Y
Longtail tuna (*Thunnus tonggol*)	-	S	R	Y
Slender tuna (*Allothunnus fallai*)	-	R	S	N
Butterfly tuna (*Gasterochisma melampus*)	-	S	C	Y
Frigate tuna (*Auxis thazard*)	-	R	-	N
Kawakawa (*Euthynnus affinis*)	S	A	-	N
Wahoo (*Acanthocybium solandri*)	C	A	-	Y
Billfish				
Black Marlin (*Makaira indica*)	A	A	S	Y[3]
Blue marlin (*Makaira mazara*)	A	A	S	Y[3]
Broadbill swordfish (*Xiphias gladius*)	A	A	S	Y
Sailfish (*Istiophorus platypterus*)	A	A	S	Y
Shortbill spearfish (*Tetrapturus angustirostris*)	A	A	S	Y
Striped marlin (*Tetrapturus audax*)	A	T	S	Y[3]
Other fish				
Barracuda (*Agrioposphyraena barracuda*)	S	S	R	N
Barracouta (*Thyrsites atun*)	-	R	R	N
Bass, Hapuka (*Polyprion* sp.)	-	-	R	Y
Blue eyes (Pseudomugilidae)	-	R	R	-
Bluenose (*Hyperoglyphe antarctica*)	-	-	R	N
Bramids, Rays Bream, Pomfrets (Bramidae)	A	A	C	N
Dealfish (*Trachipterus* sp.)	R	R	R	N
Gemfish (*Rexea solandri*)	-	R	R	Y
Globefish, Porcupine fish (Diodontidae)	R	R	R	N
Hake (*Merluccius australis*)	-	-	S	Y
Hoki, Blue Grenadier (*Macruronus novaezelandiae*)	-	S	S	Y
Kingfish (*Seriola* sp.)	S	S	R	Y
Lancetfish (*Alepisaurus* sp.)	C	C	S	N
Lantern fish (Myctophidae)	-	-	R	N
Mahimahi (*Coryphaena hippurus*)	C	C	R	Y
Oarfish (*Regalecus glesne*)	-	R	R	N
Oilfish (*Ruvettus pretiosus*)	A	A	S	N
Ragfish (*Icichthys australis*)	-	-	R	N

Species	WTP	WSP	WTeP	Retained[1]
Rainbow runner (*Elagatis bipinnulata*)	S	S	-	Y
Remora (*Remora* sp.)	R	R	R	N
Rudderfish (*Centrolophus niger*)	-	R	R	N
Sea perches, gropers (Serranidae)	-	S	-	N
Snake mackerel, Escolar (*Lepidocybium flavobrunneum*)	A	A	S	N
Sunfish (*Mola* sp)	R	C	S	N
Moonfish / Opah / Mambo (*Lampris sp.*)	A	A	S	Y
Warehou (*Seriolella brama*)	-	R	R	Y
Marine reptiles				
Green turtle (*Chelonia mydas*)	S	-	-	N
Hawksbill turtle (*Eretmochelys imbricata*)	S	-	-	N
Leatherback	-	-	-	N
Olive ridley	-	-	-	N
Turtles (unidentified)	C	S	R	N
Marine mammals				
Killer whale (*Orcinus orca*)	-	-	R	N
False killer whale (*Pseudorca crassidens*)	-	?	-	N
Pilot whale (*Globicephala* spp.)	-	-	-	N
Seal (Pinnipedia)	-	-	S	?
Common Dolphin (*Dephinus delphis*)	-	R	-	N
Marine mammal (unidentified)	R	R	-	N
Birds				
Albatross (*Diomedea* sp.)	-	-	C	N
Petrels (*Procellaria* sp.)	-	-	C	N
Other seabirds	-	S	S	N

NOTES

1. 'Y' - normally retained; 'N' - not retained, i.e. normally discarded/released. This does not take into account the differences in discarding practices that may exist between fleets or even vessels of the same fleet. For the species retained, they may be sold commercially, kept for crew consumption or given away on return to port. For shark species, the trunks are often discarded after the fins have been removed. Most observations of turtles caught by longline vessels indicate that they were released alive (FSM observer reports).

2. Moonfish (*Lampris guttatus*) sometimes refered to as **MANDAI**, which is Japanese Okinawan common name for this species. Oilfish (*Ruvettus pretiosus*) sometimes refered to as **BARAMUTSU**, which is the Japanese common name for this species (Izumi, pers. comm.).

3. There are restrictions on the landing of certain billfish species in some areas of Australian and New Zealand waters.

LEGEND

T usually a target species for fleets in this area; if not the target for all vessels, it is usually abundant in the longline catch; at least 1 per set on average.
A usually abundant in the longline catch for this area; at least 1 per set on average.
C commonly taken; usually it would be expected that at least 1 of this species would be taken every 10 sets.
S seldom caught; taken on few occasions but not considered common or rare in the catch; typically it would be expected that at least 1 of this species would be taken every few months or may only be taken at certain times of the year for that area (i.e. seasonal) or only in specific parts of that area.
R rarely taken; there may be only one taken per year for that area or, for some species, only one occurence ever.
\- no evidence of longline catch of this species found.

SOURCES

SPC RTFD records; Observer data made available to SPC by FSM (Heberer, 1993), Kiribati, PNG (Wright, 1980), Australia (Ward, pers. com.), New Zealand (Michael et al. 1987 and 1989; Burgess pers. comm.); SPC Observer reports (Farman, 1986; Palu, 1992; Labelle, 1993); various anectodal information from observers/others and personal observations by authors at unloading sites.

Table 22: Survival rates of billfish species taken by longline vessels. Sources of data are (i) AFZ observer data for the years 1979-1990 and the area of the AFZ north of 40°S and east of 140°E (Ward, pers. comm.); (ii) Mortality rates of billfish determined by the NMFS Honolulu laboratory (WPRFMC, 1986); (iii) Far Seas Fisheries Research Laboratory Data (Japan).

Species	Number of observations (N) (AFZ)	% alive at time of landing (AFZ)	% alive at time of landing (NMFS)	% alive at time of landing (Japan)
Black marlin (*Makaira indica*)	13	30.8	25.7	54.1
Blue marlin (*Makaira mazara*)	30	40.0	29.1	55.6
Broadbill swordfish (*Xiphias gladius*)	139	59.0	40.0	54.4
Sailfish (*Istiophorus platypterus*)	42	33.3	25.0[1]	42.2[1]
Shortbill spearfish (*Tetrapturus angustirostris*)	34	38.2	25.0[1]	42.2[1]
Striped marlin (*Tetrapturus audax*)	67	49.3	54.5	76.7

NOTES

1. Percentage for sailfish and short-billed spearfish combined were available only.

Table 23: **Survival rates of shark species caught by Japanese longliners in Australian waters, based on observer data for the years 1979-1990 and the area of the Australian fishing zone north of 40°S and east of 140°E (Ward, pers. comm.).**

Species of shark	Number of observations (N)	% alive at time of landing	Status[1]
Silky shark (*Carcharhinus falciformis*)	28	96	R
Tiger shark (*Galeocerdo cuvier*)	2	100	F
Great white shark (*Carcharodon carcharias*)	1	100	R
Mako shark (*Isurus oxyrinchus*)	237	68	R
Blue shark (*Prionace glauca*)	2,611	90	F
Porbeagle shark (*Lamna nasus*)	11	64	F
School shark (*Galeorhinus galeus*)	17	100	R
Thresher shark (*Alopias* sp)	22	91	R
Crocodile shark (*Pseudocarcharais kamoharai*)	7	100	D
Bronze whaler (*Carcharinus brachyurus*)	3	100	R
Silvertip shark (*Carcharinus albimarginatus*)	1	100	R
Oceanic white tip (*Carcharinus longimanus*)	7	86	R
Dogfish (*Scymnodon* sp; Squalidae)	33	94	D
Smooth lanternshark (*Etmopterus pusillus*)	1	100	D
Hammerhead shark (*Sphyrinus* sp)	2	50	R

NOTES

1. Observed landed status. 'R' - retained for commercial sale or crew consumption; 'F' - fins only retained; 'D' - entire shark discarded.

Table 24: **Comparisons of target and shark catch rates from observed longline vessel trips in the WTP since 1988 (Heberer, 1993).**

Vessel Nation	Trip	YFT CPUE	BET CPUE	SHK CPUE	Comments
FSM	(1)	0.0	0.1	0.5	Breakdown of shark species not available
Japan	(1)	0.4	0.1	0.1	Breakdown of shark species not available
	(2)	2.0	0.3	0.2	Breakdown of shark species not available
	(3)	0.6	0.8	0.3	Breakdown of shark species not available
Korea	(1)	0.1	0.5	0.8	Blue shark (*P. glauca*) - 0.4 Thresher (*Alopias* sp.) - 0.2 Grey Reef (*C. amblyrhynchos*) - 0.1
	(2)	0.3	0.3	0.4	Breakdown of shark species not available
Taiwan	(1)	2.1	1.2	1.1	Breakdown of shark species not available
	(2)	0.8	0.2	3.0	Blue shark (*P. glauca*) - 2.1 Grey Reef shark (*C. amblyrhynchos*) - 0.7 Oceanic white-tip (*C. longimanus*) - 0.2
	(3)	0.6	0.4	0.4	Breakdown of shark species not available
	(4)	0.3	0.1	1.8	Breakdown of shark species not available

Units : CPUE - number of fish per 100 hooks

Table 25: Common incidental species caught by longline vessels in the WPO stratified by quarter, based on logbook data held in the SPC Regional Tuna Fisheries Database, 1978-1991.

	WTP					WSP					WTeP				
Species	1	2	3	4	Total	1	2	3	4	Total	1	2	3	4	Total
Butterfly Tuna	-	-	-	-	-	-	9	224	-	232	442	4,889	491	-	5,822
Hoki	-	-	-	-	-	-	-	-	-	-	14	87	-	-	101
Mahi Mahi	1,289	542	64	7	1,902	1	-	20	96	117	-	-	-	-	-
Moonfish (Opah)	121	94	273	102	590	763	618	3,188	251	4,820	360	2,619	1,317	-	4,296
Oilfish	-	-	-	-	-	9	485	2,473	-	2,967	62	5,050	6,240	-	11,352
Rainbow runner	4	19	25	5	53	9	1	-	9	19	-	-	-	-	-
Slender tuna	-	-	-	-	-	2	1	-	-	3	-	330	27	-	357
Shortbill spearfish	11	6	33	-	50	32	8	20	6	66	11	-	-	-	11
Sunfish	-	-	-	-	-	221	536	1,015	-	1,772	133	3,420	1,822	-	5,375
Wahoo	1,459	842	642	432	3,375	93	54	5	136	288	-	-	-	-	-
Not specified or mixed species	12,387	10,232	17,078	9,752	49,449	3,817	11,135	18,072	3,811	36,835	5,640	102,548	57,393	-	165,581
Billfish not specified	313	142	607	670	1,732	485	577	2	68	1,132	-	-	-	-	-
Tuna not specified	305	382	923	735	2,345	-	75	44	130	249	-	9	-	-	9

NOTES

1. On some logsheet forms, there is no provision for entering species name for 'other' catch; these have been included in 'Not specified or mixed species', as listed above.

2. Due to the data storage requirements of the RTFD, there is no provision for storing individual 'other' by-catch species data where more than one occur for the day; in these cases (less than 0.1% of the SPC processed logsheet forms cater for this type of recording), the species catch are added and assigned a species code - 'Not specified or mixed species'. Data provided by NZ (MAF) and Australian data (AFMA) allow for a breakdown of 'other' species catch in the datasets provided to SPC.

3. Moonfish (*Lampris guttatus*) is sometimes refered to as **MANDAI** on logsheets, which is Japanese Okinawan common name for this species. Oilfish (*Ruvettus pretiosus*) is sometimes refered to as **BARAMUTSU**, which is the Japanese common name for this species (Izumi, pers. comm.).

Table 26: Estimates of common by-catch from longline vessels fishing in the WPO for 1987-1990.

	Number				Metric tonnes			
	1987	1988	1989	1990	1987	1988	1989	1990
Striped Marlin	28,166	34,639	41,714	26,868	1,601	2,009	2,519	1,586
Blue Marlin	84,973	108,749	91,657	69,854	4,632	6,252	5,186	3,871
Black Marlin	18,354	19,281	17,305	13,135	1,013	1,115	941	726
Swordfish	54,272	64,797	57,781	56,967	2,909	3,655	3,099	2,982
Sailfish	8,388	11,597	10,055	11,399	202	267	234	268

NOTES

1. Estimates have been determined in the following manner :

(i) Japanese billfish catch (in number) was made available to SPC from the Japanese Fisheries Agency (JFA). Catch in metric tonnes have been determined using the average weight for each species in each area (i.e. WTP, WSP and WTeP); the average weights were calculated from the RTFD (i.e. weighted average of daily logsheet data).

(ii) Taiwanese (vessels < 100 GRT and > =100 GRT) and Korean billfish catch were raised, by area, from the RTFD catches for these fleets by applying the proportion of RTFD catch to total catch estimates for albacore, yellowfin and bigeye catch (provided in Lawson, 1992).

(iii) The billfish catch reported in the RTFD for the remaining fleets were assumed to have 100% coverage.

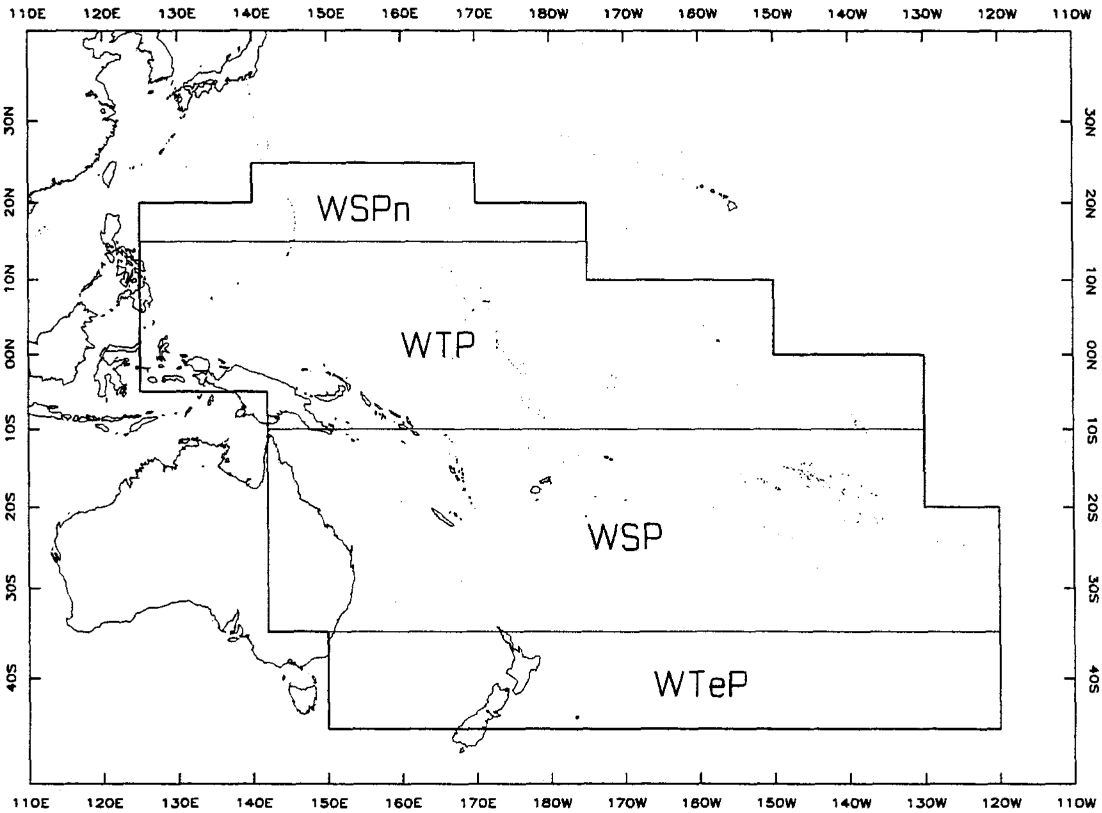


Figure 1: The SPC Statistical Area, showing tropical (WTP), subtropical (WSP) and temperate (WTeP) subdivisions used in this report.

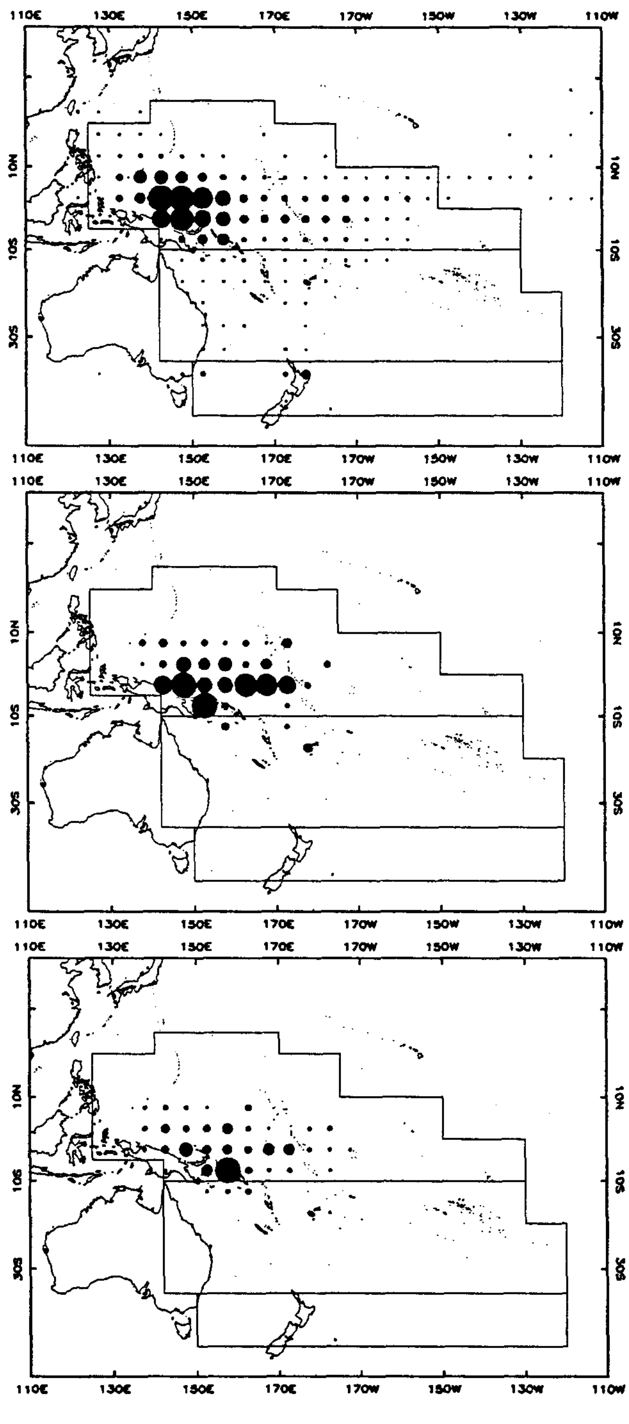


Figure 2: **Distribution of sets (top), tonnes of by-catch (middle) and tuna discards (bottom) in the western Pacific purse seine fisheries, 1975-1990**

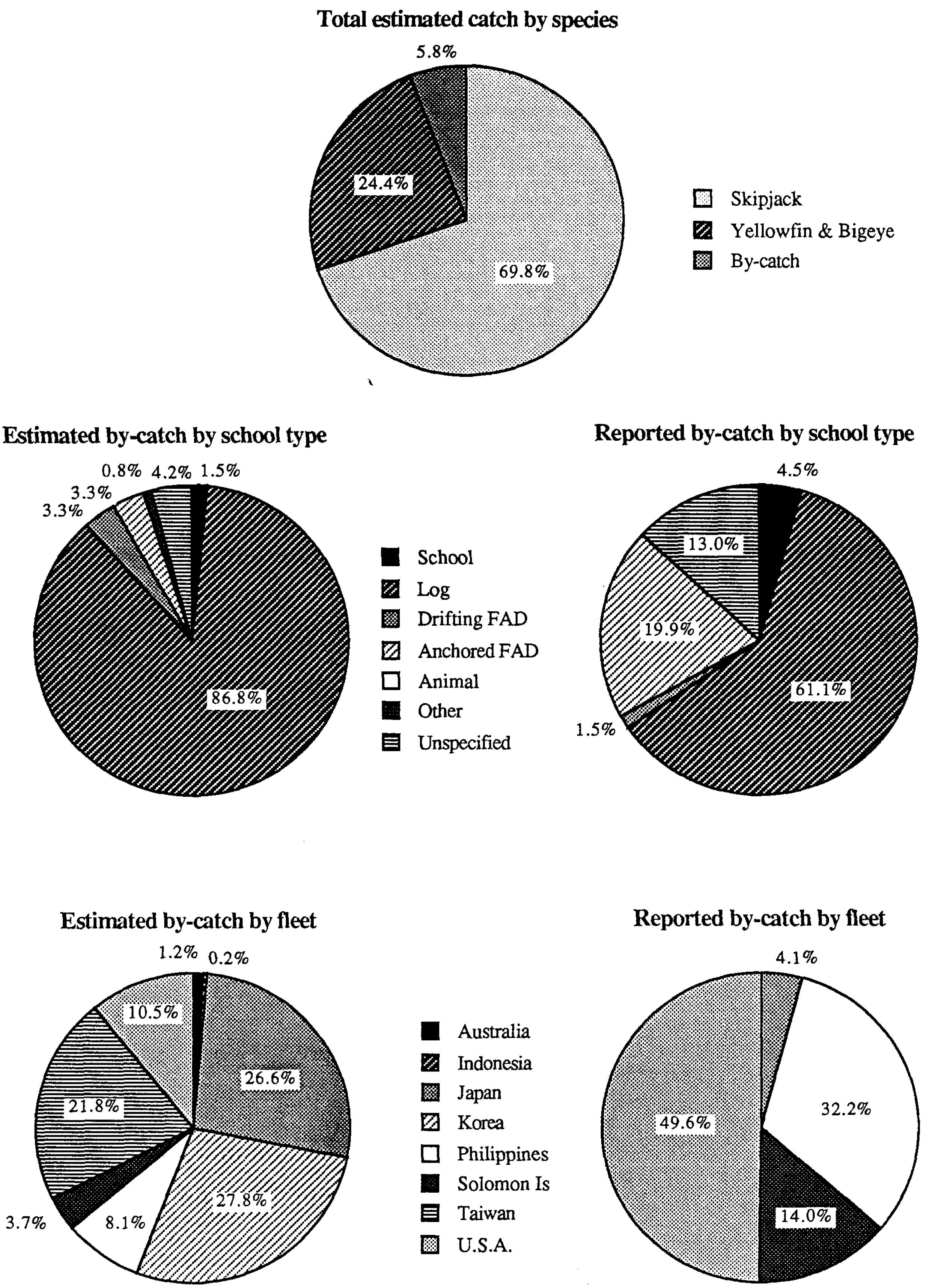


Figure 3: Estimated and reported by-catch levels (mt) for the WTP purse seine fishery, 1990

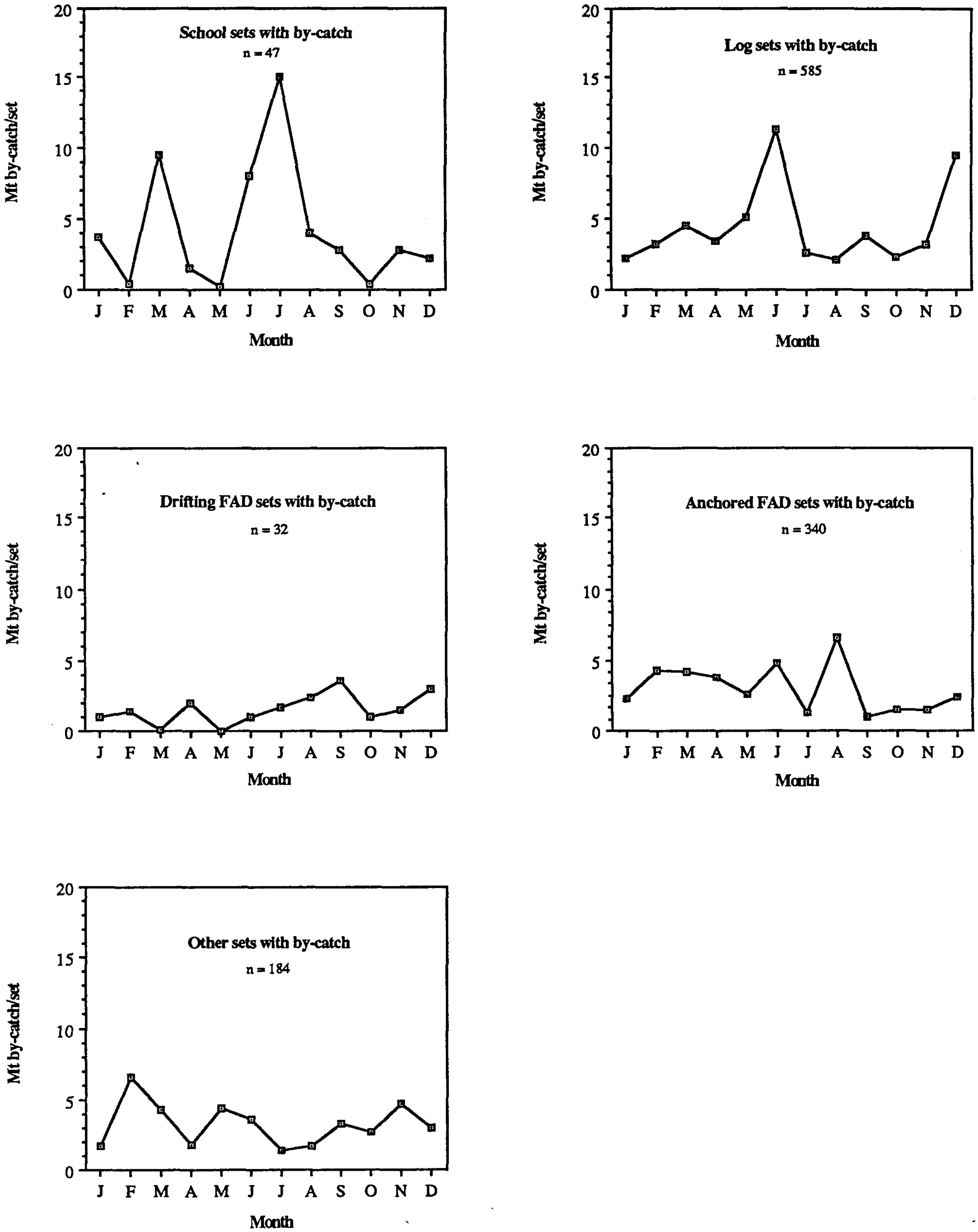


Figure 4: Seasonality of by-catch CPUE (mt per set with declared by-catch) by school association

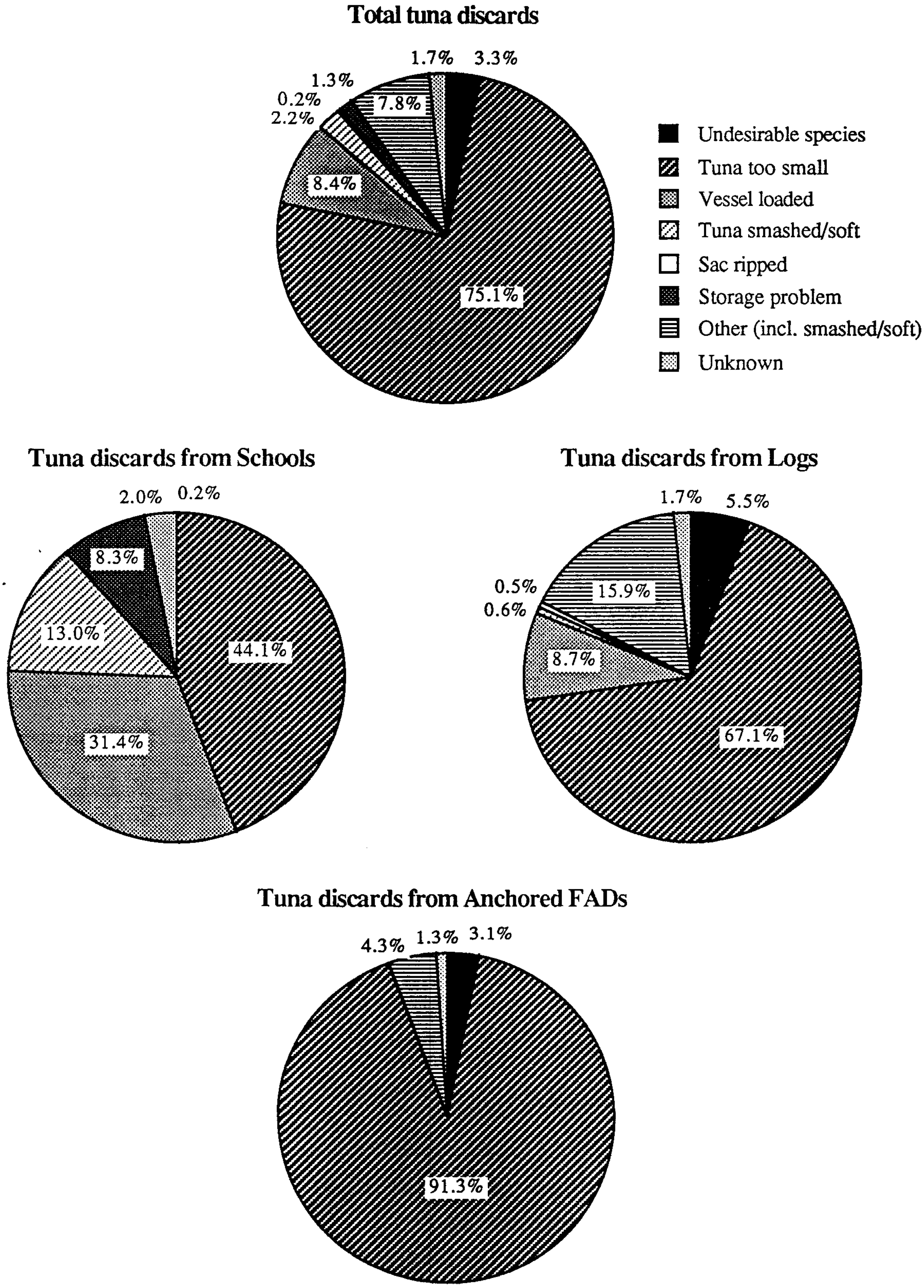


Figure 5: Tuna discard levels (mt) by reasons for discarding and school association

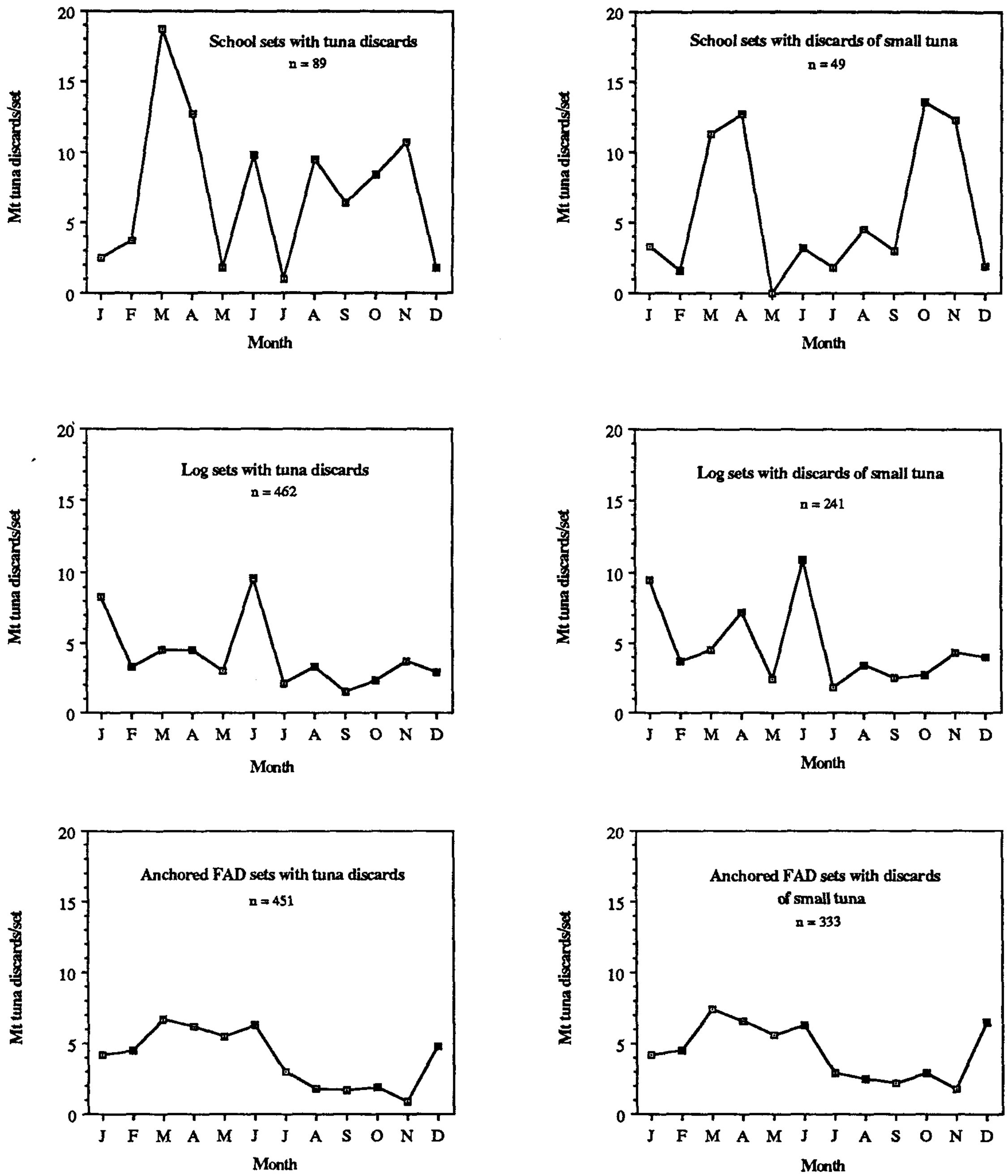
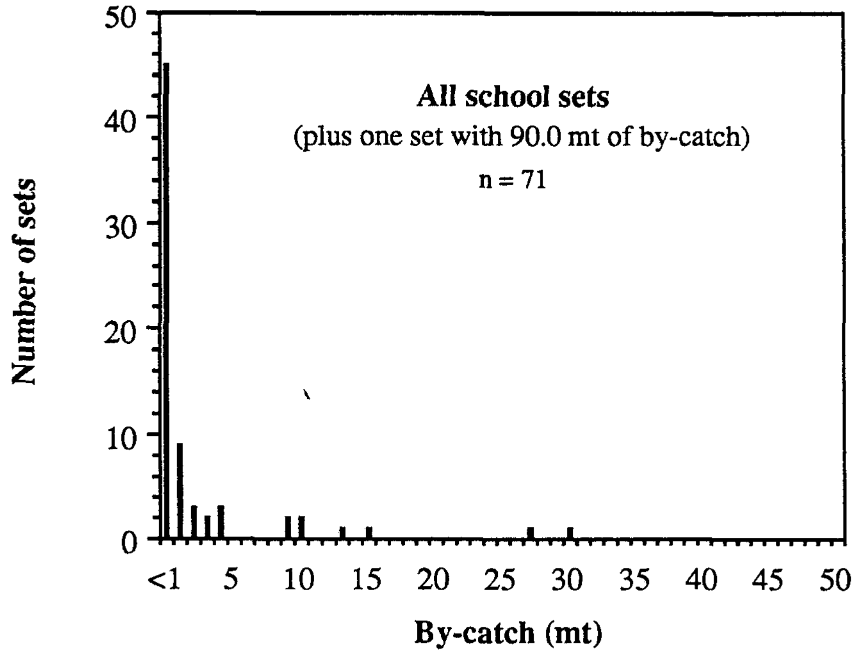


Figure 6: Seasonality of CPUE (mt per set) of all tuna discards (left) and discards of tuna too small for canning (right), by school association

Figure 7: Frequency of by-catch by school association, based on data held in the RTFD

(a)



(b)

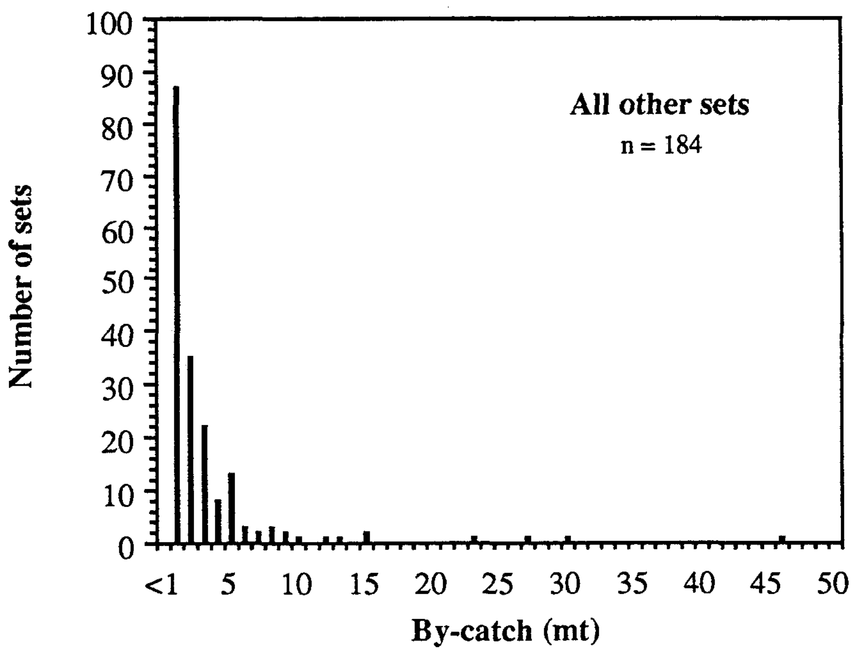
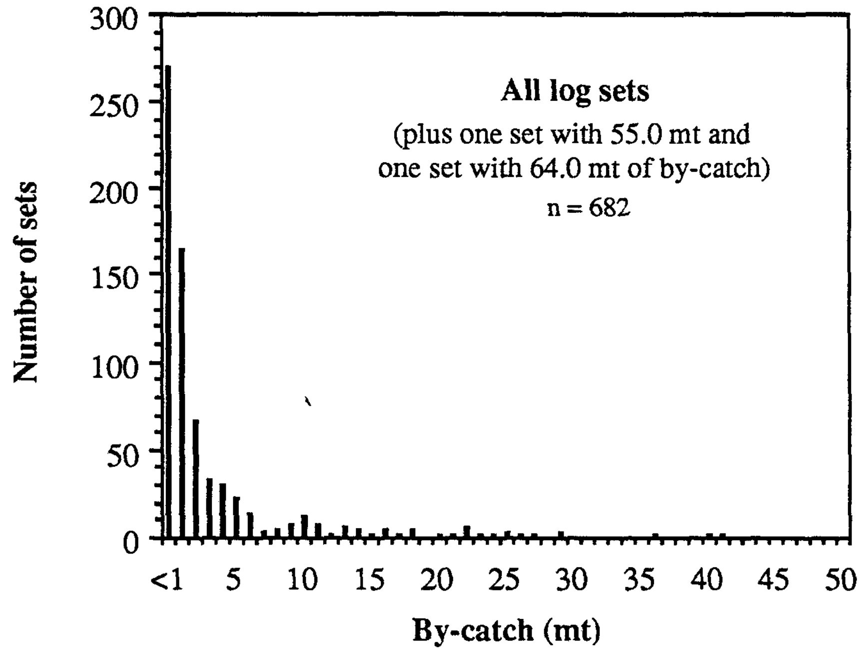
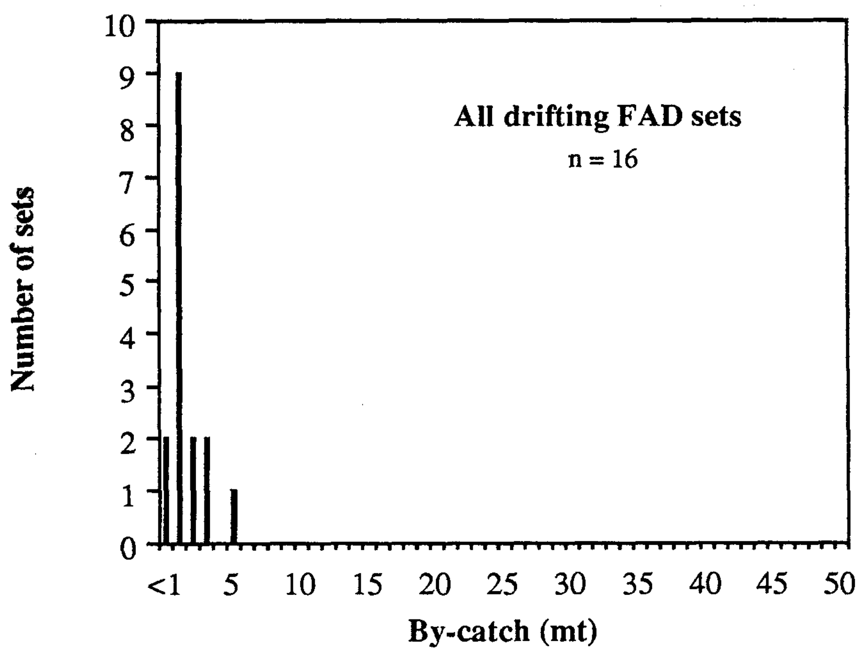


Figure 7: (continued)

(c)



(d)



(e)

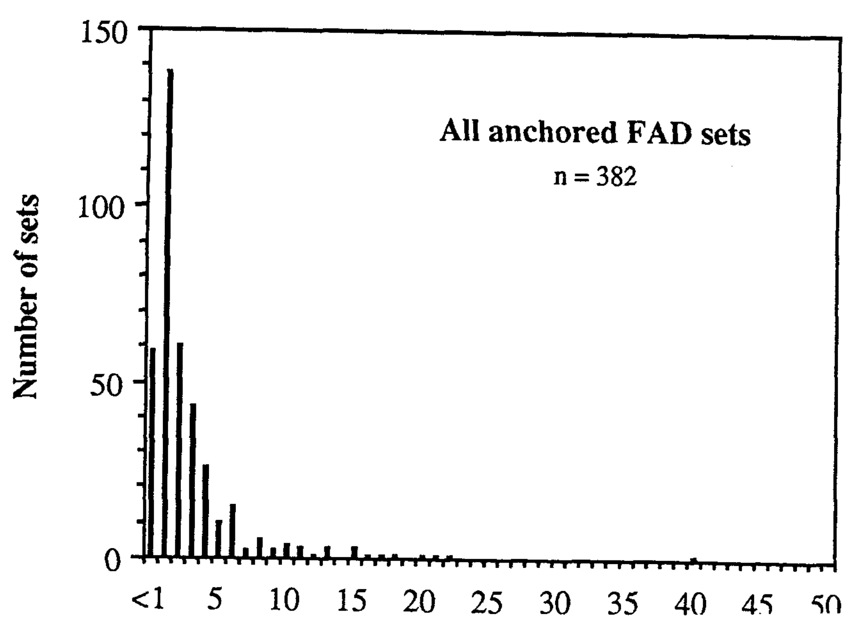


Figure 8(a): Distribution of Longline effort for the WPO, based on data held in the Regional Tuna Fisheries Database for 1978-1991.
(largest circle = 20,000 fishing days)

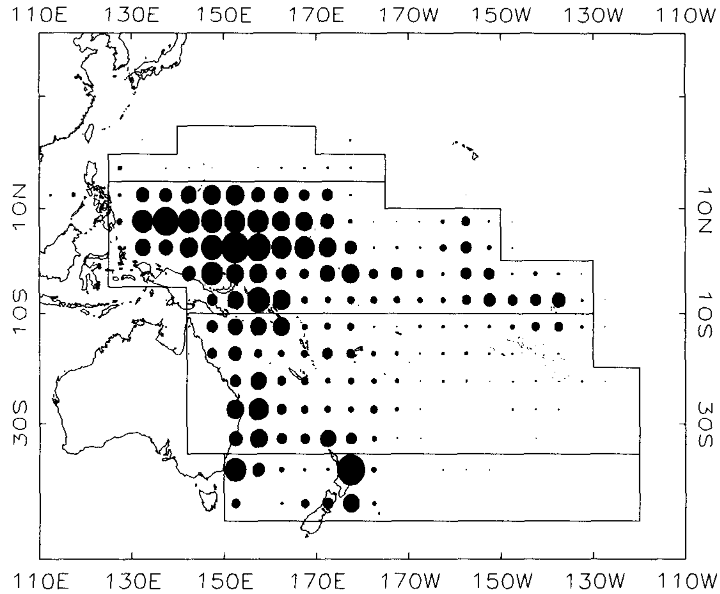


Figure 8(b): Distribution of tuna discarded in the WPO, based on data held in the Regional Tuna Fisheries Database for 1978-1991.
(largest circle = 40,000 kgs)

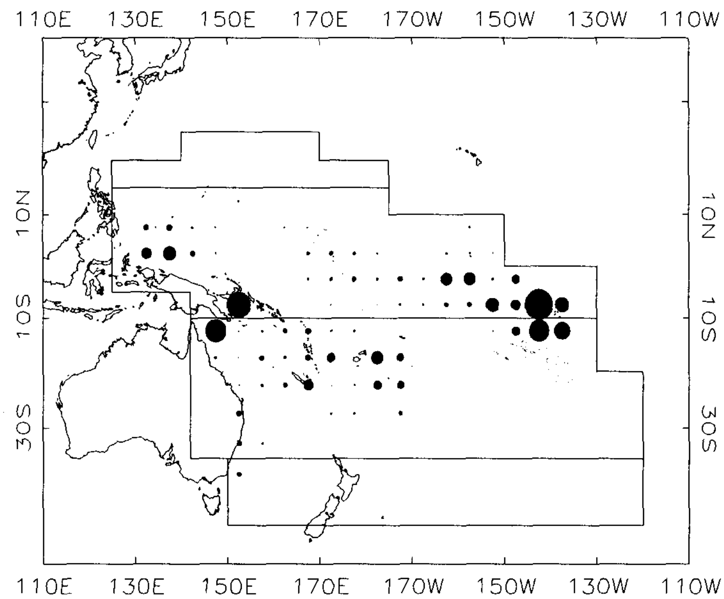


Figure 8(c): Distribution of by-catch discarded in the WPO, based on data held in the Regional Tuna Fisheries Database for 1978-1991.
(largest circle = 35,000 kgs)

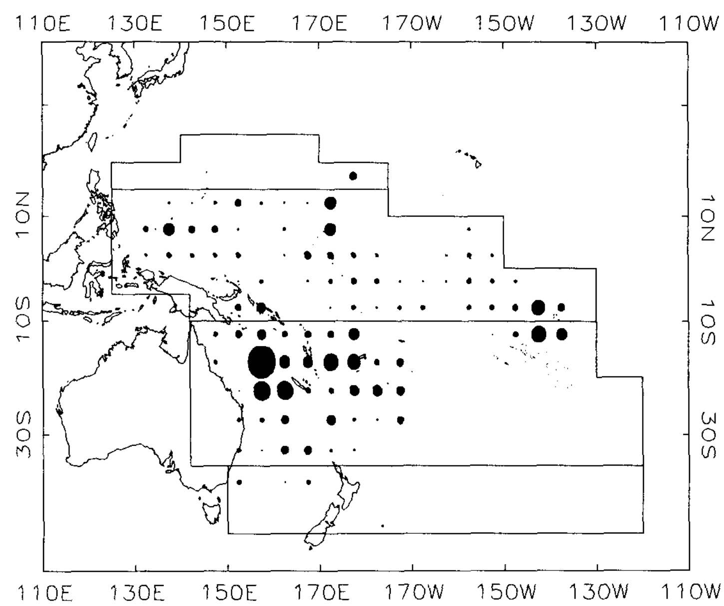


Figure 9: Distribution of seasonal longline effort for the WPO, based on data held in the RTFD for 1978-1991.

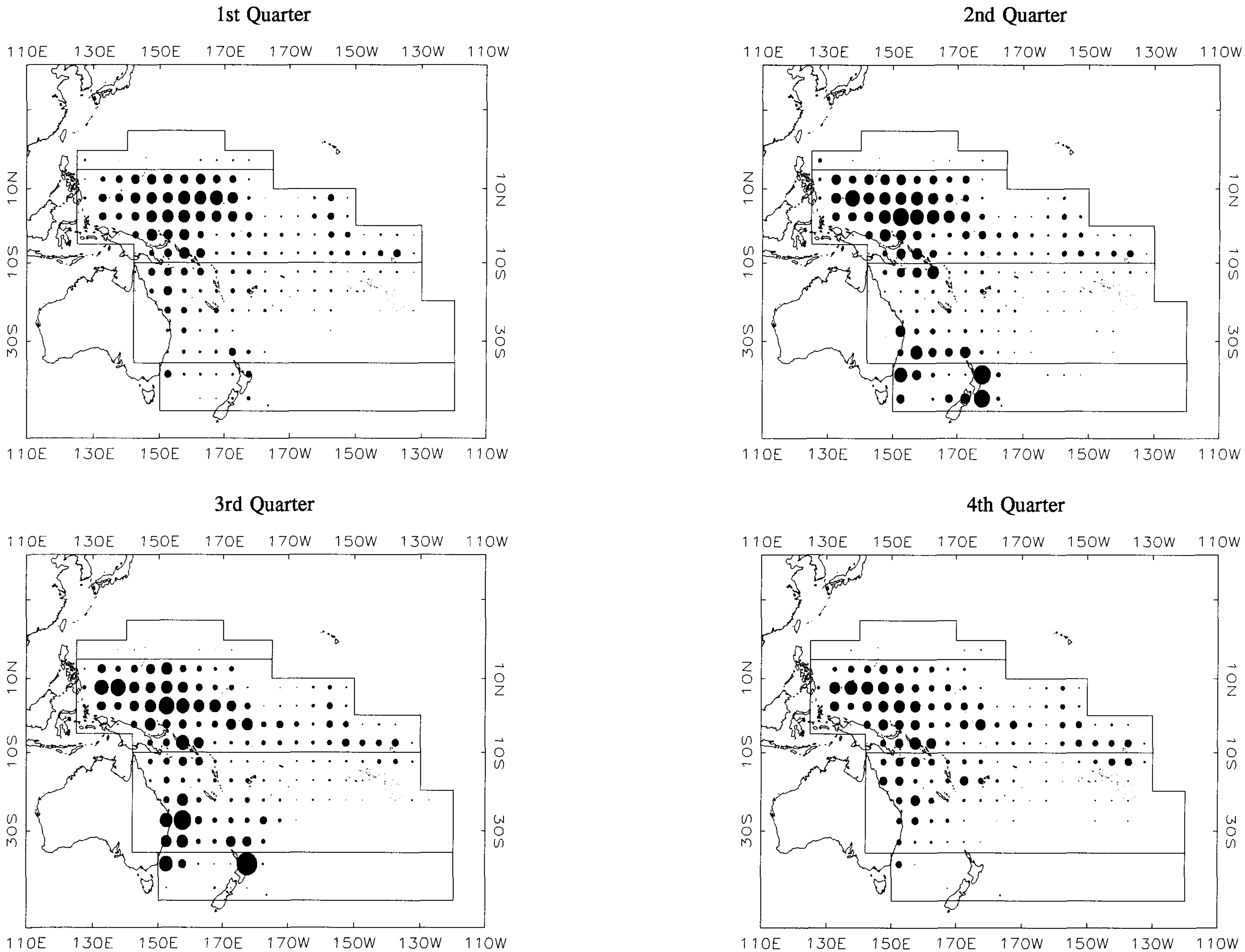
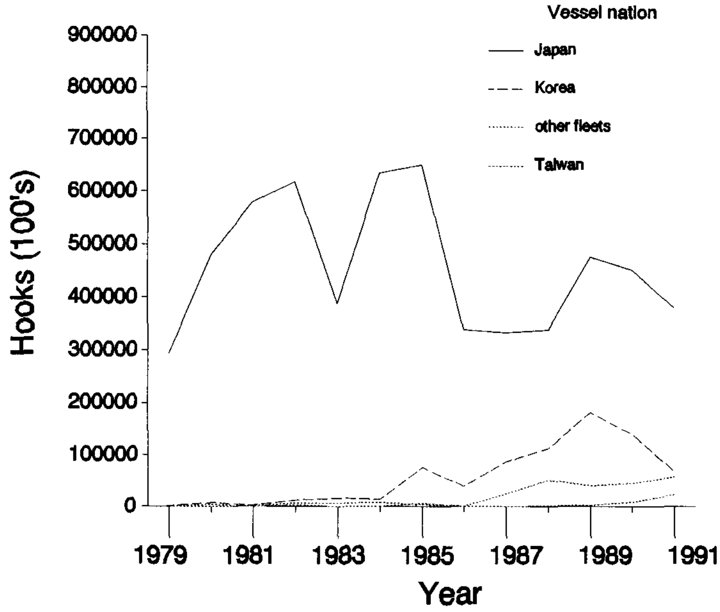
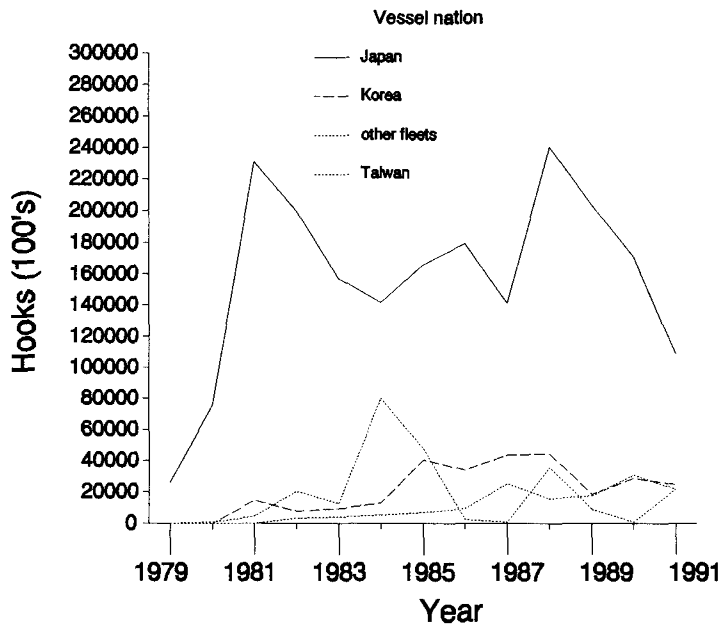


Figure 10: Annual longline effort by fleet in the WPO, based on data held in the RTFD for 1979-1991.

(a) WTP



(b) WSP



(c) WTeP

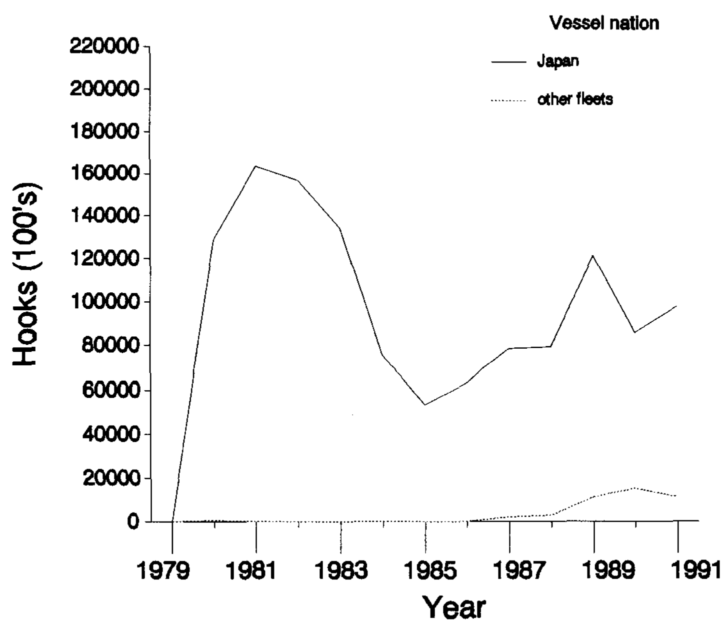


Figure 11(a): Frequency of hooks per basket used by longline vessels fishing in the WTP, stratified by year. Data in the RTFD where hooks per basket is available has been used exclusively.

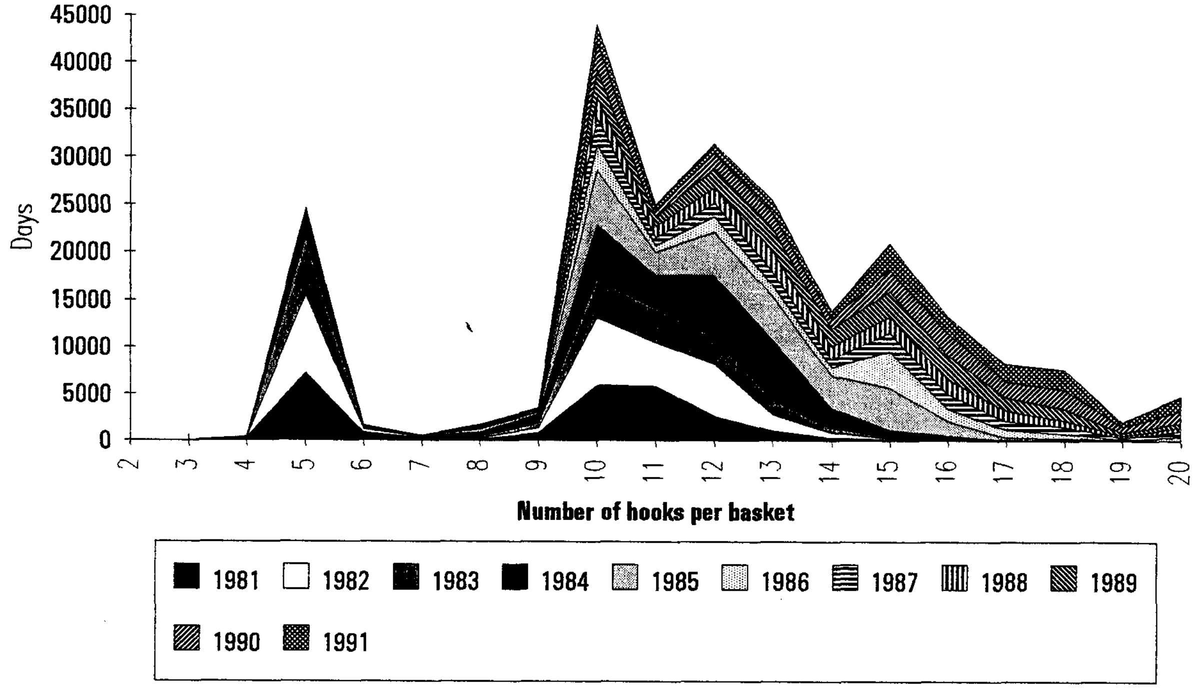


Figure 11(b): Frequency of hooks per basket used by longline vessels fishing in the WSP, stratified by year. Data in the RTFD where hooks per basket is available has been used exclusively.

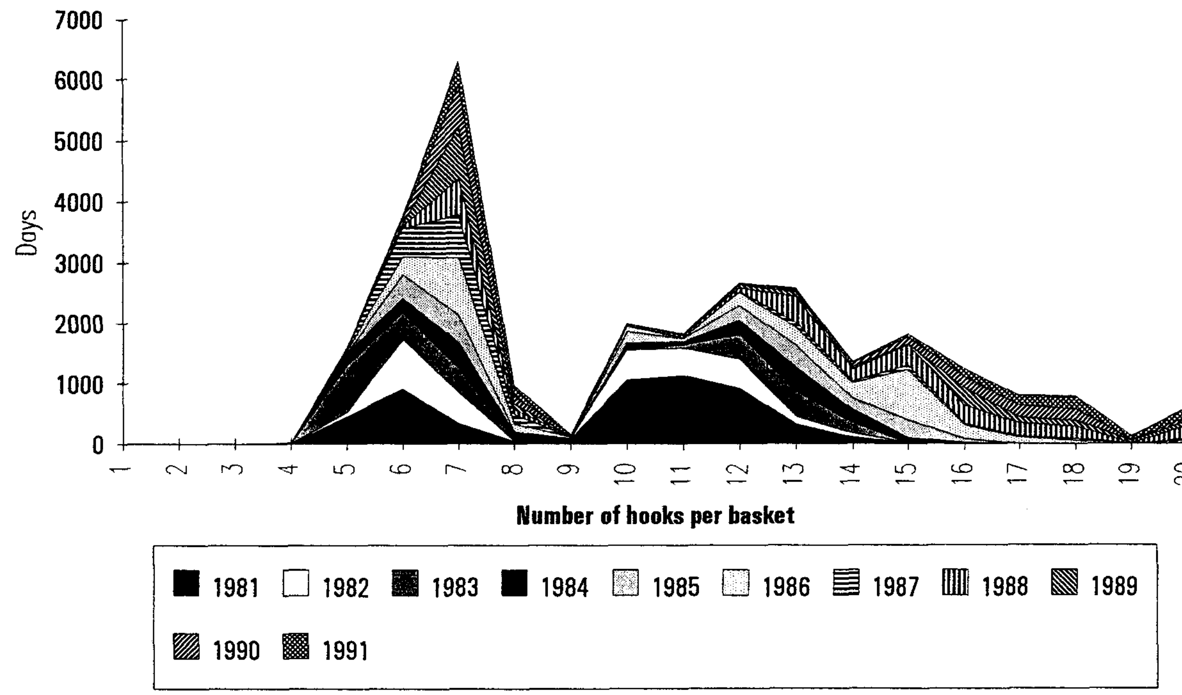
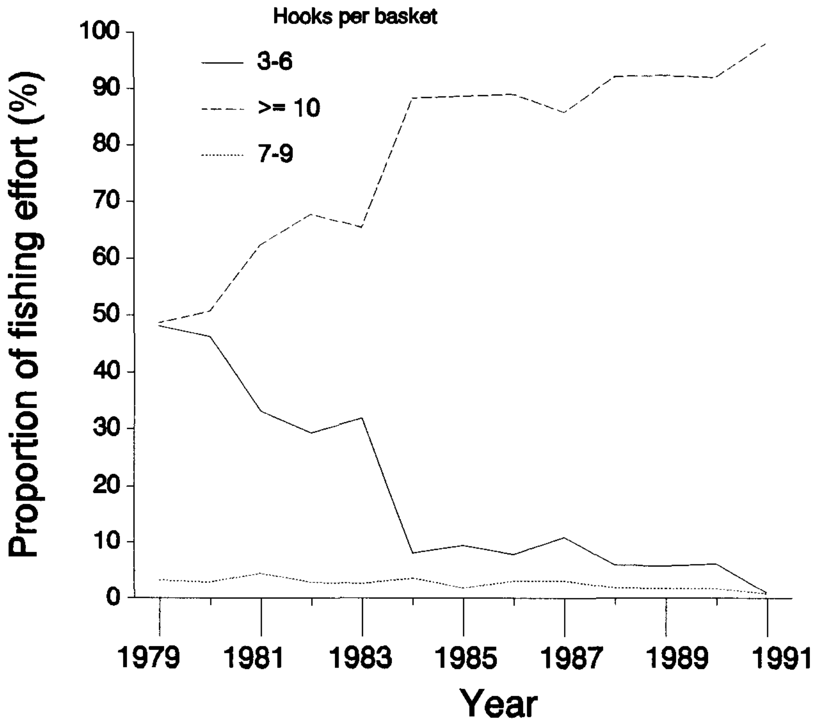


Figure 12: Annual trends in gear depth range utilisation for areas in the WPO, based on numbers of hooks per basket. Data in the RTFD where hooks per basket is available has been used exclusively.

(a) WTP



(b) WSP

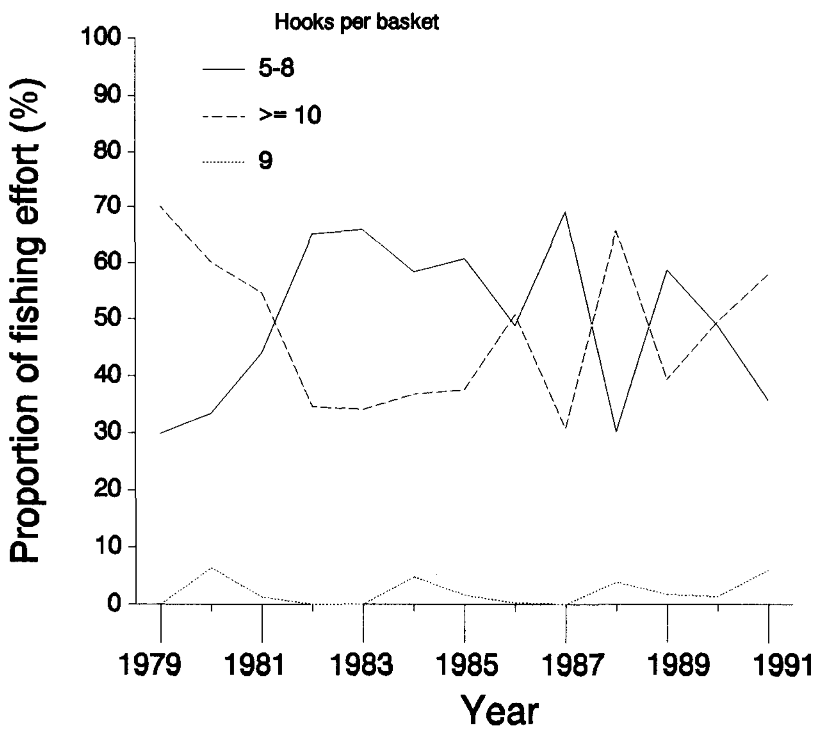
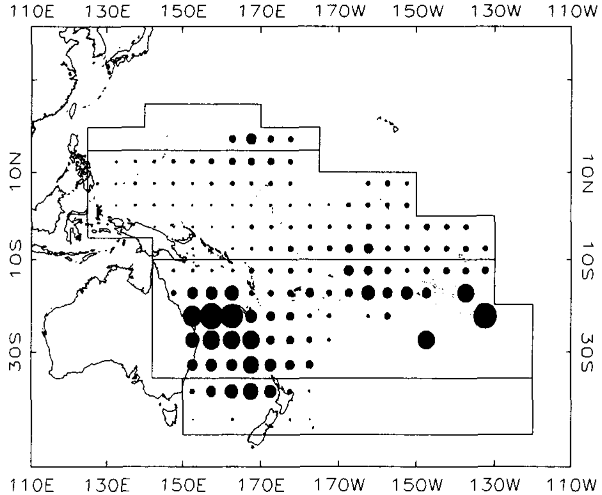
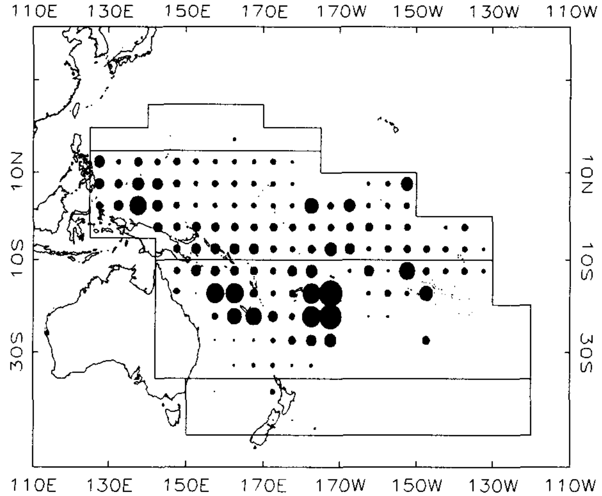


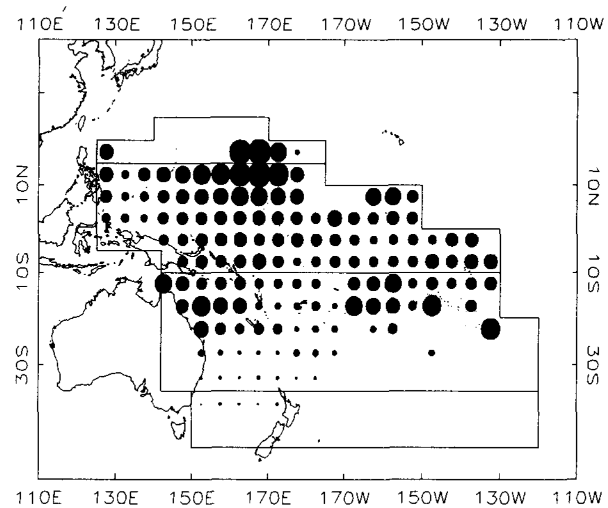
Figure 13: Distribution of nominal CPUE for common by-catch species taken by longline vessels in the WPO, based on data held in the RTFD for 1978-1991. The unit of measure is CPUE, in number of fish per hundred hooks.



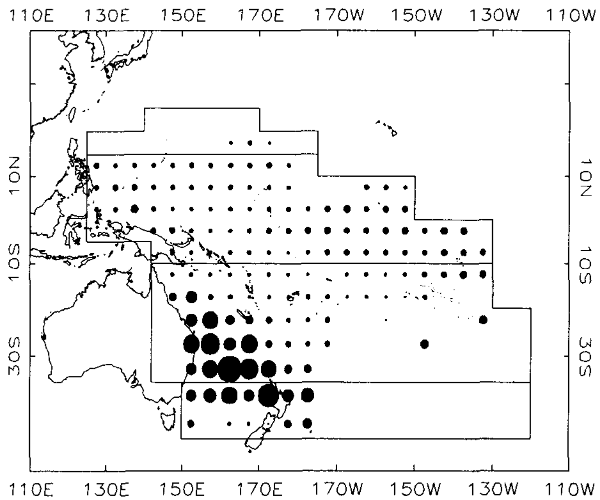
(a) Striped Marlin



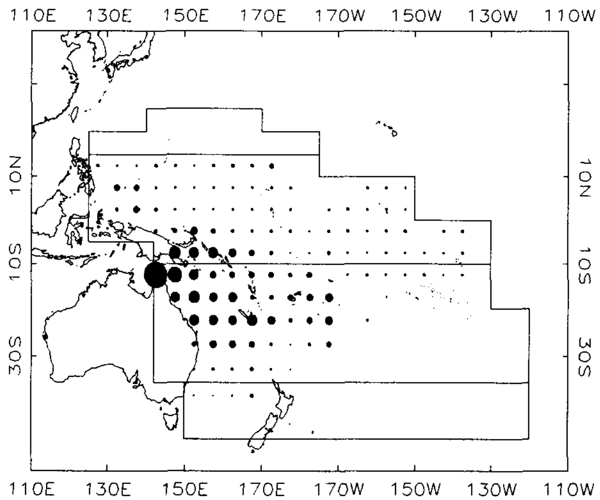
(b) Black Marlin



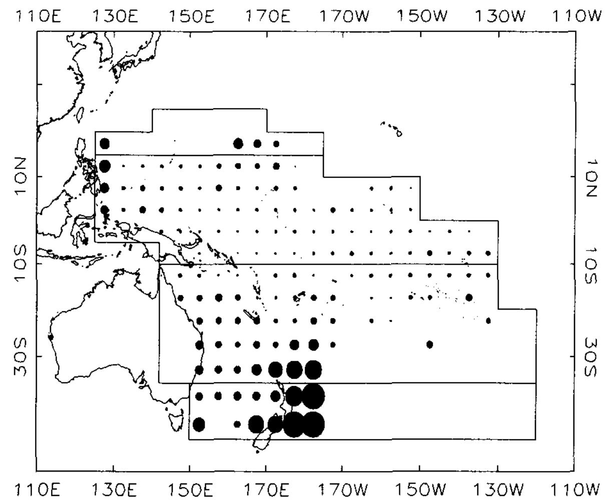
(c) Blue Marlin



(d) Swordfish



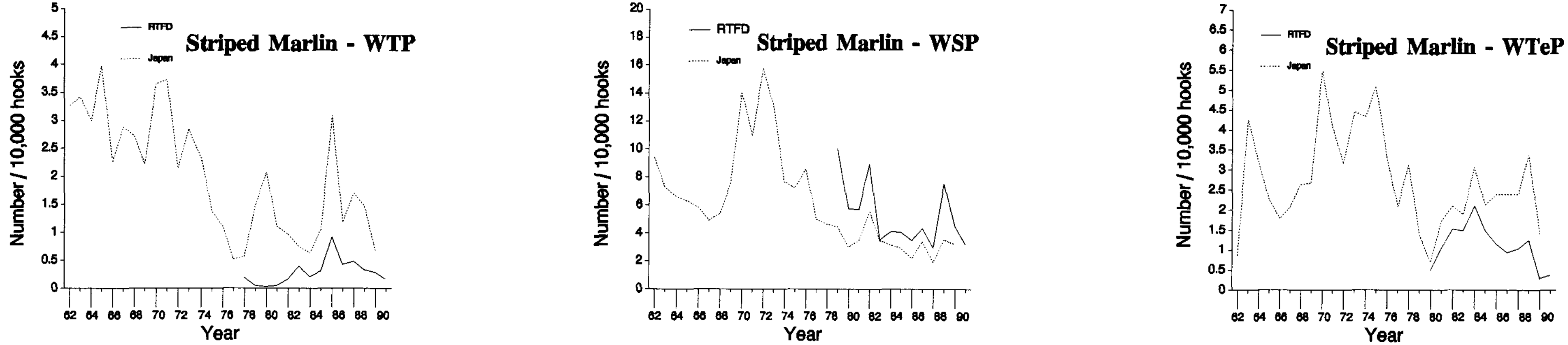
(e) Sailfish



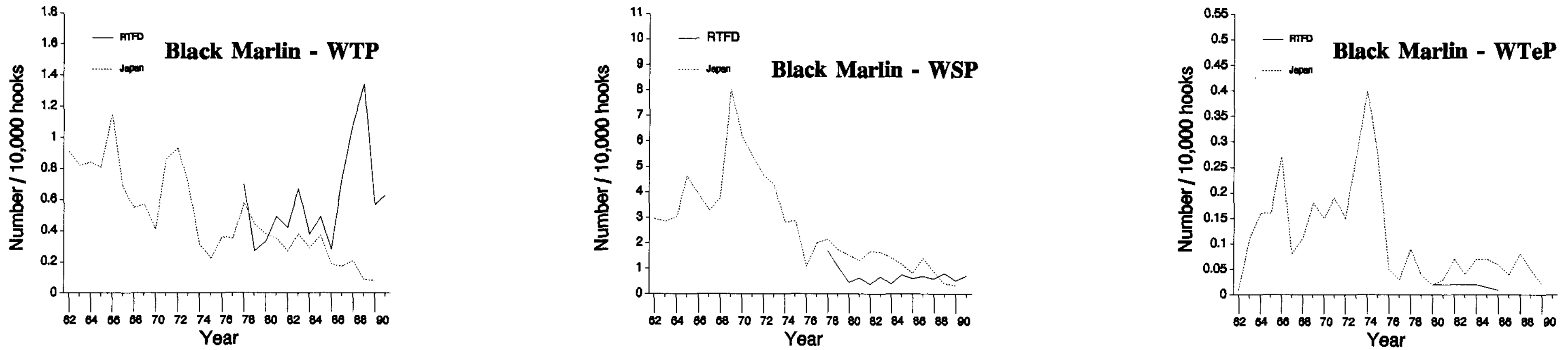
(f) Shark

Figure 14: Annual longline CPUE, in numbers per 10,000 hooks for common by-catch in the WPO for 1962-1990. Sources are data provided to SPC by the Japan Fisheries Agency (Japan) and the Regional Tuna Fisheries database (RTFD).

(a)



(b)



(c)

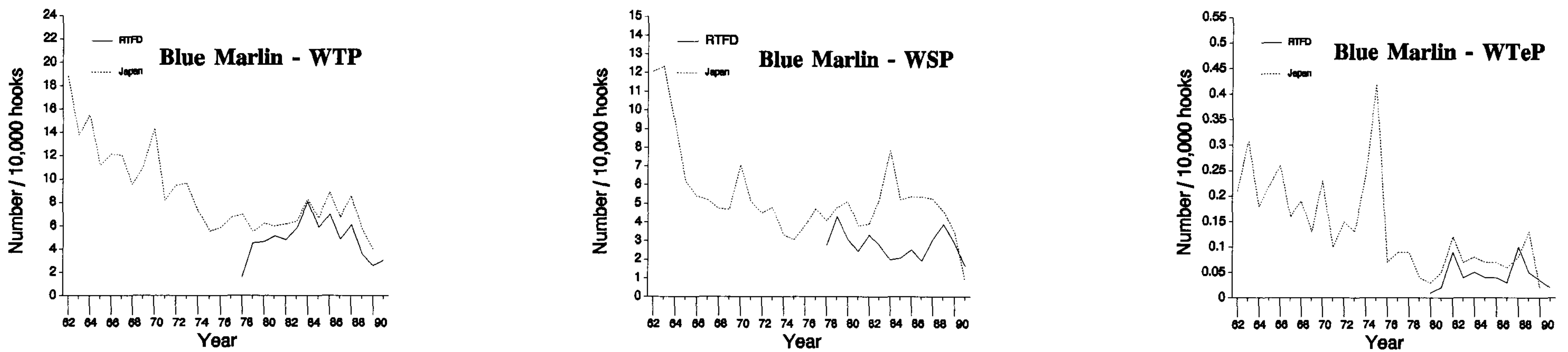
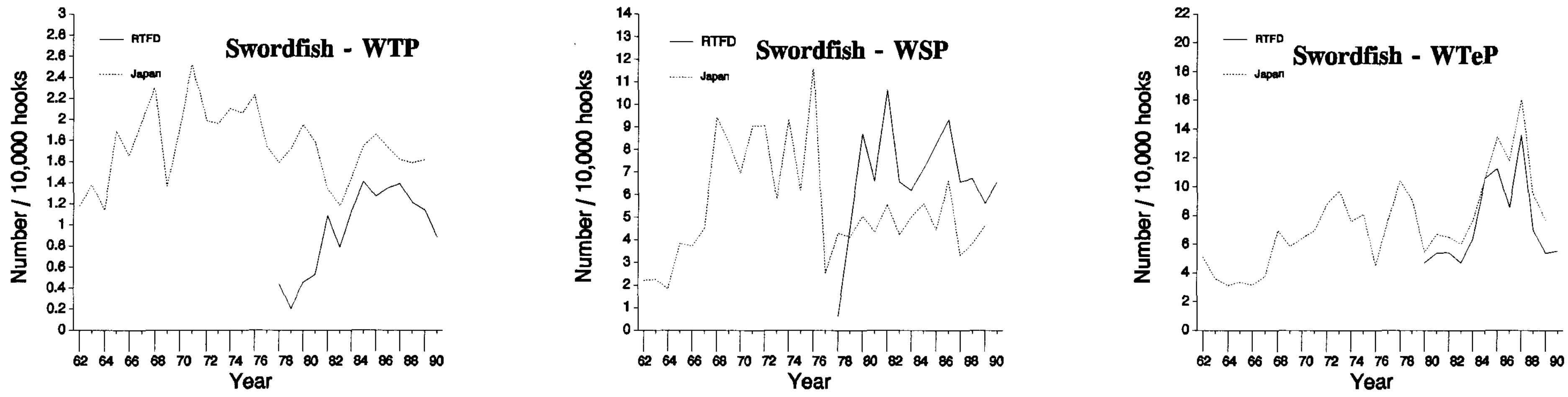


Figure 14: Annual longline CPUE, in numbers per 10,000 hooks for common by-catch in the WPO for 1962-1990. Sources are data provided to SPC by the Japan Fisheries Agency (Japan) and the Regional Tuna Fisheries database (RTFD). (continued)

(d)



(e)

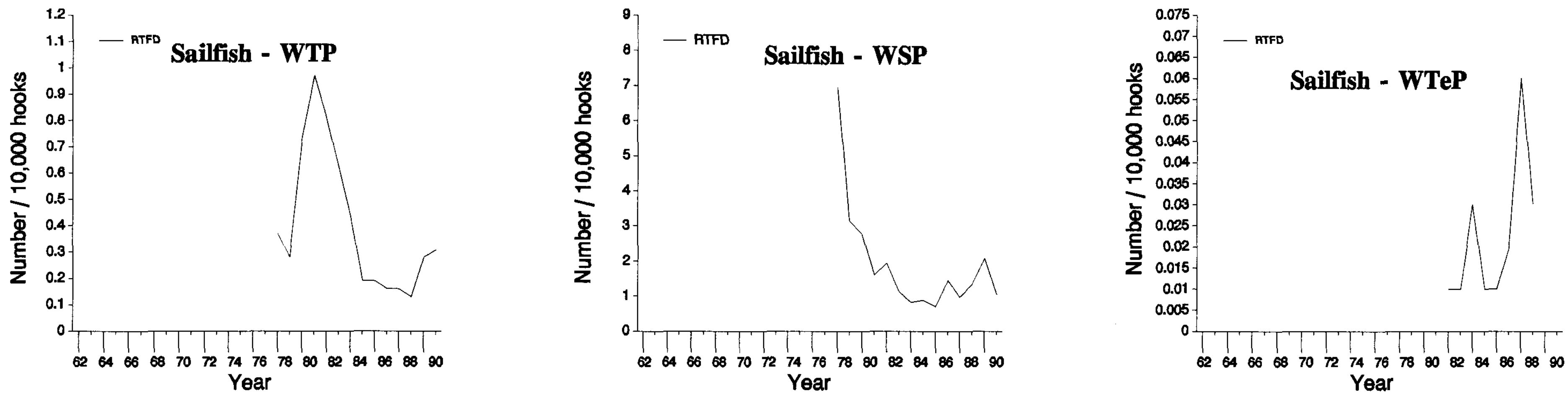


Figure 15: Seasonal longline CPUE for common by-catch species in areas of the WPO, stratified by categories of number of hooks per basket; source of data is the RTFD for 1978-1991.

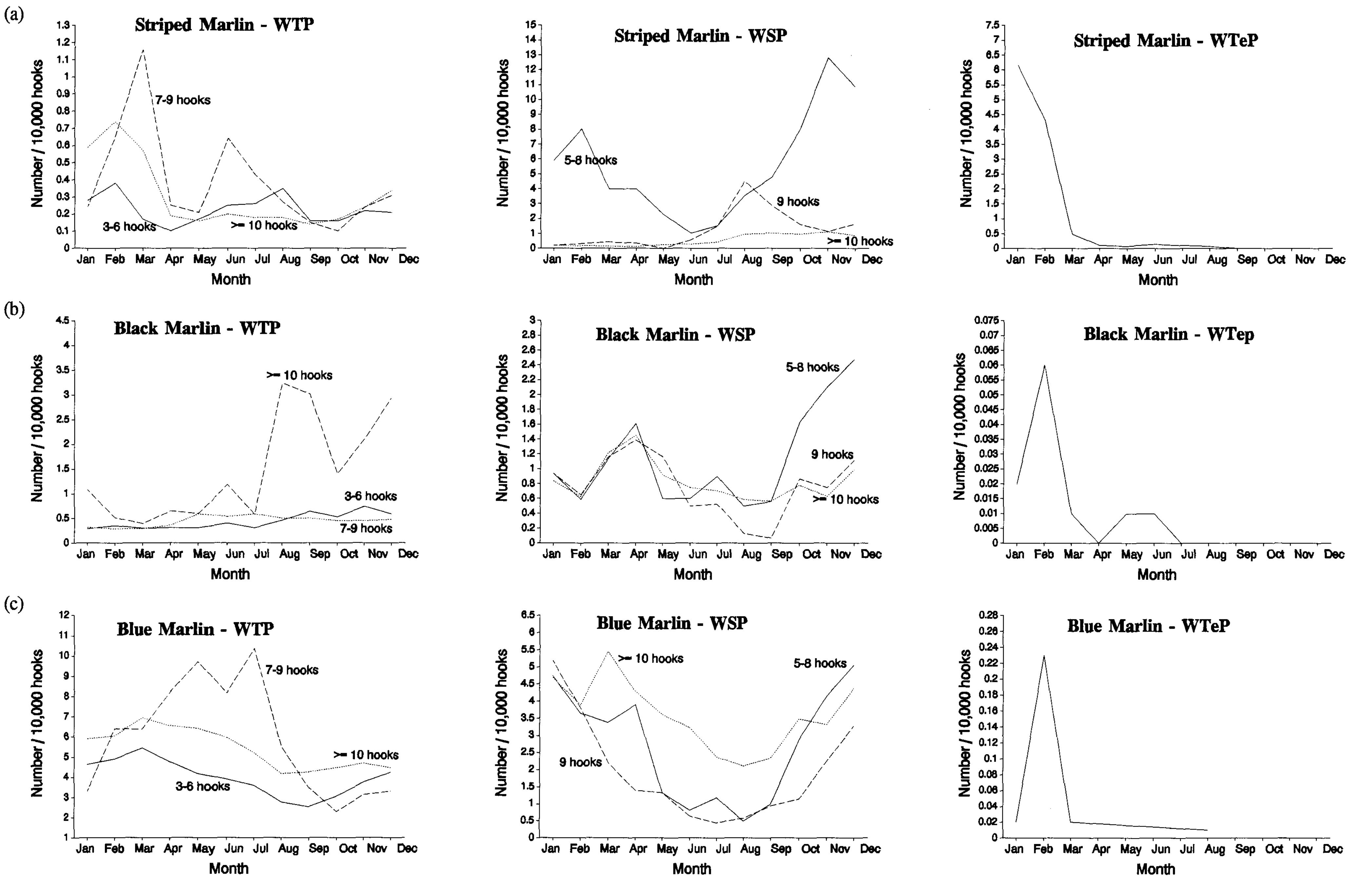
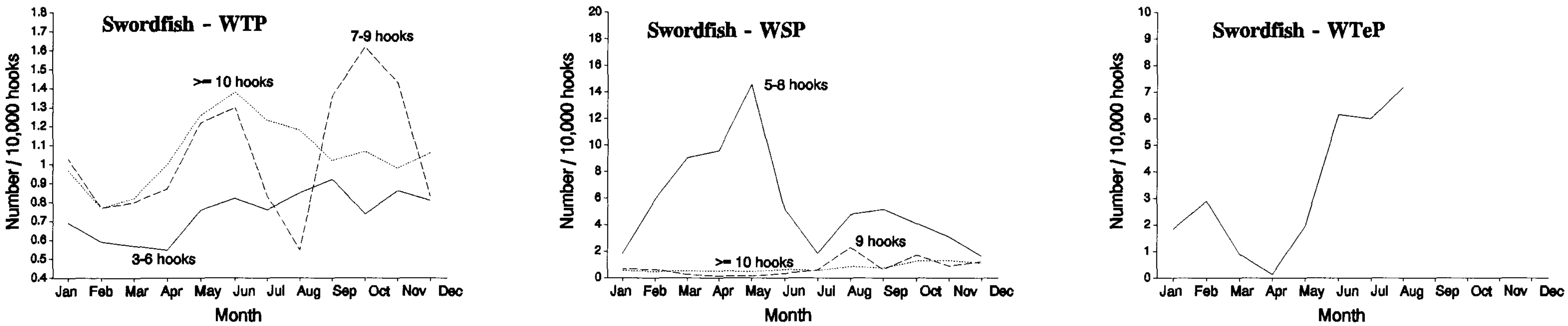


Figure 15: Seasonal longline CPUE for common by-catch species in areas of the WPO, stratified by categories of number of hooks per basket; source of data is the RTFD for 1978-1991. (continued)

(d)



(e)

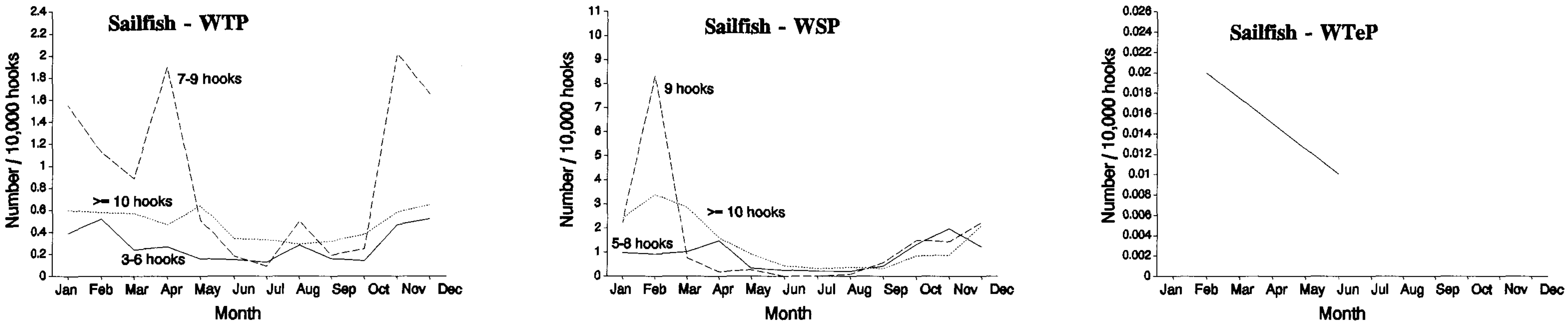


Figure 16: CPUE and percentage catch composition of common longline by-catch species in the WPO, stratified by number of hooks per basket. Source of data is the RTFD; catch composition is the percentage number of the billfish species to the total catch for days where at least one of the species was recorded.

(a) Striped Marlin - WSP

(b) Striped Marlin - WTP

(c) Black Marlin - WSP

(d) Black Marlin - WTP

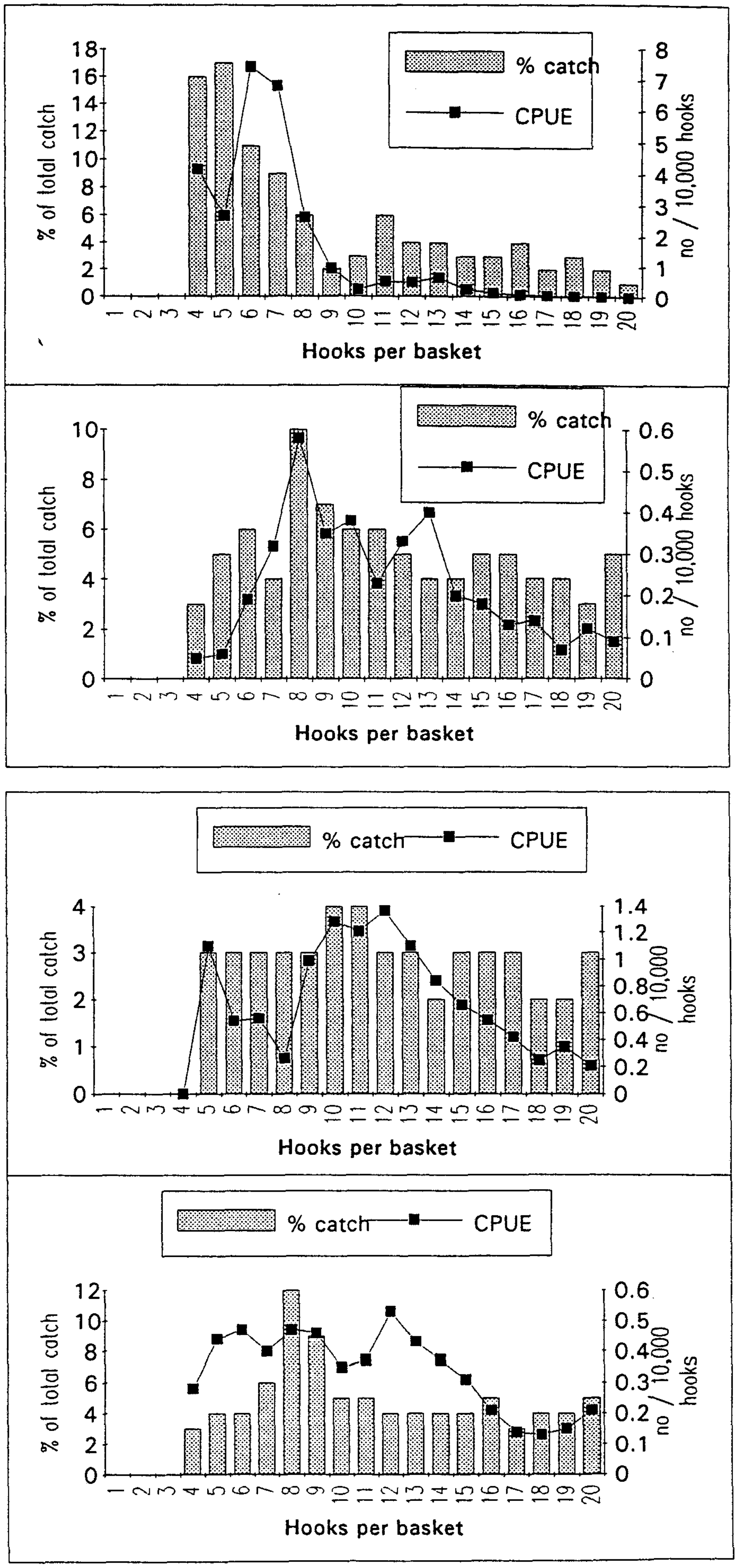
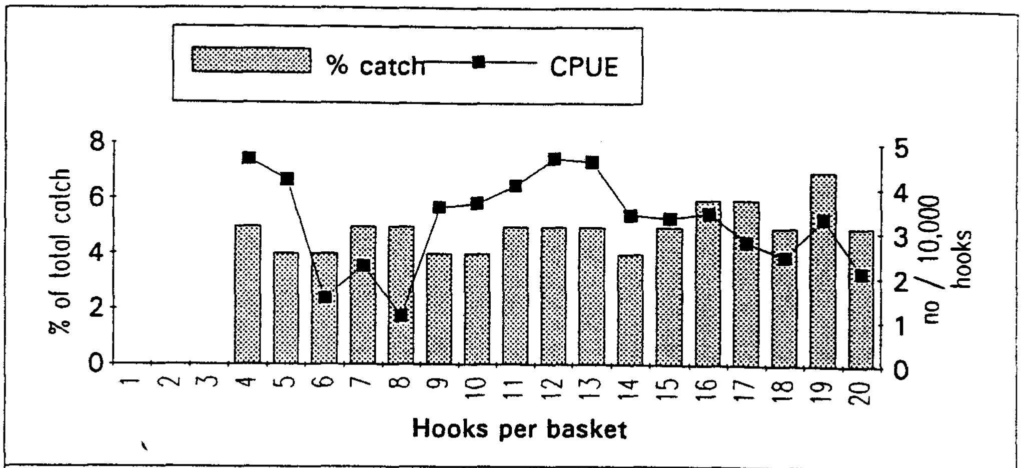
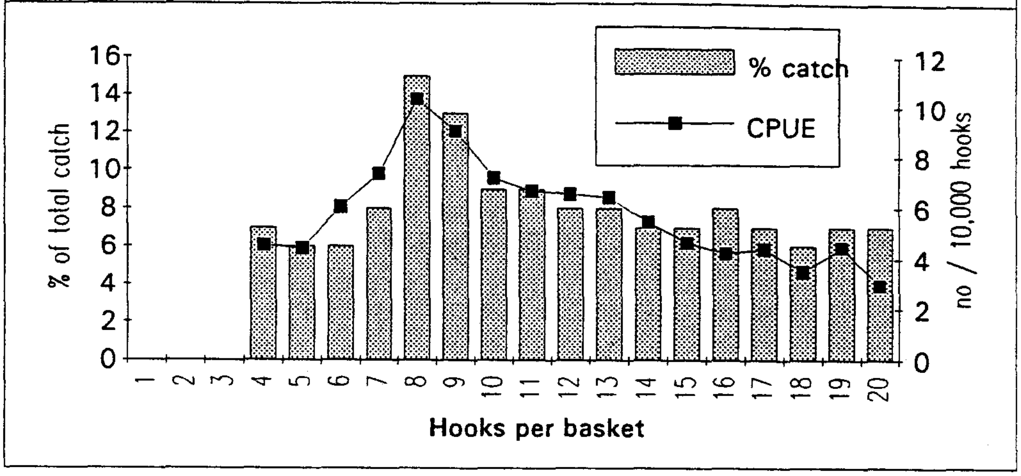


Figure 16: (continued)

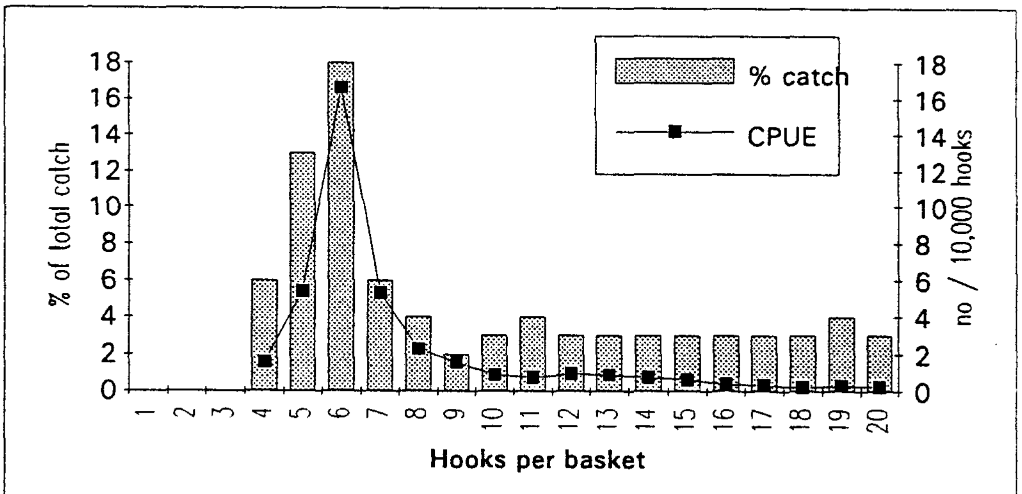
(e) Blue Marlin - WSP



(f) Blue Marlin - WTP



(g) Swordfish - WSP



(h) Swordfish - WTP

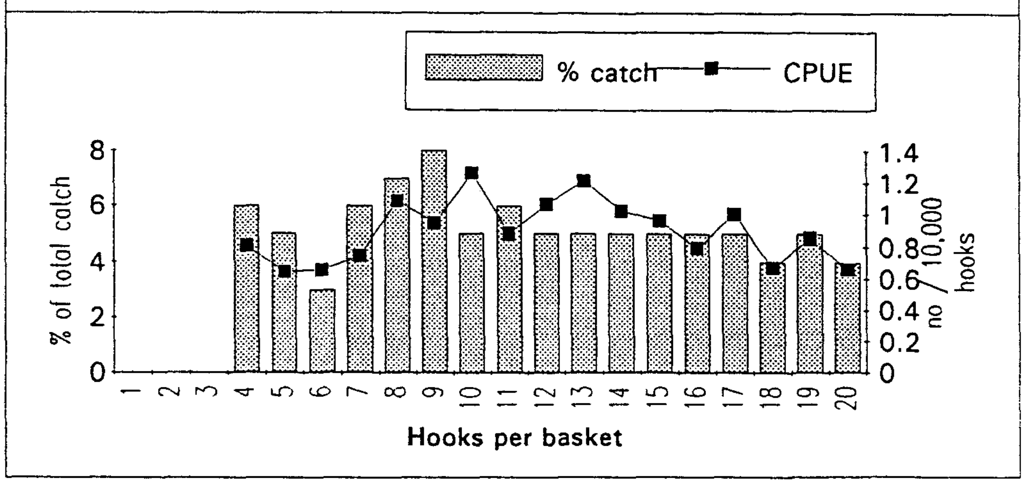
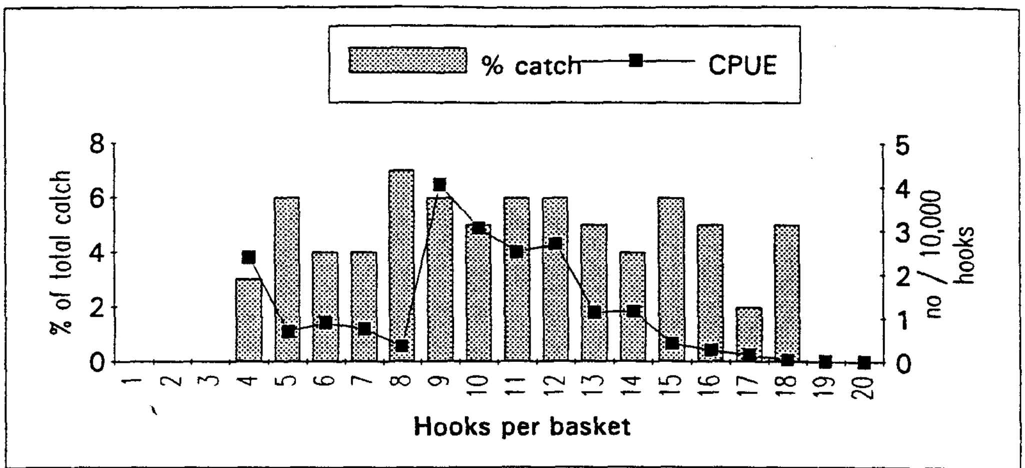


Figure 16: (continued)

(i) Sailfish - WSP



(j) Sailfish - WTP

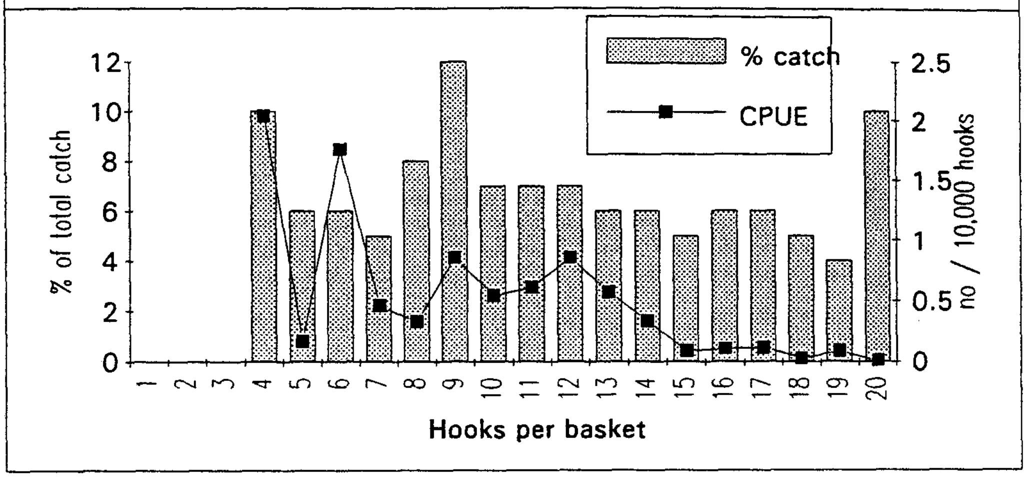
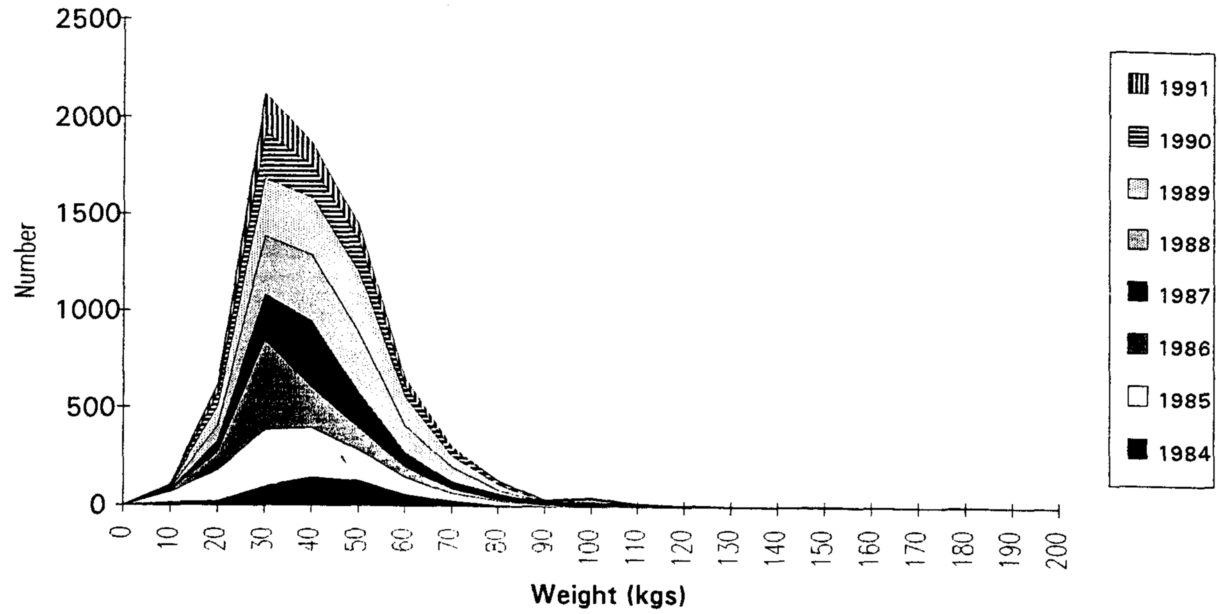
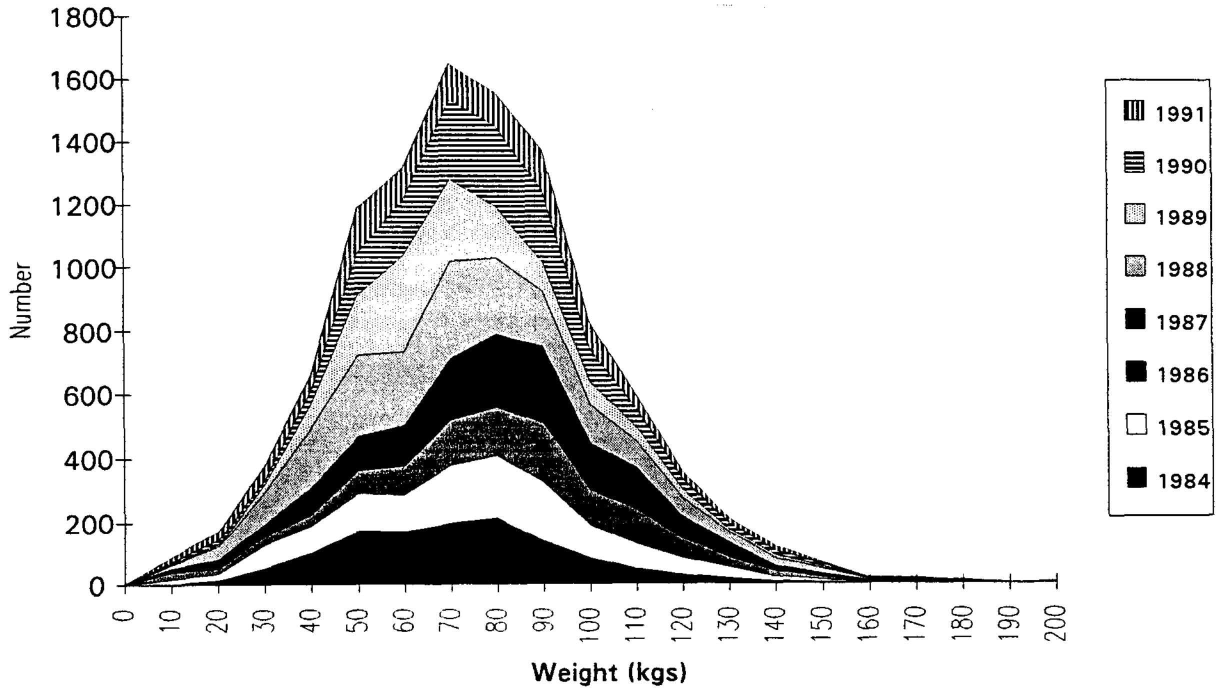


Figure 17. Size composition of STRIPED MARLIN in the WPO, by year and area. (Source : RTFD database for days where only 1 of this species was recorded on the logsheet; weights have been rounded to the nearest 10 kgs; no allowance has been made for weight loss due to processing).

(a) WTP



(b) WSP



(c) WTeP

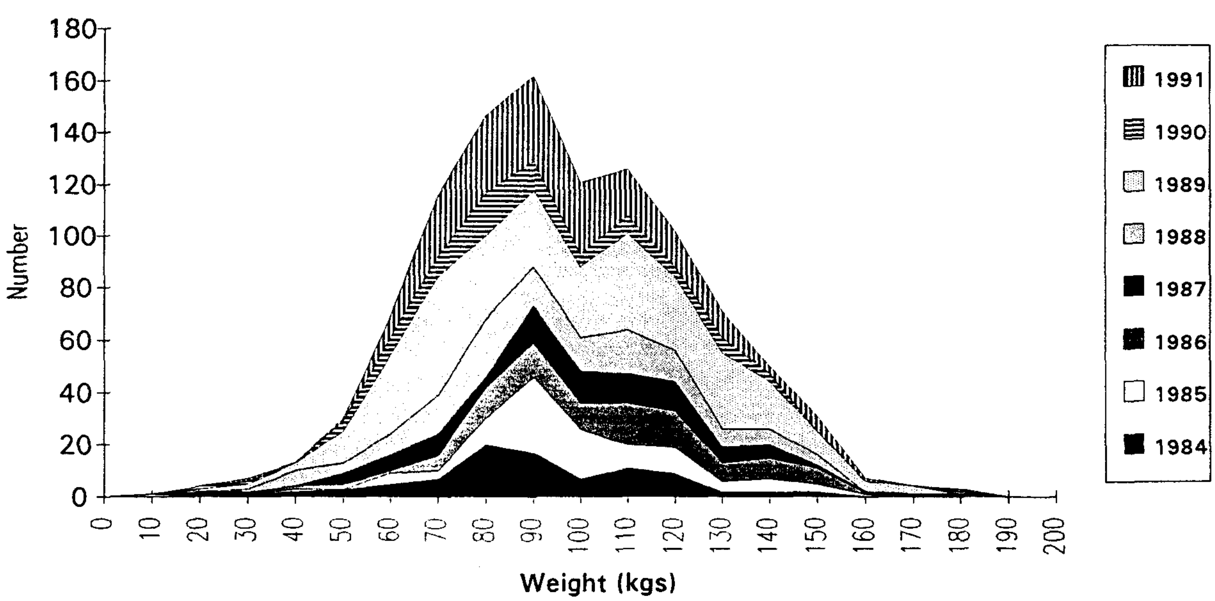
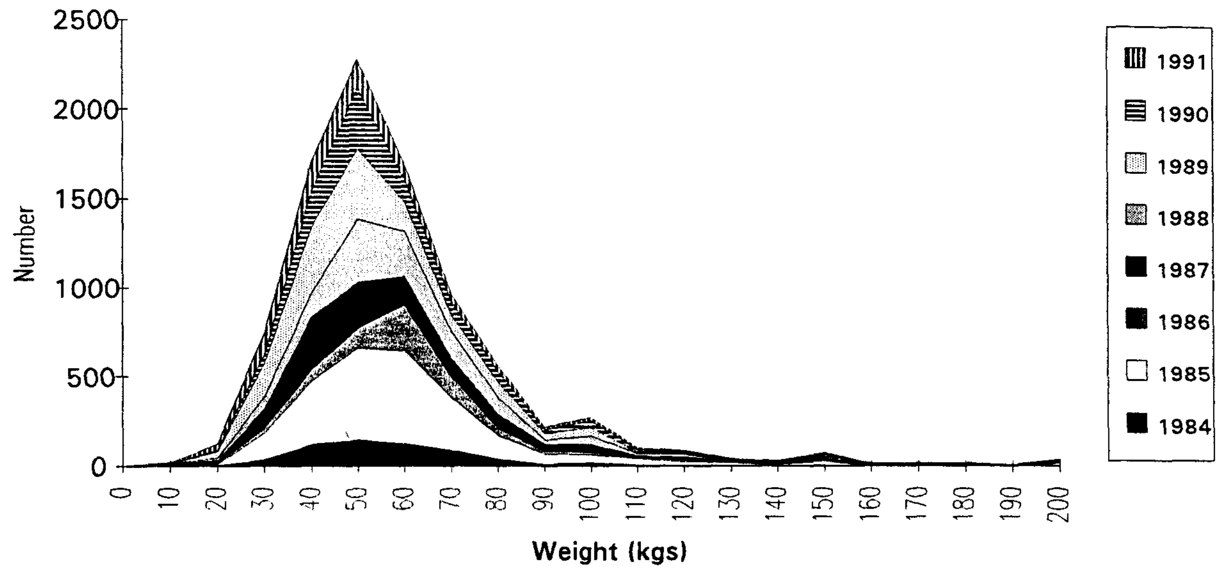


Figure 18. Size composition of BLACK MARLIN in the WPO, by year and area. (Source : RTFD database for days where only 1 of this species was recorded on the logsheet; weights have been rounded to the nearest 10 kgs; no allowance has been made for weight loss due to processing).

(a) WTP



(b) WSP

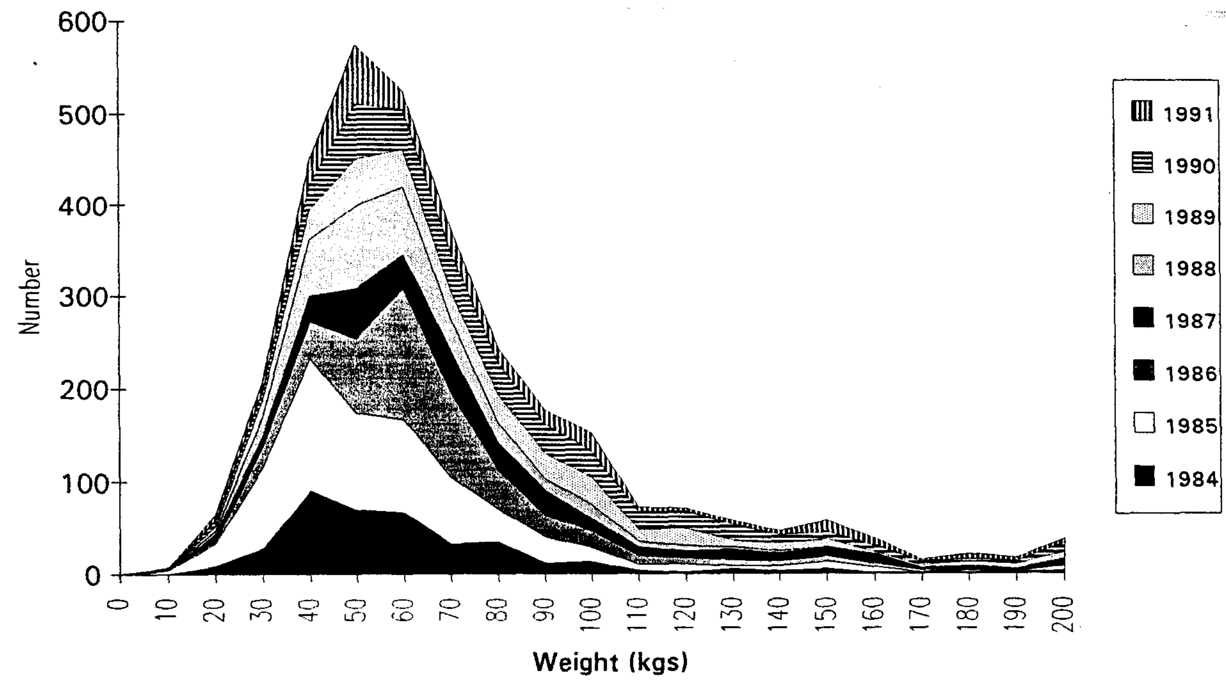
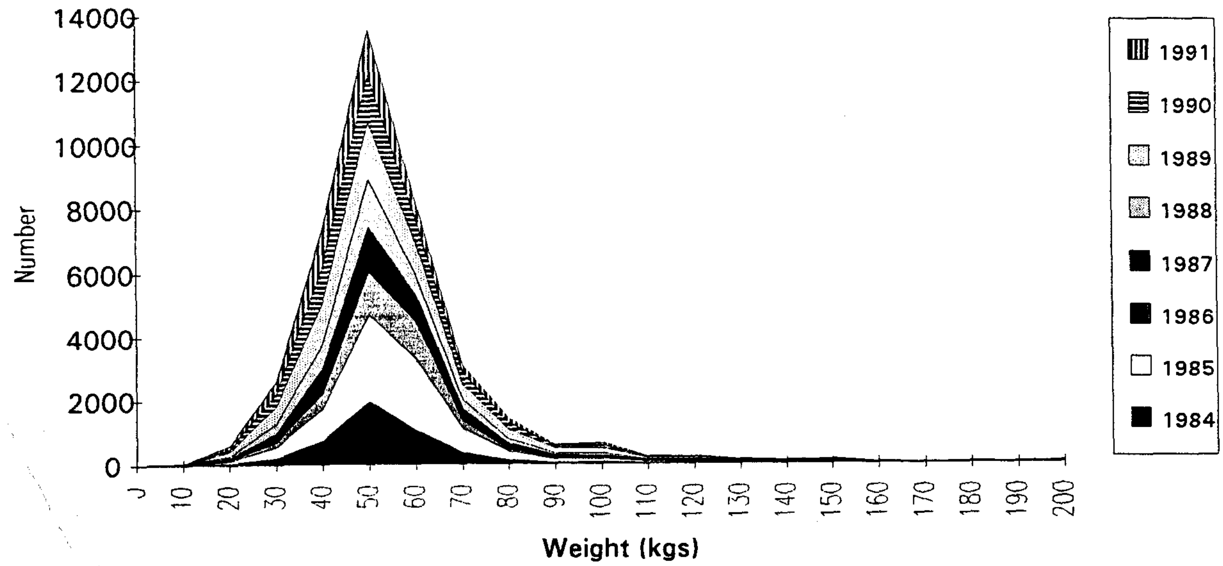
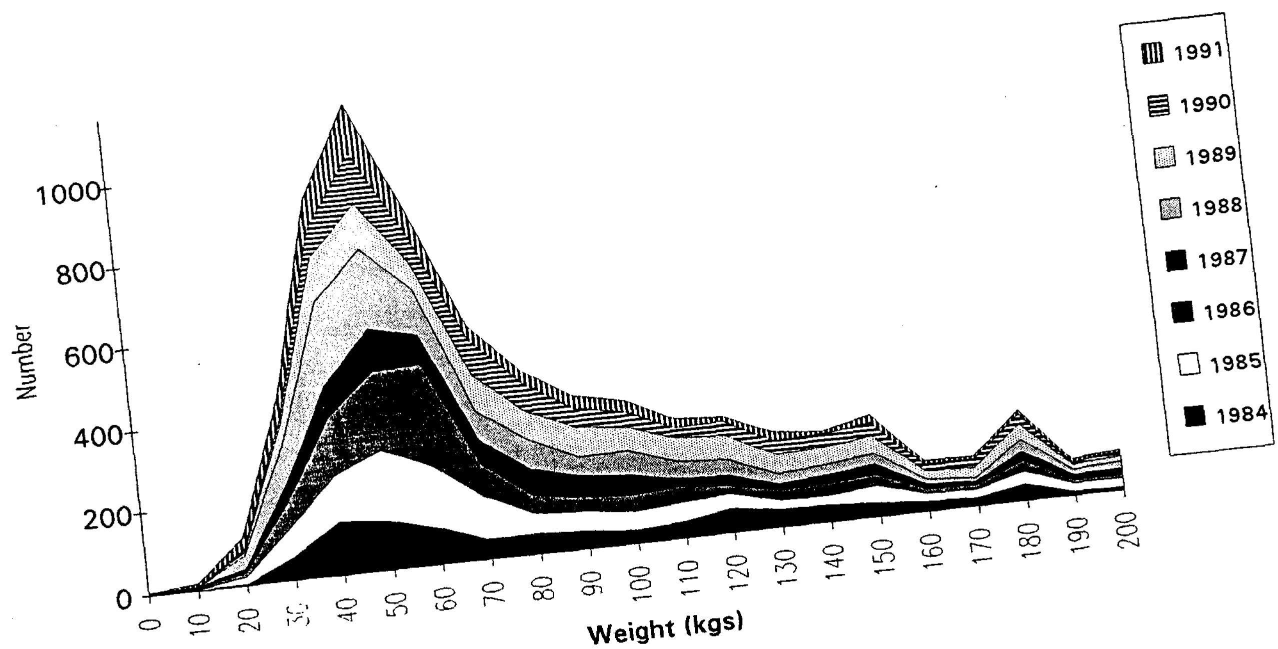


Figure 19. Size composition of BLUE MARLIN in the WPO, by year and area. (Source : RTFD database for days where only 1 of this species was recorded on the logsheet; weights have been rounded to the nearest 10 kgs; no allowance has been made for weight loss due to processing).

(a) WTP



(b) WSP



(c) WTeP

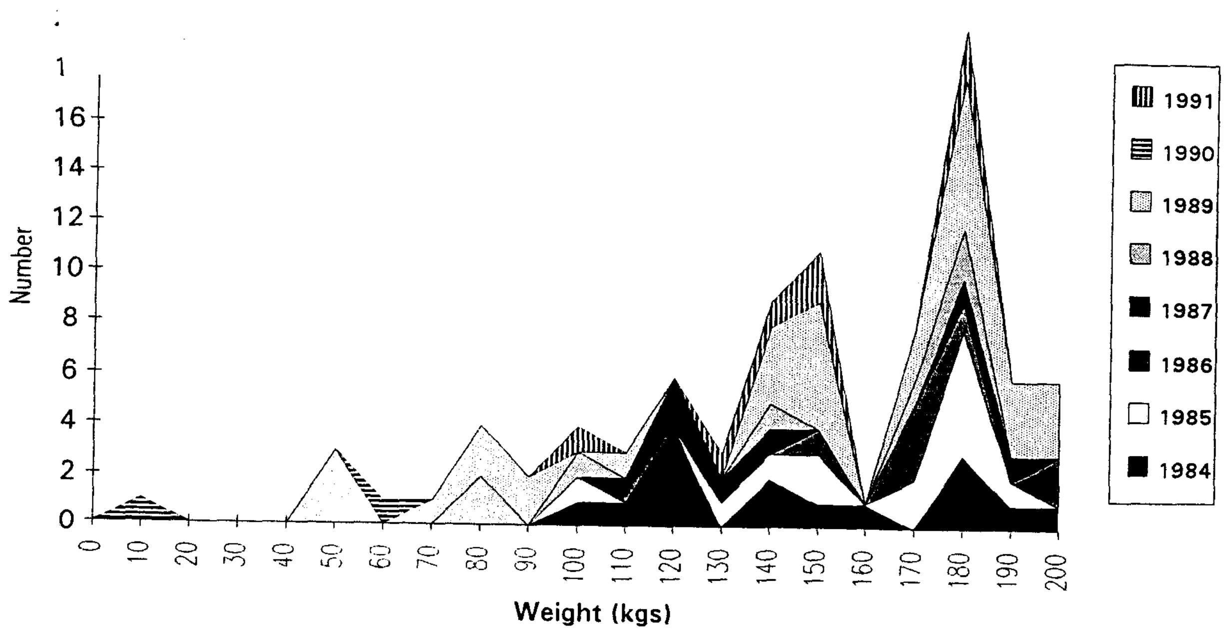
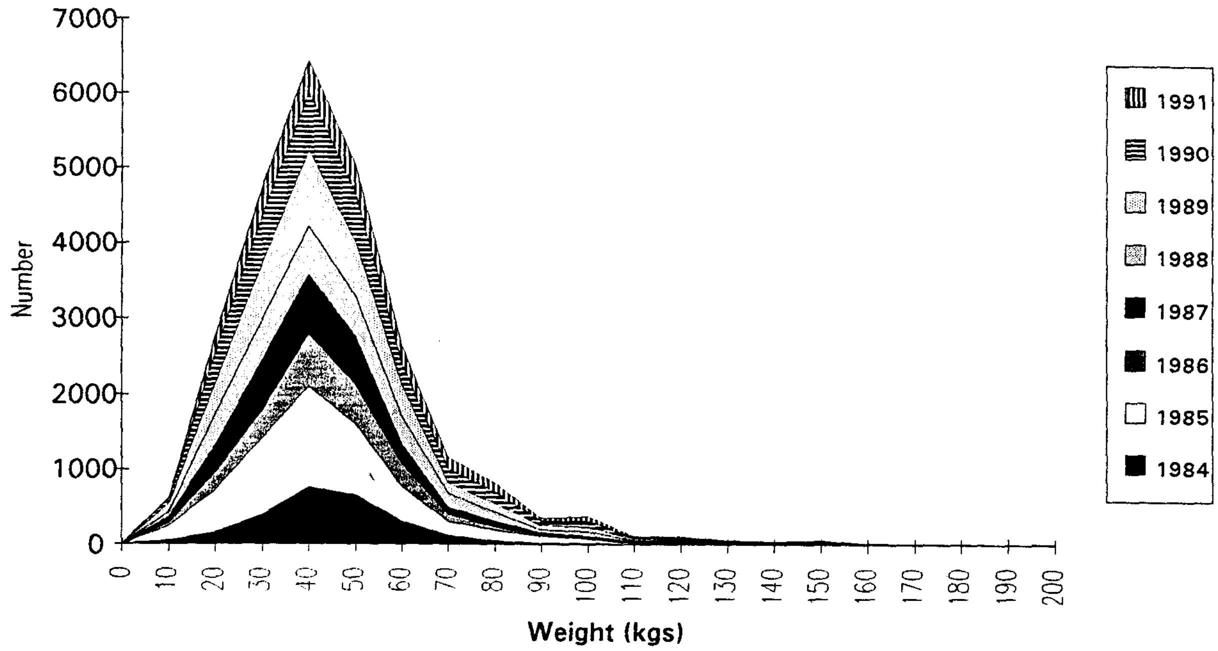
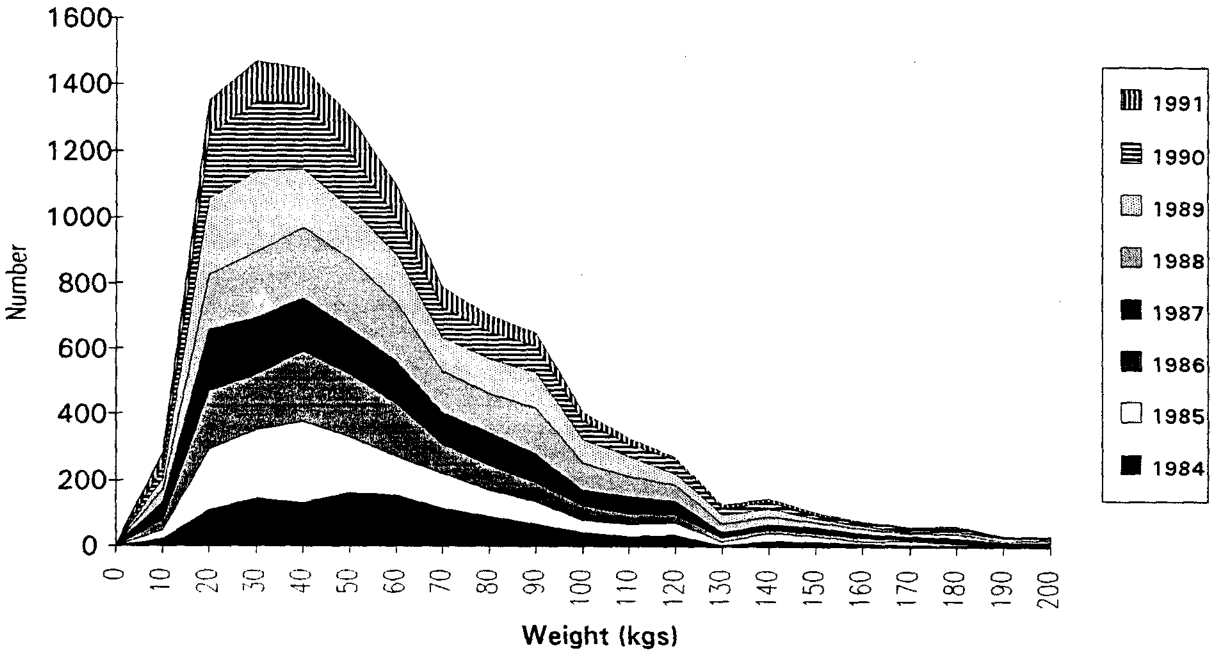


Figure 20. Size composition of SWORDFISH in the WPO, by year and area. (Source : RTFD database for days where only 1 of this species was recorded on the logsheet; weights have been rounded to the nearest 10 kgs; no allowance has been made for weight loss due to processing).

(a) WTP



(b) WSP



(c) WTeP

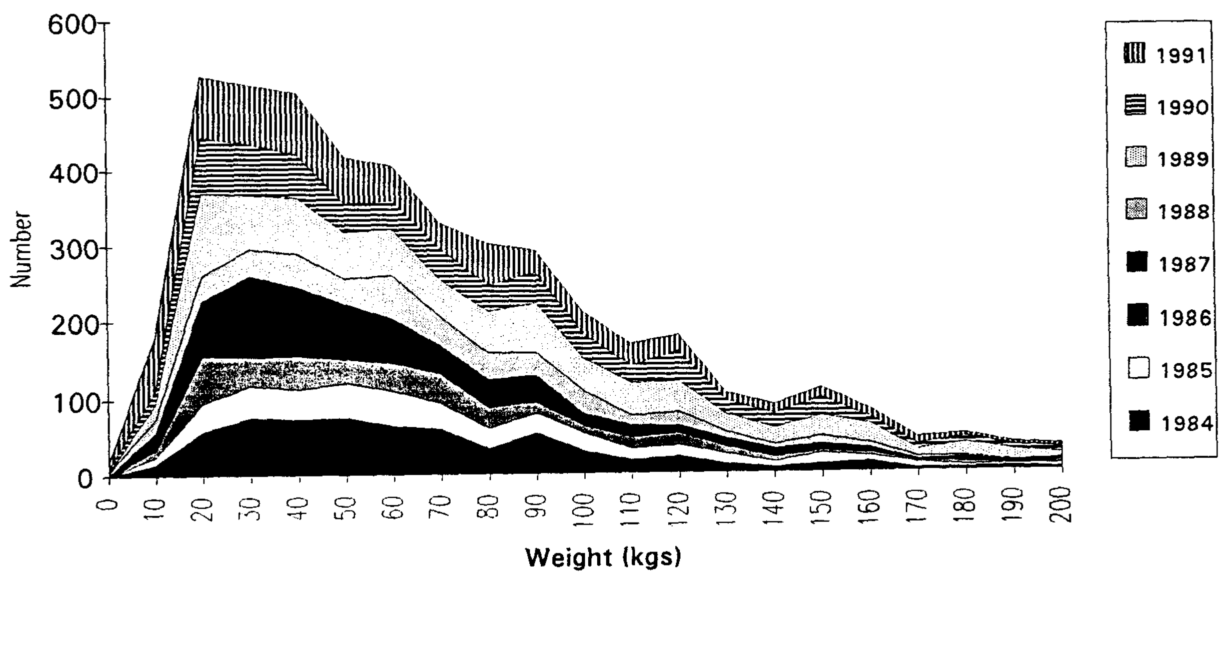
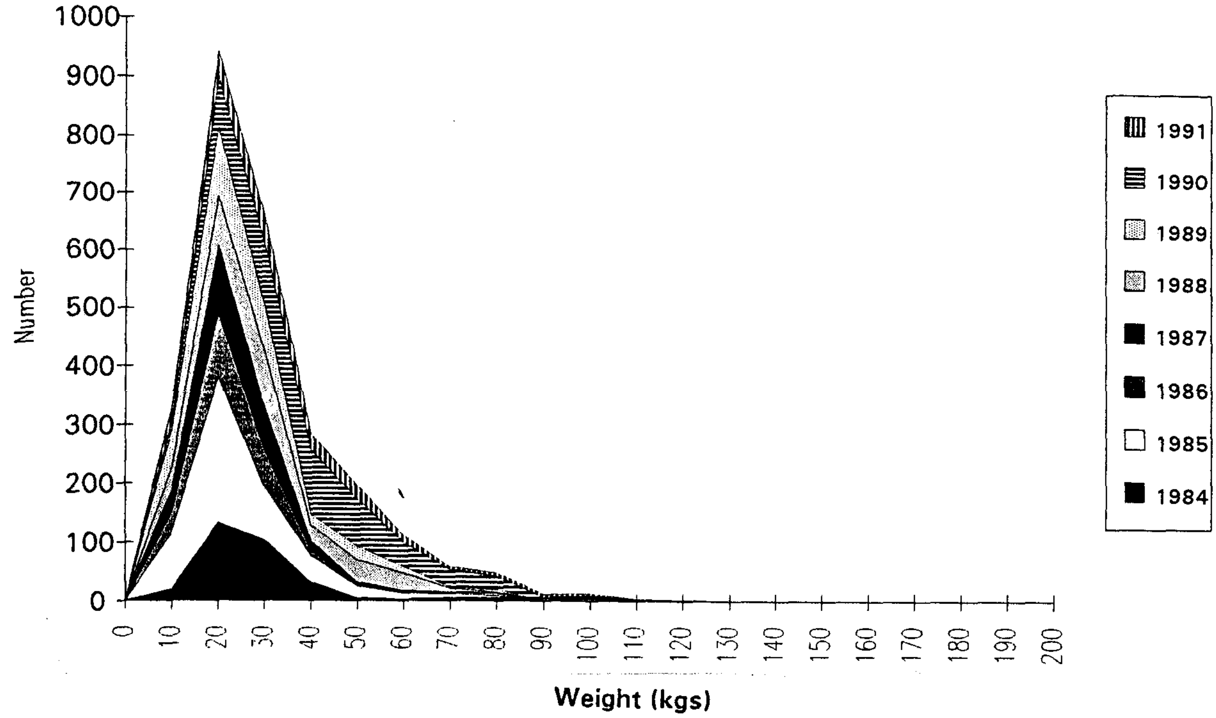
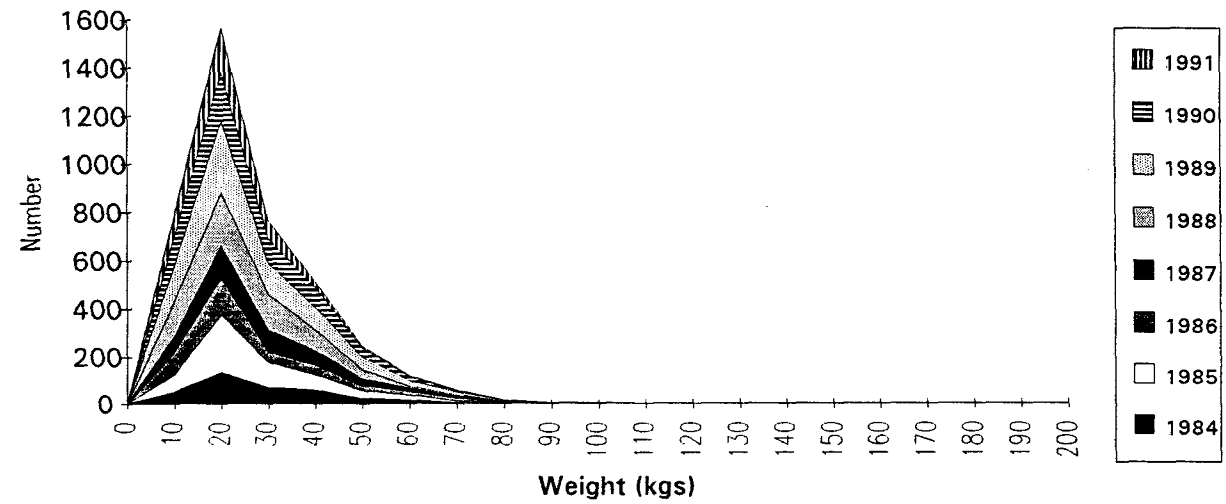


Figure 21. Size composition of SAILFISH in the WPO, by year and area. (Source : RTFD database for days where only 1 of this species was recorded on the logsheet; weights have been rounded to the nearest 10 kgs; no allowance has been made for weight loss due to processing).

(a) WTP



(b) WSP



(c) WTeP