CONFIDENTIAL REPORT TO THE MINISTRY OF FISHERIES

Tuna fisheries in the New Zealand EEZ and adjacent waters with special reference to stock status and swordfish bycatch

Talbot Murray, Kenneth Richardson, Hudson Dean, and Lynda Griggs

National Institute of Water and Atmospheric Research Ltd
(NIWA)
PO Box 14-901, Kilbirnie, Wellington

A report prepared for Ministry of Fisheries based on work funded under
Ministry of Fisheries Project TUN9701

CONTENTS

		Page
EXECUTIVE SUMMARY		iv
1	INTRODUCTION	1
2	DATA TREATMENT	2
3	TUNA FISHING METHODS	4
4	SPECIES CAUGHT IN NEW ZEALAND TUNA FISHERIES	9
5	ALBACORE	12
5.1	Distribution	13
5.2	Trends in catch and fishing effort	14
5.3	CPUE trends	14
5.4	Summary of biological data	17
6	BIGEYE TUNA	19
6.1	Distribution	20
6.2	Trends in catch and fishing effort	20
6.3	CPUE trends	21
6.4	Standardised CPUE trends	23
6.5	Summary of biological data	24
7	SKIPJACK TUNA	26
7.1	Distribution	27
7.2	Trends in catch and fishing effort	27
7.3	CPUE trends	28
7.4	Summary of biological data	30
8	SOUTHERN BLUEFIN TUNA	31
8.1	Distribution	32
8.2	Trends in catch and fishing effort	32
8.3	CPUE trends	33
8.4	Standardised CPUE trends	35
8.5	Summary of biological data	37
9	YELLOWFIN TUNA	40
9.1	Distribution	41
9.2	Trends in catch and fishing effort	41
9.3	CPUE trends	41
9.4	Summary of biological data	44

		Page
10	SWORDFISH	45
10.1	Distribution	46
10.2	Trends in catch and fishing effort	46
10.3	CPUE trends	47
10.4	Summary of biological data	49
11	DISCARD PRACTISES	50
12	DOMESTIC TUNA AND SWORDFISH LANDINGS	52
13	STOCK STATUS	55
14	ACKNOWLEDGMENTS	59
15	REFERENCES	60
APPENDIX I:	Data used for CPUE analyses, constraints applied, and examples of errors	64
APPENDIX II:	Characteristics of New Zealand tuna vessels fishing in 1996–97	68
APPENDIX III:	Catch composition by method and target species reported on CELR and TLCER forms	69
APPENDIX IV:	Summary of groomed catch and effort data by target species, method and fleet.	75
APPENDIX V:	Spatial distribution of CPUE and catch composition by species, method, and fleet	79
APPENDIX VI:	Biological parameters derived from longline caught fish	128
APPENDIX VII:	Trends in the bigeye tuna fishery in the New Zealand EEZ	131
APPENDIX VIII:	Models for southern bluefin tuna in the New Zealand EEZ	148
APPENDIX IX:	Summary of tuna and swordfish discards and status on landing on tuna longliners.	194

EXECUTIVE SUMMARY

This report summarises available information on the tuna fisheries for albacore (*Thunnus alalunga*), bigeye tuna (*T. obesus*), skipjack tuna (*Katsuwonus pelamis*), and southern bluefin tuna (*T. maccoyii*) operating within the New Zealand EEZ. Information on yellowfin tuna (*T. albacares*) and swordfish (*Xiphias gladius*), which are bycatch in these fisheries, is also discussed. Each species is treated as a major section beginning with a synopsis designed to place information derived from the New Zealand EEZ in the context of the stock as a whole, the fisheries in the Pacific Ocean and global catches. Subsequent sub-sections treat the distribution, domestic landings, foreign licensed catches, fishing effort of each fleet, frequency of each fishing method, and catch and effort trends for each species within the EEZ. Relative abundance indices are also derived for bigeye and southern bluefin tunas using standardised CPUE models. Observer data collected on board New Zealand and Japanese tuna longliners are used where possible to summarise information on sex ratios, size composition and to derive length–weight relationships for these species. In addition the main fishing methods used to catch tuna in the EEZ (ie, surface longlining, trolling and purse seining), discard practises and the data used in the various analyses are also reviewed in the report.

This report marks the first time that catch and effort from CELR forms has been incorporated. Previous reports had been restricted to the use of TLCER data due solely to difficulties in linking fields in the MFish catch effort data system which meant that several types of errors could not be detected. The effort directed at incorporating CELR data, and particularly detecting those fishing trips where catch was recorded as weight instead of number of fish caught, has enabled inclusion of the albacore troll fishery and additional domestic longline operations. The extensive data screening procedures for CELR data are described in the report. It was not possible, however, to apply corrections to positional errors in the CELR data as we have previously done with TLCER data due to lack of time. These errors will be addressed in future. The inclusion of the CELR has consequently permitted analysis of all of the major tuna fisheries operating in the EEZ.

The groomed catch and effort data was used to construct time series of CPUE for each fishery by target species and for yellowfin tuna and swordfish when they were caught. These nominal CPUE values are contrasted with similar fisheries in adjacent areas and in the case of bigeye and southern bluefin tunas, standardised using a GLM approach to provide an index of relative abundance. The section on status of the stocks reviews the trends in CPUE in the EEZ and compares the information provided in this report with analyses conducted on larger scales.

Of all stocks currently fished in the EEZ, bigeye and southern bluefin are cause for concern. In the case of albacore, skipjack and yellowfin tunas there appears to be little cause for concern over current harvest levels. Swordfish bycatch continues to increase as longline fishing effort expands and in the most recent year reached a new peak, swordfish catches, however, are still modest. In the case of bigeye, the concern is driven by surface fishery developments where increased targeting of mixed tuna schools is increasing the F's on juveniles. The extent to which declines in

standardised CPUE in longline fisheries are alarming is related to uncertainty in stock structure and the degree to which surface fishery removals may be affecting longline catches. Southern bluefin tuna continues to raise concerns that continuing increases in non-Party catches undermines CCSBT management objectives and may make current removals by Australia, Japan and New Zealand unsustainable. The most recent results of scientific analyses and stock assessment do not give cause for optimism regarding this stock.

1 INTRODUCTION

New Zealand tuna fisheries are based on stocks that occur largely outside of the 200 nautical mile Exclusive Economic Zone (EEZ), and are exploited by a number of fleets and gear types throughout the year. In New Zealand waters tuna represent important and valuable seasonal fisheries ($24.3 million in 1996). No tuna species are included in the Quota Management System and only southern bluefin tuna (*Thunnus maccoyii*), managed by the *Commission for the Conservation of Southern Bluefin Tuna*, is subject to catch restrictions, with a competitive national catch limit of 420 tonnes. Other tuna species of commercial importance to New Zealand are albacore (*T. alalunga*), bigeye (*T. obesus*), skipjack (*Katsuwonus pelamis*) and yellowfin tuna (*T. albacares*). While several billfish species are of commercial interest and comprise regular bycatch in tuna fisheries in adjacent high seas areas and EEZs, all billfish caught in the EEZ, except swordfish (*Xiphias gladius*), must be released when caught. Swordfish may not be targeted but can be landed by domestic fishers. This species has become increasingly important in the domestic tuna longline fishery as a valuable bycatch species.

Foreign licensed tuna fishing, primarily for southern bluefin tuna, has been declining since the late 1980s and no foreign licensed vessels have operated in the New Zealand EEZ since 1995–96. At the same time domestic tuna fishing has expanded through the increased use of longline for both southern bluefin and bigeye tunas. Japanese longliners on charter to the NZ Japan Tuna Company Ltd have fished five vessels each year since 1988–89 except 1990–91 (3 vessels) and 1995–96 (no vessels).

The domestic longline fishery has shown grown from 11 vessels in 1989–90 to a peak of 91 vessels in 1994–95. Fifty-three domestic longline vessels fished in 1996–97. These vessels targeted a mixture of albacore (14 vessels), bigeye tuna (42 vessels), and southern bluefin tuna (16 vessels) in 1996–97. The albacore troll fishery has a variable number of vessels fishing each year (213 to 470) over the period 1989–90 to 1996–97; in 1996–97 the albacore troll fishery included 289 vessels. The purse seine fishery for skipjack has been stable for many years at 5–6 vessels. Six vessels fished in 1996–97. Domestic tuna vessels may fish in a number of tuna and non-tuna fisheries during the year using a variety of fishing methods. Purse seiners are the only vessels that exclusively use one fishing method.

In addition to the tuna target species, several other valuable species (swordfish, marlins, mako shark and others) together with commonly caught species of little or no commercial value (eg, blue shark) comprise the incidental catch in the longline fishery. The species composition and quantity of bycatch taken in longline fisheries in the EEZ is summarised by Francis *et al.* (1998). The bycatch of gamefish species, particularly marlins, has raised concerns about the potential for interaction between commercial longline and recreational fishers. The large bycatch of some oceanic sharks has also focused attention on the potential for impacts on a range of dependant or associated species, particularly those that are rare, that have low fecundity or about which little is known. Similarly, for purse seine fishing in the EEZ a wide range of fish taxa (over 60 species) have been taken as bycatch in sets targeting skipjack tuna (Habib *et al.* 1982). Trolling and other tuna fishing methods do not appear to have an appreciable bycatch.

This report summarises the outputs of Ministry of Fisheries project TUN9701 entitled "*Stock assessment of tunas in support of New Zealand's international fishing agreements*". Additional outputs produced through this project include unpublished reports, analyses and advice to New Zealand delegations to the Commission for the Conservation of Southern Bluefin Tuna and its subsidiary bodies, and to the South Pacific Forum Fisheries Committee and its preparatory sub-committees for the Multilateral High Level Conference on Alternative Management Arrangements for Central and Western Pacific Tuna Stocks. Summary information has also been produced for the South Pacific Commission's Standing Committee on Tuna and Billfish and for its South Pacific Albacore Research Group and Western Pacific Yellowfin Research Group. Supplementary analyses have also been done for the Ministry of Fisheries as required.

2 DATA TREATMENT

The data used in this report are collected and compiled by the Ministry of Fisheries (MFish) from forms supplied by the commercial fishing sector. These data originate from forms filled out by fishers on each operation directed at catching tuna using trolling, purse seine or longlining, by licensed fish receivers, and by MFish observers. The data are provided to NIWA through "views" of the MFish *Catch and Effort* database. Data on trolling, purse seine and longlining come from the MFish Catch, Effort and Landing Return (CELR). Most data on tuna longlining, however, comes from the Tuna Longlining Catch, Effort Return (TLCER). A description and examples of these forms and the requirements for filling them out are specified in the Fisheries (Reporting) Regulations of 1990. Both the CELR and TLCER forms enable fishers to provide information on their catch (in number and in estimated weight) by species for each fishing operation together with information on the amount of fishing gear employed, area fished, and on environmental factors which might affect fishing.

The TLCER has been used in nearly the same format since it was introduced in 1980 for foreign licensed vessels. The CELR, however, has varied over the same time period. While fishers are now required to fill out the catch on the Trip Data portion of the CELR form as number of fish caught for all tunas and swordfish (for both the Lining Methods and Other Lining Methods Templates), this was not so for the first few years after the form was introduced. We found that some fishers are continuing to report their catch of tuna and swordfish as estimated weights, at least occasionally, through to 1996–97. We also found some fishers report catching tunas using method codes not associated with tuna fishing. In part this is probably due to fishers confusing the codes for trawling, trot lining, trolling, and various other lining methods. A number of unusual method codes exist in the MFish database (eg, bottom longlining, set netting), it also appears that fishers catching tuna for rock lobster bait regularly record their catch as "Rock Lobster Potting". Tuna catches by methods other than trolling, purse seine or surface longline are not included in this report but will be incorporated in future analyses when a method of dealing with erroneous codes has been developed.

In grooming data for this project we used a number of detection criteria to identify errors in catch, effort and position in a "research" version of the official MFish catch effort data. Position errors have been detected graphically and analytically to identify fishing positions and sequential position changes that are impossible. A number of range checks were also done on position, units of effort, duration of fishing, amount of catch, sea surface temperature, and operational details to detect unlikely data. All probable errors were then checked individually against the original form or, more usually, against a number of fishing operations by the vessel in question that precede and follow the operation in question. Where there was clear evidence of an error in recording or data entry (e.g., numbers transposed, longitude recorded as W instead of E, decimal point misplaced, etc) these were replaced with the value used elsewhere in the trip (if constant) or by the mean of adjacent values. Difficulty in linking fields from the MFish CELR data, which are used here for the first time, meant that positional errors could not be corrected for these data. These errors will be addressed in future analyses.

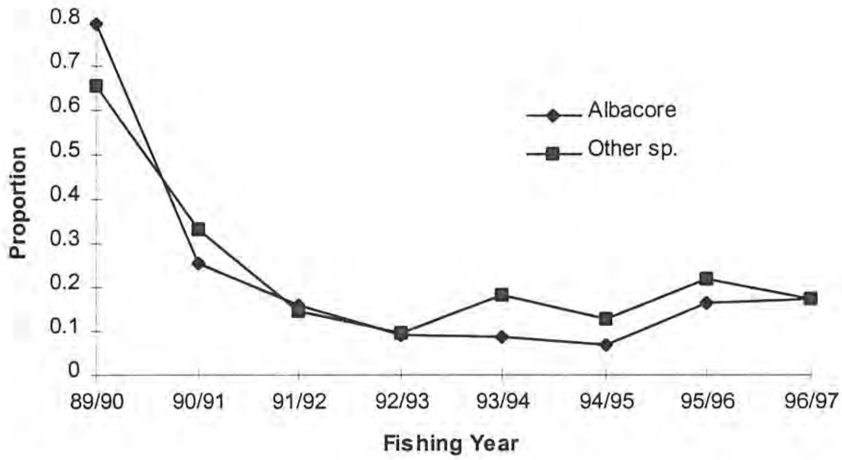
We have also applied range checks on average fish size so that the data used for CPUE analysis do not include fish that are either too small or too large to have been caught in the EEZ by a given method. Limits imposed to restrict fish size were taken from Labelle and Murray (1992) for troll caught albacore. Maximum sizes of tunas and swordfish were taken from Collette and Nauen (1983) and Nakamura (1985). Minimum fish size restrictions were derived from MFish observer data for longline caught fish. Information on minimum and maximum fish sizes were applied as constraints on CELR data only since it could be demonstrated that some fishers reported their catch as weights where number of fish was required (see Appendix I(F)). This does not appear to be the case with fishers filling out the TLCER.

Information on maximum catches per trip and duration of trip was provided by industry experts (Peter Reid for skipjack purse seining and Roger Burgess for albacore trolling). All error corrections were applied to a "research version" of the MFish data held by NIWA in a relational database. The structure and content of the NIWA tuna catch and effort database are described by Dean (1998).

Errors which were identified during analysis (i.e. those that past the first order detection and error correction) include wrongly assigned fishing method codes, target species as well as catch that appears to be wrongly assigned to species. It is not known how often this happens but an obvious example is striped marlin (STM) where this species does not occur but southern bluefin tuna (STN) are caught. These errors exist in both the TLCER, to a limited extent, and more extensively in the CELR data. The effect of these errors on the current analysis is considered to be slight. These errors, however, will be corrected or procedures developed to identify a coherent data subset for CPUE analysis in the subsequent tuna stock assessment project.

The constraints applied, examples showing the proportion of usable data, and a summary of the amount of data available for analysis by form type are given in Appendix I. Prior to the introduction of the CELR form (1988–89), tuna catch and effort were reported through the MAF Fisheries Statistics Unit on method specific catch and effort logbooks where tuna catch was recorded in number of fish. However, for the first two years following the introduction of the CELR form, catch was required to be recorded as estimated weight. Not only did this nullify the use of tuna catch data for CPUE analyses but also interrupted a time series of data. A further unfortunate consequence of the realignment of the MAF catch and effort data at this time was the corruption of data from 1976 to 1988 which was translated from catch in number to an estimated weight. From 1990–91 fishers were instructed to fill out the catch portion of the CELR as catch in number and since that time many fishers have complied. Figure 1, however, shows that there is a persistent problem with about 20% of all tuna catch recorded as weight instead of number of tuna caught even in recent years.

Figure 1. Proportion of fishing trips from CELR data where the catch of albacore and all other species, except skipjack, is recorded as weight instead of number of fish 1989–90 to 1996–97.



In addition to catch recorded as weight, our analysis indicates several other sources of error have been excluded from the analyses. These include catch recorded as weight, trips where the average weight of the catch was smaller than the lower size limit for a species, trips where the average size was larger than the maximum size for a species, trips where the catch of a species exceeded the maximum amount possible, and trips where the fishing effort was either too little or too large. Appendix I(F) demonstrates several of these errors using albacore as an example.

When all constraints are applied to the CELR data for the main target species and tuna fishing methods, a moderate proportion of troll and purse seine fishing trips are excluded from the analyses (32.4% and 39.4%, respectively). Appreciably more longline fishing trips were also excluded (48.2% of trips targeting bigeye and 61.6% of trips targeting southern bluefin tuna). Appendix I(D) lists the constraints applied to each method and species and Appendix I(E) shows the number of days fishing remaining after each constraint is applied consecutively.

3 TUNA FISHING METHODS

All tunas spend at least their juvenile life history phase near the surface where they are vulnerable to trolling, purse seine and pole-and-line fishing methods. The most effective fishing method varies with species, season and latitudinal area. Skipjack are vulnerable to surface fishing methods throughout their life while the other tuna species found in the EEZ are vulnerable to surface fishing methods as juveniles and as adults are vulnerable to longline and handline fishing. Swordfish which are an important bycatch can not be targeted in the

EEZ but are regularly caught on longlines and occasionally by recreational fishers line fishing deep. Swordfish do not appear to be vulnerable to trolling but have been reported (rarely) as bycatch in the skipjack purse seine fishery (Habib *et al.* 1982).

As tunas (except skipjack) grow into adults they tend to be found at greater depths. Consequently most tunas become less vulnerable to surface fishing methods and become increasingly vulnerable to longline fishing. Tuna longlines are set to place the hooks in the depth range preferred by a species which can be in excess of 300 m. The preferred depth for a tuna varies with species, season, areas of forage concentration and geographical area.

A wide range of vessel types fish for tuna in the EEZ. Of these, only those engaged in purse seining and some involved in tuna longlining (i.e., primarily those built in Japan) are purpose built tuna vessels. Most vessels engaged in tuna fisheries also operate in a range of other fisheries. The age, length, beam and GRT of vessels fishing for tuna are summarised in Appendix II. As well as a diverse fleet, the New Zealand tuna fisheries also employ a range of fishing methods (see Appendix I(A) for the number of vessels using each method). Although other tuna fishing methods (e.g., handline and pole-and-line) are used in New Zealand tuna fisheries, the main methods for the species considered in this report are trolling, purse seining and longlining. These methods are depicted in figure 2.

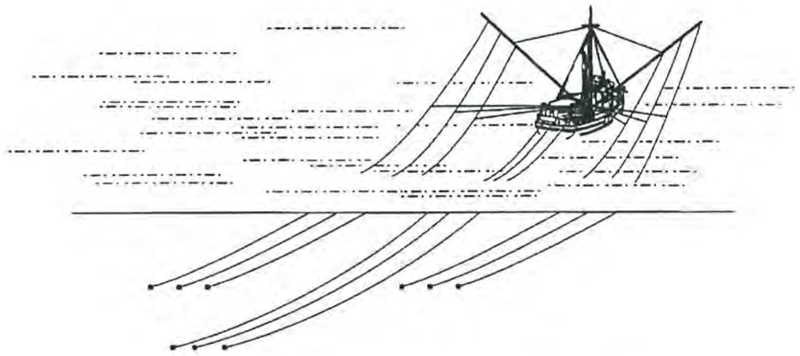
In New Zealand, albacore form the basis of a summer troll fishery primarily on the west coasts of the North and South Island, with annual landings of about 1000-6000 tonnes. Albacore are also caught throughout the year by longline (usually ≤ 1000 t per year). Bigeye, the second most valuable tuna (per kg), are caught by longline around the northern half of the North Island throughout the spring – autumn period, though landings have been < 90 t per year. Skipjack are caught in small numbers by trolling but the large majority of the catch (usually 1000–6000 t per year) is caught by purse seine during summer months. Southern bluefin tuna traditionally have been caught by handline and trolling during winter months off the West Coast of the South Island from small vessels. These methods are still occasionally used. Most southern bluefin tuna, however, are caught by medium to large (20-50 m) longline vessels in autumn – winter months. Southern bluefin catches, restricted to a national competitive catch limit of 420 t since 1989, have usually been below this limit.

Yellowfin, caught in small numbers in the troll and purse seine fisheries, are generally a bycatch of longline sets targeting bigeye in summer months and landings are < 200 t per year. Like yellowfin, swordfish is a bycatch of longline sets targeting bigeye or southern bluefin tunas. Swordfish catches have been increasing over the last five years but are still < 300 t per year. Swordfish are caught around both the North and South Islands.

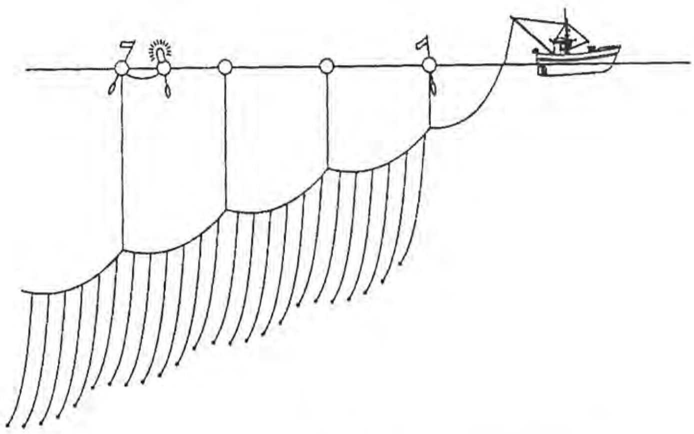
Trolling

Trolling dates from the 1960s and was one of the earliest methods developed for tuna fishing in New Zealand waters. The primary target species is albacore during summer. A wide range of vessel sizes use this method primarily for albacore during summer months when they are not engaged in other fisheries (eg, inshore trawl, rock lobster potting, danish seine, scallop dredge, other lining methods, etc). Trolling is a dawn to dusk operation with catches usually declining during the middle of the day. Most trolling operations last up to 17 hours per day in summer (mean = 12.5 hours) with shorter periods associated with shorter day lengths (eg winter) or part day fishing.

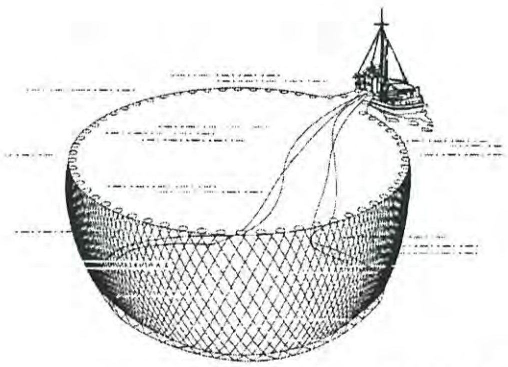
Figure 2. Primary fishing methods for albacore, bigeye and southern bluefin tunas in the New Zealand EEZ (adapted from Carocci and Majkowski, 1996).



Trolling



Tuna Longline Fishing



Purse seine Fishing

In albacore trolling 10–12 lines are usually spaced across the stern and along two outriggers so the lines trail behind the boat while it steams at 7–9 knots, though a few vessels will fish up to 20 lines (mean = 11.7 lines). Each line has an artificial lure with a double barbless hook and is set to lie in or just outside the vessel's wake. Lines across the stern tend to be the shortest while those which are spread to the side of the boat by the outriggers are progressively longer the further they are from the boat. Typically lines are hauled by hand. Albacore are not processed but are held on ice with trips generally 3.1 to 4.7 days (derived from CELR data for 1989–90 to 1996–97). Some trolling is occasionally done during winter for southern bluefin tuna. In this fishery fewer lines are trolled at slower speeds but the method is otherwise similar. Detailed descriptions of how to rig a vessel for trolling can be found in Dotson (1980) and Chapman (1992).

Longlining

Two longline fleets operate in the EEZ. A growing and very diverse fleet of New Zealand owned and operated longliners uses monofilament mainline and a fleet of five Japanese owned and operated longliners chartered by the NZ Japan Tuna Company Ltd. which are increasingly using 8-strand multi-filament rather than the traditional kuralon mainline.

Longlines are played out as the vessel is steaming while the crew place buoy lines and dropper lines (or snoods) at regular intervals. The buoy line allows the mainline to sink to a predetermined depth and the rate at which the mainline is set allows it to sag so that the hooks fish a broad depth range. Regularly spaced between each buoy are a variable number of dropper lines, each with a single baited hook or artificial squid lure. The greater the sag in the mainline and the larger the distance between floats, the deeper hooks can fish. These factors are varied to allow fishers to target different depths for each target species which in tropical waters can exceed 400 m (Boggs, 1992). Observers report that longline fishers usually try to set hooks shallower than 155 m regardless of whether they target bigeye or southern bluefin tunas and do attempt to set lines as deep as 290 m and as shallow as 50 m in the New Zealand EEZ.

The number of hooks between each buoy (termed, for historical reasons, a basket) is related to the distance between floats and hence the depth to which hooks can sink. Mainline material and how the gear is set also affect the depth which hooks reach with increased line shooting speed resulting in more longline sag and hence hooks reaching greater depths. The depth that the gear can fish is also affected by currents and surface weather conditions. Yano and Abe (1998), using monofilament and multifilament mainlines in tropical waters, demonstrated that multifilament longlines fish deeper (about 50 m) and sink faster (about 2 m/min) than monofilament longlines. The maximum depth these authors found hooks to reach averaged 211.4 m for multifilament longlines with 10 hooks per basket and 119.8 m for the same material with 5 hooks per basket. Observers have collected data on the longline characteristics of vessels in each fleet which is summarised in Table 1. In New Zealand the number of hooks per basket ranges from 6.2 (foreign licensed vessels) to 10.2 (domestic vessels) with charter vessels using an intermediate configuration (6.9 hooks per basket). Although we lack direct measurements of hook depth, the results of Yano and Abe (1998) suggest that longlines set in the EEZ are typically fishing at maximum depths of 100–211 m.

Table 1. Summary of the characteristics of tuna longlines used in the EEZ based on observer data (D = NZ owned and operated, C = charter vessels, F = foreign licensed).

Longline characteristic	Fleet	mean	Lower 95% C. I.	Upper 95% C. I.	n
longline length, km	D	63.4	22.6	115.7	407
	C	135.6	114.0	151.0	808
	F	132.1	89.0	152.0	501
Number of hooks per set	D	1363	540	2730	407
	C	3037	2520	3500	808
	F	2942	2400	3600	507
Number of baskets per set	D	133	32	274	407
	C	438	285	530	808
	F	471	400	530	505
Buoy line length, m	D	12.6	8.0	15.0	407
	C	13.9	11.0	15.0	808
	F	16.7	10.0	41.0	504
Snood length, m	D	11.3	8.0	20.0	407
	C	38.2	33.0	46.0	237
	F	37.6	35.0	41.6	65
Setting time, h	D	3.7	1.9	6.1	407
	C	5.5	4.4	6.2	808
	F	5.4	4.4	6.1	507
Soak time, h	D	7.9	2.6	14.2	407
	C	4.7	3.8	5.4	808
	F	4.7	4.1	5.3	506
haul time, h	D	8.4	4.2	14.4	407
	C	12.1	10.4	13.8	808
	F	11.9	10.2	13.4	506

The number of hooks each vessel sets in a single fishing operation depends largely on vessel size. Japanese vessels (foreign licensed and charter fleet) and a few domestic longliners originally built in Japan are about 50 m LOA and set about 3000 hooks in each fishing operation. The more diverse domestic owned and operated vessels set anywhere from a few hundred to 3000 hooks (average = 1363 for observed vessels). Michael *et al.* (1987) give a detailed description of Japanese longlining in New Zealand waters, but comparable information on domestic practices is not yet available. Charter vessels typically stay at sea for the length of the fishing season (usually May–July) and blast freeze their catch. Domestic vessels either blast freeze or use an ice slurry to hold their catch, consequently most trips are relatively short (average 2.9–7.0 days based on CELR data). There is a tendency for larger vessels with blast freezers to have trips of longer duration.

Longlining can be separated into three stages: setting, soaking and hauling. Based on observer information (see Table 1) setting typically takes 3.7–5.5 hours depending on longline length. The longline is then left to fish or "soak" for 3.8–5.4 hours (Japanese vessels) or 2.6–14.2 hours (domestic vessels). After the longline has been left to "soak" the vessel retrieves the line by steaming slowly along the line recovering and storing the mainline, removing buoy lines, snoods and processing fish in preparation for the next longline set. Hauling the longline is the longest part of the operation and on average takes from 8.4 hours (domestic vessels) to about 12 hours (Japanese vessels).

Purse seining

Purse seine fishing for skipjack tuna began in 1975–76 with two domestic and three USA super seiners. Purse seine vessel numbers peaked at nearly 20 vessels in the early 1980s. A brief review of this fishery to 1985–86 is given by West (1991). All purse seiners operating in the EEZ have been "Marco- rigged", which refers to the power block being raised on a boom in the stern to lift the net during hauling. The main difference between US and domestic vessels was size (US vessels were typically larger than 1000 Ton GRT, whereas domestic vessels have mostly been smaller than 500 Ton GRT). With the exception of an occasional set to test gear after repair work in New Zealand US purse seiners have not fished in the EEZ for many years. Six domestic purse seine vessels, ranging in size from 119–410 Ton GRT, operated in the EEZ in 1996–97.

Bailey (1983) provides a general description of purse seine fishing in New Zealand that is based mainly on the large purse seiners operating at the time. Purse seine fishing is a highly specialised technique where surface schooling fish (skipjack tuna and various coastal pelagic species) are located visually (using fixed wing aircraft in New Zealand) and the vessel is directed by the spotter so it can surround the school with a net. The purse seiner steams to intercept the school, which is often moving, and drops a heavy motorised skiff (about 9 tonnes) to which one end of the net is attached. The skiff serves to anchor the net while the purse seiner continues steaming to encircle the school with the net as it falls off the stern. The net, which may be 1100 m long and 100 m deep, takes about 20 minutes to set.

Once the purse seiner has encircled the school, the skiff comes along the inside of the purse seiner to transfer the headline (24 mm diameter) and the wire purse rope (20 mm diameter). The skiff then moves over these to position itself outside the net and helps position the purse seiner by holding it off of the net. With the headline and the purse rope back on board the purse seiner, the rings and chains can be recovered to close the bottom of the net and completely enclose the school. The power block is used to lift the net for retrieval and stacking for the next set. Winching of the net can take about 1.5 hours.

The net is gradually retrieved which concentrates the school in the reinforced section of the net (the bunt) and the skiff is used to help support the last section of the net so fish can be brailed on board. Brailing is the process where fish are netted at the side of the vessel in a one tonne scoop net and lifted aboard. Fish are put directly into brine freezer wells (-3–5° C) until the end of the trip. The maximum catch of skipjack is 160 tonnes per set with up to 7 sets per day possible (1.4–2.4 sets per day on average). While most purse seine trips are short (4.2–11.8 days long based on CELR data), trips of up to 30 days are possible.

4 SPECIES CAUGHT IN NEW ZEALAND TUNA FISHERIES

The pelagic ecosystem, particularly in the subtropical northern waters, in the New Zealand EEZ is diverse. As a result of this diversity many species, in addition to the target species, are caught in New Zealand tuna fisheries. The most detailed accounts of these species are derived from observer data (see Francis *et al.*, 1998; Habib *et al.*, 1982; Bailey *et al.*, 1996) while the most extensive data are available from CELR and TLCER data supplied by fishers. The former data, while detailed and covering commercial and non-commercial species equally, are limited in temporal and spatial coverage. Observer data and reports are restricted to the purse seine fishery in 1975–1981 and the longline fishery since 1987. No observer data are available from the troll fishery and bycatch information comes from research cruises in 1984–1992.

Catch and effort data from commercial operations reported on CELR and TLCER forms show a similar range of species caught incidentally in each fishery. Table 2 summarises the top 99% of catch and ranks each species for each method and target over the period 1989–90 to 1996–97.

The complete record of species reported on CELR and TLCER forms are summarised by method and target in Appendix III. Several of the minor catch components are clearly in error. The problem of mis-specified fishing methods, mentioned previously, undoubtedly contributes to the strange records in this summary (e.g. flatfish, gurnard and ribaldo caught by trolling or snapper, butterfish, spinyfin, orange roughy, oyster spat and porae by longline).

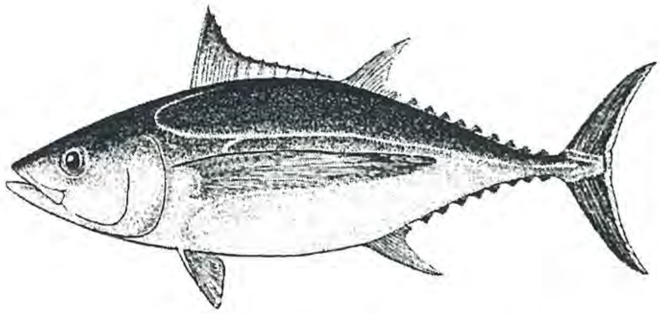
Table 2. Tuna fishery catch composition (upper 99% of the catch) with species ranked in order of importance by fishing method and target.

		Purse seine	Troll	Longline	
Code	Species	Skipjack	Albacore	Bigeye	Southern bluefin
ALB	albacore		1	1	1
BIG	bigeye tuna			4	12
BSH	seal shark			15	
BTU	butterfly tuna			22	4
BWS	blue shark			2	2
EMA	blue mackerel	2			
JMA	jack mackerel	3			
KAH	kahawai		4		
KIN	kingfish		3	17	
MAK	mako shark			9	10
MIX	mixed fish			21	
MOO	moonfish			3	6
OFH	oilfish				11
OFH	oilfish			7	
OSD	other sharks & dogfish			8	
POS	porbeagle shark				14
RBM	Ray's bream			19	9
RUD	rudderfish			13	17
SCH	school shark				15
SHA	shark			10	8
SHF	shark fins			14	13
SKJ	skipjack tuna	1	2	18	
STM	striped marlin			11	
STN	southern bluefin tuna			16	3
SWO	swordfish			5	7
THR	thresher shark			20	16
UNI	unidentified			12	5
YFN	yellowfin tuna			6	

Erroneous species codes may also contribute to errors in these summaries (e.g. southern bluefin tuna "STN" recorded as striped marlin "STM"). For the most part, however, the catch reported on CELR and TLCER forms is consistent with observer information on species caught by each method.

Available information indicates that few species are caught incidentally in the troll fishery (these include skipjack tuna, yellowfin tuna, mahi mahi and on occasion a seabird). In the purse seine fishery Bailey *et al.* (1996) note that 46 species of sharks, rays and fish are caught in the EEZ, with the most common species being sunfish, manta rays and porcupine fish. In contrast to US super-seiners, New Zealand purse seiners are reported as having a regular bycatch of coastal species which Bailey *et al.* (1996) attribute to sets being made on the continental shelf (depths < 200 m). They also note a high frequency of catches of mako sharks (73% of observer records). In the longline fishery Francis *et al.* (1998) reports 70 species which can comprise the incidental catch. However, 97% of the bycatch is made up of 17 species including other tunas, oceanic sharks, oilfish, moonfish, swordfish, lancetfish, dealfish, school shark, deepwater dogfish and rudderfish. In addition to fish bycatch the longline fishery also has an incidental catch of seabirds, fur seals, occasionally other marine mammals and on rare occasions leatherback turtles (see Baird, 1998).

5 Albacore

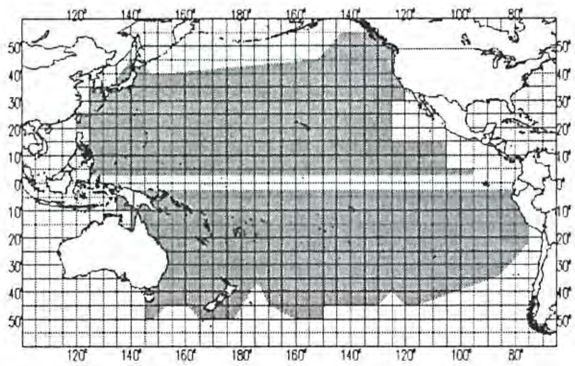


Thunnus alalunga **(Bonnaterre, 1788)**

Summary Information on Albacore in the Pacific Ocean

Stocks	separate North and South Pacific stocks
Fishing Methods	caught by longline, troll and pole-and-line
Catches	approximately 80 000–160 000 tonnes from the entire Pacific Ocean (about 47–62% of the global catch) per year for the period 1984–93 approximately 20 000–40 000 tonnes from the South Pacific Ocean (about 22–27% of the Pacific catch) per year for the period 1984–93
Parties Fishing	Canada, Chile, China, Chinese Taipei, Japan, Korea, Mexico, South Pacific States and territories, USA
Spawning	summer months in both hemispheres: 10–20° S, west of 140° E for the South Pacific stock; 10–30° N, west of 170° E for the North Pacific stock
Fish Size	maximum size of 127 cm fork length and 40 kg reported: longline caught albacore are usually 95–115 cm long; troll caught albacore are usually 55–80 cm long

Area of commercial fishing operations for albacore, 1991–93

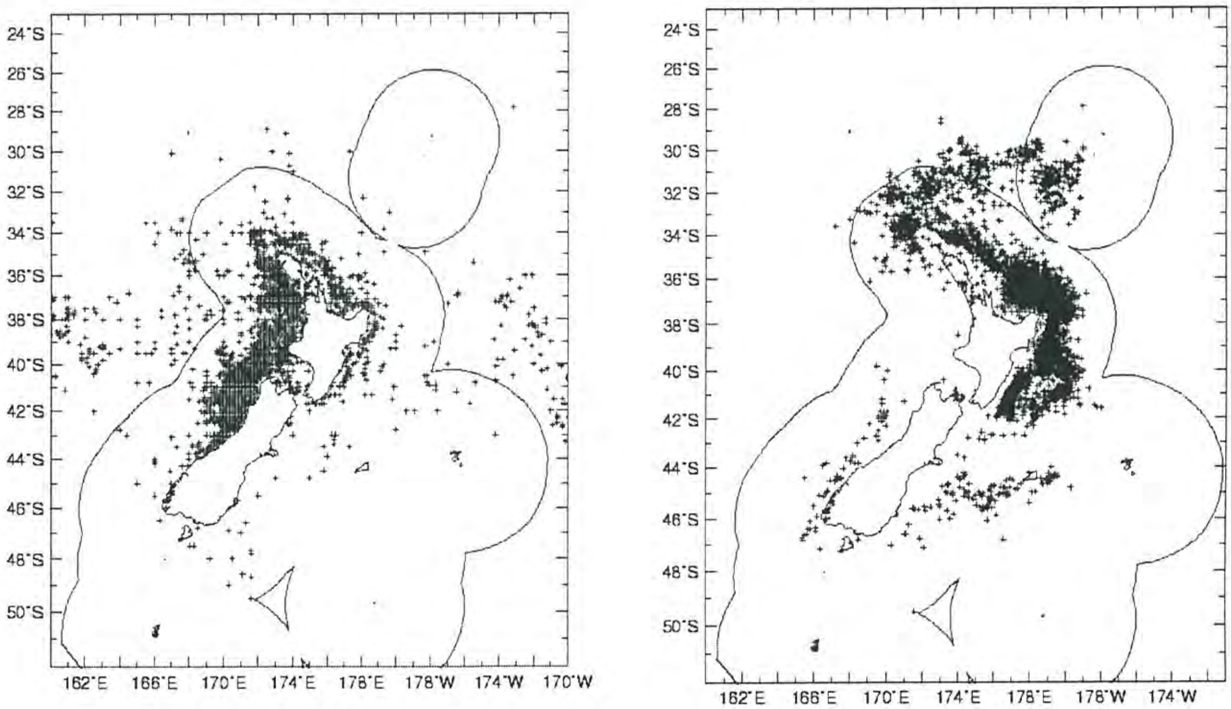


5.1 Distribution

Albacore caught within the EEZ are part of a single South Pacific stock that occurs from about 5–50° S. Albacore are caught by trolling in summer months mainly between 34° S and 44° S from the coast of Australia eastward to the Chilean EEZ. While up to half of the surface fishery catch occurs in the New Zealand EEZ, substantial catches are also made along the northern boundary of the Sub-tropical Convergence Zone, mostly by US trollers. Figure 3 shows the distribution of troll fishing effort in the EEZ and adjacent high seas areas during the period 1989–90 to 1996–97. Additional effort by New Zealand vessels, not shown in this figure, occurred across the Tasman Sea to the Australian EEZ and eastward to the central South Pacific. It is clear from Figure 3 that the troll fishery operates primarily along the west coasts of the North and South Islands but to a limited extent also operates in the Bay of Plenty and along the east coast of the North Island. Positions shown in Figure 3 north of 32° S and south of 43° S (on the east coast) are position errors in the CELR data.

All longline fleets operating in the South Pacific regularly catch albacore as bycatch but only a few South Pacific island countries, including occasional New Zealand vessels, and Taiwanese longliners target albacore. Increased surface catches and declining production costs of yellowfin and skipjack tunas since 1980 coupled with a stable demand and increased production costs for albacore (Lightfoot & Friberg personal communication) has led to a declining number of vessels targeting albacore. Longliners catch albacore throughout the year across the South Pacific from 5° S to 40° S. Figure 3 shows that most of the longline catch of albacore, unlike the troll fishery, occurs along the east coast of the North Island with much less fishing on the West Coast.

Figure 3. Distribution of albacore fishing effort in the EEZ by trolling (1989–90 to 1996–97) on the left, and longlining (all fleets, 1979–80 to 1996–97) on the right.



5.2 Trends in catch and fishing effort

Groomed catch and effort data are summarised by method, fleet and fishing year in Appendix IV(A). This table shows the domestic troll fishery increasing its effort and catch from 1989–90 through to its peak in 1994–95 to less than half this level in 1996–97. The very low troll effort and catch in 1988–89 is due to most catch data (about 80%) being recorded as weight in the CELR data or failing other constraints in the data quality control process for CPUE analysis. The troll fishery is typically variable and the decline over the past two fishing years is not unusual for the South Pacific surface fishery.

Longline fleets operating in the EEZ regularly catch albacore as bycatch and occasionally also report albacore as a target. Data from albacore target sets are summarised in Appendix IV(A). Japanese and Korean longliners have not targeted albacore since 1988–89 in the case of Korea due to increasing restrictions on access to northern waters and since 1991–92 for Japanese vessels. Domestic longliners, however, have regularly targeted albacore but at much lower levels than for bigeye or southern bluefin tunas. The relative effort targeting albacore has been less than 20% that of bigeye and about 20–30% that of southern bluefin tuna. Domestic longline catch and effort has shown the same trend as the troll fishery, increasing its effort and catch from 1989–90 through to its peak in 1994–95 followed by a decline to almost half this level in 1996–97. That both the troll and longline fishery follow the same trend suggests that factors other than change in abundance may explain the recent decline.

5.3 CPUE trends

The trend in CPUE for the New Zealand albacore troll fishery, shown in figure 4a, has regularly declined over the period 1989–90 to 1996–97. However, the slope of the trend line (a decrease of 2.8 fish per 100 hook-hours per year) is sufficiently small to characterise the decline as slight. Figure 5 shows the spatial distribution of albacore CPUE and troll catch composition for 1996–97. Earlier years data aggregated in 5-year periods are shown in Appendix V.

Albacore troll CPUE in 1996–97, as expected, was highest off the west coasts of the North and South Islands from the Three Kings Rise south to Fiordland. High CPUE values were also realised along the north-east coast of the North Island north of 36° S. Comparison of figure 5 with equivalent figures in Appendix V indicate that albacore trolling in 1996–97 was almost exclusively within the EEZ, while in previous years substantial high seas catches were made by New Zealand troll vessels.

The pie charts in each 1° latitude by 1° longitude square show low bycatch levels that were mostly comprised of skipjack and yellowfin tunas north of 39° S. Squares showing catches south of 46° S for longline those south of 43° S (on the east coast) or north of 32° S for trolling are likely to be uncorrected position errors in the CELR data and should be disregarded.

Figure 4a. Trend in albacore CPUE (number of fish per 100 hook-hours) in the New Zealand troll fishery, 1989–90 to 1996–97.

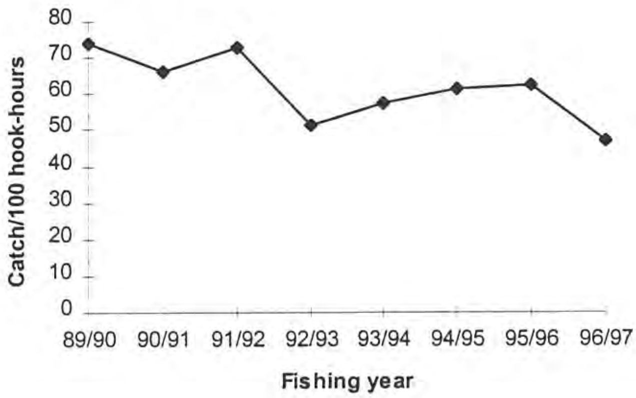
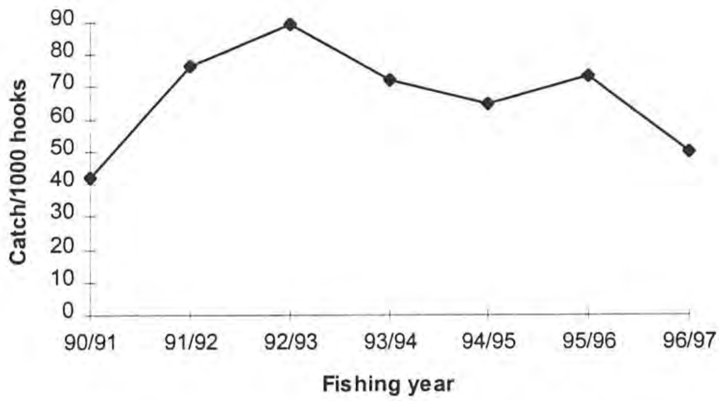


Figure 4b. Trend in albacore CPUE (number of fish per 1000 hooks) in the New Zealand longline fishery where albacore was the reported target, 1989–90 to 1996–97.

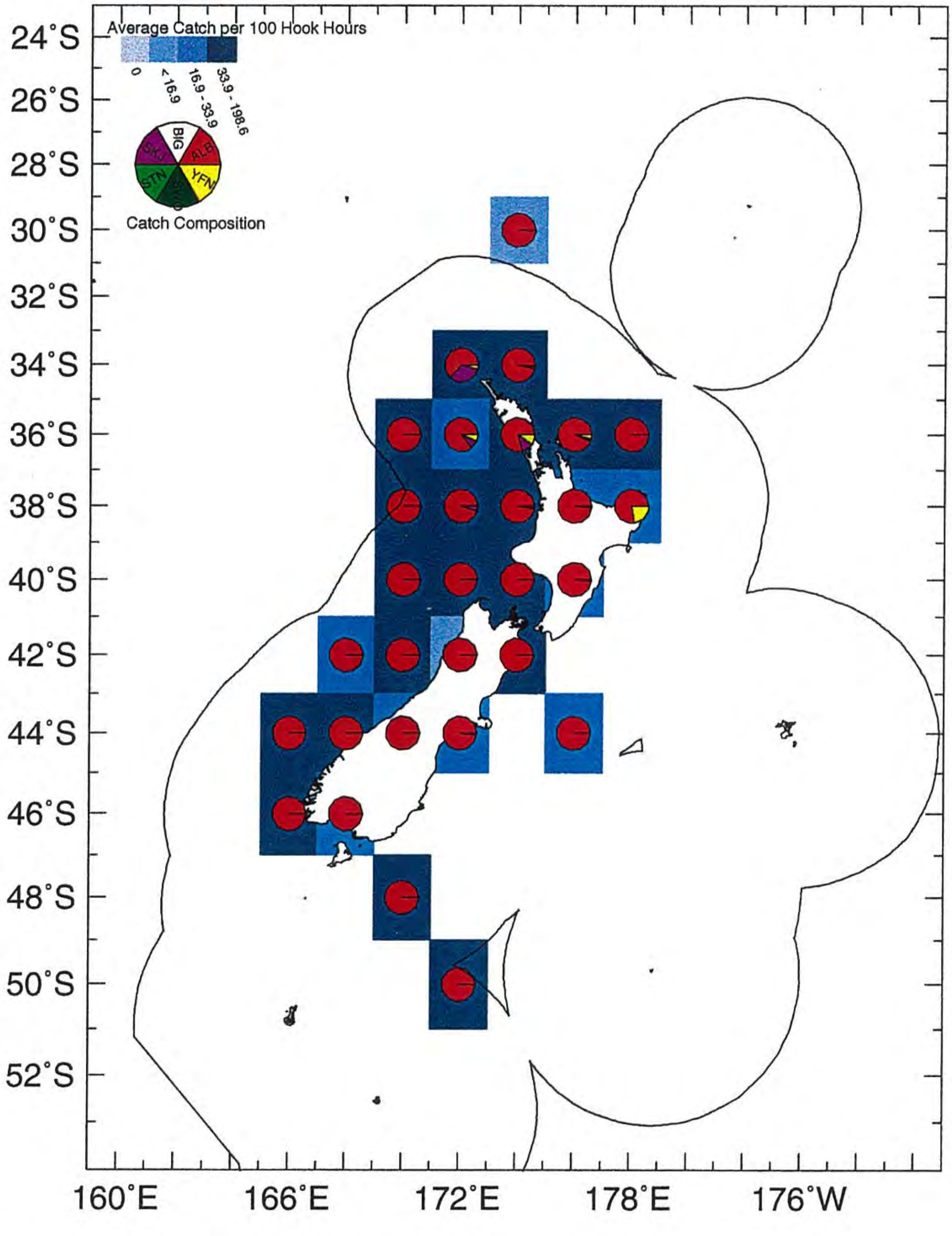


The trend in longline CPUE where albacore was targeted by domestic fishers is shown in figure 4b. Longline CPUE shows an increase from about 40 fish per 1000 hooks in 1989–90 reaching a maximum of nearly 90 fish per 1000 hooks in 1992–93, declining gradually to about 50 fish per 1000 hooks in 1996–97. These CPUE values are much higher than other albacore longline target fisheries in the South Pacific (eg CPUE < 30 fish per 1000 hooks for Taiwanese vessels) where comparable years were reported in Anon (1997).

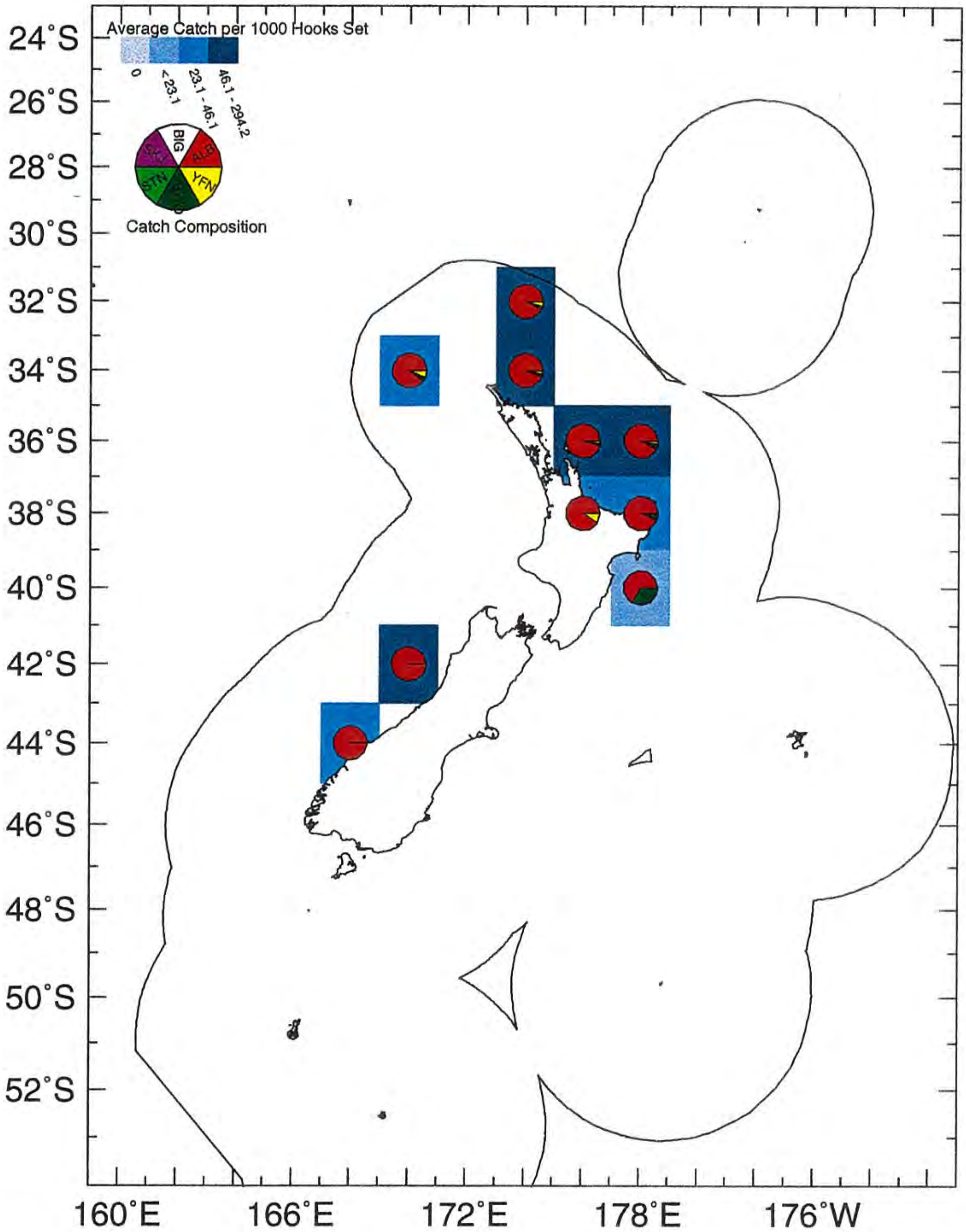
The spatial distribution of domestic longline CPUE targeting albacore is shown in figure 5, and earlier years aggregated in 5 year periods are given in Appendix V for all fleets that have targeted albacore. With the exception of scattered catches of albacore off the West Coast, most high CPUE values have been realised around the North Island north of 41° S. Bycatch was limited to yellowfin and swordfish.

Figure 5. Spatial distribution of albacore CPUE and catch composition by domestic troll and longline fisheries in 1996–97.

Trolling for Target ALB
Domestic Fleet 1996/97



Surface Longlining for Target ALB
Domestic Fleet 1996/97



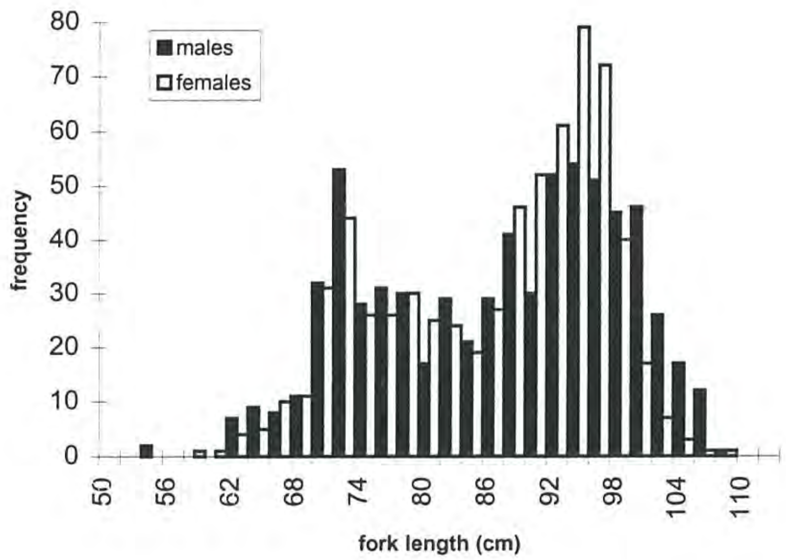
5.4 Summary of biological data

Statistical summaries of biological data on albacore may be found in Appendix VI.

Size composition

Albacore caught in the EEZ range in size from as small as 34 cm (Roberts and James, 1974) to 118 cm fork length. The size composition of albacore differs between the troll and longline fishery, with the troll fishery catching juveniles that are mostly 55–80 cm fork length. In contrast the longline fishery catches sub–adult and adult albacore generally ranging in size from 70 cm up to 118 cm. The size composition of albacore caught by longline, shown in Figure 6 is bimodal with peaks at 73 cm and at 95 cm. There is appreciable overlap in the sizes of albacore caught, particularly towards the end of the troll fishery season in April–May. Smaller albacore in the longline fishery catch are likely to be under-represented in Figure 6 because canneries prefer albacore larger than 20 pounds (9.1 kg) in weight (corresponding to fish about 75–77 cm fork length). This results in substantial discarding of albacore in most months. Discarding is described in Section 11 of this report.

Figure 6. Size composition of longline caught albacore by sex for the period 1991–92 to 1996–97.



As can be seen in Figure 6 there is no significant difference in the size of males and females caught by the longline fishery. The similarity in sizes between the sexes is also apparent from the descriptive statistics in Appendix VI, eg, the mean length of albacore in this fishery is 86.2 cm for males and 85.6 cm for females.

Sex ratio

Sex ratios in longline caught albacore vary year to year (0.8–2.9 M:F) with males usually more common than females (20% more males over all years). Sex ratio is significantly different ($P<0.005$) from a 1:1 ratio.

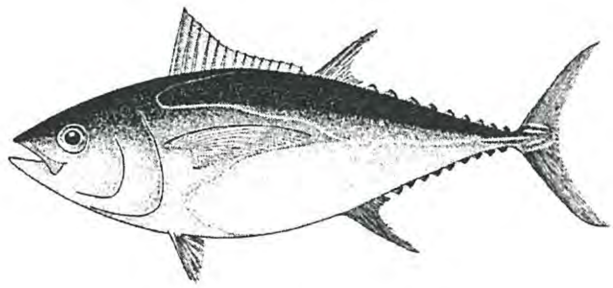
Length - weight relationships

Relationships predicting green weight from length were derived from observer data for males and females separately and combined for all fish where sex was known. The estimated relationships are as follows (weight in kg, length in cm):

males	$\ln(\text{weight}) = 0.038 * \text{length} - 0.822$	$R^2 = 0.91$
females	$\ln(\text{weight}) = 0.039 * \text{length} - 0.864$	$R^2 = 0.90$
sexes combined	$\ln(\text{weight}) = 0.038 * \text{length} - 0.837$	$R^2 = 0.90$

The standard errors of the parameters and sample sizes used to derive these equations are in Appendix VI.

6 Bigeye tuna

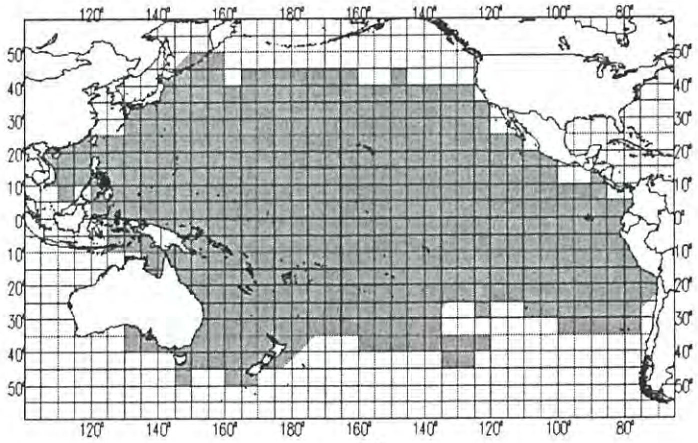


Thunnus obesus (Lowe, 1839)

Summary Information on Bigeye tuna in the Pacific Ocean

Stocks	single Pacific Ocean stock
Fishing Methods	longline, hand line, purse seine, pole-and-line
Catches	approximately 103 000–164 000 tonnes from the entire Pacific Ocean (about 32–40% of the global catch) per year for the period 1984–93
Parties Fishing	Canada, Chinese Taipei, Colombia, Costa Rica, Ecuador, El Salvador, Japan, Korea, Mexico, Panama, South Pacific States and territories, USA, Venezuela
Spawning	in both hemispheres in Spring and early summer months, mostly between 10° S and 30° N west of 160° W
Fish Size	maximum sizes exceeding 200 cm fork length and 197 kg reported; longline caught bigeye tuna are usually 100–170 cm, purse seine caught bigeye tuna (often mis-identified as juvenile yellowfin) are 40–80 cm

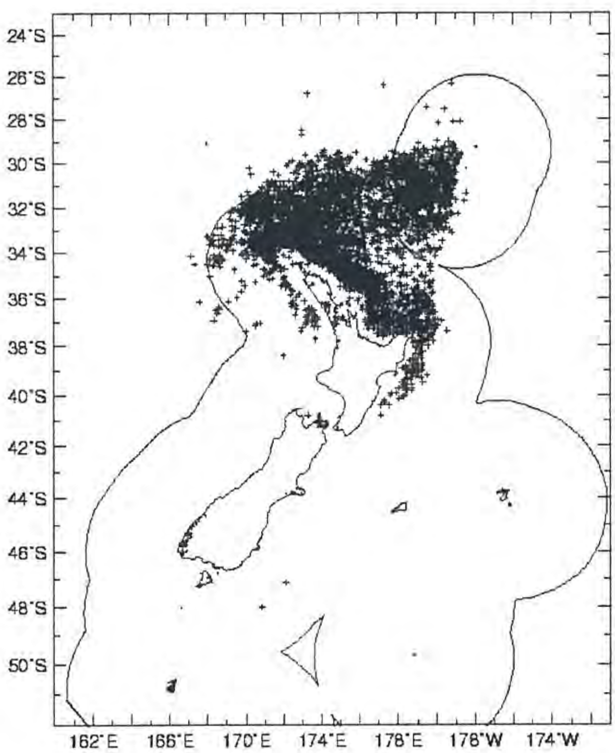
Area of commercial fishing operations for bigeye tuna, 1991–93



6.1 Distribution

Bigeye tuna caught within the EEZ are part of a single Pacific-wide stock that is widely targeted by longline. Substantial numbers of juvenile bigeye are also caught incidental to purse seine operations for skipjack and yellowfin tuna in tropical waters. In the EEZ bigeye tuna are caught around the North Island (see Figure 7) primarily in FMA1 and FMA10 with less effort south of East Cape to the northern Wairarapa coast and off the west coast to the North Taranaki Bight. Longline set positions shown off the South Island in this figure are CELR data with position errors.

Figure 7. Distribution of bigeye tuna longline effort in the EEZ (all fleets, 1979–80 to 1996–97).



6.2 Trends in catch and fishing effort

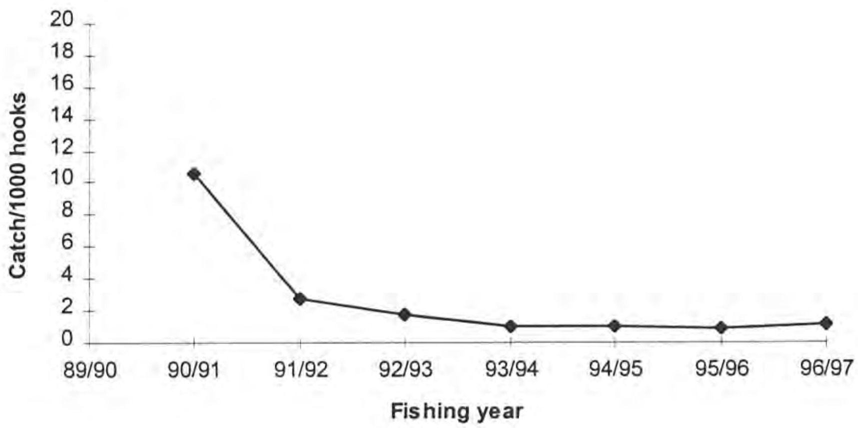
Groomed catch and longline effort data are summarised by fleet and fishing year where bigeye tuna are reported as the target species in Appendix IV(B). This table shows the domestic fleet regularly increasing its effort since 1989–90. Over one million hooks have been set for bigeye tuna in each of the last three years. In all years except 1989–90 when effort was very low, bigeye catch has fluctuated between 820 and 1301 fish. Although bigeye tuna is the target for this fleet, albacore bycatch is many times higher and in several years has exceeded 40,000 fish. The bycatch of yellowfin tuna and swordfish has also been greater than the bigeye target catch in most years.

The charter and foreign licensed fleets which have operated in the EEZ have also targeted bigeye tuna, usually at the end of the southern bluefin tuna season. The catch and effort for these fleets is also shown in Appendix IV(B). The charter vessels targeted bigeye to a minor extent, and then only prior to 1994–95. The foreign licensed fleet, which has not fished in the EEZ since 1994–95, had shown a decline in bigeye targeting beginning in the late 1980s and by 1992–93 had stopped targeting bigeye tuna in the EEZ. This decline in effort can partly be explained by fewer licenses being taken up and partly the increasing restrictions on longline fishing as a result of the imposition of the "Billfish Moratorium" in FMA 1 and FMA 9 in 1987. Bigeye catches by the foreign licensed fleet peaked in 1986–87 at 11,594 fish. The charter fleet's catch was the smallest of the three fleets targeting bigeye with a maximum catch of 342 fish in 1990–91.

6.3 CPUE trends

The trend in CPUE for bigeye targeted by the domestic longline fleet is shown in figure 8. CPUE trends for the other fleets are excluded because they have not continued to target bigeye. The initial high CPUE in 1990–91 (10.6 bigeye per 1000 hooks) has not been maintained in this fishery and for the past four years catches have been about one fish per 1000 hooks.

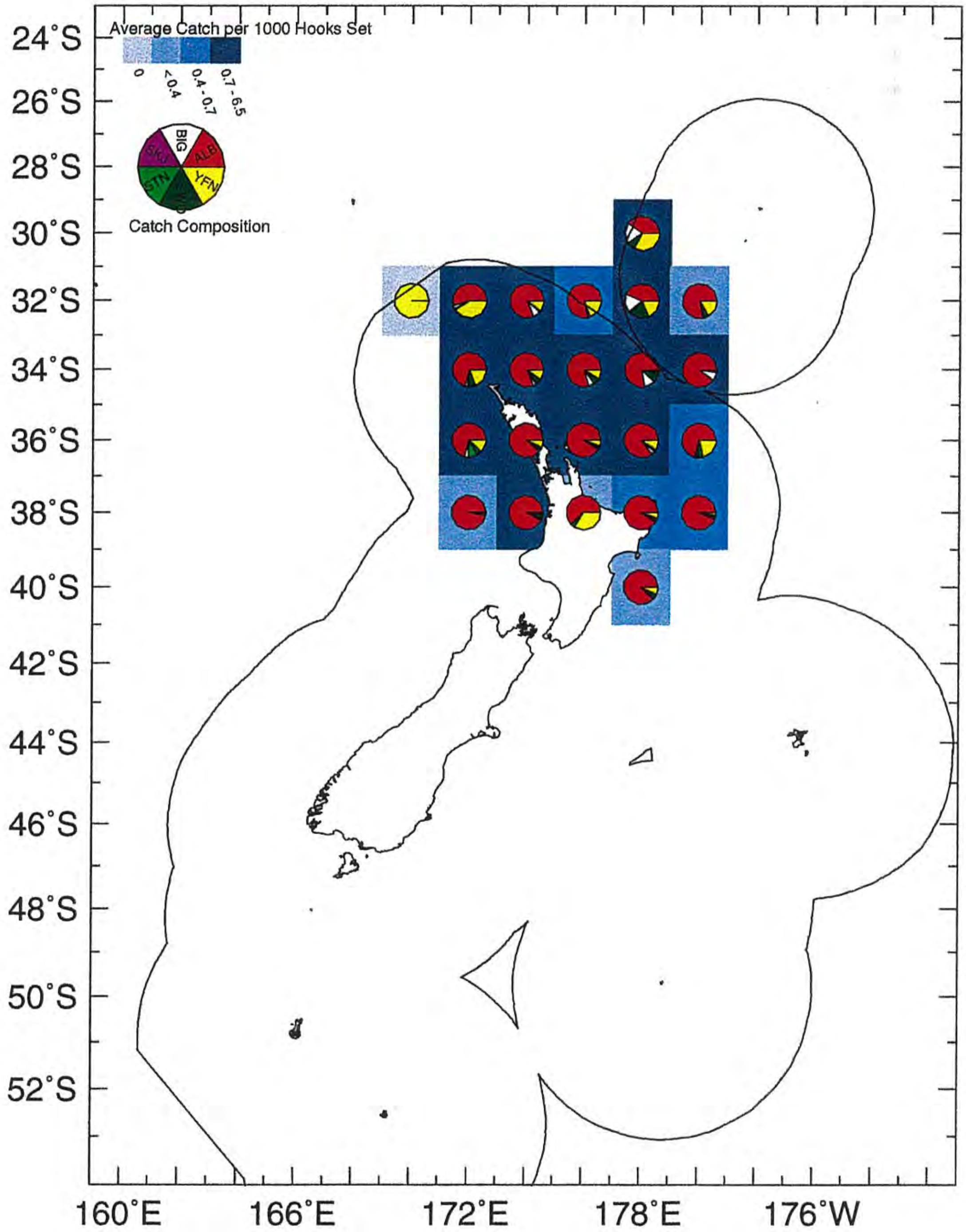
Figure 8. Trend in bigeye tuna CPUE (number of fish per 1000 hooks) in the New Zealand longline fishery where bigeye was the reported target, 1990–91 to 1996–97.



The spatial distribution of bigeye CPUE is shown in figure 9 for the domestic longline fishery in 1996–97 and for all fleets operating in earlier periods in Appendix V. Bigeye tuna is mostly caught in FMA 1, FMA 9 and FMA 10, and to a lesser extent in FMA 2. Figure 9 indicates that highest CPUEs (0.7–6.5 fish per 1000 hooks) were realised primarily between 31° and 38° S along the Three Kings Rise and in the South Fiji Basin. Moderate catch rates (0.4–0.7 fish per 1000 hooks) were realised off East Cape. This pattern is also repeated in earlier years by other fleets (see Appendix V). Reports of bigeye targeting off the South Island by Japanese vessels are likely to be in error since bigeye are generally absent from these catches which are predominantly swordfish. The pie charts in each 1° latitude by 1° longitude square show a very high bycatch of albacore with smaller amounts of yellowfin, southern bluefin and swordfish. Despite bigeye being the reported target, even in the highest CPUE squares it is caught in low numbers.

Figure 9. Spatial distribution of bigeye tuna CPUE and catch composition by the domestic longline fishery in 1996–97.

Surface Longlining for Target BIG
Domestic Fleet 1996/97



6.4 Standardised CPUE trends

Declines in CPUE have been reported for the Pacific-wide bigeye tuna stock that appear to have been underway for several decades (Anon, 1998 a). The trends seen in bigeye CPUE in the New Zealand EEZ are certainly consistent with declines seen elsewhere. Standardised CPUE analyses have been done for bigeye tuna by Miyabe and Takeuchi (1998), Sun and Yeh (1998) and in this report (see Appendix VII). Miyabe and Takeuchi (1998) provide age specific CPUE (for fish aged 3–6 years old) based on Japanese longline data. Their data suggest declines of the order of 50% over the period 1965–95 for these ages. Sun and Yeh (1998) show larger declines (about 75%) in CPUE for Taiwan's distant water fleet over the period 1967–96. However, Taiwan's small boat fleet based in some Pacific Island EEZs show either no trend or a slight increase in CPUE over the period 1988–97. These latter data may not reflect actual abundance since such vessels are highly mobile and have not been consistently fishing the same area over this period.

Standardisation of bigeye CPUE was done for this report using an effort-weighted negative binomial generalised linear CPUE response model for this fishery (see Appendix VII). The construction of the main effects GLM used the S function `step` to select predictor terms which were tested with the usual F statistic.

Predictor variables tested for inclusion in the model were:

1. Factors
   - *year*
   - *month:* February to August
   - *fleet:* Foreign (Japanese or charter), Domestic (NZ owner operator)
2. Covariates
   - *moon phase*
   - *sea surface temperature (SST)*
   - *latitude*
   - *longitude*

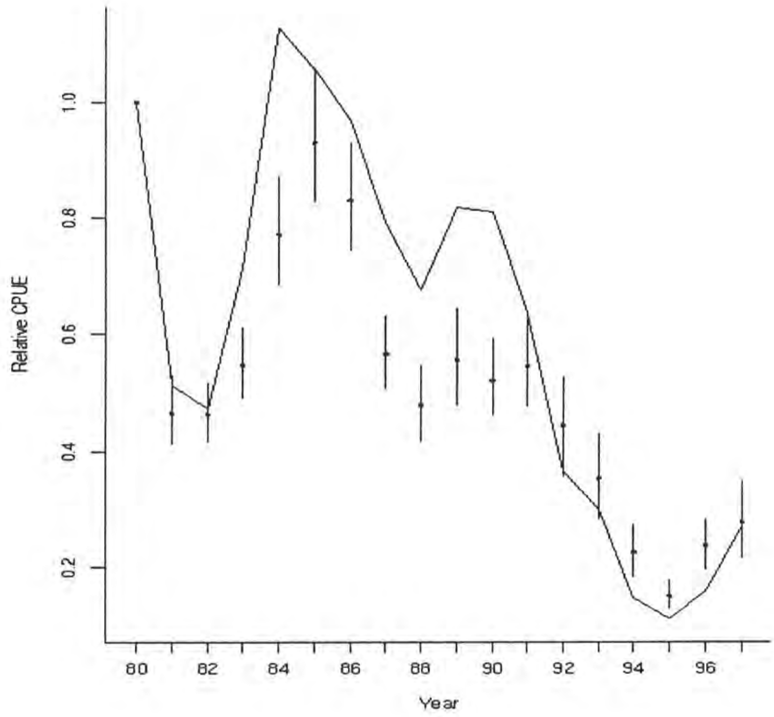
Covariates were treated as Hermite polynomials up to order 4. The order of the polynomial was chosen by `step`.

The final model is given (in S notation) as:

CPUE ~ year + month +longitude +poly(latitude,4)+poly(SST,4).

Between 1980 and 1997, there are only small differences between the estimated coefficients and the nominal (mean) CPUE values (see Figure 10). Nominal and standardised CPUE exhibit similar trends with low relative abundance indices in 1981–83 compared with 1980 followed by an increase to about 80% (standardised) of the 1980 level during 1984–86. Since this time the standardised relative abundance index of bigeye in the New Zealand EEZ has declined to about 20% of the 1980 level.

Figure 10. Bootstrap mean year coefficients from the negative binomial model for bigeye tuna with 95% confidence intervals compared to the nominal CPUE derived from TLCER data.



Bigeye CPUE in the New Zealand EEZ over the period 1980–97 reached its lowest level at about 15% of 1980 levels in 1995. Thereafter CPUE has increased to about 20–30% of what it was in 1980. It is not clear whether this is merely fluctuation at low levels or local improvement from an historically low abundance level. The CPUE trend in the New Zealand EEZ is certainly consistent with declines seen elsewhere for this stock. The magnitude of the decline is also consistent with the hypothesis that abundance of the bigeye stock is exhibiting more rapid changes at the extremes of its geographical distribution.

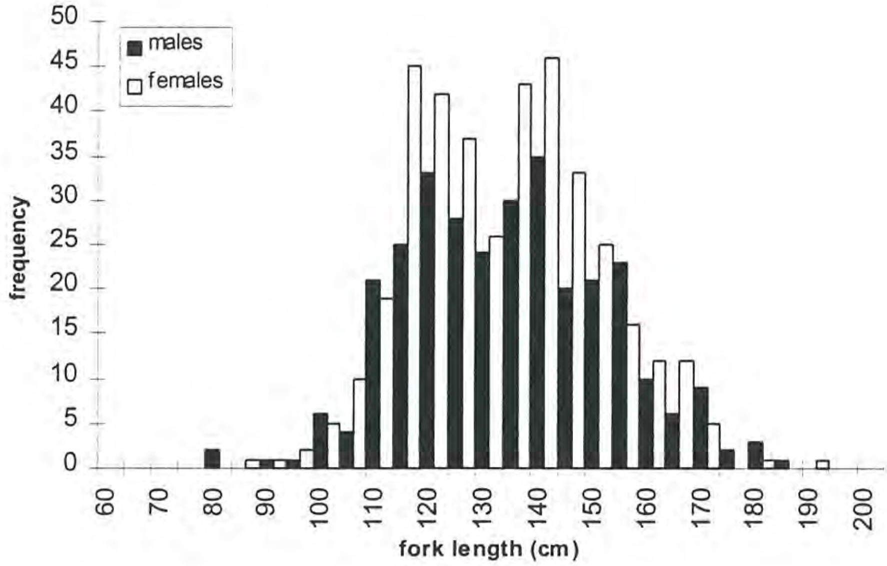
6.5 Summary of biological data

Statistical summaries of biological data on bigeye tuna may be found in Appendix VI.

Size composition

Bigeye tuna caught in the EEZ range in size from 78 cm to 190 cm fork length. The size composition of the longline fishery, shown in Figure 11 is bimodal with peaks at 120 cm and at 140 cm. The size composition of male and female bigeye are very similar (see Appendix VI) with the average size of males 132.5 cm and that of females 130.7 cm.

Figure 11. Size composition of longline caught bigeye tuna by sex for the period 1991–92 to 1996–97.



Sex ratio

Sex ratios in longline caught bigeye tuna vary year to year (0.2–1.2 M:F) with males usually less common than females (20% fewer males over all years). Sex ratio is not significantly different from a 1:1 ratio.

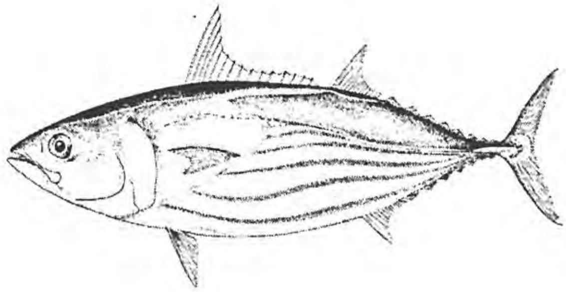
Length - weight relationships

Relationships predicting green weight from length were derived from observer data for males and females separately and combined for all fish where sex was known. The estimated relationships are as follows (weight in kg, length in cm):

males	ln (weight) = 0.023 * length + 0.829	$R^2 = 0.93$
females	ln (weight) = 0.021 * length + 1.084	$R^2 = 0.90$
sexes combined	ln (weight) = 0.022 * length + 0.954	$R^2 = 0.92$

The standard errors of the parameters and sample sizes used to derive these equations are in Appendix VI.

7 Skipjack tuna

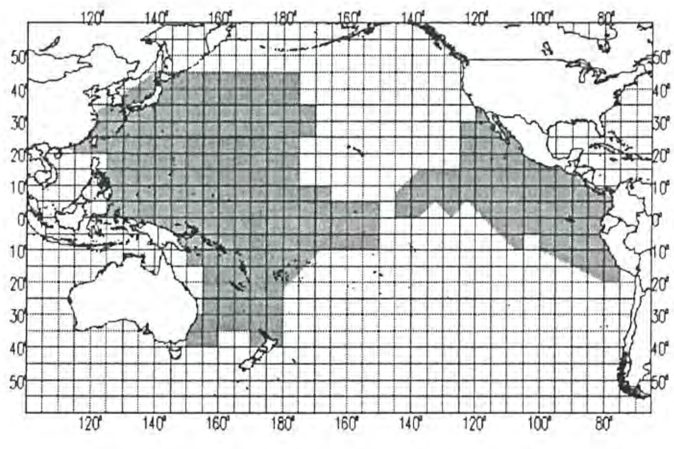


Katsuwonnus pelamis (Linneaus, 1758)

Summary Information on Skipjack tuna in the Pacific Ocean

Stocks	single Pacific Ocean stock
Fishing Methods	purse seine, pole-and-line, ring net, trolling
Catches	approximately 660 000–1 150 000 tonnes from the entire Pacific Ocean (about 70–78% of the global catch) per year for the period 1984–93
Parties Fishing	Canada, Chinese Taipei, Colombia, Costa Rica, Ecuador, El Salvador, Japan, Korea, Mexico, Peru, Philippines, South Pacific States and territories, USA, Venezuela
Spawning	year round; mostly between 10° S and 30° N west of 150° W
Fish Size	maximum size of about 108 cm fork length and 32.5–34.5 kg; commonly reach 80 cm and 8–10 kg

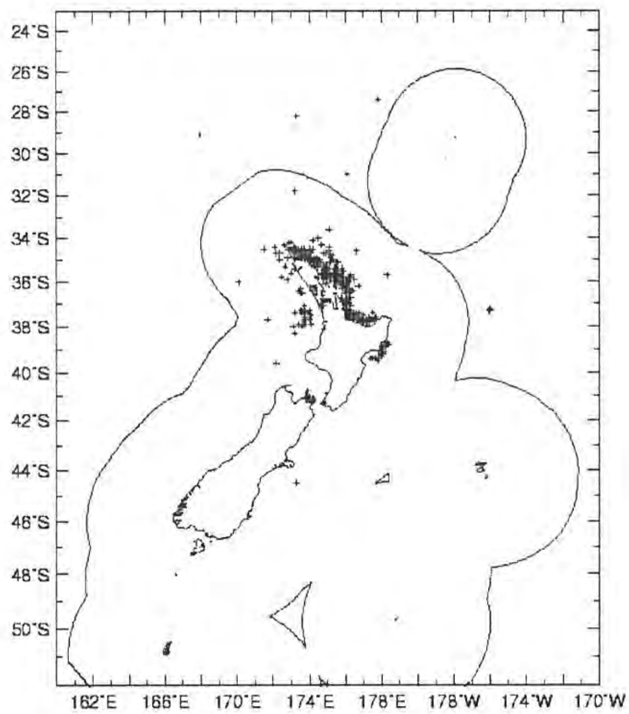
Area of commercial fishing operations for Skipjack tuna, 1991–93



7.1 Distribution

Skipjack tuna caught in the EEZ are part of a single Pacific-wide stock that supports a fishery of over 900,000 tonnes per year, caught mostly in the western equatorial Pacific. In the EEZ skipjack occur as far south as the Wairarapa coast in the east (E. Beetham, personal communication) and on the west coast as far south as Kahurangi Point on the South Island (P. Talley, personal communication). Although skipjack schools are regularly seen off the west coast of the North Island (see Figure 12) and in some years purse seined, most fishing is done in the Bay of Plenty and along the north-east coast of the North Island.

Figure 12. Distribution of domestic skipjack tuna purse seine effort in the EEZ (1989–90 to 1996–97).



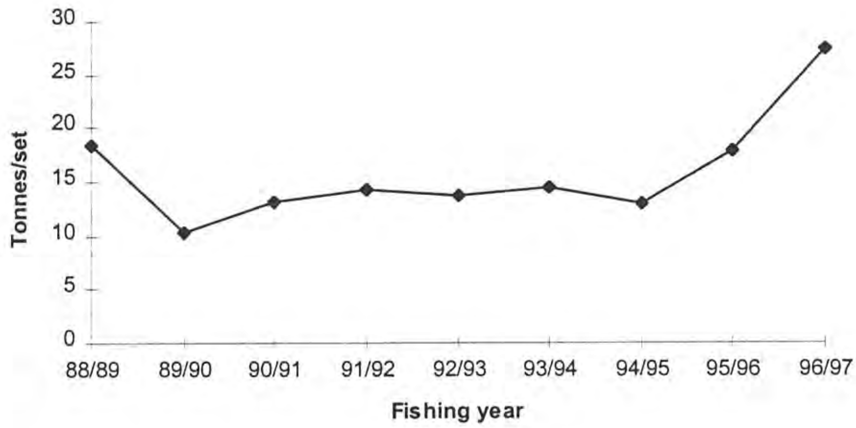
7.2 Trends in catch and fishing effort

Groomed catch and effort data are summarised by fishing year for the domestic purse seine fishery in Appendix IV(C). This table indicates that purse seine effort targeting skipjack tuna has declined from 288 sets in 1989–90 to less than 200 sets per year (67–187 sets) since 1991–92. The small amount of catch and effort in 1988–89 is due to errors in the CELR data and hence is excluded from the discussion of trends. The catch during this period is variable, ranging from 862.5 t (1994–95) to 5102.2 t (1996–97) and is often independent of the number of purse seine sets made.

7.3 CPUE trends

The trend in CPUE for the domestic purse seine fishery for skipjack tuna is shown in figure 13. The initial point in this series (1988–89) is based on only three purse seine sets and may not be representative of CPUE in that year. However, CPUE appears to be relatively stable prior to 1995–96 at about 14 tonnes per set, doubling over the last two years. Catch rates by the domestic purse seine fishery are equal to, or greater than purse seine catch rates in many parts of the western Pacific Ocean (Anon 1997).

Figure 13. Trend in skipjack tuna CPUE (tonnes per set) in the New Zealand domestic purse seine fishery, 1988–89 to 1996–97.

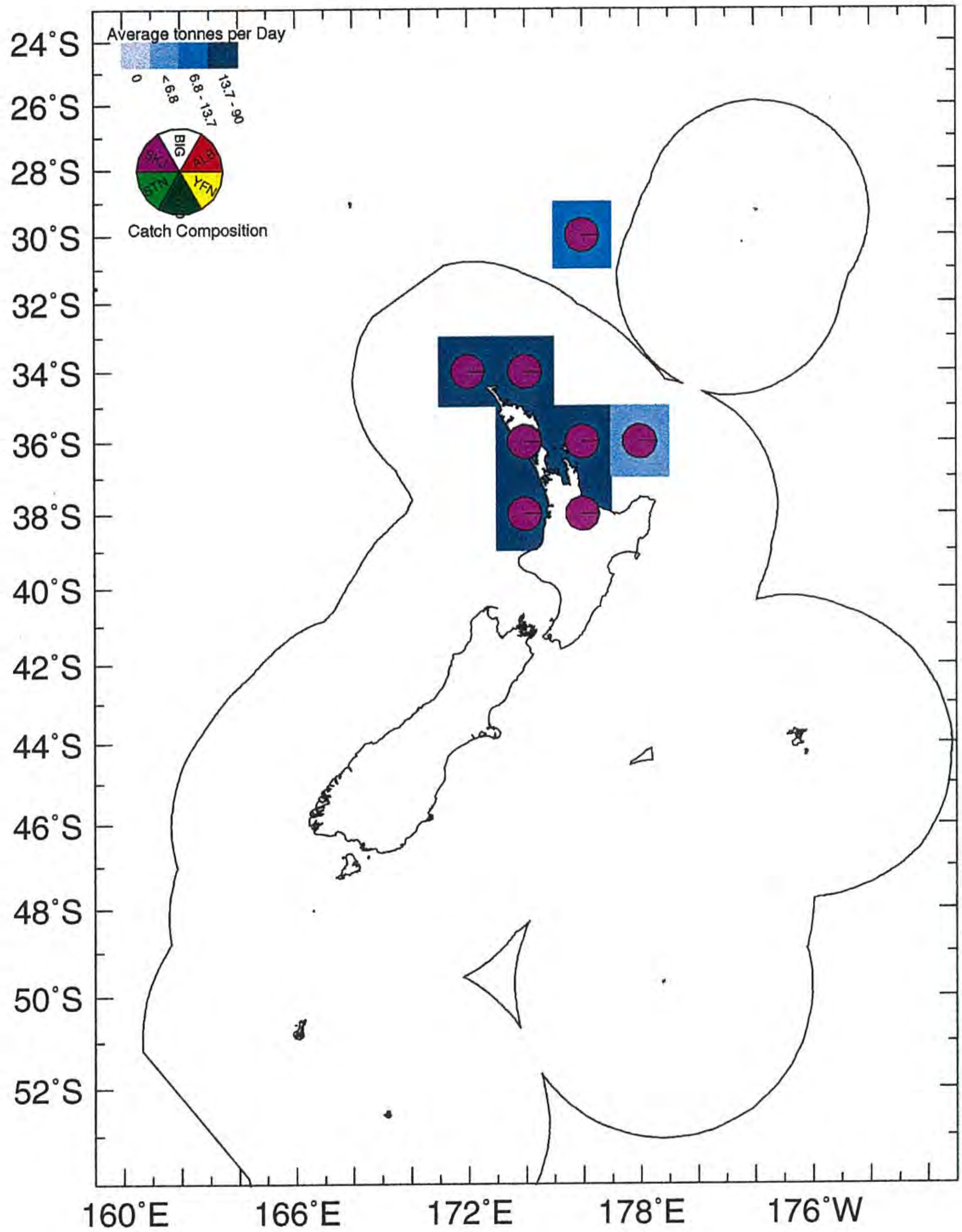


The spatial distribution of skipjack CPUE is shown in figure 14 for the domestic purse seine fishery in 1996–97 and for earlier periods in Appendix V. The domestic purse seine fishery operates only in FMA 1 and FMA 9, mostly in the former. Figure 14 shows that CPUE was uniformly high (13.7–90.0 tonnes per set) throughout most of the area fished in 1996–97 relative to the period covered by the CELR data.

The pie charts in each 1° latitude by 1° longitude square show little or no bycatch in 1996–97.

Figure 14. Spatial distribution of skipjack tuna CPUE and catch composition by the domestic purse seine fishery in 1996–97.

Purse Seine for Target SKJ
Domestic Fleet 1996/97



7.4 Summary of biological data

There has been no catch or port sampling of skipjack tuna since the early 1980s and the following information has been drawn from published information on studies from that time.

Size composition

Skipjack tuna in the EEZ range in size from 32 cm (Vooren 1976) to 72 cm (Ichikawa, 1981). The latter author attributing the sizes caught in the EEZ as corresponding to 2–3 year old fish. Argue and Kearney (1983) report the average size of skipjack tuna in the EEZ as 46.6 cm which is consistent with the major modes described in other surveys (46 cm by Ichikawa, 1981; 44–50 cm and 44–48 cm and 46–50 cm depending on area and month by Iwasa *et al.* 1982; and 44–47 cm by Vooren, 1976.

Sex ratio

Ichikawa (1981) and Iwasa *et al.* (1982) report skipjack tuna sex ratios in the EEZ respectively as 1.1 and 0.6 males:females.

Length - weight relationships

Length–weight relationships have been reported by Vooren (1976) as:

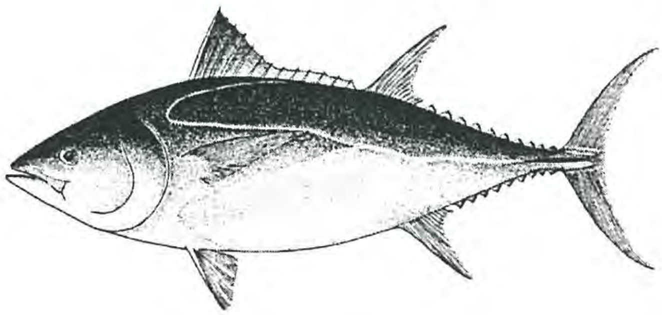
$$\ln(\text{weight}) = 3.19 * \ln(\text{length}) - 11.99$$

and by Iwasa *et al.* (1982) as:

$$\ln(\text{weight}) = 3.20 * \ln(\text{length}) - 11.97$$

where length is fork length measured in mm and weight is green weight in grams.

8 Southern bluefin tuna

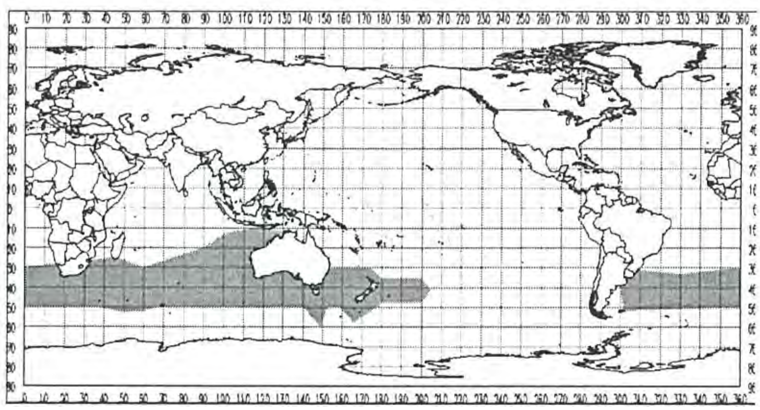


Thunnus maccoyii (Castlenau, 1872)

Summary Information on Southern bluefin tuna in the Pacific Ocean

Stocks	single southern hemisphere stock present in the Atlantic, Indian and Pacific Oceans
Fishing Methods	longline, purse seine, trolling, handline, and pole-and-line
Catches	estimated to be 15 104 tonnes in 1997 (28% caught outside of CCSBT quotas by non-party fleets)
Parties Fishing	Australia, Chinese Taipei, Indonesia, Japan, Korea, New Zealand
Spawning	late spring and summer months; mostly 10°–30° S in the southeast Indian Ocean, south of Java
Fish Size	maximum size of 225 cm fork length and 200 kg reported; fish of 170–190 cm common on the spawning grounds

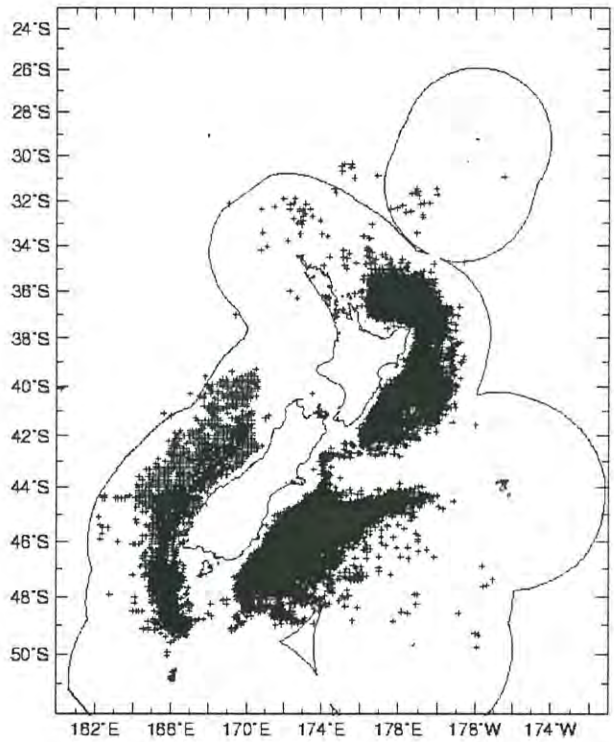
Area of commercial fishing operations for Southern bluefin tuna, 1991–93



8.1 Distribution

The southern bluefin tuna caught in the EEZ are part of a single southern hemisphere stock that occurs in the Pacific, Indian and Atlantic Oceans mostly south of 30° S. New Zealand appears to be the easternmost extent of the range of this species, although there have been unconfirmed reports of fishing by Japanese longliners on the high seas southeast of Chatham Islands. Figure 15 shows the distribution of longline fishing effort by all fleets since 1979–80. Since this time the area where commercial catches have been made has progressively contracted (see Figure 4.2 in Appendix VII) until most fishing takes place off Fiordland and off East Cape.

Figure 15. Distribution of southern bluefin tuna longline effort in the EEZ (all fleets, 1979–80 to 1996–97).



8.2 Trends in catch and fishing effort

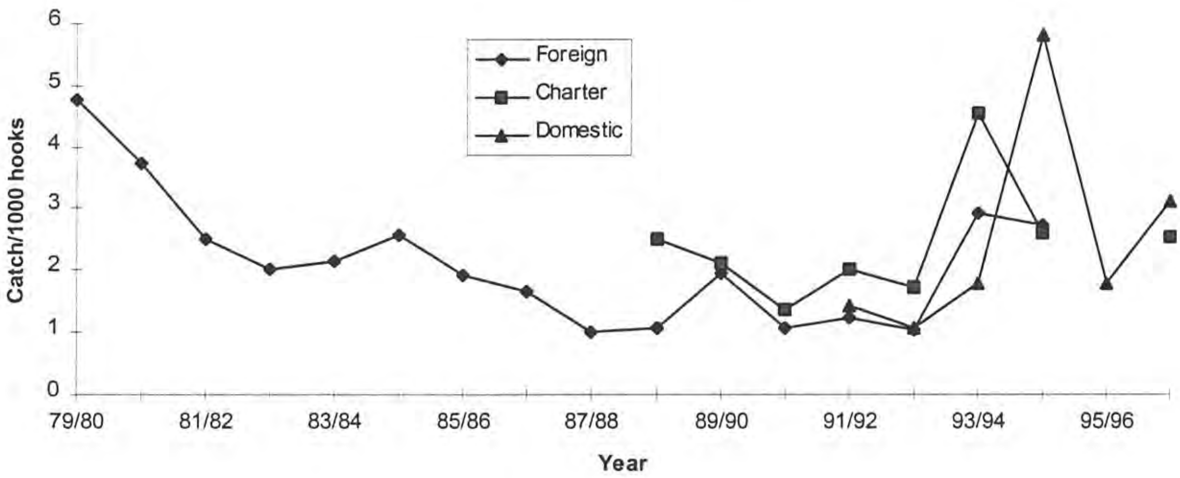
Groomed longline catch and effort data are summarised by fleet and fishing year in Appendix IV(D) where southern bluefin tuna were targeted. The largest fleet and longest time series of data exists for the Japanese foreign licensed fleet which stopped fishing in the EEZ in 1994–95. Fishing effort by the foreign licensed fleet had been declining since 1979–80. The chartered Japanese fleet also stopped fishing in the EEZ in 1995–96 but returned to fish in 1996–97. Fishing effort by the charter fleet has been relatively stable with 1.2–1.5 million hooks set in most years. In contrast to foreign licensed and charter fleets, domestic fishing effort for southern bluefin tuna increased rapidly from 1989–90 to a peak of 0.9 million hooks in 1994–95 before declining to less than 0.4 million hooks in 1996–97.

The trend in southern bluefin tuna catch has followed the effort trend with the foreign license catch declining since 1979–80 where more than 119,000 southern bluefin were caught to the last two years (1993–1995) when fewer than 600 fish were caught. In contrast the catch of the charter fleet, like the trend in effort, has been relatively stable. The trend in the southern bluefin tuna catch by the domestic fleet mirrors the effort trend. In the case of each fleet there is a substantial bycatch of albacore, and in the case of the foreign licensed and domestic fleets substantial catches of swordfish.

8.3 CPUE trends

The trend in CPUE is shown for each fleet in figure 16. This figure shows the regular decline of CPUE for the foreign licensed fleet from 1979–80 to 1992–93. The subsequent increase in CPUE in 1993–94, due to recruiting year classes not seen in the EEZ since the early 1980s, did not appear to persist as CPUEs again declined. This change, apparent in both the foreign licensed and charter fleets, was also seen in the domestic longline fleet with the CPUE increase persisting for an additional year to reach a peak in 1994–95 higher than any seen before the start of data collection in 1979. The CPUE of southern bluefin in the domestic fleet has also subsequently declined to about what it was in the mid-1980s.

Figure 16. Trend in southern bluefin tuna CPUE (number of fish per 1000 hooks) by fleet.

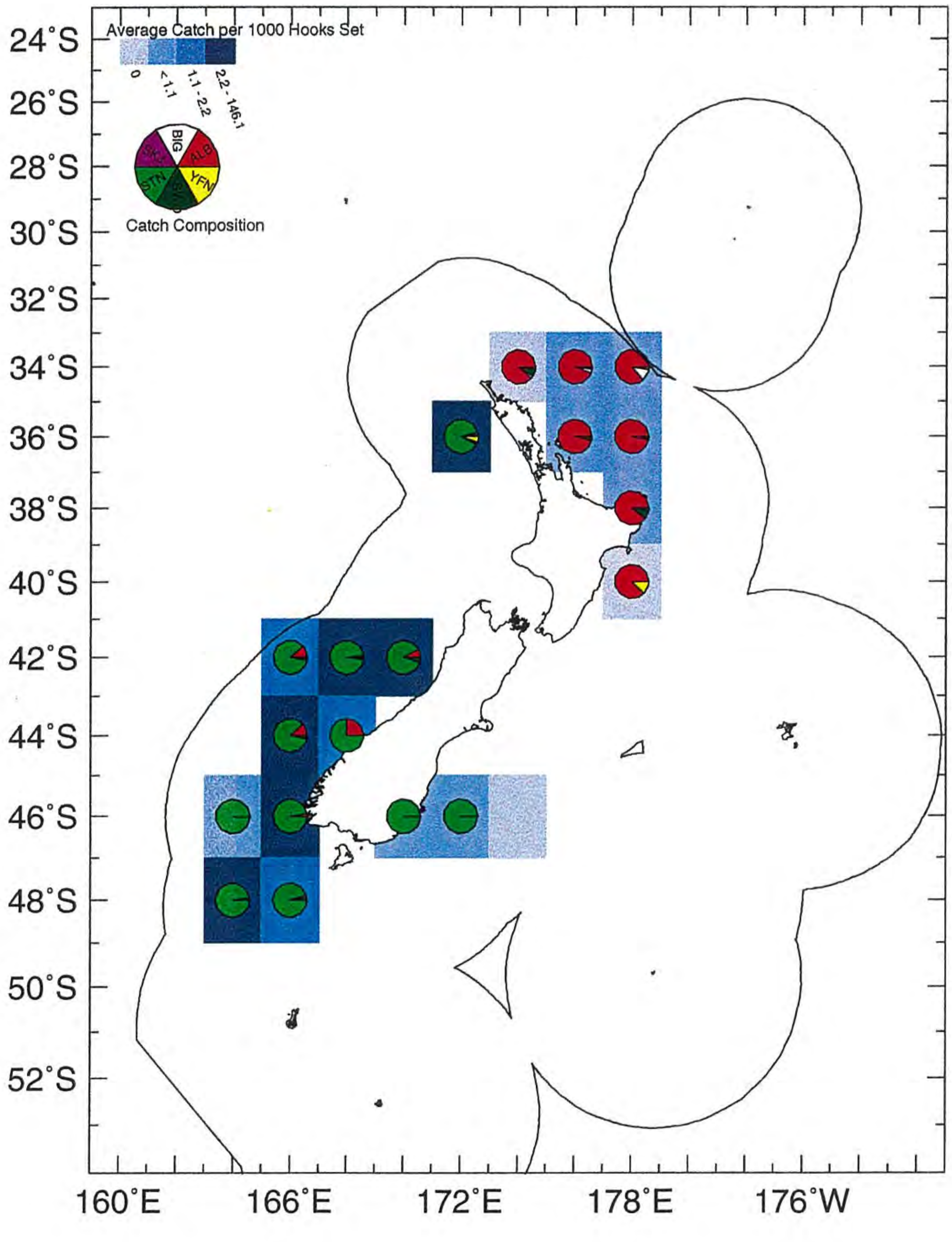


The spatial distribution of southern bluefin CPUE is shown in figure 17 for the domestic and chartered Japanese longline fishery in 1996–97 and for all fleets in earlier periods in Appendix V. High domestic fleet CPUE was off the West Coast and Southland while for charter vessels, high CPUEs occurred in similar areas but also off the east coast of the South Island and off East Cape in 1996–97. The high catch rate at around 36° S off the west coast in 1996–97 is probably a position error in the CELR data. The change in the spatial extent of high CPUE areas can be seen in Appendix V, particularly for the foreign licensed fleet, shows that high CPUE areas have progressively contracted into the two areas where high CPUEs can now be realised.

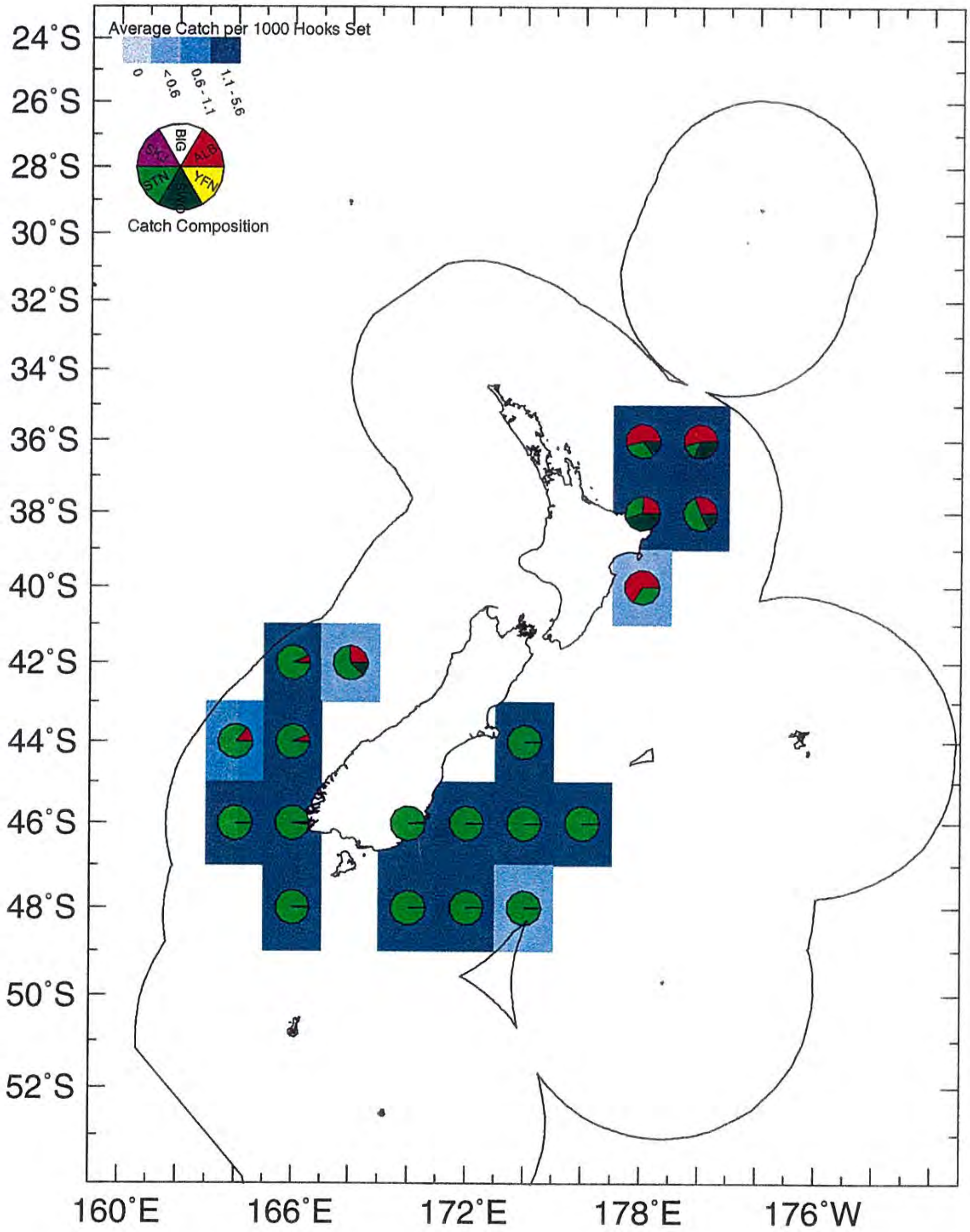
The pie charts in each 1° latitude by 1° longitude square show high bycatch of albacore around the North Island and of swordfish off East Cape, particularly by charter vessels in 1996–97.

Figure 17. Spatial distribution of southern bluefin tuna CPUE and catch composition by the domestic and chartered Japanese longline vessels in 1996–97.

Surface Longlining for Target STN
Domestic Fleet 1996/97



Surface Longlining for Target STN
Charter Fleet 1996/97



8.4 Standardised CPUE trends

As for bigeye tuna (above), standardisation of CPUE for this report was done using an effort-weighted, negative binomial generalised linear response model. Main effects and interaction terms were chosen using S and tested for significance with an analysis of deviance. Covariates were Hermite polynomials up to order 3.

Predictor variables used included:

1. Factors
   - *year*
   - *month:* February to August
   - *fleet:* Foreign (Japanese or charter), Domestic (NZ owned and operated)
2. Covariates
   - *moon phase*
   - *sea surface temperature*
   - *latitude*
   - *longitude*

The final model is given (in S notation) as:

East Cape

CPUE ~ year + poly(moonphase,3) + month + poly(latitude,3) + poly(longitude,3)

West Coast

CPUE ~ year + poly(latitude,3) + poly(moonphase,3) + month +poly(longitude,2)

Chatham Rise

CPUE ~ year + month + poly(moonphase,3) + poly(longitude,3) + poly(SST,2) + poly(latitude,3)

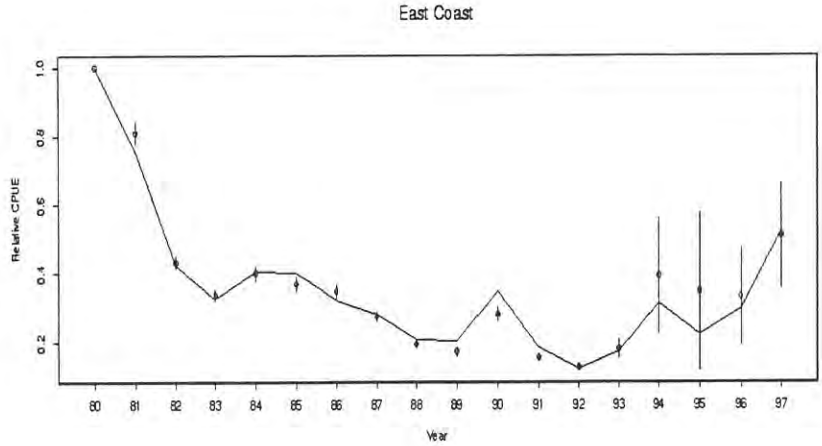
The predictor variables for year, month, moon phase, latitude and longitude, were always significant. Sea surface temperature was significant in the Chatham Rise.

The year effect was not significant for the domestic fleet data when modelled separately, and the fleet factor in a combined model was not significant in any region. Separate main effects models for each of the three regions in the EEZ are described below and provide no evidence of any improvement in the CPUE abundance index for southern bluefin tuna in the EEZ.

East Cape

Between 1980 and 1996, there are only marginal differences between the estimated coefficients and the nominal (mean) CPUE values (see Figure 18). There is an apparent increase in both CPUE and fitted coefficient in 1997, but this results from three very high CPUE sets. A similar short-term event was observed in 1990.

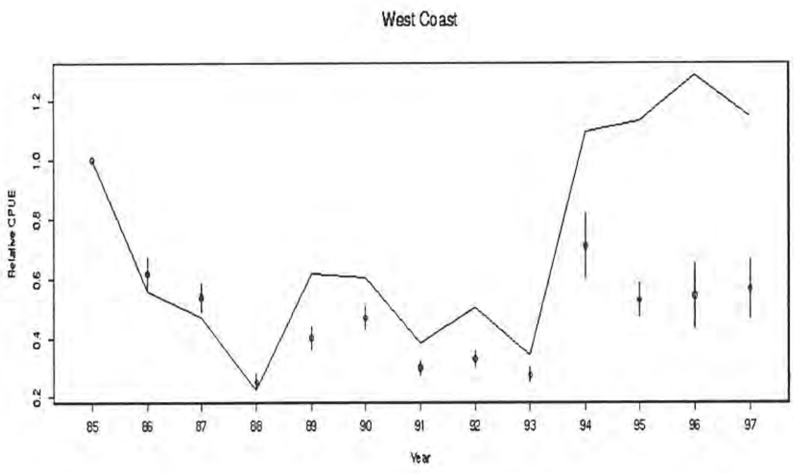
Figure 18. Standardised and nominal CPUE for southern bluefin tuna off East Cape, 1979–80 to 1996–97.



West Coast

There appear to be some differences between mean yearly CPUE values, and estimated year coefficients (Figure 19). However, there was a sharp reduction in effort after 1993 particularly in 1994, 1996, and 1997 which is reflected in the increase in the size of the error bars over that period. Since the estimated errors almost certainly understate the actual uncertainty, it is difficult to be certain about the status of and trends in the fishery for the West Coast region. It is interesting to note that although the GLM year coefficients show a similar trend to the mean CPUE estimates, the magnitude of fluctuations is smaller. This behaviour is not seen in the other two regions.

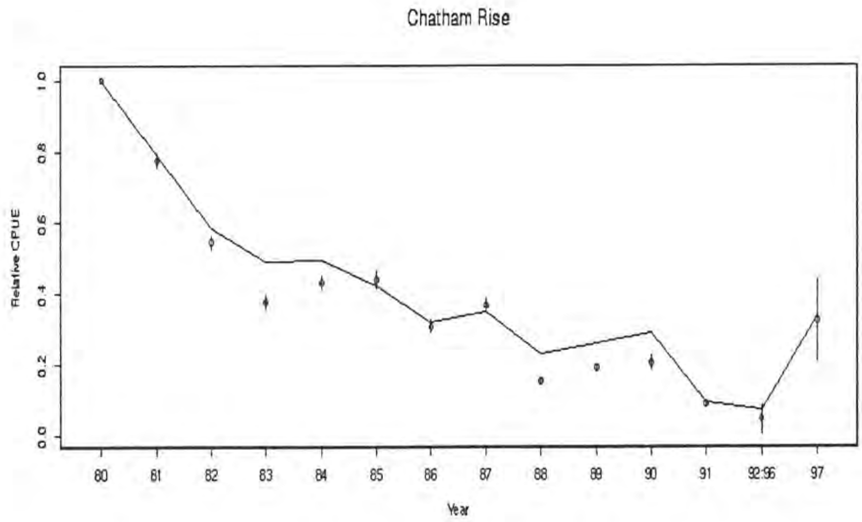
Figure 19. Standardised and nominal CPUE for southern bluefin tuna off the West Coast of the South Island, 1984–85 to 1996–97.



Chatham Rise

Figure 20 shows the results when years 1992 to 1996 are combined (since there was very little fishing in this period). The comments made above for the East Coast region, particularly the 1997 result, are relevant here also, although the increase in 1997 does not appear to have come from only a small number of sets.

Figure 20. Standardised and nominal CPUE for southern bluefin tuna off the Chatham Rise area, 1979–80 to 1996–97, very low effort necessitated the combination of data from 1992 to 1996.



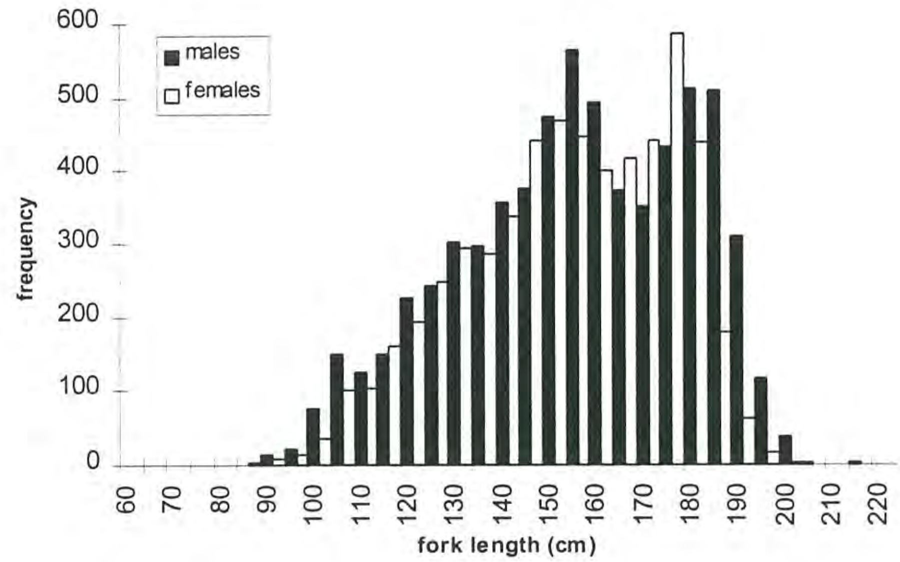
8.5 Summary of biological data

Statistical summaries of biological data on southern bluefin tuna may be found in Appendix VI.

Size composition

Southern bluefin tuna caught by longline in the EEZ range in size from 67 cm to 215 cm fork length. The size composition, aggregated over the period 1991–92 to 1996–97, shown in Figure 21, is bimodal with peaks at 155 cm and at 180 cm. This bimodality, however, is probably due to compositing data across years and each mode is likely to be comprised of several age classes (Fournier *et al.* 1990). Richardson *et al.* (1998) show that frequency distributions of processed weight over this period are unimodal in all years except 1991 and 1992, with the mode varying between years (see Figure 4.5a, b in Appendix VIII). It is of interest that Figure 21 indicates little difference in size composition due to sex with males averaging 153.1 cm and females 150.4 cm fork length.

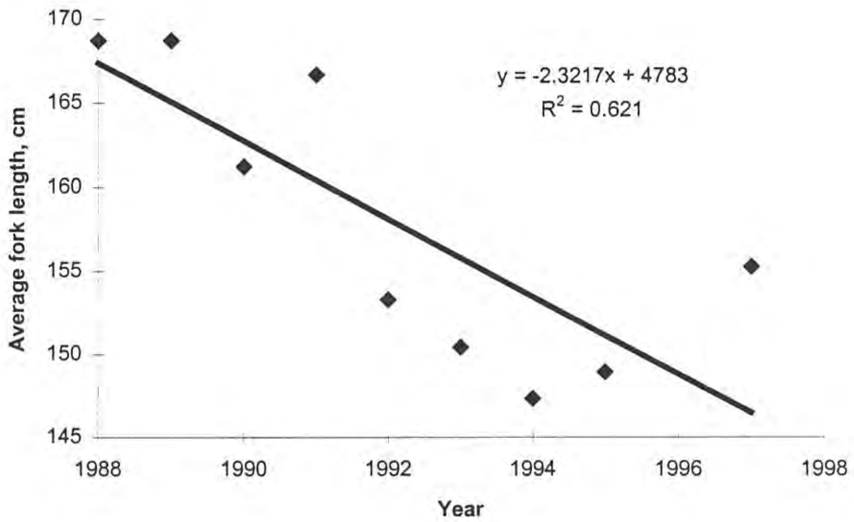
Figure 21. Size composition of southern bluefin tuna by sex for the period 1991–92 to 1996–97.



Substantial changes in size composition of southern bluefin tuna have been observed in the EEZ since the start of data collection in the domestic and foreign licensed fisheries in the early 1980s. Figure 4.5a & b of Appendix VIII show these changes for the domestic fishery. It is clear from this figure that fish smaller than 20 kg processed weight, present in the very early 1980s, disappeared and were not seen again in EEZ catches until 1989. The occurrence of small fish, starting in 1990, has been variable through to the mid-1990s. However, in 1996 and 1997 small southern bluefin tuna have been a predominate component of the catch and in these same years fish larger than 80 kg have been virtually absent.

Average size of southern bluefin tuna since 1988, when all fleets are combined, has exhibited a roughly linear decline from 168.7 cm in 1987–88 to 147.3 cm in 1993–94, though average fish size increased again in 1996–97 to 155.2 cm. fork length. The linear trend shown in Figure 22 indicates that average fish size decreased by 2.3 cm per year. The decrease in fish size is attributable to the increasing abundance of juvenile southern bluefin tuna during the early to mid-1990s and the continuing decline in abundance of large adults during the same period. The decline in small fish since 1994–95 may account for the subsequent increase in average fish size seen in 1996–97.

Figure 22. Average fork length (cm) of southern bluefin tuna caught by all observed longliners during the period 1988–97 (n = 10, 697).



Sex ratio

Sex ratios in longline caught southern bluefin tuna vary year to year (1.0–1.6 M:F) with males more common than females (10% more males over all years). Sex ratio is significantly different ($P<0.005$) from a 1:1 ratio and is independent of year.

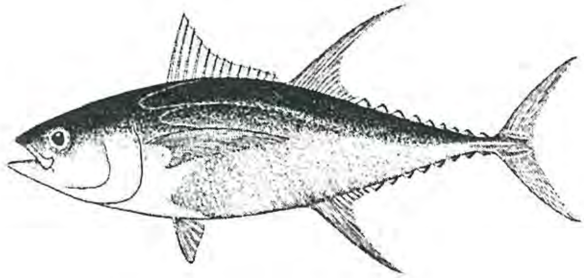
Length - weight relationships

Relationships predicting green weight from length were derived from observer data for males and females separately and combined for all fish where sex was known. The estimated relationships are as follows (weight in kg, length in cm):

males	ln (weight) = 0.021 * length + 1.069	$R^2 = 0.95$
females	ln (weight) = 0.021 * length + 1.045	$R^2 = 0.94$
sexes combined	ln (weight) = 0.021 * length + 1.061	$R^2 = 0.95$

The standard errors of the parameters and sample sizes used to derive these equations are in Appendix VI.

9 Yellowfin tuna

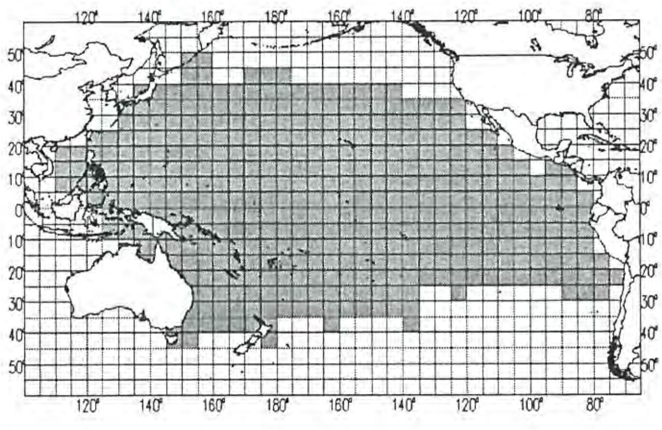


Thunnus albacares (Bonnaterre, 1788)

Summary Information on Yellowfin tuna in the Pacific Ocean

Stocks	a western and central Pacific stock that is genetically distinguishable from an eastern Pacific stock
Fishing Methods	longline, purse seine, handline, and pole-and-line
Catches	approximately 411 000–732 000 tonnes from the entire Pacific Ocean (about 61–69% of the global catch) per year for the period 1984–93
Parties Fishing	Canada, China, Chinese Taipei, Colombia, Costa Rica, Ecuador, El Salvador, France, Japan, Korea, Mexico, Panama, South Pacific States and territories, USA, Venezuela
Spawning	spawning year round; mostly between 10° S and 30° N in the central and western Pacific and between 10° S and 20° N in the eastern Pacific
Fish Size	maximum size exceeding 200 cm fork length and 176 kg reported; yellowfin tuna commonly reach 150 cm

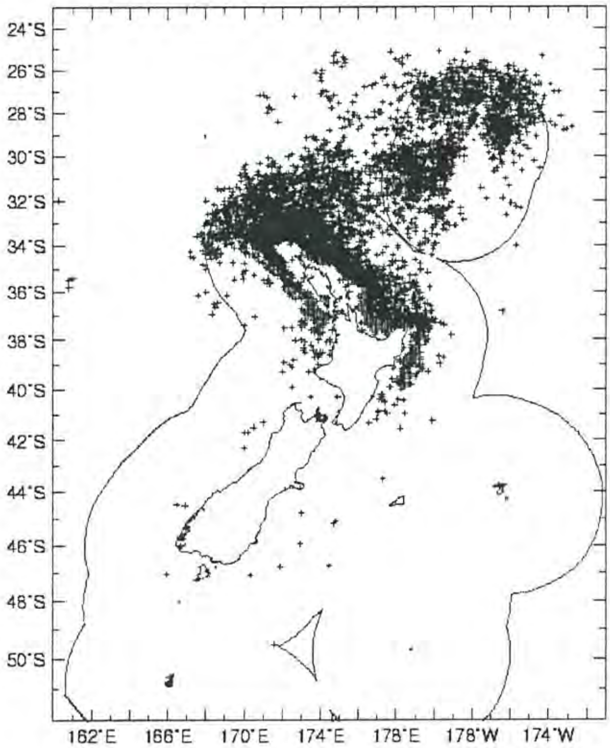
Area of commercial fishing operations for Yellowfin tuna, 1991–93



9.1 Distribution

Yellowfin tuna caught in the EEZ are part of a central and western Pacific stock whose eastern boundary is generally taken to be about 150° W. This stock supports a surface fishery of about 200,000 t per year in the western equatorial Pacific Ocean and a widely distributed longline fishery of over 44,000 t. Figure 23 shows that yellowfin tuna are caught primarily in FMA1 and FMA10 but also south to about 40° S on both east and west coasts.

Figure 23. Distribution of longline effort in the EEZ (all fleets, 1979–80 to 1996–97) where yellowfin tuna were caught.



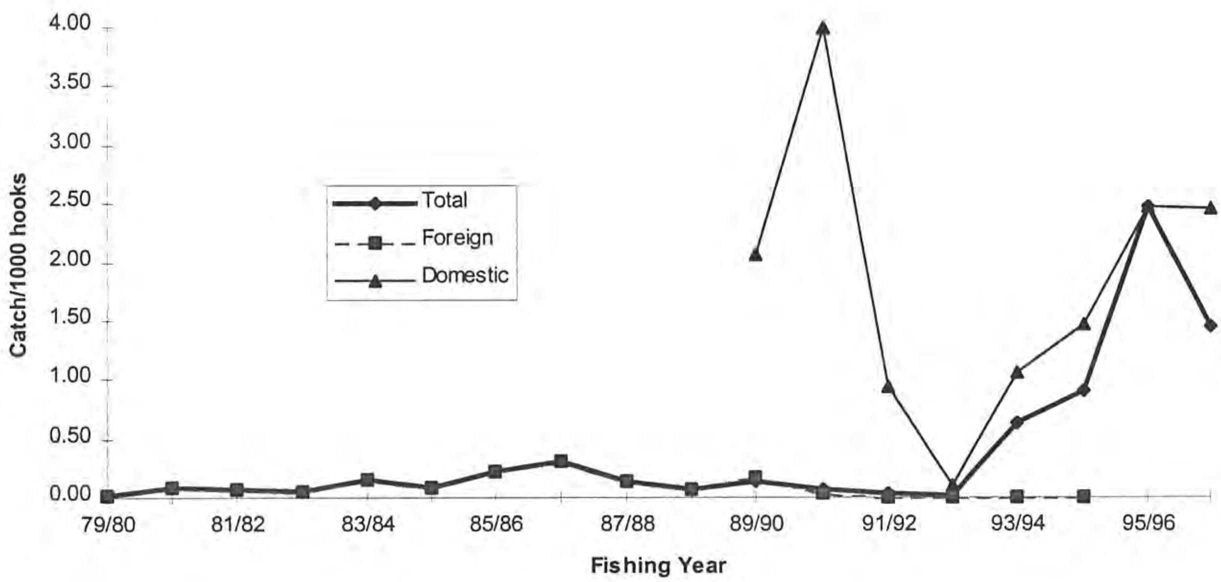
9.2 Trends in catch and fishing effort

Yellowfin although only occasionally targeted in the EEZ, is regularly a bycatch component in the longline fishery targeting bigeye tuna (see Figure 9). Total catches in the EEZ reached a minimum (see Table 5) in 1992–93 which coincides with the dramatic reduction in foreign licensed fishing in FMA 1 and FMA 9 and the development of the domestic longline fishery in these areas. The catch of yellowfin tuna in the EEZ since 1991–92 has been almost entirely by domestic longline vessels.

9.3 CPUE trends

The trend in longline CPUE where yellowfin tuna were caught is shown in figure 24. Since yellowfin are only occasionally reported as a target species in the EEZ this figure combines data where it is caught regardless of the stated target species. CPUE by the foreign licensed fleet has been uniformly low throughout the time this fleet operated in the EEZ (annual average CPUE = 0.1 fish per 1000 hooks). The domestic fleet, however, has exhibited an increase in CPUE each year since 1992–93. Prior to this year the high CPUEs are due to very few sets and are not considered reliable. The domestic fleet's yellowfin CPUEs are lower than adjacent areas (eg New Caledonia, Fiji and Australia, see Anon 1998b).

Figure 24. Trend in yellowfin tuna longline CPUE (number of fish per 1000 hooks) whether it was targeted or caught as bycatch, 1979–80 to 1996–97

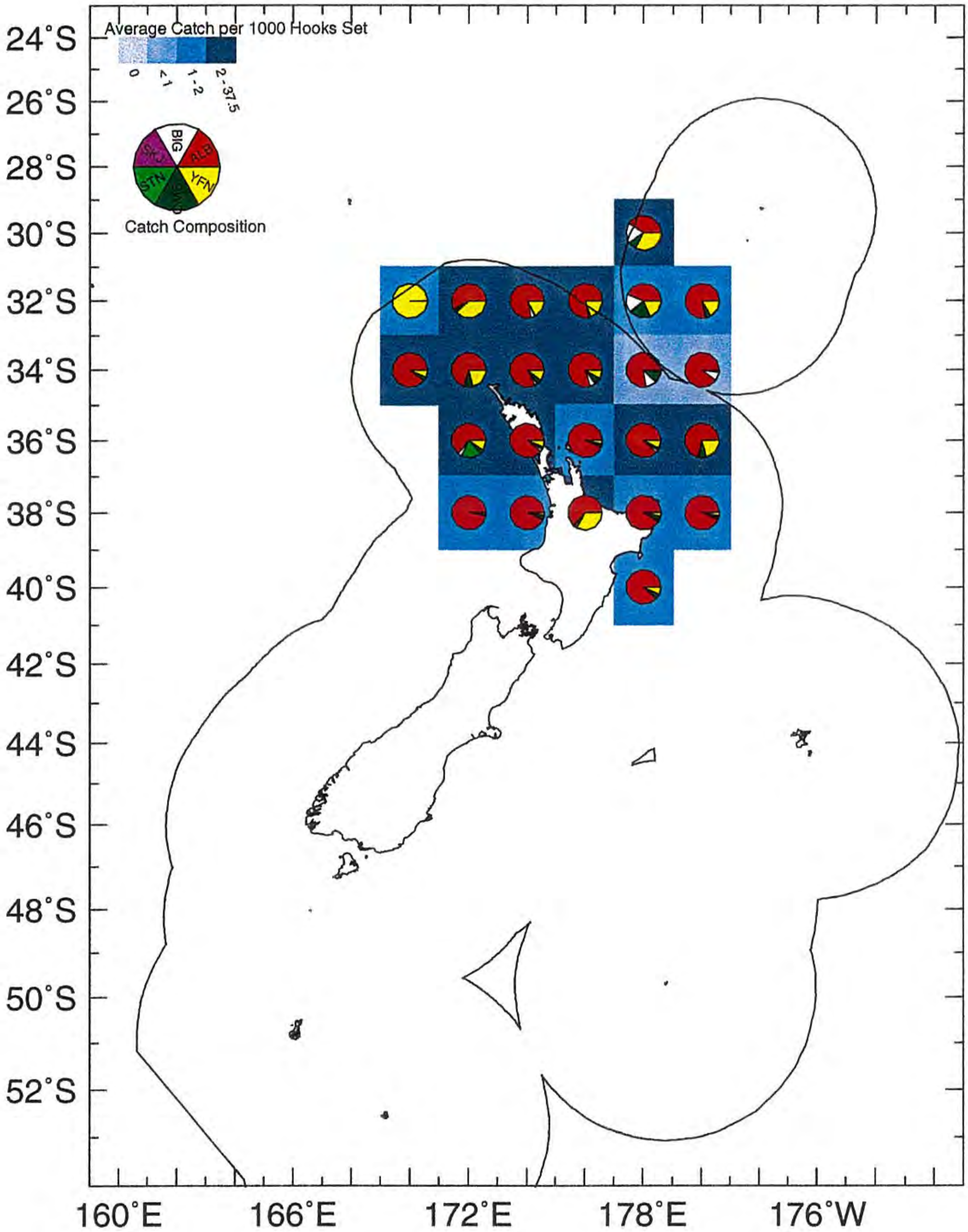


The spatial distribution of yellowfin CPUE is shown in figure 25 for the domestic longline fishery in 1996–97 and for all fleets in earlier periods in Appendix V. Since yellowfin is only occasionally reported as a target species in the EEZ this figure shows the CPUE whether or not yellowfin was reported as a target species. It is clear that yellowfin are primarily caught in FMA 1 and FMA 9 and that the highest CPUEs (2.0–37.5 fish per 1000 hooks) are associated with the Three Kings Rise and southern parts of the Kermadec Ridge.

The pie charts in each 1° latitude by 1° longitude square show high bycatch of albacore with some bigeye tuna and swordfish also caught.

Figure 25. Spatial distribution of yellowfin tuna CPUE and catch composition by the domestic longline vessels in 1996–97.

Surface Longlining for YFN
Domestic Fleet 1996/97



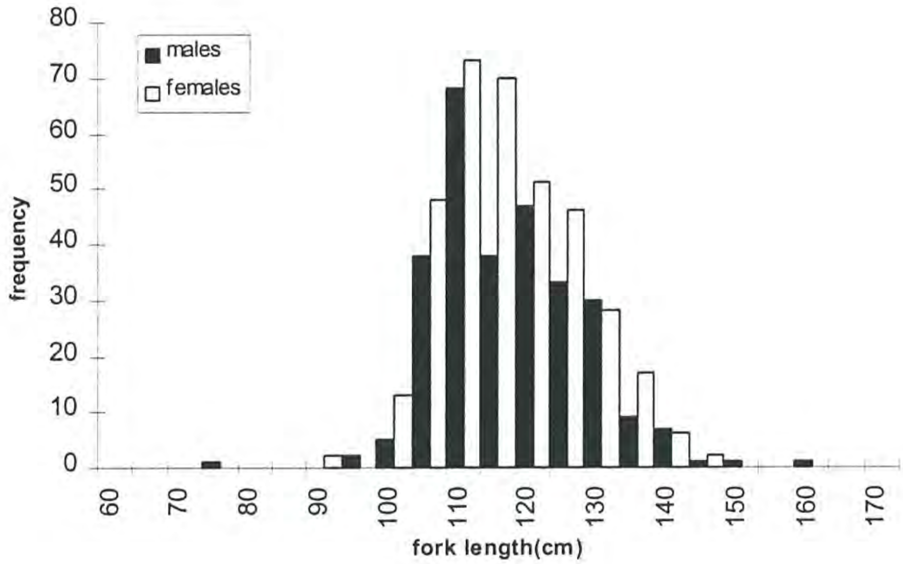
9.4 Summary of biological data

Statistical summaries of biological data on yellowfin tuna may be found in Appendix VI.

Size composition

Yellowfin tuna caught in the EEZ by longline range in size from 66 cm to 160 cm fork length. The size composition shown in Figure 26 is unimodal with a peak close to the median length of 113 cm. The size composition of males and females are nearly identical with mean length of males 115.1 cm and for females 114.7 cm.

Figure 26. Size composition of longline caught yellowfin tuna by sex for the period 1991–92 to 1996–97.



Sex ratio

Sex ratios in longline caught yellowfin tuna vary year to year (0.7–1.5 M:F) with males less common than females (20% fewer males over all years). However, sex ratio is not significantly different from a 1:1 ratio and is independent of year.

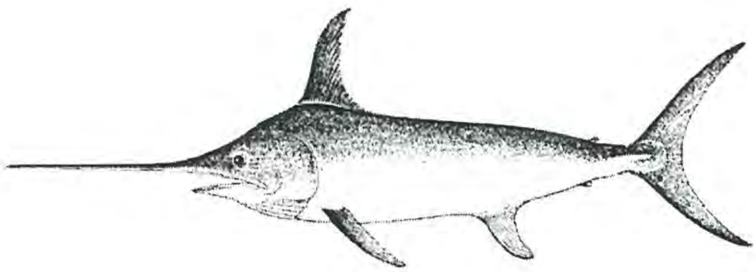
Length - weight relationships

Relationships predicting green weight from length were derived from observer data for males and females separately and combined for all fish where sex was known. The estimated relationships are as follows (weight in kg, length in cm):

males	ln (weight) = 0.026 * length + 0.294	$R^2 = 0.88$
females	ln (weight) = 0.025 * length + 0.365	$R^2 = 0.92$
sexes combined	ln (weight) = 0.026 * length + 0.292	$R^2 = 0.91$

The standard errors of the parameters and sample sizes used to derive these equations are in Appendix VI.

10 Swordfish

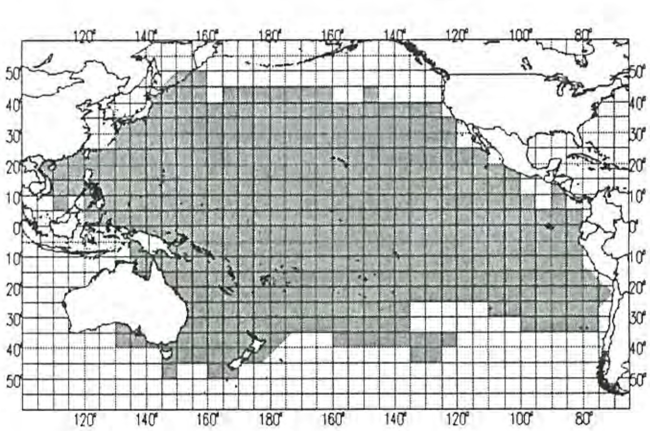


Xiphius gladius (Linnaeus, 1758)

Summary Information on Swordfish in the Pacific Ocean

Stocks	uncertain
Fishing Methods	primarily by longline
Catches	approximately 18 000–35 000 tonnes from the entire Pacific Ocean (about 33–44% of the global catch) per year for the period 1984–93
Parties Fishing	Chile, Chinese Taipei, Colombia, Ecuador, Japan, Korea, Mexico, Peru, Philippines, South Pacific States and territories, USA
Spawning	late spring and summer months; mostly 20° S–30° N west of 150° W
Fish Size	maximum size of 445 cm total length (about 380–390 cm eye—fork length) and 540 kg reported; most swordfish larger than 140 kg are females

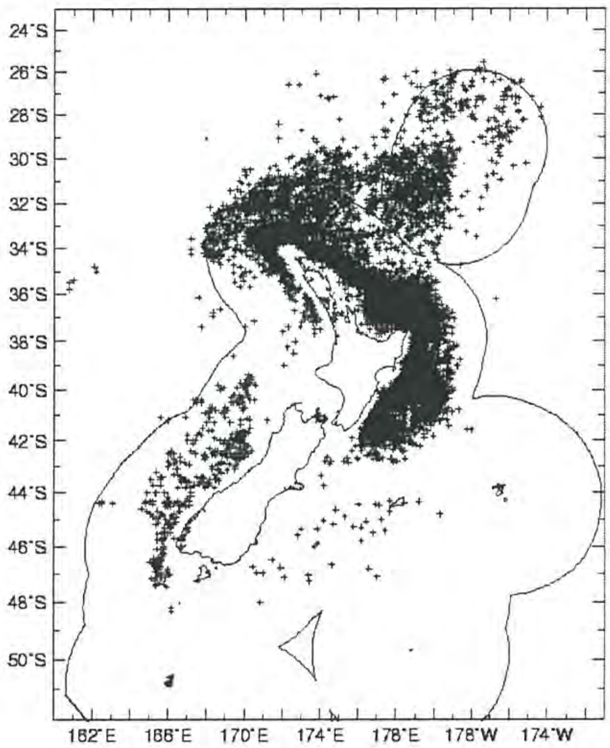
Area of commercial fishing operations for Swordfish, 1991–93



10.1 Distribution

Swordfish are caught by tuna longlines throughout the Pacific Ocean, usually as bycatch. In the western Pacific south of 20° S they are the most common billfish caught on longlines (Carocci and Majkowski 1996). Figure 27 shows that swordfish commonly occur around the North and South Islands, particularly north of 43° S. Prohibitions on targeting billfish and area exclusions since 1987 under the "Billfish Moratorium" have dramatically reduced the apparent area of swordfish occurrence compared to that shown in Figure 27.

Figure 27. Distribution of longline effort in the EEZ (all fleets, 1979–80 to 1996–97) where swordfish are caught.



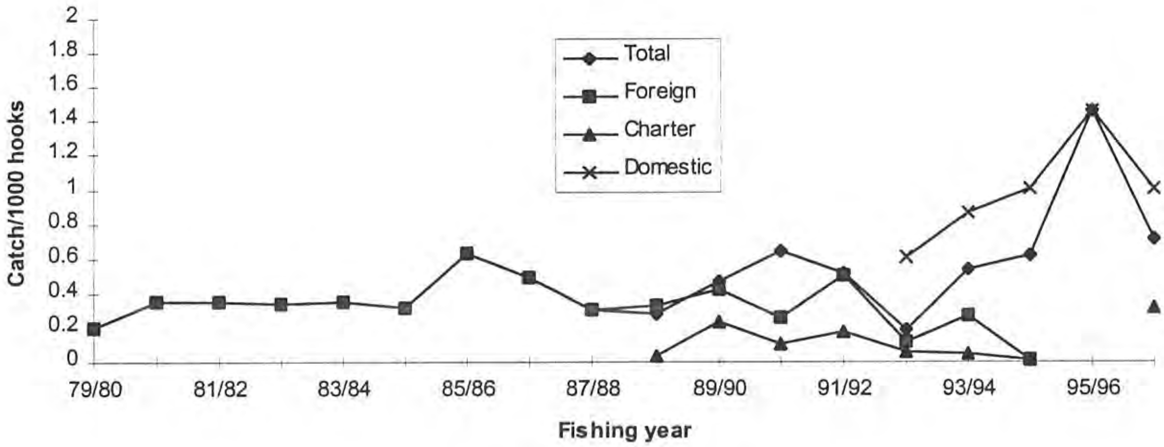
10.2 Trends in catch and fishing effort

Swordfish, although occasionally reported as a target species in the EEZ, is generally a bycatch component in the longline fisheries regardless of the target (Carocci and Majkowski, 1996; also see Figure 5, 9, 17 & 25). Total catches in the EEZ have declined since the establishment of the "Billfish Moratorium" in 1987. Prior to that time and especially in the early 1980s when foreign licensed longline fishing was at its peak swordfish catches on the order of 4000 to 9000 fish per year occurred. Since 1987 swordfish catches have been lower, on the order of 1000–4000 fish per year. The catch of swordfish in the EEZ since 1993–94 has been almost entirely by domestic longline vessels while prior to that catches were by foreign licensed and chartered Japanese longliners.

10.3 CPUE trends

The trend in swordfish CPUE is shown in figure 28 by longline fleet. This figure indicates that for foreign licensed and chartered fleets CPUE has been relatively stable. The increase for the charter fleet in 1996–97 appear to be an exception to an otherwise stable CPUE. The increase in CPUE for the domestic fleet from 1992–93 to 1995–96 is probably attributable to increasing longline effort for bigeye and southern bluefin tunas.

Figure 28. Trend in swordfish CPUE (number of fish per 1000 hooks) in the New Zealand longline fishery, 1979–80 to 1996–97.

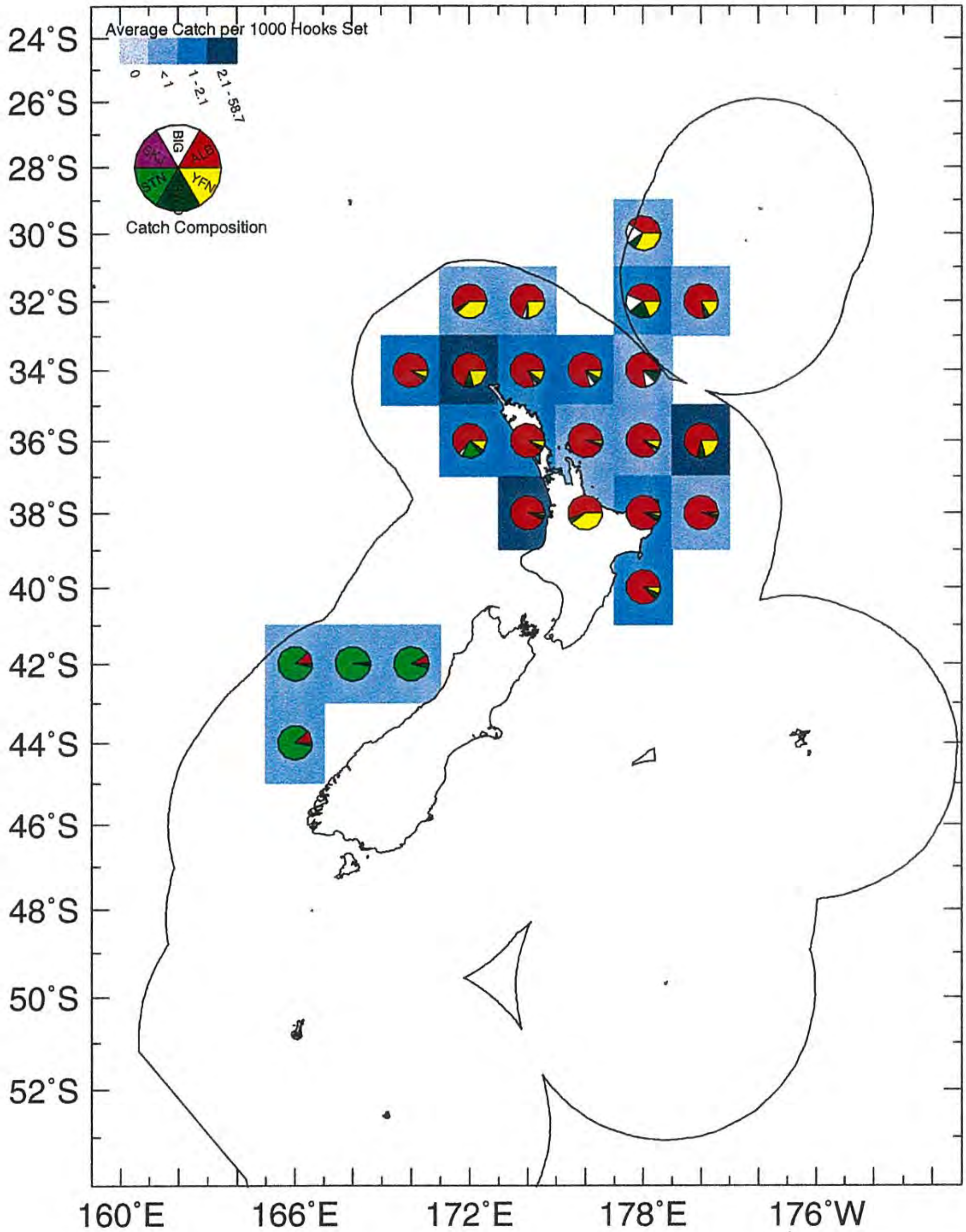


The spatial distribution of swordfish CPUE is shown in figure 29 for domestic and chartered longliners in 1996–97 and for all fleets in earlier periods in Appendix V. Swordfish is only occasionally reported as a target species in the EEZ and this figure shows the CPUE regardless of whether it was reported as the target. It is clear that swordfish are primarily caught in FMA 1, FMA 9 and FMA 7 with highest CPUEs (2.1–58.7 fish per 1000 hooks) associated with the Three Kings Rise and East Cape.

The pie charts in each 1° latitude X 1° longitude square show high bycatch of albacore and yellowfin tuna in the north and of southern bluefin tuna in the south.

Figure 29. Spatial distribution of swordfish CPUE and catch composition by domestic and chartered longline vessels in 1996–97.

Surface Longlining for SWO
Domestic Fleet 1996/97



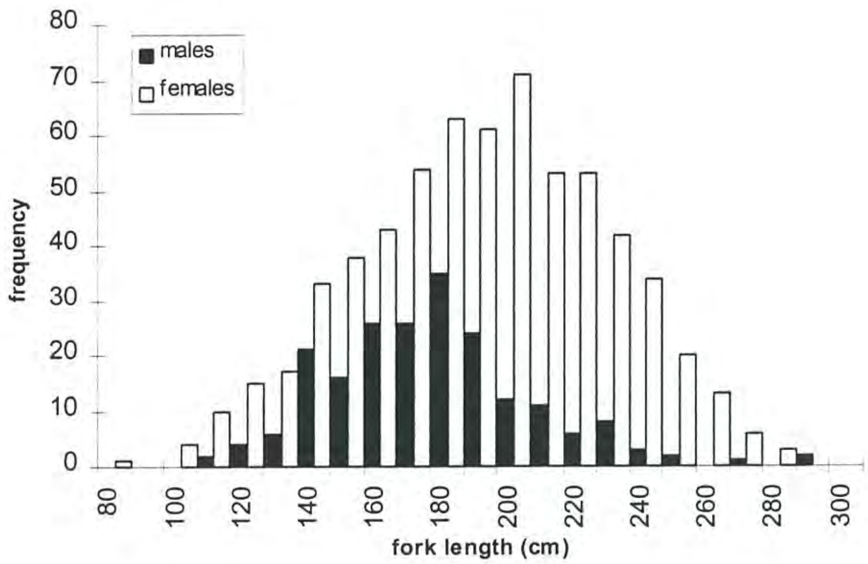
10.4 Summary of biological data

Statistical summaries of biological data on swordfish may be found in Appendix VI.

Size composition

Swordfish caught in the EEZ range in size from 42 cm to 289 cm body length (distance from the tip of the lower jaw to the end of the median caudal ray). While the size range is similar for males and females, it is clear from Figure 30 that males are usually substantially smaller than females with the average body length of males 172.0 cm and females 185.8 cm. Nakamura (1985) reports that females are larger than males and that most swordfish heavier than 140 kg (141 cm) are females.

Figure 30. Size composition of longline caught swordfish by sex for the period 1991–92 to 1996–97.



Sex ratio

Sex ratios in longline caught swordfish vary year to year (0.0–0.8 M:F) with males less common than females (30% males over all years). Sex ratio is significantly different from a 1:1 ratio and varies from year to year.

Length - weight relationships

Relationships predicting green weight from length were derived from observer data for males and females separately and combined for all fish where sex was known. The estimated relationships are as follows (weight in kg, length in cm):

males	ln (weight) = 0.018 * length + 1.141	$R^2 = 0.89$
females	ln (weight) = 0.018 * length + 1.141	$R^2 = 0.90$
sexes combined	ln (weight) = 0.018 * length + 1.153	$R^2 = 0.90$

The standard errors of the parameters and sample sizes used to derive these equations are in Appendix VI.

11 DISCARD PRACTISES

Discarding of fish has not been reported in the albacore troll fishery in the EEZ (based on limited observer coverage in the 1980s). However, low levels of discarding (about 1.7% of catches) of small albacore has been observed in the high seas troll fishery east of New Zealand (Labelle and Murray 1992). Shark damaged albacore (less than 0.1%) are also discarded in this fishery.

There are little or no data on discard practises in the domestic skipjack purse seine fishery in the EEZ although discarding of bycatch is generally not at issue. Bailey *et al.* (1996) noted regular catches of mako sharks and a number of coastal species in the domestic purse seine fishery in data from 1976 to 1982.

Discard practices within the EEZ are only known from observer coverage on longliners targeting southern bluefin and bigeye tunas. Observer data forms did not include provision of discard information before 1991–92. Details of the number of albacore, bigeye, southern bluefin and yellowfin tunas and for swordfish discarded or lost and their status on release are given by fishing year and fleet in Appendix IX.

The aggregated observer data (1991–92 to 1996–97) suggests that discarding of albacore, bigeye, southern bluefin and yellowfin tunas and swordfish is minor on longliners operating in the EEZ. Similarly the proportion of the catch that is lost before landing is also low (< 1.0% over all species, fleets and years). For albacore 3.3% are discarded and 0.6% are lost before landing (n = 17 307 fish). For bigeye tuna 6.1% are discarded and 0.8% lost before landing (n = 385 fish). Discards are especially low for southern bluefin tuna where 1.0% are discarded, 0.7% are lost before landing (n = 10 475 fish). The highest discards appear to be of yellowfin at 10.6% with losses only 0.1% (n = 687 fish). Discards of swordfish are only 4.9% with losses of 0.9% (n = 1241 fish).

While observers frequently do not recorded why fish are discarded, when the reason is specified, most appears to be because of damage. Nearly all damaged fish are the result of sharks although occasionally killer whales, seals or the propeller are reported as the cause of damage. Damage has been observed in 40% of albacore, 32% of bigeye, 42% of southern bluefin, 18% of yellowfin and 26% of swordfish which are discarded when all fleets and years are combined.

For albacore and southern bluefin tuna about 3% of discards are attributed to small size of fish while no bigeye tuna have been recorded as discarded for this reason. Small size is more frequently recorded as the reason for discarding yellowfin tuna and swordfish (27% and 18% respectively).

Table 3 summarises the discards, as a percentage of the catch, for species covered by this report for each fleet by fishing year. It is clear from this table that the frequency of discards varies between years and fleets (maximum rates are 11.8% for albacore, 19.1% for bigeye, 2.6% for southern bluefin, 18.5% for yellowfin and 100% for swordfish). However, we did not test for significant differences between fleets and years because of the absence of data from domestic vessels in 1992–93, charter vessels in 1991–92 and 1995–96 and foreign vessels in 1995–96 and 1996–97. While we would expect to address this issue for the domestic and charter fleets next year it does appear that discards in the southern bluefin tuna fishery are particularly low (0.2–1.2% on average).

Table 3. Discards of tuna and swordfish as % of fish caught, by species, fleet and fishing year in the tuna longline fishery (ALB = albacore, BIG = bigeye, SBT = southern bluefin, YFN = yellowfin tunas, SWO = swordfish; D = domestic, C = chartered and F = foreign licensed longliners; n–a refers to no fishing or to no catch of a particular species).

Species	Fleet	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	All years
ALB	D	6.7	n–a	0.0	1.8	9.2	1.2	4.4
	C	n–a	2.6	3.4	3.7	n–a	1.2	2.1
	F	0.1	3.3	3.2	11.8	n–a	n–a	2.1
	All fleets	1.3	3.3	3.3	2.4	9.2	1.2	3.3
BIG	D	6.3	n–a	n–a	0.0	13.5	19.1	8.6
	C	n–a	n–a	0.0	n–a	n–a	n–a	0.0
	F	0.0	0.0	0.0	0.0	n–a	n–a	0.0
	All fleets	5.2	0.0	0.0	0.0	13.5	18.3	6.1
SBT	D	0.0	n–a	n–a	1.1	2.3	0.2	0.9
	C	n–a	2.6	1.4	0.3	n–a	1.0	1.2
	F	0.2	0.6	0.0	0.0	n–a	n–a	0.2
	All fleets	0.2	1.7	1.2	0.4	2.3	0.9	1.0
YFN	D	n–a	n–a	n–a	7.2	18.5	5.3	10.7
	C	n–a	n–a	0.0	n–a	n–a	n–a	0.0
	F	n–a	n–a	n–a	n–a	n–a	n–a	n–a
	All fleets	n–a	n–a	0.0	7.2	18.5	5.3	10.6
SWO	D	18.8	n–a	n–a	7.7	12.2	2.4	6.5
	C	n–a	0.0	13.0	0.0	n–a	3.0	3.9
	F	1.8	10.1	0.0	100.0	n–a	n–a	5.1
	All fleets	2.5	9.6	7.3	10.5	12.2	2.9	4.9

5t

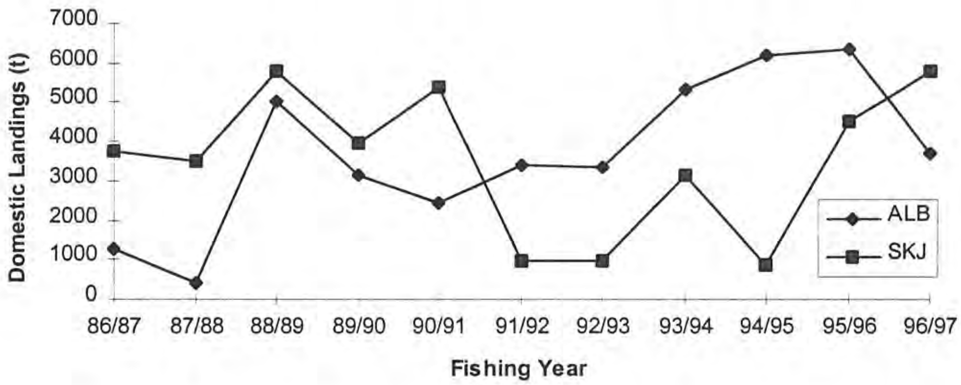
6%

We were similarly constrained by the scarcity of data on the status of discarded catch (ie whether alive or dead) and consequently have pooled fleets and years to estimate the proportion of the discarded catch which was alive when released. The data from which the estimates are presented are in Appendix IX. In the case of albacore 12.1% of discarded fish are alive when released (n = 339), for bigeye 47.6% are alive (n = 21), southern bluefin 55.4% (n = 101), yellowfin 80.8% (n = 73) and for swordfish 38.2% are alive (n = 55) when released. This would lead us to conclude that the portion of the catch that is discarded and dead is a small but measurable source of mortality. The high proportion of albacore which are discarded and dead can probably be attributed to high grading of catch due to low market price for albacore smaller than 20 pounds (9.1 kg).

12 DOMESTIC TUNA AND SWORDFISH LANDINGS

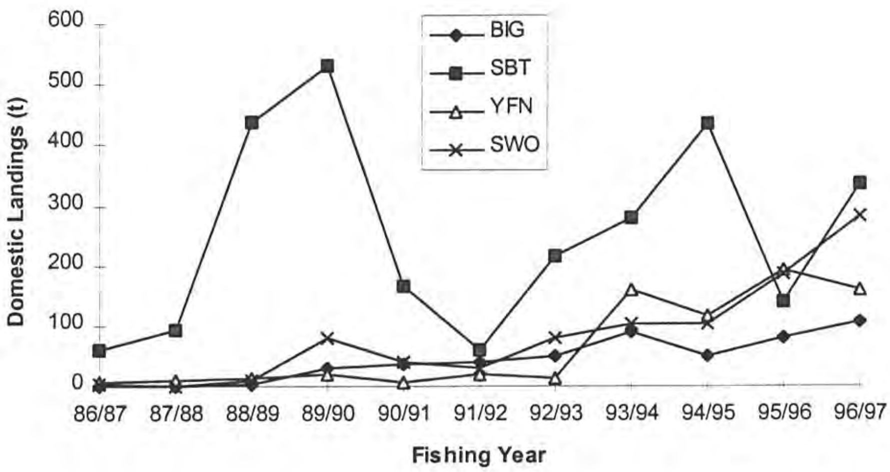
The largest annual landings by species are from the summer surface fisheries for albacore and skipjack tuna. Figure 31 indicates that the variability of landings has been more extreme for skipjack tuna (860.5–5780.5 t) than for albacore (409.6–6315.8 t) since 1986–87. With the exception of the period 1991–92 to 1994–95 skipjack tuna appear to have supported annual landings of 4000–6000 t. Albacore in contrast appear to have shown a regular but moderate fluctuation around a gradual increase in landings that peaked in 1995–96. In the context of the stock as a whole skipjack landings represent a small fraction of the more than 900,000 t landed annually in the Pacific. Albacore landings in contrast represent roughly half of the surface fishery landings taken from the South Pacific stock.

Figure 31. Domestic landings (tonnes) of albacore and skipjack tuna by fishing year from LFR reports.



The annual landings of those species caught primarily by longline are shown in Figure 32. However, prior to 1990–91 the only tuna longlining was by 3–5 Japanese vessels operating under charter and primarily targeting southern bluefin tuna, hence landings of bigeye, yellowfin and swordfish represent occasional catches at the end of the season. Of particular note is the regular increase in the landings for each of these species following the expansion of the domestic longline fishery starting in 1990–91. While landings (and catches) of southern bluefin tuna have been quite variable the fluctuation seen in Figure 32 is exaggerated by the charter vessels reporting the catch on LFRRs in some but not all years. The marked decline in landings of southern bluefin tuna in 1990–91 and 1991–92 are likely to be due to Charter vessels not reporting in these years. Similarly the low landings in 1995–96 can be attributed to charter vessels not operating in the EEZ in that year. The three years since 1982 in which New Zealand exceeded its southern bluefin tuna catch allocation under the trilateral management arrangements (later formalised as the CCSBT) can also be seen (ie, 1988–89, 1989–90 and 1994–95).

Figure 32. Domestic landings (tonnes) of bigeye, southern bluefin and yellowfin tunas and swordfish by fishing year from LFR reports.



A summary of the 1996–97 landings by month compared to the previous five year monthly average is shown in Table 4 for albacore, bigeye, skipjack, southern bluefin and yellowfin tunas and for swordfish. From this table it appears that despite an early start to the albacore season, landings were lower than average throughout the summer. Higher than average winter longline catches were too small to compensate. The result was that the 1996–97 albacore landings were 24% below the 5-year average. In contrast the summer skipjack tuna fishery appeared to start slightly later than usual and last slightly longer with above average landings throughout most of the season resulting in landings that were more than double those of the previous 5-year average. Substantial increases in landings of bigeye, southern bluefin and yellowfin tunas and swordfish were realised with increases on the order of 48–184% relative to the preceding 5-year average. The largest increase in landings was seen in swordfish.

Table 4. Domestic landings (tonnes) in 1996–97 relative to the 1991–92 to 1995–96 average by month and fishing year.

	Albacore			Bigeye			Skipjack		
	5 Yr Avg.	1996–97	Change	5 Yr Avg.	1996–97	Change	5 Yr Avg.	1996–97	Change
October	5.8	2.6	-3.2	1.9	1.8	-0.1	0.0	0.1	0.1
November	12.9	13.7	0.8	4.8	11.4	6.6	0.3	0.3	0.0
December	108.0	258.3	150.3	6.4	14.0	7.6	173.5	0.9	-172.6
January	1251.8	972.7	-279.1	8.0	12.6	4.6	475.7	1554.9	1079.2
February	1751.4	1080.2	-671.2	8.9	11.0	2.1	460.5	1826.0	1365.5
March	1088.1	685.4	-402.7	8.5	12.6	4.1	587.9	1460.8	872.9
April	431.6	259.8	-171.8	6.9	14.0	7.1	297.8	188.4	-109.4
May	150.4	232.9	82.5	7.0	9.0	2.0	82.1	609.4	527.3
June	76.8	130.0	53.2	4.9	6.8	1.9	11.9	139.8	127.9
July	24.7	63.2	38.5	1.9	6.4	4.5	0.1	0.0	-0.1
August	9.0	17.0	8.0	0.7	3.0	2.3	0.1	0.0	-0.1
September	2.7	9.7	7.0	1.8	2.3	0.5	0.0	0.0	0.0
Total	4913.2	3725.5	-1187.7	61.7	121.8	60.1	2090.0	5780.5	3690.5

	Southern bluefin			Yellowfin			Swordfish		
	5 Yr Avg.	1996–97	Change	5 Yr Avg.	1996–97	Change	5 Yr Avg.	1996–97	Change
October	0.0	0.1	0.1	20.7	2.3	-18.4	1.4	0.2	-1.2
November	0.1	0.1	0.0	3.0	12.1	9.1	3.0	1.5	-1.5
December	0.4	0.1	-0.3	7.1	26.0	18.9	2.5	5.6	3.1
January	0.1	0.1	0.0	20.4	33.1	12.7	3.9	18.2	14.3
February	0.7	0.2	-0.5	22.3	20.2	-2.1	10.7	25.7	15.0
March	1.1	0.9	-0.2	16.9	29.1	12.2	20.4	39.5	19.1
April	11.2	4.0	-7.2	6.7	24.4	17.7	16.4	39.9	23.5
May	15.9	12.9	-3.0	1.8	7.5	5.7	15.6	45.0	29.4
June	86.9	122.0	35.1	0.5	1.2	0.7	11.5	30.0	18.5
July	61.8	190.4	128.6	0.0	0.2	0.2	6.1	66.3	60.2
August	47.3	2.3	-45.0	0.0	0.0	0.0	5.4	5.5	0.1
September	0.1	0.2	0.1	0.4	3.4	3.0	2.7	5.4	2.7
Total	225.8	333.5	107.7	99.8	159.5	59.7	99.7	282.8	183.1

Estimates of the total catches of tuna and swordfish in the EEZ are derived from LFRR data for domestic and charter vessels and from TLCER data from foreign licensed vessels. These estimates are summarised in Table 5 for the period 1986–87 to 1996–97. It is clear from this table that the foreign licensed component of total catches has been declining since 1991–92 for most species and has been absent since 1995–96. The maximum catch of each species during this period was 6316 t for albacore, 649 t for bigeye, 5780 t for skipjack,1927 t for southern bluefin, 140 t for yellowfin, and 501 t for swordfish. The maximum catches for each of these species, except albacore which has always been dominated by the domestic fishery, would be higher if we compiled the estimates from the early 1980s or even earlier due to the very large foreign fishing effort at that time.

Table 5. Total catches (tonnes) from the New Zealand EEZ, 1986–87 to 1996–97.

Fishing	Albacore			Bigeye			Skipjack		
Year	Domestic	Foreign	Total	Domestic	Foreign	Total	Domestic	Foreign	Total
1986–87	1265.2	668.8	1934.0	0.1	648.7	648.9	3762.7	0.0	3762.7
1987–88	409.6	562.1	971.7	0.0	247.2	247.2	3509.4	0.0	3509.4
1988–89	4999.8	280.4	5280.1	3.5	176.1	179.6	5768.8	0.0	5768.8
1989–90	3144.3	385.1	3529.4	30.7	344.0	374.7	3971.7	0.0	3971.7
1990–91	2451.3	404.0	2855.3	36.0	158.9	194.9	5371.1	0.0	5371.1
1991–92	3417.5	296.8	3714.2	41.1	83.7	124.8	988.2	0.0	988.2
1992–93	3322.7	66.8	3389.5	48.8	3.3	52.1	945.6	0.0	945.6
1993–94	5315.2	5.3	5320.5	89.3	0.1	89.3	3136.4	0.0	3136.4
1994–95	6194.8	1.6	6196.4	49.8	0.0	49.8	860.5	0.0	860.5
1995–96	6315.8	0.0	6315.8	79.3	0.0	79.3	4519.5	0.0	4519.5
1996–97	3725.5	0.0	3725.5	104.9	0.0	104.9	5780.5	0.0	5780.5

Fishing	Southern bluefin			Yellowfin			Swordfish		
Year	Domestic	Foreign	Total	Domestic	Foreign	Total	Domestic	Foreign	Total
1986–87	59.9	1867.4	1927.3	5.6	139.6	145.2	4.7	496.3	501.0
1987–88	94.0	1059.3	1153.3	11.6	39.8	51.5	0.9	235.6	236.6
1988–89	437.0	760.7	1197.8	12.8	13.8	26.6	11.4	149.9	161.3
1989–90	529.3	880.8	1410.1	19.0	33.1	52.1	78.8	161.9	240.7
1990–91	164.6	905.6	1070.1	6.3	16.1	22.4	40.7	184.9	225.6
1991–92	59.8	585.3	645.1	19.8	0.2	20.0	28.5	160.8	189.2
1992–93	216.4	250.8	467.1	11.8	0.0	11.8	79.0	25.6	104.6
1993–94	277.0	26.2	303.2	159.7	0.0	159.7	102.3	2.3	104.6
1994–95	435.3	37.3	472.5	114.5	0.0	114.5	101.9	0.0	101.9
1995–96	140.5	0.0	140.5	193.4	0.0	193.4	186.8	0.0	186.8
1996–97	333.5	0.0	333.5	159.5	0.0	159.5	282.8	0.0	282.8

13 STOCK STATUS

As summarised in previous sections, albacore, bigeye, skipjack, southern bluefin and yellowfin tunas and swordfish caught in the New Zealand EEZ represent a small portion of large stocks of highly migratory fish available to New Zealand fishers seasonally. These stocks are prosecuted by a wide range of surface and longline fisheries elsewhere in the Pacific both within EEZs and on the high seas. A number of research agencies address specific fleets or national fisheries but information on stocks as a whole is only compiled by the Commission for the Conservation of Southern Bluefin Tuna with respect to that species and by the Oceanic Fisheries Programme of the Secretariat of the Pacific Community for South Pacific albacore, bigeye, skipjack and yellowfin tunas. New Zealand actively participates in these organisations and in the scientific work that results in this stock status information. The following summary is compiled from that participation.

<u>South Pacific albacore</u>

Albacore are targeted primarily by longliners from Taiwan and to a lesser extent by longliners from several South Pacific countries as adults and as juveniles by trolling. Substantial catches are also made as bycatch in other tuna longline fisheries across the entire South Pacific Ocean. Catches by all gear types have been less than 40,000 t in all but a few years since 1962 and substantially lower than this level earlier (Anon 1998b). An economic analysis of this fishery suggests that the South Pacific albacore fishery may remain at its current level for the forseeable future. Lightfoot (1997) suggests that the existing distant water freezer vessels targeting albacore (mostly Taiwanese) are not lucrative and declining profitability of canned albacore means the prospects of increased effort are small.

Stock production models (reviewed by Murray 1994) estimated MSY to be in the range 31,000–37,000 t. However, given the uncertainties in these models and assumptions made, these results should be viewed with caution. Preliminary results are available from work by the Oceanic Fisheries Programme (Secretariat of the Pacific Community, Noumea) using length based catch-at-age models for this stock. These model results suggests that this fishery may be strongly affected by recruitment fluctuations associated with *el nino* events. This model suggests a strongly increasing trend in biomass to the late 1970s followed by a decline in biomass to at least 1990 (Anon 1998b). Recent exploitation rates from this model are estimated to be low (less than 10% per year) suggesting that current catches are sustainable.

Bigeye tuna

The status of bigeye tuna is highly uncertain and, like southern bluefin tuna, is a stock whose status is of great concern. Bigeye tuna catches, mostly by longline, have generally been less than 140,000 t by all fleets since 1960 (Anon 1998b). However, recent increases in the catch of small bigeye tuna by purse seine fleets, primarily in the eastern tropical Pacific but also spreading into the western Pacific coupled with declines in standardised longline CPUE has raised concerns over the sustainability of recent catches. Declining longline CPUE is evident in the eastern Pacific from the early 1950s through the 1990s while CPUE has been essentially stable in the western Pacific since the late 1960s.

Stock structure for bigeye is still uncertain, although current evidence supports a single rather than two stock model. Production models run under both hypotheses suggest that the stock is fully exploited under the single stock hypothesis and over-exploited (for both stocks) under a two stock hypothesis (Anon 1998b).

Skipjack tuna

Anon (1998 b) reports that skipjack tuna catches in the western and central Pacific have increased from about 50,000 t to about 900,000 t in the 1990s. Most of this increase is attributed to expanding purse seine effort by vessels from the US, Japan, Korea and Taiwan during the 1970s and 1980s. CPUE for both purse seine and pole-and-line fleets are variable and undoubtedly affected by improving technology during this expansion. Nevertheless they show no evidence of serious impacts on the stock, even at recent historically high levels. There is, however, some concern that changes in fishing practices (ie, the frequency of fishing on free-swimming vs associated schools) may be obscuring changes in CPUE (Sakagawa and Coan, 1998). Analysis of extensive tagging of skipjack, however, shows that fishing mortality is relatively low ($F < 0.1$ month^{-1}) across all size classes (Anon, 1998 b). Even the large catches of very small skipjack by the Philippines fishery may not be cause for concern because of the age specific natural mortality with very high M for small skipjack tuna that is

6–8 times that for larger fish ($M \cong 0.8$ month^{-1}). Anon (1998 b) infer that it is unlikely that fisheries catching small skipjack would have a significant impact on those fisheries targeting large fish. Current exploitation rates (95% confidence interval of 0.16–0.25) are considered to be low to moderate. There would appear to be little cause for concern over skipjack tuna stock status in the short to medium term.

Southern bluefin tuna

The total catch of southern bluefin tuna has declined from its peak of more than 80,000 t in the early 1960s to about 16,000 t in 1996. Catch by the parties to the Commission for the Conservation of Southern Bluefin Tuna have catches restricted by quotas or catch limits to 11,750 t (Australia – 5265 t, Japan – 6065 t and New Zealand – 420 t). Increasing catches by non-parties (chiefly Indonesia, Korea and Taiwan) now exceed 4,000 t and are considered a serious threat to the sustainability of the stock.

During the past year scientists from the three parties met to review southern bluefin tuna stock status as part of their commitment to the CCSBT. The results of analyses presented show reasonable agreement about the current state of the stock although there remains considerable disagreement as to the probability of parental stock recovery to levels in the 1980s by the year 2020 (a stated management goal of the CCSBT). Key points raised in the 1998 assessment include:

- Japanese coarse scale standardised CPUE for adult SBT (8+ year old fish) show a continuous decline from 1969. The abundance of SBT in 1997 is about one-third that in 1980 regardless of which standardisation is used. All indices exhibit relatively stable CPUEs over the last 5+ years (Nishida and Tsuji 1998).
- Australian abundance indices indicate similar declines as seen in the Japanese indices although to slightly lower levels. Juvenile abundance is also similar (Hearn and Polacheck 1998).
- Japanese coarse scale standardised CPUE for juvenile SBT (4, 5 and 6–7 year old fish) show an increase in abundance beginning in the late 1980s after a long period of declining abundance from 1969 beginning in 1987 for 4 year old fish , 1989 for 5 year old fish and 1993 for 6–7 year old fish . Declines in juvenile abundance after 1994 suggest that this increase in abundance has not continued although 1997 juvenile abundance of 5 and 6–7 year old fish was slightly higher than in 1996 (Nishida and Tsuji 1998, and Hearn and Polacheck 1998).
- Annual aerial survey of 2–4 year old SBT off Australia has shown a statistically significant decline from 1993–98 with biomass density in 1998 up to half that in 1993 (Cowling and Millar 1998).
- Fishing mortality rates for SBT aged 3–8 years are 0.03 to 0.19 during the period 1992–97. Estimates of F have increased over the last 2–3 years such that the F's on 3–5 year old fish in 1997 is more than twice that in 1994 suggesting recent increased fishing for small fish (Polacheck *et al.* 1998).

There are three aspects of the 1998 southern bluefin tuna stock assessment which have implications for sustainability of the stock:

- total catches;
- parental biomass, both its level and trend; and
- recruitment trends.

While the CCSBT parties have restrained their catches, following the 1989 imposition of restrictive quotas, non-party catches continue to increase.

The parental biomass in 1997 remains at historically low levels while catches on the spawning ground have increased since 1989, largely due to the expanding Indonesian longline fishery. Recent information from direct ageing of SBT caught on the spawning ground suggests that maturity may be reached later (possibly at 12 – 15 years) than previously thought (8 years) implying a longer time for parental biomass recovery.

Recruitment has been estimated to have declined in all VPA analyses conducted this year. Declining recruitment has also been observed in the aerial survey results.

The implications of this information are that current catches are not stable, recovery of the parental biomass has not increased but may have stabilised, recovery will likely take longer than previously thought and recruitment can not be counted on to allow stock recovery.

Yellowfin tuna

Yellowfin catches in the western and central Pacific Ocean have steadily increased since 1970 from about 100,000 t to 300,000–400,000 t, mostly due to increasing surface catches. Standardised CPUE for Japanese longliners in sub-equatorial waters show a marked decline (by about 50%) over the period 1978–93. Nominal CPUE after 1993, however, increases (Anon 1998b). Longline CPUE may be confounded to some extent by increased targeting of deeper dwelling bigeye since the mid-1970s. CPUE from the surface fishery is variable and shows no clear trend.

Tagging studies by the Oceanic Fisheries Programme, like those for skipjack, indicate age specific mortality that is high on small fish ($Z = 0.35$–0.55 per month for fish smaller than 40 cm) and low ($Z = 0.05$–0.20 per month) for larger fish. The higher mortalities on small fish should tend to reduce the potential for interaction between surface and longline fisheries. Preliminary results from production modelling incorporating all surface and longline fishery components suggests that MSY may be of the order of 670,700 t (Anon 1998b). While there is some uncertainty as to the status of the western Pacific yellowfin stock, mostly related to CPUE information from the longline fishery, tagging data indicate current exploitation rates are moderate.

Swordfish

Most of the annual Pacific Ocean swordfish catch (30,000–35,000 t in the 1990s) is bycatch in tuna longline fisheries although swordfish target fisheries exist in Hawaii, Japan, Australia and Fiji. Williams and Bigelow (1998) note that since 1980, catches have been relatively stable at 10,000–16,300 t in the western and central Pacific from temperate latitudes. The size, distribution and productivity of the Pacific Ocean swordfish stock(s) is uncertain.

14 ACKNOWLEDGMENTS

Thanks are gratefully acknowledged to the dedicated group of professionals who spend most of their year at sea collecting data on New Zealand and Japanese tuna longliners - the Scientific Observers of the Ministry of Fisheries Observer Programme. The dedication of these individuals has resulted in valuable data on operational details, catch rates, discard practises, size and sex composition of longline catches that contributed significantly to this project and to New Zealand's international fishery commitments. Thanks are also due to Sandy Black, Carol Fabling and the rest of the "key punch team" for their data entry efforts. Alan Blacklock assisted with the graphics and his help is gratefully acknowledged. The considerable efforts of the data entry staff at the Ministry of Fisheries who made the catch and effort data accessible is particularly appreciated.

Thanks is also gratefully acknowledged to members of the domestic tuna industry for providing valuable information used to insure the accuracy of information derived from the Ministry of Fisheries catch and effort system. Special thanks are offered to Roger Burgess and Peter Reid in this respect and to Sanford's Ltd, Tauranga for information on purse seining and to Solander Fisheries Ltd., Nelson for information on longlining.

15 REFERENCES

Anon. 1995. FAO Fisheries yearbook, fishery statistics, catches and landings Volume 76. FAO Fisheries Series No. 44, xxviii + 687 pp.

Anon. 1997. South Pacific Commission tuna fishery yearbook 1996. Vi + 104 pp, South Pacific Commission, Noumea, New Caledonia.

Anon. 1998 a. Report of the eleventh meeting of the Standing Committee on Tuna and Billfish, 28 May – 6 June 1998, Honolulu, Hawaii, USA. iii + 108 pp. Secretariat of the Pacific Community, Noumea, New Caledonia.

Anon. 1998 b. Status of tuna stocks in the western and central Pacific Ocean. PTF10/INFO.H, 36 pp. Tenth Annual Consultation between the Parties to the Treaty on Fisheries between Certain Pacific Island States and the Government of the United States of America, 30 March – 3 April 1998, Vava'u, Kingdom of Tonga

Anon. 1998c. Report of the [CCSBT] Scientific Committee, 1998. Commission for the Conservation of Southern Bluefin Tuna, Deakin Australia. 14 pp.

Argue, A.W. and R.E. Kearney. 1983. An assessment of the skipjack and baitfish resources of New Zealand. Skipjack Survey and Assessment Programme Final Country Report No. 6, ix + 68 pp. South Pacific Commission, Noumea, New Caledonia.

Bailey, K.N. 1983. Food and feeding habits of fish associated with skipjack tuna in New Zealand. M.Sc. thesis, xii + 206 pp. Victoria University of Wellington.

Bailey, K., P.G. Williams and D. Itano. 1996. By-catch and discards in western Pacific tuna fisheries: a review of SPC data holdings and literature. Oceanic Fisheries Programme Technical Report No. 34, South Pacific Commission, Noumea, New Caledonia.

Baird, S.J. 1998. Annual review of bycatch in southern bluefin and related tuna fisheries in the New Zealand 200 n. mile Exclusive Economic Zone. CCSBT-ERS–9806–31.

Boggs, C.H. 1992. Depth, capture, and hooked longevity of longline–caught pelagic fish: Timing bites of fish with chips. Fishery Bulletin 90:642–658.

Carocci, F. and J. Majkowski. 1996. Pacific tunas and billfishes, atlas of commercial catches. Rome, FAO. iii + 9pp, 28 maps.

Caton, A.E. 1994. Review of aspects of southern bluefin tuna biology, population, and fisheries. FAO Fisheries Technical Paper 336–2:296–343.

Chapman, L. 1992. How to rig for albacore trolling. Australian Fisheries March 1992, 5 pp.

Collette, B.B. and C.E. Nauen. 1983. FAO species catalogue Volume 2: Scombrids of the world. FAO Fisheries Synopsis No. 125, Vol. 2, vii + 137 pp.

Cowling, A. and C. Millar. 1998. Data analysis of the aerial surveys (1991–1998) for juvenile southern bluefin tuna on the Great Australian Bight. CCSBT/SC/9807/8

Dean, H. 1998. Database documentation: tuna. NIWA Internal Report No.37, 19 pp.

Dotson, R.C. 1980. Fishing methods an equipment of the U.S. West Coast albacore fleet. NOAA-TM-NMFS-SWFC-8, 126 pp.

Fournier, D.A., J.R. Sibert, J. Majkowski and J. Hampton. 1990. MULTIFAN a likelihood-based method for estimating growth parameters and age composition from multiple length frequency data sets illustrated using data for southern bluefin tuna (*Thunnus maccoyii*). Canadian Journal of Fisheries and Aquatic Science 47:301–316.

Francis, M.P., L.H. Griggs, S.J. Baird, T.E. Murray and H. Dean. 1998. Bycatch of non-target fish species in New Zealand tuna longline fisheries. Final Research Report on Ministry of Fisheries Project ENV9702, 22 pp. NIWA.

Habib, G., I.T. Clement, K.N. Bailey, C.L. Carey, P.M. Swanson and G.J. Voss. 1982. Incidental fish species taken in the purse-seine skipjack fishery, 1975–81. Fisheries Research Division Occasional Publication: Data Series No. 5, 49 pp.

Hearn, W.S. and T. Polacheck. 1998. Applying General Linear Models to CPUE to estimate indices of SBT abundance – 1998. CCSBT/SC/9807/21.

Ichikawa, W. 1981. Report of the albacore survey by the RV Kaio Maru No. 52 in New Zealand waters, 1981. 117 pp. Japan Marine Fishery Resource Research Center, Tokyo.

Iwasa, K., G. Habib and G.I.T. Clement. 1982. Report of the albacore research survey by the RV Kaio Maru No. 52 in New Zealand waters, 1982. 150 pp. Japan Marine Fishery Resource Research Center, Tokyo.

Labelle, M. and T. Murray. 1992. South Pacific albacore observer programme summary report, 1988 – 1991. South Pacific Commission Tuna and Billfish Assessment Programme Technical Report No. 26, Noumea, New Caledonia. vii + 23 pp.

Lightfoot, C. 1997. Albacore freezer longline fishery, a review of the current situation in the South Pacific. 20 pp. Paper presented at the *FFA/ADB Workshop on Tuna Industry Development in Pacific Island Countries*, Maui. Hawaii 3–4 November 1997.

Michael, K.P., J.B. Jones and K.N. Bailey. 1987. Report on observer trips on Japanese southern bluefin tuna longliners off East Cape, June–July 1987. Fisheries Research Centre Internal Report No. 80, 54 pp.