MINISTRY OF FISHERIES
Te Tautiaki i nga tini a Tangaroa

ISSN 1175-1584

Characterisation of striped marlin fisheries in New Zealand

J. Holdsworth
R. K. Kopf

New Zealand Fisheries Assessment Report 2005/31
June 2005

Characterisation of striped marlin fisheries in New Zealand

J. Holdsworth
R. K. Kopf

Blue Water Marine Research Ltd
RD3
Whangarei

New Zealand Fisheries Assessment Report 2005/31
June 2005

Published by Ministry of Fisheries
Wellington
2005

ISSN 1175-1584

Citation:
Holdsworth, J.; Kopf, R.K. (2005).
Characterisation of striped marlin fisheries in New Zealand.
New Zealand Fisheries Assessment Report 2005/31. 63 p.

This series continues the informal
New Zealand Fisheries Assessment Research Document series
which ceased at the end of 1999.

EXECUTIVE SUMMARY

Holdsworth, J.; Kopf, R.K. (2005). Characterisation of striped marlin fisheries in New Zealand.

New Zealand Fisheries Assessment Report 2005/31. 63 p.

Striped marlin (*Tetrapturus audax*) (Philippi, 1887) are found throughout the tropical and temperate Indian and Pacific Oceans. Much of what we know about the distribution, movement, and possible stock status of striped marlin comes from catch records. Surface longline is the method responsible for almost all striped marlin commercial landings (retained catch). Data from the Ministry of Fisheries and the Ocean Fisheries Programme (OFP) of the Secretariat of the Pacific Community (SPC) were used to describe tends in commercial longline reported landings, effort, and CPUE for striped marlin in New Zealand waters and the wider southwest Pacific. The Japanese had the first and largest surface longline fleet and have keep records of landings and effort since first moving into the South Pacific in 1952.

Japanese surface longline vessels started fishing around New Zealand in 1956 and their striped marlin landings and CPUE was initially high (2500 fish at 3.0 fish or more per 1000 hooks). The discovery of the lucrative southern bluefin tuna fishery shifted the focus of the Japanese fleet in New Zealand waters south. OFP data for the area around northern New Zealand (north of 35° S) shows a declining trend in striped marlin CPUE in the 1950s and 1960s followed by lower catch rates and no clear trend.

There has been a fundamental change in the surface longline fishery in New Zealand's EEZ, partly as a result of the billfish moratorium introduced in 1987 and subsequent changes to fishing regulations which prohibit commercial fishers from landing marlin and other istiophorid billfish. Foreign licensed distant water fishing vessels, mainly from Japan and Korea, have not fished in New Zealand waters since 1995. Four or five Japanese vessels are still chartered for a few months each year by a New Zealand company and over 100 smaller domestic surface longline vessels entered the fishery during the 1990s.

New Zealand commercial catch records available on the *tuna* database include domestic, chartered, and foreign licensed vessels start in 1980. According to these the annual striped marlin landings were highest in 1982 at 2798 fish (275 t). The recreational catch (landed and tag and release combined) peaked in 1999 at 2368 fish (estimated 208 t): 67% of these fish were tagged and released. The number of marlin landed in the southwest Pacific per season in the OFP database peaked at almost 80 000 in 1954, but since 1964 it has fluctuating between 13 000 and 40 000 fish per year (annual mean 23 000 s.d. 6 500). Total longline fishing effort in the southwest Pacific has been steadily increasing from about 20 million hooks per year in the 1950s to 174 million hooks in 2001.

Sea surface temperature appears to have a strong influence on striped marlin distribution. In New Zealand waters they prefer surface water temperatures of 20 °C to 23 °C, although occasionally fish are found in 14 °C water.

The highest striped marlin landings for the surface longline method are recorded in January-February and the highest recreational catch is in February and March. Longline records show that striped marlin have been landed in New Zealand waters in every month, with lowest catches in November and December and an intriguing spike in catch rates in October, particularly in the far north of the New Zealand EEZ around the Kermadec Islands.

For many years recreational fishing clubs have kept catch records for pelagic gamefish. The Bay of Island Swordfish Club (BOISC) have made their catch records which start in 1924 available. The spread of surface longing into the southwest Pacific Ocean appears to have affected the size structure of striped marlin in the New Zealand recreational fishery. Since 1960 there has been greater interannual variability

in average weight and there has been a significant declining trend in mean weight from about 120 kg to 95 kg in the BOISC records. There is also a trend in the striped marlin weight distributions. The proportion of small and medium sized striped marlin (less than 100 kg) has consistently increased in each decade since commercial fishing started and that trend appears to be continuing.

BOISC records show a sharp decline in the incidence of multiple striped marlin captures (more than one fish caught by one boat on a single day) in the late 1950s. If the proportion of multiple captures averaged over 20 seasons is used as a measure of relative fishing success, then the recreational striped marlin fishery was nearly three times better in the 1940s and 1950s than it was in the 1960s and 1970s. The proportion of multiple captures has increased since 1988. Advances in fishing tackle, vessels, and technology may contribute to this. Also some Bay of Islands based boats started fishing the banks north of the Three Kings Islands in the late 1980s, where catch rates are generally higher than on the coast. Since then, the Three Kings fishery has become an important component of the New Zealand gamefish fishery. Changes in the number of multiple catches per boat day in the New Zealand recreational fishery may not be reflected in CPUE from other fisheries, and there is no simple way to translate the index into one that may relate to relative abundance.

Recreational striped marlin CPUE (fish per boat day averaged over the season) has been collected from east Northland charter boat skippers (excluding the Three Kings) for 27 years. CPUE has been consistently above average (0.18 to 0.25 striped marlin/boat day) since the mid 1990s. It was also high in the early 1980s and more boats and fishers started targeting pelagic gamefish at that time.

Lengths of striped marlin (n = 622) caught in the New Zealand recreational fishery between 1985 and 1994 were used to calculate a length–weight conversion equation. The mean lower jaw fork length for all fish was 2373 mm (s.d. = 167 mm) and males (mean = 2310 mm, s.d. = 158 mm) were generally smaller than females (mean = 2417 mm, s.d. = 163 mm).

Length at age data derived from a previous study were applied to the von Bertalanffy growth model and the following parameters were obtained: $L\infty$=3010 mm, K=0.22 annual, and t_0= -.04. These estimates should be treated with caution because the growth of striped marlin may not be well described by the von Bertalanffy curve and the length at age estimates are unvalidated.

The New Zealand cooperative tagging programme began in 1975. Tagging records show that most striped marlin were tagged and released from recreational vessels fishing off east Northland or the Three Kings Islands since 1988. Recaptures have been widespread throughout the southwest Pacific Ocean, but not beyond. The preliminary results of a project using pop-up satellite archival tags deployed on New Zealand striped marlin are discussed.

Striped marlin is the main target species for an important recreational and tourist fishery in northern New Zealand, and they were a small but valued component of the commercial surface longline catch of foreign licensed vessels in the region until 1987. The billfish moratorium and subsequent regulations prohibit commercial fishers from landing striped marlin taken from New Zealand fisheries waters. This appears to have had a positive effect on recreational CPUE.

1. INTRODUCTION

Striped marlin are one of a range of oceanic pelagic species that are caught by recreational and commercial fishers in New Zealand waters. These species are most abundant in summer and autumn around the North Island. Northern New Zealand has one of a few recreational fisheries in the world where striped marlin is clearly the main target species. Arguably it is also the best, as 16 of the 22 saltwater line class world records are held by striped marlin caught in New Zealand. Surface longlining is the main commercial method that catches striped marlin. The Japanese longline fleet moved into the South Pacific in the early 1950s and fishing effort expanded rapidly. Striped marlin is mainly a bycatch, though occasionally a target species, for surface longline vessels and Pacific wide the annual catch is estimated at 15 000 t.

A sport fishery developed in New Zealand targeting marlin and sharks in the 1920s. International tourists brought heavy tackle and new fishing methods that proved highly successful. The quality of the fishery was praised by best selling author of the time, Zane Gray, in his book 'Tales of the Angler's Eldorado, New Zealand' and others. Fishing clubs were established, and they weighed and recorded fish. Charter boats were responsible for most of the catch as they had the specialist tackle and experience (Saul & Holdsworth 1992). Today, many private boats from 5 to 30 m in length participate in the fishery and there are about 100 charter boats that target striped marlin seasonally.

Gamefish club records provide almost a complete record of striped marlin catch throughout the history of the fishery, but not all have been captured electronically. Since 1990, 60% of the recreational catch has been tagged and released with only estimated weights available for these fish.

Commercial reporting of surface longline landings on New Zealand forms became mandatory in 1980. These records are available on the Ministry of Fisheries *tuna* database. Since October 1987, commercial fishers have been required to release all marlin (dead or alive), and since that time the number of marlin caught on commercial vessels has not been reliably captured. Scientific observers record all fish caught and released, but to date observer coverage has been poor in the areas and season when striped marlin are caught.

Logsheet landings data exist for most longline fleets that fish in the southwest Pacific. The Ocean Fisheries Programme (OFP) of the Secretariat of the Pacific Community (SPC) has maintained a catch and effort database for tuna and billfish in the western and central Pacific Ocean since its inception in 1981. The programme has also been provided with substantial historical aggregated logsheet data for the three main distant water surface longline fleets of Japan, Korea, and Taiwan. Data from all other fleets in western and central Pacific has been added where available. The public domain data for longline hook count and landings by species by 5 degree square by month from 1952 to 2001 offers a comprehensive picture of the history of this fishery across the whole southwest Pacific region.

Striped marlin have been tagged by recreational fishers in New Zealand since 1975. The number of fish tagged has increased dramatically since the N.Z. Big Game Fishing Council introduced a voluntary minimum weight of 90 kg for striped marlin in 1988. Recaptures have been distributed widely throughout the southwest Pacific Ocean, but not beyond. This observation is supported by the preliminary results of a NZ Marine Research Foundation project using pop-up satellite archival tags.

This report draws together information on the New Zealand fishery for striped marlin and places it in a regional context.

2. BIOLOGY

2.1 Systematics and identification

Striped marlin (*Tetrapturus audax*) (Philippi, 1887) is one of eight species of billfish in the family Istiophoridae (scientific names for species used in this paper are listed in Appendix 1). Five of the istiophorid species have been recorded in New Zealand waters, but striped marlin is most common. The white marlin, found only in the Atlantic Ocean, is very similar in appearance to striped marlin. Research into differences in mitochondrial DNA indicates that white marlin and striped marlin are closely related, and if they are separate species they are of very recent origin (Finnerty & Block 1995, Graves & McDowell, 2003).

The striped marlin is the smallest and most slender of the three species of marlin occurring in New Zealand. Striped marlin can most easily be distinguished from other marlin of the Pacific Ocean by a tall first dorsal fin, which is at least equal in height to 90% maximum body depth (straight line). The height of the first dorsal fin in blue and black marlin is markedly less than body depth. The high dorsal fin is easiest to recognise in small striped marlin, but may be less reliable as a casual identifier in the largest fish. The ability of the striped marlin to fold pectoral fins against the body differentiates it from the black marlin (Ueyanagi & Wares 1975). The pectoral fins of the black marlin are locked in an outward position away from the body in adults. Colour during life of striped marlin is metallic blue with 10–15 prominent vertical stripes that may remain present for several hours after death. The body cross section of a striped marlin is slab sided and more elliptical than the oval of blue or black marlin. The striped marlin lower jaw is long and slender, even acutely pointed, and the flesh more orange than the pale or pinkish flesh of other marlin (Pepperell & Grewe 2001)

The striped marlin is called tekeketonga in Maori, makajiki (Japan), marlin raye (France), and A'u (Hawaii). The scientific name *Tetrapturus audax* roughly means "bold, with four winged tail", which is in reference to the two pairs of caudal keels at the base of the tail (Pepperell 2001).

2.2 Distribution

Striped marlin are apex predators in the tropical, subtropical, and temperate pelagic ecosystem of the Pacific and Indian Oceans. They are not uniformly distributed, having a number of areas of high abundance, and undergo extensive seasonal migrations. Occasionally they have been caught on the Atlantic side of the Cape of Good Hope (Nakamura 1985), but this is rare. Striped marlin are epipelagic and oceanic spending most of their time above the thermocline in waters with a surface temperature between 20 and 25 °C. Spawning grounds are believed to be widespread in subtropical regions of the north and south Pacific and tropical Indian Ocean. Juveniles generally stay in warmer waters of the range, while adults move into higher latitudes and temperate water feeding grounds in summer (southern hemisphere 1st quarter of the year ,and 3rd quarter in the northern hemisphere). The latitudinal range estimated from longline data extends from 45° N to 40° S in the Pacific and from continental Asia to 45° S in the Indian Ocean (Nakamura 1985). The central and western equatorial region of the Pacific from 10° N to 10° S has very low and intermittent longline catch of striped marlin and is not considered part of their normal distribution (Ueyanagi & Wares 1975). In New Zealand, striped marlin are generally caught between January and May off the north half of the North Island.

2.3 Stock structure

Striped marlin stock structure in the Pacific Ocean has not been well determined. The simplest theory is that striped marlin have a continuous distribution in a horseshoe pattern around the Pacific Ocean (Figure 1). Seasonal movements of striped marlin to and from spawning grounds in the northern and southern hemispheres appear out of phase, implying that there may be two separate stocks. However, there is limited evidence from tagging, and from morphometric and genetic studies identifying movement between northern and southern hemispheres in the eastern Pacific Ocean. There is also some evidence of separate striped marlin stocks in the eastern and western central south Pacific. The results of mitochondrial DNA analysis are consistent with shallow population structuring within striped marlin in the Pacific (Graves & McDowell 2003)

2.4 Feeding

Striped marlin are opportunistic feeders that rely on food availability rather than on specific prey items. Stomach contents analysis from New Zealand, recorded over 28 fish and 4 cephalopod species (Appendix 2) (Morrow 1953, Baker 1966, Saul 1984, Kopf 2005). Striped marlin frequently forage on schools of pelagic and epipelagic organisms ranging from squid and nautilus to mackerel and saury. Longline commercial fishing vessels have significantly higher catch rates of striped marlin at depths shallower than 150 m, which also suggests that feeding occurs most often in the upper level of the water column (Boggs 1992). Although striped marlin are primarily epipelagic predators, occasionally benthic and demersal prey items such as snapper and rays (Batoidea) have been found in their stomachs (Morrow 1953, Baker 1966).

Off the coast of New Zealand the most frequent prey items of striped marlin are saury and arrow squid followed by jack mackerel (Figure 2) (Morrow 1953, Baker 1966, Saul 1984, Kopf 2005). Saul (1984) found a small variety of prey species in individual striped marlin stomachs from New Zealand, 73% of 147 stomachs containing only one or two prey species. This suggests that feeding occurs during short intense events rather than continuously throughout the day and that digestion is rapid. Specific feeding times have not been identified, but catch rates from Australian longline vessels indicate a tendency for daytime feeding (Bromhead et al. 2004).

Reports of marlin moving their head and bill from side to side in a slashing motion to stun prey are more common than accounts of prey being speared (Baker 1966). However, large prey items, such as mako sharks and tuna, have exhibited signs of being speared (Saul 1984). Numerous researchers have documented marlin with broken bills, without any identified as being in less than average condition (Morrow 1951). These findings suggest that the bill may occasionally facilitate prey capture but marlin are not dependent on it for feeding. The gastrointestinal tract of striped marlin is similar to that of most top predators, and can be described by a large capacity stomach and short intestine (Davie 1990). Large capacity stomachs allow striped marlin to take advantage of patchy feeding opportunities in the pelagic ecosystem.

2.5 Reproduction

Striped marlin are oviparous and spawn in the open ocean (Nakamura 1985). The pelagic ecosystem provides little protection for eggs, larvae, and juvenile fish, which probably results in low survival rates. Striped marlin overcome this challenge by using a high fecundity reproductive strategy that can yield over 20 million eggs per female, but is highly dependent on female size (Eldridge & Wares 1974). Fertilisation is external and eggs are about 1–1.5 mm diameter. Water temperature may influence the location of spawning grounds as most larvae are collected in sea surface temperatures above 24 °C (Ueyanagi & Wares 1975).

Most larvae captures have occurred in offshore waters between 25 and 27 °C during the summer in both hemispheres (Gonzalez Armas et al. 1999).

Striped marlin are known to spawn in the Coral Sea between Australia and New Caledonia. Their ovaries start to mature in this region during late September or early October (Hanamoto 1977). Spawning peaks in November and December and 60–70% of fish captured at this time are in spawning condition. There is no clear evidence of striped marlin reproductive activity in New Zealand waters. However, the 200 nautical mile EEZ around Raoul Island on the Kermadec Ridge extends the New Zealand zone into the subtropics, and in some years striped marlin are present in moderate numbers from October to December according to longline landing records (see Section 5.3). It is therefore possible that this represents a spawning aggregation at that time.

2.6 Maturity

The minimum size of mature fish recorded in the Coral Sea is estimated at 143 cm eye-fork length (EFL) or about 170 cm lower jaw-fork length (LJFL) and 36 kg. Ueyanagi & Wares (1975) estimated maturity in the central Pacific Ocean at about 160 cm LJFL. Striped marlin captured in New Zealand are rarely less than 200 cm LJFL, suggesting that these fish are all mature. Age at first maturity is unclear, but applying age at length data to size at maturity it is probable that fish become reproductively active between ages 2 and 4 (Ueyanagi & Wares 1975, Skillman & Yong 1976, Davie & Hall 1990).

2.7 Age

Davie & Hall (1990) estimated ages of striped marlin in New Zealand using dorsal spine growth rings and found between two and eight bands (ages). Melo-Barrera et al. (2003) identified between 2 and 11 bands (ages) in Mexico and Skillman & Yong (1976) classified up to 12 age groups in Hawaii. However, none of these studies were able to validate the estimated ages. Maximum age estimates of striped marlin are distinctly less than black and blue marlin (≈ 13–25 years) (Hill 1986, Speare 2003).

2.8 Maximum size

Data from Japanese surface longline vessels reveal that striped marlin are longest in the southwest Pacific, with a modal size of 190 cm EFL (Squire & Suzuki 1990). Recreational catch records kept by the International Game Fish Association (IGFA) list the heaviest striped marlin as 224.1 kg, caught in New Zealand in 1975. A positively identified striped marlin weighing 243.6 kg was landed in the Bay of Islands in 1995, but was subsequently disqualified as a world record claim. The largest striped marlin in Australian gamefish records is 191.5 kg (Bromhead et al. 2004).

3. DESCRIPTION OF THE FISHERIES

3.1 Expansion of commercial fleet in the South Pacific Ocean

A harpoon fishery and a gillnet fishery for billfish including striped marlin has operated in Japan for many years. During the 1950's Japan developed a large surface longline fleet that expanded into the southwest Pacific in 1953. The 1954 Bikini nuclear bomb test in the northwest Pacific was larger than expected and spread radioactive debris over 130 000 km^2 (Republic of the Marshall Islands Embassy website, http://www.rmiembassyus.org). Radioactive contamination of tuna seriously affected the market for tunas and caused a market shift toward billfish (Ueyanagi 1974). Of the billfish species, striped marlin attained the highest price in Japanese markets as it was most suitable for sashimi and sushi. In the mid 1950s, surface longline fleets targeted blue and striped marlin in the South Pacific. As the fleet expanded east in the late 1950s, yellowfin and bigeye tuna were the primary catch. There was a sharp increase in market price for striped marlin after 1967, when new freezer technology was introduced to the fleet (Ueyanagi et al. 1989).

The Japanese surface longline fleet covered virtually the entire distribution of striped marlin by 1965. During the late 1960s and early 1970s southern bluefin tuna was a prime target species in the cool waters off New Zealand and southern Australia. During the mid 1970s, the Japanese fishery made a substantive operational change with many vessels setting more hooks between successive floats to fish their gear deeper in tropical and subtropical areas, primarily for bigeye tuna (Ueyanagi et al. 1989). Longline vessels set between 15 and 25 hooks between floats to fish at depths of up to 400 m. In contrast, fishers targeting swordfish in subtropical waters typically set fewer than 10 hooks between floats (Peter Williams, Secretariat of the Pacific Community, pers. comm.) The depth of fishing is acknowledged to be a factor in striped marlin catch, with most fish taken on hooks set to 150 m or less (Boggs 1992). During the 1970s, surface longline vessels from Korea and Taiwan also expanded their range into the southwest Pacific. These vessels targeted albacore and yellowfin and at times may have taken a significant bycatch of striped marlin.

3.2 Description of the surface longline fishery in New Zealand waters

Striped marlin are principally taken by surface longline. The first reported surface longline catch in the area that is now the New Zealand EEZ was made by Japanese distant water vessels in 1955. The first two years of fishing were mainly northeast of New Zealand (July–December) and reported landings primarily consisted of albacore, yellowfin, bigeye tuna, and striped marlin (SPC longline database). In 1957, the main target species for the fishery became southern bluefin tuna, which were caught during winter and spring in waters south of 35° S. Since that time striped marlin have been a relatively minor proportion of the annual surface longline catch for most vessels. By the 1970s, Japanese surface longliners began fishing off the east coast of the South Island (January–April), moving up the east coast of the North Island in May and June and by July fishing mainly off East Cape. If catch rates for southern bluefin were poor in January and February, most vessels moved north of 35° S to fish for bigeye and yellowfin until catch rates of the vessels fishing in the south improved (Gibson 1982).

A northern fishery targeting albacore was also used by Korean and a few Japanese surface longliners beginning in 1981. They fished around northern New Zealand from March to September. In 1978, New Zealand declared its EEZ out to 200 nautical miles. Licences for access to the tuna fishery were granted to countries which had bilateral relationships with New Zealand. Vessels issued a Southern Licence could fish in all areas of the EEZ, except the west coast of the South Island. Vessels issued a Northern Licence were permitted to fish north of 38° S on the west coast and north of 34° S on the east coast. In 1981 there were 87 Southern Licences issued for Japanese vessels and 11 Northern Licences for Korean vessels (Table 1). In 1983 the fee for the Northern Licence was NZ$3,000 and NZ$36,000 for the Southern Licence. By 1985 the fee had increased to NZ$7,500 for the Northern and NZ$74,000 for the Southern Licence, and over the next few years the number of Southern Licences halved, while the number of Northern Licences doubled (Table 1).

A three year billfish moratorium was introduced in October 1987 in response to concerns over the decline in availability of striped marlin to recreational fishers. The moratorium prohibited access to the foreign licensed and chartered tuna longline vessels in the EEZ around the north half of the North Island, known as the Auckland Fisheries Management Area (Auckland FMA), from 1 October and 31 May each year. Licence restrictions required that all billfish, including broadbill swordfish, caught in the Auckland FMA be released.

In 1990 the moratorium was renewed for a further 3 years with some amended conditions and it was renewed for a further year in 1993.

Since 1988, regulations have prohibited domestic commercial vessels from retaining billfish if caught in the Auckland FMA. In 1991 these regulations were amended to allow the retention of broadbill swordfish and prohibited the retention of marlin species (striped, blue and black marlin) by commercial fishers in the whole EEZ. These regulations and government policy changes on foreign licensed surface longline access have replaced the billfish moratorium.

New Zealand domestic vessels began fishing with surface longlines in 1989, and the number of vessels and their fishing effort expanded rapidly during the 1990s. Also in 1989, licences were issued to charter up to five surface longline vessels (Japanese) to fish on behalf of New Zealand companies. Korean fishing companies have not taken up licences to fish since 1990. Also fewer Japanese vessels picked up licences at that time, and since the 1995–96 season no foreign licensed longliners have operated in the New Zealand EEZ. The domestic fleet reached a peak of over 120 relatively small vessels landing fresh chilled fish (with one or two exceptions). These boats did not simply replace the effort of the distant water fishing vessels. Rather, they fished year-round in different parts of northern New Zealand using different gear, resulting in a different catch composition (Francis et al. 1999).

3.3 Customary fishery in New Zealand

Maori were skilled fishers who ate a wide variety of seafood (kai moana). They fished with nets of all sizes, spears, hooks, and towed lures. No record of specific marlin fishing methods has been found. An early report from the Dominion Museum stated that nearly all fish of sufficient size were eaten by Maori at one time or another (Hamilton & Mackay 1908).

3.4 Recreational fishery in New Zealand

The seasonal fishery for large pelagic species that arrive with warm oceanic currents in summer and autumn is an important component of the recreational fishery and local tourist industry in northern New Zealand. Striped marlin is the primary gamefish targeted in northern New Zealand, with blue marlin increasing in importance, and small numbers of black marlin and shortbill spearfish also caught. Yellowfin tuna, mako sharks, and swordfish are also targeted in some areas or taken as a bycatch of the marlin fishery.

The first striped marlin caught on rod and reel in New Zealand was taken in 1915 by visiting Scottish angler A.D. Campbell who had arrived with his own heavy tackle fishing gear (Mossman 2002). Subsequently, there has been a dedicated gamefish charter fleet in the Bay of Islands for 80 years. The reputation of the marlin fishery on the northeast coast of New Zealand was greatly enhanced by the visits of Zane Grey, an American angler and author, from 1926 to the early 1930s. His book 'Tales of the Angler's Eldorado, New Zealand', published in 1926, told ripping yarns of catching large marlin and sharks that were abundant in northern New Zealand. Grey also introduced new gear and fishing methods such as the overhead reel and trolling skip baits. Gamefish clubs were established in Northland and the Bay of Plenty to provide facilities for anglers. Since the 1920s, they have kept accurate catch records for almost all recreational marlin catch including date, vessel, and weight of fish. Records are kept for each fishing season which starts 1 July and ends 30 June.

From the 1930s to the late 1980s most marlin were targeted using surface trolled baits, usually kahawai that skipped and splashed in the boat's wake. With this method the marlin were often hooked deep in the stomach or throat. There was a major drive to encourage tag and release of 50% of the recreational striped marlin catch in 1987–88, the first year of the billfish moratorium. A voluntary minimum size of 90 kg was adopted by the New Zealand Big Game Fishing Council, based on the average size of striped marlin from the Bay of Islands Swordfish Club records (John Chibnall, NZBGFC, pers. comm.). Fish under this weight were not recognised in contests or for club trophies. At the time, there was intense debate over the survival of marlin caught on baits and the merits of tag and release. By 1990 most boats were towing artificial lures. These could be towed faster than baits, increasing the search area, and causing less injury to the fish as they are more often hooked in the mouth or bill. The proportion of recreationally caught striped marlin that were tagged rose from less than 1% in the 1986–87 season to 46% in the 1989–90 season (Saul & Holdsworth 1992). Since then surface trolling with artificial lures trolled at speeds ranging from 4 to 10 knots has been the predominant method of fishing. There has been a slight trend back towards the use of live baits for billfish, but most marlin are still caught on lures.

Until the 1980s, gamefish charter boats caught most of the recreationally caught marlin each season. Today there are hundreds of private boats ranging in size from 5 to 20 m, which participate to various degrees in this fishery. An increasing number of trailer boats are geared up for marlin fishing. Their ability to launch from ramp or beach has caused an expansion of the area fished (west coast of the North Island in particular). In 1989, recreational charter boats started fishing the waters around the Three Kings Islands, the King Bank, and the Middlesex Bank, 50 nautical miles northwest of North Cape. At times, large numbers of marlin where present particularly late in the season (May, June) and catches of over 10 fish per boat day have been recorded. Occasionally striped marlin are seen in the waters around the South Island. A 100.4 kg striped marlin caught in February 1999 at Jackson Bay on the west coast is the most southern marlin (latitude 44° S) taken on rod and reel in New Zealand (NZ Fishing News 1999).

The striped marlin is one of the world's best-known gamefish. New Zealand has a proven reputation for producing the largest striped marlin in the world. Sixteen of the 22 saltwater line class world records, including the all tackle world record of 224.1 kg, have been caught in New Zealand waters (IGFA 2004). The IGFA all tackle world record for the very similar looking Atlantic white marlin is 82.5 kg.

4. DATA SOURCES AND METHODS

4.1 Catch and effort

The Ocean Fisheries Programme (OFP) of the Secretariat of the Pacific Community (SPC) has maintained a catch and effort database for tuna and billfish in the western and central Pacific Ocean since its inception in 1981. The programme has been provided with substantial historical aggregated logsheet data for the three main distant water surface longline fleets of Japan, Korea, and Taiwan, which form the basis of historical time series of landed catches. Billfish landings data exist for most longline fleets that have provided logsheets detailing the catch of tuna, but there have been a number of problems that leaves the data set incomplete. There are instances where annual summaries are provided, but not the spatial and temporal data. Observer data have shown that discarding of billfish varies with vessel and species' marketability (Bailey et al. 1996), although a recent review showed that retention of all marlin species was high in domestic and foreign vessels operating in the Pacific Islands (Sharples et al. 2000). In some cases OFP have estimated catch weight using average weight estimates which are stratified temporally, but not by latitude. Also there have been accounts of misidentification of some billfish species or grouping of a number billfish species into a general category. Although some data may be missing or some extrapolation and interpretation has been required, the OFP public domain data for longline hook count and catch by species by 5 degree squares by month from 1952 to 2001 offers the most comprehensive picture of the history of this fishery across the whole southwest Pacific region.

Detailed commercial catch and effort records for surface longline vessels have been required by the Ministry of Fisheries since 1980. The forms used have been the Tuna Longlining Catch Effort Return (TLCER), which records effort and catch in numbers of fish and an estimated weight for each set, the Catch Landing Return (CLR), which records the actual landed weight by species for each trip, and the Catch Effort Landing Return (CELR,) which is a form used across many fisheries which records effort and estimated weight of the top five species landed per set. These data are stored in the *tuna* database. An extract that included all records of striped marlin on this database was used in summaries by calendar year for the New Zealand EEZ. These returns probably underestimate the actual catch of striped marlin. Before 1988, fish that were damaged or not wanted would have been returned to the sea and not recorded (discards). The introduction of the billfish moratorium, striped marlin were required to be returned to the sea, and very few fishers recorded their discards. In 1995, Ministry of Fisheries instructed that marlin catches be recorded on TLCERs, however compliance with this requirement was inconsistent. Some records in the tuna database refer to catch outside the EEZ; these data were excluded.

The recreational catch of striped marlin has been recorded by gamefish clubs and published in their annual reports. Clubs provide weigh stations with certified scales and recognition of landed catch and fish tagged and released is an important part of gamefishing culture for anglers and skippers. Most clubs will also weigh and record fish caught by non-members. Records of striped marlin are also kept by clubs and added to boat and angler tallies for the season. The New Zealand Big Game Fishing Council (NZBGFC) is an umbrella group for gamefish clubs and produces a yearbook with national line class records and catch tallies for all affiliated clubs. These records are used as the best estimate of national recreational catch. A few marlin are not recorded, but it is estimated that these would amount to less than 10% of the recreational catch (Jeff Romeril, President, NZBGFC, pers. comm.).

The Bay of Islands has been a highly regarded tourist and sport fishing area for many years. The Bay of Island Swordfish Club (BOISC) has published annual catch records since 1925. Records from 126 and 1928 have been lost and there are gaps in the early 1930s (great depression) and the early 1940s (World War II). An electronic database of individual fish weights, date of capture, and name of vessel has been generated from BOISC records containing 15 163 striped marlin. This database includes estimated weights, date, and vessel for fish tagged and released.

Since 1977, an annual postal survey of Northland gamefish charter skippers has provided information on the number of days fished per vessel where marlin was the target species (whether under charter or fishing with friends) and the catch of billfish by species for the season. The survey was administered by the Ministry of Agriculture and Fisheries until 1996, and has been continued with support from the New Zealand Marine Research Foundation. The measure of CPUE that was available throughout the time series is the number of striped marlin caught per boat day per season averaged across all respondents.

4.2 Statistical analysis

All statistical comparisons in the study were based on the 0.05% level of significance. F tests were conducted to evaluate monthly and annual differences in weight from the BOISC database. Length weight relationship (slopes) and conditions between, sexes, months, and years, 1985–94, were compared using Student's t tests and F tests for multiple slopes. Parameters of the von Bertalanffy growth model were estimated using a gauss-Newton algorithm in SAS Statistical Analysis Software, version 8.

4.3 BOISC weight data

Striped marlin weights recorded in the BOISC data base were grouped into 10 kg categories (e.g., 90 kg = 90 to 99.9 kg) and divided into annual and monthly histograms. Weights were not converted to length in order to maintain the integrity of the data. A voluntary minimum size for recreational striped marlin was introduced by the NZBGFC in 1988, and since the early 1990s over half of the weights have been estimated for fish which were tagged and released. Average weight is calculated by fishing season (July to June) but 99% of all striped marlin in the BOISC records are taken between January and June.

4.4 Total New Zealand catch by weight

The annual longline landed catch by weight was calculated from the estimated weights reported by foreign licensed vessels (TLCERs) plus the estimated weights from domestic vessels (TLCERs and CELRs). Where only number of fish and no weight was recorded (TLCERs and CELRs) that number was multiplied by the average weight in BOISC records for that season. A small number (0.3%) of the records had no weight or number of striped marlin and were excluded.

Annual recreational landings by weight were calculated from the NZBGFC's national landed catch in numbers of fish multiplied by the average weight of landed fish in BOISC records each season. The weight of fish tagged and released by recreational fishers was estimated from the number of fish tagged nationally by recreational fishers multiplied by the average estimated weight of tagged fish in BOISC records by season.

All striped marlin caught by commercial fishing vessels are required to be released. New Zealand observer records indicate an overall estimate of striped marlin discards released alive from longline gear at 72% (Francis et al. 2004). The estimated weight of striped marlin dead on arrival was added to landed weight to estimate overall fishing mortality. These totals are likely to be under estimates because post-release mortality, which may be significant, is not included. In addition, there is under-reporting of striped marlin captures in commercial records over many years.

4.5 Length-weight relationship

Measurements of weight (kg), length (L, mm, Lower Jaw-Fork Length), and sex of striped marlin captured by anglers in New Zealand were recorded between 1985 and 1994. All measurements were taken with a measuring tape over the curve of the body. In 2004 lower jaw fork length was also measured as a straight line using calipers. Lengths and weights were fitted to the power function given below (Ricker 1975). The b value represents the slope of the L-W relationship and is important because it is the isometry coefficient. The isometry coefficient $b = 3$ indicates isometric growth, $b>3$ positive allometric growth, $b<3$ negative allometric growth (Ricker 1975). Change in b may occur annually, between sexes, or locations and can be used to compare the general condition of the same species of fish (Ricker 1975).

($W = aL^b$) derived from ($\log W = a' + b * \log L$)

W= weight (kg)
a= antilogarithm of a'
L= length (mm, LJFL)
a' = y axis intercept of log length-weight relation
b = slope of log L-W relation and isometry coefficient same in both equations

4.6 Von Bertalanffy growth model

From measurements of cross sections from the third dorsal spine collected by Davie& Hall (1990), a relationship between L and R (R, grouped in 0.3 mm categories) was calculated (Melo-Barrera et al. 2003). Spines with vascular erosion of the core were discarded in the present study.

$$L = aR^b$$

Where L = lower jaw-fork length; R = spine radius; a and b = fit parameters of model

Length at age was backcalculated from dorsal spine measurements using an equation (Ehrhardt 1992) designed to compensate for lengths in underrepresented age groups. This backcalculation is suitable for pelagic game fishes where sampling (recreational fishing) captures a large proportion of older individuals.

$$\text{Log Li} = [\log \text{Ri} (\log L - \log a)/ \log R] = \log a$$

Where Li = lower jaw-fork length at age; Ri = Spine radius at age; L = lower jaw-fork length; a = Y axis intercept of (L-R) relationship; R = spine radius

Individual growth was modelled by fitting backcalculated lengths at age to the von Bertalanffy growth equation.

$$Lt = L\infty\,[1 - e{-k(t\text{-}to)}]$$

Where Lt = length at age; L∞= asymptotic length; K= annual growth rate; t= age; to= age at length zero

5. CATCH AND EFFORT

5.1 Commercial catch in the southwest Pacific Ocean

There is evidence from tagging, shifts in catch rates, and genetic studies that striped marlin taken in New Zealand are part of a wider stock. Catch rates of striped marlin in the western equatorial Pacific Ocean are generally low and the area between 10° N and 10° S is not considered part of normal striped marlin distribution (Ueyanagi & Wares 1975). Longline reported catch and effort for all nations compiled by the Secretariat of the Pacific Community Ocean Fisheries Programme (OFP) in the western subtropical and western temperate Pacific Ocean (10° S to 50° S and 140° E to 130° W) is summarised below.

The number of marlin landed in the southwest Pacific per season in the OFP database peaked at 80 000 in 1954, then declined for 10 years, but has not shown any obvious trend from 1964 to 2001, fluctuating between 13 000 and 40 000 fish per year (Figure 3) (annual mean 23 000, s.d. 6500 fish). Total longline fishing effort in this region has been steadily increasing from about 20 million hooks per year in the 1950s to 174 million hooks in 2001 (Figure 3). Fishing effort increased rapidly in the early 1970s, but dropped significantly in 1975 in the face of very high oil prices.

In the southwest Pacific, striped marlin was the primary billfish landed by weight in most years until 1980, when broadbill swordfish landings increased sharply. Striped marlin reported landings in tonnes were high *(6000 t in 1954) at the start of the fishery and flat to slightly declining since the mid 1960s* (Figure 4). They have ranged between 900 and 2500 t since 1964 (mean 1600 t, s.d. 450 t) compared with a total landings across the entire Pacific Ocean of about 15 000 t

The proportion of landed catch by weight was also highest in the mid 1950s, when striped marlin were the third most important component of catch behind yellowfin and albacore tuna (Figure 5). In 1957 there was a large increase in "other" species in the region, which included southern bluefin tuna. Albacore remains the *dominant* species, making up more than 40% of landed catch by weight for most years since the mid-1960s. According to OFP data, striped marlin are 2–5% of the southwest Pacific longline landings since 1964, with a declining trend in proportion of landings since then (Figure 5). The linear regression of striped marlin as a proportion of landings since 1964 is $p = -0.0005year + 1.075$ ($R^2 = 0.36$) Note, the proportion of bigeye tuna in the catch more than doubled in the mid 1970s as much of the fleet switched to setting gear deeper and targeted this species.

The trends in striped marlin fishing effort (Figure 6) and CPUE (Figure 7) since 1952 have been summarised in 16 blocks (10° lat by 20° long) across the southwest Pacific. In subtropical and warm-temperate waters, the trend in CPUE for most 10 x 20 degree blocks show high initial catch rates that declined rapidly. In the block to the north of New Zealand CPUE fell from 4.5 striped marlin/1000 hooks in 1954 to 1.3 striped marlin/1000 hooks in 1959, and in the north Tasman Sea CPUE started at 14.4 striped marlin/1000 hooks, and fell to 3.5 striped marlin/1000 hooks by 1959. For most blocks in Figure 7 there is a declining trend in CPUE and at times high annual variability during the 1960s, followed by relatively low and variable catch rates since 1970. CPUE in the 10 x 20 degree blocks around the North Island of New Zealand (30 – 40° S and 170° E – 170° W) appear not to show high catch rates in the 1950s and 1960s, less than 0.5 striped marlin per 1000 hooks, in most years (Figure 7). Although striped marlin were always present, it may be that most of the fishing effort in this area was expended at a time of year when marlin were less abundant. Large catches of southern bluefin tuna were being taken from this area at that time.

The blocks between 20° S to 30° S across the region had the highest initial CPUE. In particular, the north Tasman Sea block had the highest CPUE both in the initial years (12,000 striped marlin at 14.4 fish/1000 hooks in 1953) through to the present (9000 striped marlin at 0.74 fish/per 1000 hooks in 2001) (Figure 7). The area between New Zealand and Fiji shows a marked decline in fish landed and catch rate, from 17 000 striped marlin at just over 3 fish/1000 hooks in 1955, to 165 striped marlin at 0.015 fish per 1000 hooks in 1974 (an average of 1 striped marlin for each 66,000 hooks set).

There is little correlation between good years or poor years across the region. A spike in CPUE may appear in a few blocks in one year and in others the following year. The spike in 1978 is the most obviously consistent. This was the year when overall fishing effort was very low across the region, and may reflect altered fishing practices at the time.

CPUE (number of striped marlin/1000 hooks) by month has been plotted for the same 10 x 20 degree blocks of the southwest Pacific as above for the combined 18 year period from 1970 to 1987 (Figure 8). This period was selected as it contains relatively consistent catch rates and is before the introduction of the billfish moratorium which changed fishing patterns around New Zealand. In the northern areas (10 – 20° S) striped marlin CPUE is low year round with only a slight rise in spring in the north Coral Sea (northwestern block) (Figure 8). By contrast there is very high striped marlin CPUE in spring and early summer in the north Tasman Sea/south Coral Sea with the other blocks in the 20° S to 30° S region showing low CPUE most of the year with a peak in October. The Central Tasman and northern New Zealand blocks (30–40° S) show relatively high CPUE (1 to 1.7 striped marlin/1000 hooks) in January and February, which tapers off in April and May, then rather unexpectedly rises in September and October. The increase in December in the central Tasman is likely to be an artefact of a few marlin landed in one year and generally very little fishing effort in this block during that month. From 1970 to 1987 there were very low striped marlin catch rates throughout the year east of New Zealand (30° S to 40° S) and in the southern blocks (40° S to 50° S) (Figure 8).

5.2 Striped marlin reported in New Zealand's EEZ

Data on striped marlin catch from commercial catch records (TLCERs, CLERs) and data collected by scientific observers provide detail on catch and other parameters by set. Catch by fleet shows that the highest landed catches were reported by Japanese vessels during the 1980s, with landings peaking at 2798 fish in 1982 (Figure 9). There were very few striped marlin reported by commercial vessels in the early 1990s, but domestic capacity and reporting of discards increased in the mid 1990s and 1546 striped marlin were reported by the domestic fleet in 1999. The number of striped marlin landed or discarded by season and fleet is summarised in Table 2. Some striped marlin were landed by foreign licensed vessels outside the Auckland Fisheries Management Area between 1988 and 1990. The recreational catch is plotted for comparison and reported catch also peaked in 1999 at 2368 fish (Figure 9). Total striped marlin catch for combined fleets was very similar in the early 1980s and the late 1990s with a period of low catch and/or reporting in between.

The total weight of striped marlin landings and discards by season on TLCERs and CELRs is difficult to ascertain. There has been under-reporting of fish released by commercial fishers since 1987. Many TLCERs and CELRs record the number of striped marlin discards but not the estimated weight. These can be converted to an estimated weight using the average weight by season from Bay of Island Swordfish Club records. Not all striped marlin are released alive, and dead discards are added to landings to estimate fishing mortality in weight. New Zealand observer records give an overall estimate of fish released alive from longline gear at 72% (Francis et al. 2004). The total weight of striped marlin landed by commercial and recreational methods plus the estimate of those fish returned to the sea dead is plotted in Figure 10. Landings peak in 1982 at 275 t with a further 1.1 t tagged and released. Total landings plus the known longline mortality in 1999 are estimated to be 251 t with a further 241 t released alive by recreational and commercial fishers (Figure 10). Since 1994, the mean weight of striped marlin tagged and released or discarded alive is 130 t per year (sd = 46.5 t). Since 1980, the mean weight of fish landed or returned to the sea dead is 146 t per year (s.d.= 56.9 t). Because of under-reporting and post release mortality these figures should be treated as minimum estimates of catch.

The average number of striped marlin caught per set is very similar between Japanese and domestic fleets according to TLCERs which record striped marlin (Figure 11). Over 60% of sets catching striped marlin caught one or two fish. However, the domestic vessels catching striped marlin usually set between 600 and 1400 hooks (mode at 1000), the Japanese vessels usually set between 2400 and 3000 hooks (mode at 2600) (Figure 12). For domestic vessels to catch a similar number of striped marlin per set with less than half as many hooks indicates that the cate rate by domestic vessels is higher than that on Japanese vessels. However, these fleets may be fishing at different times of the year and they even fished during different decades, with almost no overlap (See Figure 9). Therefore, direct comparisons of striped marlin CPUE between fleets will not be particularly informative. The number of striped marlin caught per set by Korean vessels is more variable but follows a similar trajectory to the other fleets (See Figure 11).

New Zealand observer records show that 80% of striped marlin are caught in waters 20 °C or warmer, but are occasionally caught in waters 17 to 19 °C (Figure 13). The overall range from observer records is 15.8 to 24.2 °C. The TLCER forms comprise a much larger database of striped marlin catch from all fleets since 1980. A higher proportion of striped marlin are captured in 17 to 19 °C water according to these records, although there may be a large proportion of fishing effort at these temperatures while targeting southern bluefin tuna. Overall, the pattern of catch at temperature is similar to the observer data with a mode at 20 and 21 °C and a sharp decline at 19 °C (Figure 13). There are some very low sea temperatures recorded for striped marlin captures on TLCERs, outside the expected range for this species. It is possible that a few records may be correct. Most are probably incorrect and may be due to the recording or punching of the wrong code, STM (striped marlin) when it should have been STN (southern bluefin tuna).

For example, many "striped marlin" reported from cold water came from latitudes higher than 45° S and for 31 fish reported in waters between 10 and 12 °C the average weight was just 18 kg, a weight consistent for southern bluefin tuna but not for striped marlin.

Very few striped marlin in the TLCER database are reported south of 42° S (Figure 14). Most striped marlin reported on TLCERs were caught north of 38° S. Japanese and Korean vessels took most of striped marlin between 31° S and 38° S with a peak at 33 °S, while the domestic fleet caught more marlin in the Bay of Plenty, East Cape area, 37° S (Figure 14). This difference may be due to the different areas fished during the months when striped marlin are most abundant in New Zealand waters.

Striped marlin catch is also affected by how and where the gear is set. A study by Francis et al. (2000) used discriminant function analysis of observer data to investigate a range of environmental and fishing variables to determine whether longline sets that caught striped marlin could be distinguished from those that did not. Longline sets catching striped marlin in New Zealand could be identified with a low error rate (14%) using a suite of variables, primarily when sea surface temperature exceeds 18 °C and fish was the main bait used. The effective fishing depth of longline gear will also affect striped marlin catch rate, with the highest catches coming from the shallowest hooks (Hanamoto 1978).

Striped marlin landings and reported discards (TLCERs) by 1 degree square for the years 1980–2002 combined have been plotted in Figure 15. A large proportion of this catch is from the northeast coast (87% in FMA 1) and is taken from within 120 nautical miles of the coast (first and second 1 degree squares from the coast). On the west coast of the North Island most catch is taken within 60 nautical miles of the coast (Figure 15), reflecting where most of the fishing effort has been applied. The highest recorded catch for this period was 1408 striped marlin from 33° S 171° E square which is northeast of the Three Kings Islands.

The weight distribution of landed and reported discards was derived from TLCERs (1980–2002 combined) for shots where only one striped marlin was caught and an estimated weight is given. The weight distribution of these striped marlin is plotted by fleet in Figure 16. Korean vessels report catching a high proportion of very small striped marlin compared with other fleets. It is possible that the weight reported is a processed weight, but even so it is still hard to believe. The Japanese report most striped marlin in the 50 to 110 kg range with a broad mode between 70 and 100 kg (Figure 16). New Zealand surface longline weights are similar to the weight distribution of recreationally caught fish from Bay of Island Swordfish Club Records for the same years as covered by the TLCERs (1980 to 2002). Striped marlin recorded on Japanese vessels tend to be smaller than those caught by New Zealand vessels.

There has been some striped marlin bycatch reported from the purse-seine method, particularly in New Zealand (Bailey et al. 1996). Recreational fishers witnessed one incident in March 1994 when they picked up two dead marlin released after being tangled in a purse-seine net from the outside as it was hauled. The vessel was fishing for skipjack tuna between the Hen and Chicken Islands and the Mokohinua Islands at the time. This is only one observed incident, but may be indicative of a cryptic incidental mortality caused by another fishery.

5.3 Longline catch off northern New Zealand

Surface longline catch and effort has also been summarised from a subset of OFP data for the 5 degree squares that encompass most of the area of the EEZ around northern New Zealand (30 to 40° S and 170° E to 175° W, plus the Kermadec Islands 25 to 30° S and 180 to 175° W). This area was selected because it encompassed the main areas in which striped marlin were likely to be caught in New Zealand waters. However, this area also includes the waters of East Cape that have been fished extensively for southern bluefin tuna during winter, when striped marlin would not be a likely component of catch. It also includes an area just outside the New Zealand EEZ to the north, where distant-water longline vessels are known to operate and catch striped marlin.

Surface longline landed catch by month in the northern New Zealand box (all years, 1952 to 2001 combined) peaks in January and February, whereas fishing effort peaks in June and July (Figure 17). Rather surprisingly, the striped marlin catch drops away until June and another mode appears in August, with more fish caught than in March, April, or May. The number of fish reported from northern New Zealand is lowest in November and December (Figure 17).

Striped marlin longline CPUE by month for each 5 degree square shows high catch rate in the north eastern area (25° S to 30° S) around the Kermadecs in October (Figure 18). For the three squares between 30 and 35° S catch peaks during January and February. South of 30° S, CPUE peaks in February and is low for June to November. The exception is October in the 5 degree square off the west coast of the North Island (Figure 18). A review of the data suggests that this is the result of very low overall fishing effort in that area during this month and a report of a large number of striped marlin in on year (October 1964). It is not a consistent occurrence and may be an error.

Striped marlin landings by surface longline in this box around northern New Zealand ranged from 500 to 3000 fish per year from 1956 until the first full year of the billfish moratorium in 1988 (mean 1493 fish, s.d. 1017 fish for that period). An exceptionally high catch of 5143 striped marlin was reported in 1971.

The annual fishing effort in the box around northern New Zealand ranged between 2 million and 5 million hooks until 1971. Fishing by surface longliners changed from seasonal to year round in the 1970s and annual fishing effort fluctuated widely. Fishing effort declined sharply in 1975 and again in 1978, probably due to very high oil prices in those years. During the 1980s effort was more consistent but declined from 12 million hooks after 1982.

The reported annual commercial landings of striped marlin for the northern New Zealand box peaked at 400 t (5143 fish) in 1971 and averaged 115 t per year (sd 80.3 t) (1493 fish) between 1956 and 1987 (Figure 19). Very few blue or black marlin are reported from this area, although they are present in modest numbers in the recreational catch. The large increase in the catch of broadbill swordfish landed since 1980 (Figure 19) probably has more to do with changes in retention and marketability of small fish, and targeting by some fishers, rather than changes in availability.

Striped marlin have not been a major component of the surface longline reported catch in the northern New Zealand box since the 1950s. Reported landings are similar to the proportion of yellowfin tuna retained (Figure 20). Albacore and 'other species', which includes southern bluefin tuna, dominated annual landings for may years. Since the early 1980s, bigeye tuna and swordfish have become a more significant component of landed catch (Figure 20).

The data set compiled by OFP is incomplete for the catch from some nations in some years. It contains a long time-series of catch, mainly based on Japanese logbook data, and trends in CPUE should be interpreted with caution. Nominal striped marlin CPUE in the 5 degree square over the Kermadec fisheries management area produced relatively high catch rates in the 1950s; these declined during the 1960s and are quite variable between the 1970s and 1990s (Figure 21). This area has experienced low fishing effort for the last 16 years (mean = 78 000 hooks, s.d. = 130 000 hooks per year) (Figure 22). The three 5 degree squares in the far north of New Zealand (30° S and 35° S) produced moderate CPUE between 0.5 and 2 fish per 1000 hooks until the mid 1970s, followed by lower catch rates and no clear trend (See Figure 21). CPUE exceeded 1 fish per 1000 hooks in the area around North Cape in 1956, 1958, 1967–1971, 1975, and 1976. These three 5 degree squares combined had an average of 750 000 hooks set per year since 1970. The three 5 degree squares across the central North Island (35° S to 40° S) have mostly had low striped marlin CPUE, especially in the two squares with most fishing effort, which averaged over 4 million hooks per annum since 1970. Periodically the west coast of the North Island experiences CPUE above 1 fish per 1000 hooks. This occurred in 1964, 1971, 1976, and 1999 (See Figure 21).

5.4 Striped marlin recreational catch

There is a long tradition amongst New Zealand gamefish clubs of keeping records of catch. The Bay of Islands Swordfish Club has published details of individual striped marlin caught in their area or by their members fishing elsewhere since 1925. The New Zealand Big Game Fishing Council (NZBGFC), which is an umbrella group for gamefish clubs, also keeps national records such as heaviest fish for each line class and awards national trophies. NZBGFC has kept a record the first marlin caught each season since 1979. It is invariably a striped marlin usually caught in mid to late December. Over the last 25 years one striped marlin was caught in November (11 November 1993) and twice the first marlin was taken in January. Although there is some competition between keen anglers and skippers to catch the first marlin of the season fishing effort increases significantly after 25 December when many boat owners head for holiday destinations over the Christmas and New Year break. The fishing season spans New Year, and club records are kept by fishing season, starting 1 July and ending 30 June the following year.

The annual recorded recreational catch of striped marlin (landed and tagged fish combined) ranges from a low of 75 fish in 1969–70 to a high of 2368 in 1998–99 (Figure 23). 1948–49 was an exceptional season with 1365 striped marlin reported. Even with advances in vessels and fishing gear and a larger population of active fishers, this record national tally was not surpassed until 1993–94 (Figure 23). Recreational catch tallies were relatively low during the 1960s and early 1970s, then show a steady increase until the early 1980s. This series of successful seasons led to an increase on participation in the fishery. New boats were built and the charter fleet expanded. Three seasons of much lower catch followed (1984–85 to 1986–87) which led to demands for management controls on surface longline vessels, and a three year moratorium on landing billfish on commercial vessels was introduced in October 1987. Total recreational striped marlin catch increased in two seasons to the peak levels seen in 1980–81, maintained that level for 5 years, then doubled in 1994–95 and was consistently high for the rest of the 1990s (Figure 23). Bay of Islands Swordfish Club (BOISC) records show a similar trend. This single club recorded 50% of the national catch in the 1960s and 1970s, but as the fishery expanded during the 1990s many more clubs were formed and new areas fished and the proportion of the recreational catch taken by the BOISC declined (Figure 23).

There are no records of the total number of boats that participate in the recreational striped marlin fishery. Trends in participation and fishing success can be inferred from the BOISC records of the number of boats recording one or more striped marlin per year. Boat names were not recorded until 1934. Between 12 and 18 boats were catching striped marlin during the 1930s, and the maximum number recorded in any season before 1975–76 was 27 (Figure 24). There followed a period of steady growth, apart from the mid 1980s, to a peak of 127 boats recording striped marlin in 1994–95. The numbers of successful boats has declined to a mean of 72 boats over the last four seasons (Figure 24).

There are no historical records of fishing effort for the BOISC fleet. Although the number of boats participating has increased, many of these are private vessels that fish only a few days a year. Rather than using catch per season or month, catch per day is used here to indicate changes in catch rate. When fishing is good more than one striped marlin may be caught by a boat in a single day. The frequency of these multiple captures can be summarised by fishing season (Appendix 3). For example, in 1934 15 boats recorded catching 106 striped marlin for the season. Sixteen times that season a boat caught two striped marlin in a day, four times a boat landed three fish in a day, and once four fish were landed in a single boat day. In 1986–87, 48 boats landed 106 striped marlin and only once were two fish landed in a single boat day.

The number of striped marlin caught in multiple captures per season was relatively high in the 1940s and 1950s and again in the 1990s (Figure 25). However, it was very low during the 1960s, 1970s, and mid 1980s. 1948–49 again stands out as a very successful season for the members of the BIOSC, with 328 striped marlin caught in multiple captures (Figure 25).

The number of vessels and annual catch has increased since 1934. As total catch increases, the number of multiple captures would be expected to increase. Striped marlin taken in multiple captures are plotted as a proportion of total catch for each season in Figure 26. In four of the seasons before 1950 the proportion of striped marlin taken in multiple captures is close to 60%. Overall, between 1934 and 1958–59 the average proportion was 36%, while for the period 1959–60 to 1986–87 multiple captures accounted for just 13% of striped marlin on average, and seldom exceeded 20%. There is a higher proportion of multiple captures since 1988 (mean 30% of total catch) but many of these can be attributed to boats fishing the banks north of the Three Kings Islands. The reason they travel that distance and endure the rough seas is that catch rates are generally higher than on the coast, where fishing was located in the early years.

Recreational striped marlin CPUE (fish per boat day) has been collected from east Northland charter boat skippers since 1977. Some skippers were able to provide records for preceding seasons. The number of respondents and mean CPUE per season are listed in Appendix 4. Recreational CPUE rose initially over the first five years to a peak of 0.25 striped marlin/boat day in 1979–80 (Figure 27). CPUE was low for three years in the mid 1980s, e.g., in 1984 to 1987 mean = 0.06 striped marlin/boat day. CPUE reached 0.25 striped marlin/boat day in the 1993–94 and 1994–95 seasons, and peaked again in 1998–99 (0.26 striped marlin/boat day). For 6 of the last 7 years reported, recreational CPUE has remained above the long term average of 0.16 striped marlin /boat day (Figure 27).

Environmental and fishing-related factors for 1981 to 1997 were modelled using stepwise multiple regressions to investigate the amount of variability they can explain in gamefish charter CPUE (Holdsworth et al. 2003). Factors investigated were sea surface temperature during the fishing season, El Nino southern oscillation index, the position of the 20 °C isotherm at the beginning of the fishing season, annual commercial landings of striped marlin in the New Zealand 200 mile zone, and surface longline CPUE in the wider southwest Pacific.

Surface longline CPUE in the general SW Pacific (10° to 40° S, 165° E to 160° W) had a strong positive correlation with New Zealand recreational CPUE ($P = 0.001$) (Holdsworth et al. 2003). However, this correlation was not found with longline CPUE from the western Tasman Sea and Coral Sea (10° to 40° S, 145° to 165° E) where catch rates are generally higher and some targeting is likely. The total surface longline landings of striped marlin in New Zealand each season were negatively correlated with recreational CPUE ($P = 0.019$), which indicates a possible interaction between these fisheries (Holdsworth et al. 2003).

6. SIZE AND GROWTH

6.1 Size structure of recreational striped marlin catch

The best time series of catch records is available from BOISC yearbooks. Of the 15 163 striped marlin recorded as landed or tagged and released since 1925, 15 127 have individual weights. Overall, the mean weight was 104.8 kg (s.d. = 22.82 kg) with a median of 103.8 kg and a weight distribution that is very close to normal (D = 0.0305) (Figure 28). However, there has been a declining trend in average size over this time. Before 1960 average striped marlin weights ranged between 106 and 124 kg per season (Figure 29). Since then the average weight each season shows more inter-annual variability and a declining trend

$$wt = -0.30(year) + 700.9 \quad (R^2 = 0.27)$$

The plot of cumulative weight frequencies in 16 year blocks in the early years, then 10 year blocks from 1960 on, show that the proportion of small fish has increased and the number of large fish has decreased (Figure 30). The proportion of striped marlin under 100 kg in the recreational catch before 1945 was 15%, but during the 1990s the proportion in under 100 kg was 58%. The proportion of fish 130 kg and overhas not changed over the last three decades (Figure 30).

Lengths of striped marlin (n = 622) from New Zealand between 1985 and 1994 ranged from 1760 mm fish (33 kg) to a 2820 mm female (141.6 kg). The mean lower jaw fork length for all fish was 2373 mm (s.d. = 167 mm) and males (mean = 2310 mm, s.d. = 158 mm) were generally smaller than females (mean = 2417 mm, s.d. = 163 mm) (Figure 31). Over 99% of striped marlin in this data set are longer than 2000 mm and female striped marlin were 10% longer and 16% heavier than males. Only fish landed at club weigh stations were measured, and, following negotiations over the introduction of the billfish moratorium (1987–88 season), a voluntary minimum size was introduced and recreational anglers lifted the proportion of striped marlin tagged and released from less than 1% to over 50%. Generally, more small marlin were tagged and released than large marlin, particularly in the late 1980s. The sex ratio observed when almost all fish where landed was 1:1 (n = 61). This changed in fish landed from 1987–88 to 1993–94 to 3:4 male to female (n = 561) following the introduction of the 90 kg voluntary minimum weight.

6.2 Length-weight

Length-weight conversion equations have been derived from these data for male, female, and both sexes combined for striped marlin caught by recreational anglers in New Zealand (Table 3). There was no statistical difference between the length-weight regressions of males and females (Figure 32). Lower jaw fork lengths used in these calculations were measured with a tape over the curve of the body. A sample of 35 striped marlin, ranging from 2185 mm to 2656 mm, was also measured with callipers in 2004. Measuring over the curve of the body added, on average, 1.87% (s.d. = 0.868 %) to the straight line lower jaw fork length (Appendix 5).

6.3 von Bertalanffy growth estimates

There have been a number of published estimates of striped marlin growth rates using the von Bertalanffy growth model. Davie & Hall (1990) estimated eight age classes from ring counts in dorsal spines of 211 New Zealand striped marlin from the same sample used in the length weight relationship above. A significant relationship was identified between length and dorsal spine radius (r^2 = 0.83). Dorsal spine ring counts and spine radius were used to backcalculate length at age to describe growth. Length at age data were applied to the von Bertalanffy growth model and the following parameters were obtained: L_∞=3010 mm, K=0.22 annual, and t_o= -.04. These estimates should be treated with caution because the growth of striped marlin may not be well described by the von Bertalanffy curve and the length at age estimates are invalidated. The New Zealand striped marlin growth model predicts slower growth in the first year and greater annual growth in older fish compared with others from the Pacific region (Figure 33). The mean lengths at age from the three models are presented in Table 4.

There is little information on striped marlin growth from the New Zealand gamefish tagging programme. Attempts at measuring marlin in the water have not proved successful and only estimated weights are available on release. The longest term recapture was at liberty for 2 years 10 months and was reported to weigh 74 kg dressed or about 104 kg whole weight on recapture. This fish was estimated to be 95 kg when tagged and released.

7. COOPERATIVE TAGGING PROGRAMME

7.1 Background

The New Zealand Cooperative Gamefish Tagging Programme was initiated by the Ministry of Agriculture and Fisheries in 1975 following requests from game fishing clubs. Initially, assistance was received from the NMFS Billfish Tagging Program based in La Jolla, California. Although the tags were intended for billfish, a variety of species was tagged and acceptance of tag and release of striped marlin was slow because of the value placed by New Zealand anglers on retaining their catch for food (Saul & Holdsworth 1992). Less than 5% of recreationally caught billfish were tagged and released before 1987. As part of the negotiations surrounding the billfish moratorium recreational fishers were asked to substantially increase tagging of billfish, with a target of 50% for striped marlin. This was achieved with the assistance of the New Zealand Big Game Fishing Council which persuaded member clubs to accept a voluntary minimum size for landed fish of 90 kg.

The Gamefish Tagging Programme is now funded by the New Zealand Ministry of Fisheries who contract out the "Management of data from the gamefish tag recapture programme" (PEL2003/01) and the New Zealand Big Game Fishing Council who purchase and distribute tags to fishing clubs and anglers at cost. Tags are supplied free to commercial fishers who express an interest in tagging billfish.

7.2 Release information

The proportion of the recreational striped marlin catch tagged and released increased dramatically in the late 1980s, and has been fairly consistent at between 60% and 70% since 1993–94 (Figure 34). Therefore the data collected from anglers on tag cards can be used to describe a large proportion of the fishery. Striped marlin tagged by MFish statistical reporting area shows that east Northland (areas 002 and 003) have the highest proportion of catch with about 29% each, followed by area 048 to the North with the King Bank and Middlesex Bank marlin contributing about 22% of tagged fish (Figure 35). The Bay of Plenty (areas 008, 009, and 010) contribute about 8% of tag numbers. This is quite a change from the 1940s and 1950s when the fishing, particularly around Mayor Island, rivalled that from the Bay of Islands. The west coast of the North Island (areas 40 to 46) provides some very productive fishing in good years with about 6% of tagged fish from this region. Area 47 includes the Three Kings Islands as well as Ninety Mile Beach and contributes about 8% of tag numbers from the far north and west coast areas (Figure 35). Recreational fishers tag 98% of the striped marlin on record; most of the rest have been tagged on surface longline vessels.

7.3 Recapture information

There have been 64 recaptures of striped marlin from 11 777 releases (Holdsworth & Saul 2004). The overall recapture rate of 0.5% is less than in the other striped marlin tagging programmes and for other marlin species (Ortiz et al. 2003). The highest recapture rate for billfish species (just over 2%) is claimed by white marlin, the close Atlantic relative of striped marlin. Most striped marlin recaptures worldwide have been made within a year of release and the New Zealand programme is no different (97% <1 year). Of 26 recapture reported in 1997–98 and 1998–99 15 were reported by recreational anglers (58%) and only one was reported by a domestic longline vessel. In the subsequent four years there have been only six striped marlin recaptured by recreational fishers in New Zealand with most other reports coming from surface longline vessels from around the southwest Pacific.

Despite a low recapture rate, the New Zealand tagging programme has provided a useful insight into the movements of striped marlin in the southwest Pacific. A third of all recaptures have been made in distant waters, more than 1200 km from their release point, including Australia, Solomon Islands, New Caledonia, Fiji Islands, Kingdom of Tonga, Western Samoa, Tahiti, and Marquesas Islands (Figure 36).

8. SATELLITE TAGGING PROGRAMME

8.1 Background

A New Zealand Marine Research Foundation project attached six pop-up archival satellite tags (PSATs) to striped marlin caught by recreational methods off New Zealand in 2003. These tags have sensors that collect detailed information on water temperature, depth, and light levels. These data are stored while the tag remains on the fish, then at a predetermined time the tag releases from the fish, floats to the surface, and starts transmitting summary information to orbiting satellites. Daily positions can be estimated from day length and the time of sunrise and sunset. Five of the six tags deployed in 2003 delivered data and two released early. Durations of actual deployments were between 20 and 60 days, indicating that these five fish all survived capture and release on standard recreational fishing gear. The tag that failed to transmit was programmed to release after 109 days (Sippel 2005).

8.2 Temperature and depth preferences

Results from the PSATs showed that New Zealand striped marlin strongly prefer the upper mixed layer, spending more than 95% of the time in waters of 20 °C. One marlin tagged late in the season swam straight for the tropics and recorded waters warmer than the other tagged fish (up to 29 °C). Patterns of day-night temperature preferences are hard to discern from the limited data set. In near-shore New Zealand waters there is a trend toward the marlin spending night time in surface waters which are slightly warmer compared to during the day, when they venture to deeper cooler waters more of the time. Although not statistically significant, this suggests that striped marlin may use daytime warm surface waters to raise their body temperature after deep dives into cooler water (Sippel 2005).

Striped marlin studied in Hawaii (Brill et al. 1993) spent less than 1% of their time in water less than 20 °C. In California, Holts & Bedford (1990) described striped marlin seeking the warmest water available (18–20 °C) but showing occasional excursions into deeper water of 10–12 °C. The New Zealand tagged fish recorded maximum daily temperature ranges between 15 and 26.1 °C (Sippel 2005). This is a greater daily range of temperatures than observed in Hawaii and California, despite such ranges being available in Hawaii. The result may be related to the large size of New Zealand striped marlin and the opportunity this presents to use thermal inertia of the body to behaviourally thermoregulate.

New Zealand striped marlin spend more than 65% of daytime in the upper 5 m of the water column and more than 78% of night in the upper 5 m. Deepest dives were to 310 m, deeper than striped marlin have been recorded before (less than 100 m, California; Holts & Bedford 1990: less than 180m, Hawaii; Brill et al. 1993).

8.3 Movements and migration

Estimates of fish locations using light-based geolocation are accurate to within about 0.5° of longitude and 1.5° of latitude. At best, a given estimate of location is within a 50 nautical mile radius. A sea surface temperature model was used to help refine estimates of latitude. Striped marlin tagged in coastal waters during 2003 quickly moved out of the range of most recreational vessels. No marlin remained within 22 km of the coast (12 nautical miles) for more than a day or two after tag deployment. Only one marlin spent appreciable amounts of time within 100 km of shore; the other four moved beyond 100 km from the coast within 1 to 3 days. As a proportion, of the total distance through which these four marlin swam, less than 4% of their total distance traversed was within 100 km of New Zealand (Sippel 2005).

One fish remained relatively near New Zealand and spent most of its time near the King Bank. Two fish stayed north of New Zealand during February, March, and early April, and one fish started moving away from New Zealand in mid April ending up 1630 km northeast of the release point. A striped marlin tagged in early May at the King Bank moved rapidly north to Vanuatu, a straight line distance of 2140 km in 33 days. This is a displacement rate of 58 km per day. These movement data are consistent with patterns seen from recaptures in the cooperative tagging programme using conventional tags.

9. DISCUSSION

The striped marlin is truly an oceanic pelagic species, distributed throughout the subtropical and warm temperate waters of the Pacific and Indian Oceans. They do not appear to be common in the warmest tropical waters along the equator and in the western central Pacific (warm pool), at least in sizes which appear in catch records. The distribution of juvenile striped marlin is not well known, but they tend to be found in the warmer part of the adult range. The adults migrate seasonally into higher latitudes and cooler waters after spawning in late spring (November and December in the southern hemisphere).

Striped marlin generally arrive in New Zealand's northern waters during December and January as warm oceanic water pushes south, aided by the East Auckland Current. They prefer surface water temperatures of 20 to 23 °C according to data from scientific observer records and pop-up satellite archival tags on New Zealand striped marlin, although occasionally fish are found in water down to 14 °C.

TLCER records of very small striped marlin being caught off the lower South Island in waters of 10–12 °C are highly doubtful. A possible explanation for this is the miscoding of southern bluefin tuna (STN) for striped marlin (STM), either on the forms or at time of data entry. Most striped marlin caught by longline in New Zealand have been north of 38° S and very few have been from south of 42° S. If miscoding is occurring, it does not seem to affect a significant number of records at higher latitudes.

Striped marlin carrying pop-up archival satellite tags in Mexico spent 95% of their time in 20–25 °C water (Domeier et al. 2003) and recreational catch rates in Mexico are highest in waters between 22 and 24 °C. Domestic longline standardised catch rates off eastern Australia are highest in waters of 24 and 25 °C, while 97% of striped marlin catch came from areas with surface water temperatures between 18 and 27 °C (Bromhead et al. 2004). Francis et al. (2000) investigated the factors affecting striped marlin catch rates in New Zealand using commercial catch records and found that there was a significant difference between sea surface temperature (SST) in sets that caught marlin (mean SST 21.8 °C) and those that did not (mean SST 19.6 °C). Striped marlin were caught predominantly when SST was higher than 18 °C and when fish was the main bait type. Striped marlin in New Zealand waters spend a high proportion of their time at or near the surface (67% ±4% during the day and 78% ±2% at night) (Sippel 2005). Sea surface temperature appears to have a strong influence on striped marlin distribution. This is of particular significance in northern New Zealand which is located on the southern boundary of their preferred temperature range in summer and autumn.

In New Zealand, the highest striped marlin catch and catch rates from longline and recreational methods occur just to the north of the North Island. Some gamefish charter boats specialise in fishing trips to the Three Kings Islands where high catch rates are recorded from the King Bank and Middlesex Bank in particular (both about 33° 55' S). Longline catch in New Zealand is highest right across the 33° S to 34° S latitude. Striped marlin catch declines markedly south of East Cape (37° 40' S) on the east coast and Cape Egmont (39° 10' S) on the west coast of the North Island.

Annual longline catch rates of striped marlin around New Zealand have been variable but relatively low compared to the higher catch rates in the North Tasman and Coral Sea where they are available year round. However, much of the longline effort around New Zealand is in areas and/or months when striped marlin are generally not available. CPUEs in the North Tasman and Coral Sea have declined significantly since the 1950s and appear to be continuing to trend down. Changes in target species and the tendency to set the gear deeper since the mid 1970s may have contributed to this trend, although given the continued downward trend, it is very important to determine the actual contribution of such changes in fishing practices to catch rates. Logbook records of individual surface long line sets from a wide area would be required to standardise striped marlin CPUE.

Myers & Worm (2003) aggregated catch rates across tuna and billfish species for each fishery type and interpret this as a time-series measure of "community biomass". This literal interpretation of longline CPUE as a relative index of fish abundance led them to conclude that "industrialized fisheries typically reduced community biomass by 80% during the first 15 years of exploitation", and that "large predatory fish biomass today is only about 10% of pre-industrial levels" (Myers & Worm 2003). However, it seems implausible that the steep decline in CPUE in the first few years is solely caused by an equivalent decline in the stock biomass when the fishery had only just started and removed the first few thousand tonnes of tuna and billfish. Longlines do not randomly sample pelagic populations but tend to select mainly the largest and oldest members of the population, so to infer that the CPUE indexes the entire population, or even the entire adult population, in this instance is incorrect (Hampton et al. Unpublished report to Standing Committee on Tuna and Billfish 2003). The biomass trajectory proposed by Myers and Worm does not fit with more comprehensive species specific stock assessment models. Possible explanations for the high initial CPUE are abnormally high recruitment at the time; and very high effectiveness of longline gear during the initial years. The segment of the striped marlin population of large old fish that were most susceptible to longline gear may have declined quite rapidly in the South Pacific during the 1950s.

In New Zealand, the highest monthly catch for the surface longline method is recorded in January-February, and the highest recreational catch is in February and March. In some seasons large numbers of striped marlin are found in the Three Kings recreational fishery in April and May. Longline records show that striped marlin have been caught in New Zealand waters in every month, with lowest catches in November and December and an intriguing spike in catch rates in October, particularly around the Kermadec Islands.

The dramatic increase in catch rates during October also occurs in the wider southwest Pacific, north and east of New Zealand. Possible explanations for this are an increase in catchability of striped marlin before spawning or an increase in targeting of pre-spawning striped marlin by surface longline vessels (this is when the flesh turns becomes more orange and they attain the highest price in Japan).

There has been a fundamental change in the surface longline fishery in New Zealand's EEZ as a result of the billfish moratorium introduced in 1987, and subsequent changes to fishing regulations and policy which prohibit commercial fishers landing marlin and other istiophorid billfish. Foreign licensed distant water fishing vessels, mainly from Japan and Korea, have not fished in New Zealand waters since 1995, and a large number of smaller domestic surface longline vessels entered the fishery during the 1990s. Also up to five Japanese vessels are chartered to fish for southern bluefin tuna on behalf of a New Zealand company (See Table 1).

Surface longline is the main commercial fishing method that catches striped marlin. Before 1988 the reported longline landings around northern New Zealand were variable, peaking at about 400 t and over 5000 fish in 1971. Striped marlin generally made up less than 5% of longline landings by weight, although some vessels did target the species (Bailey et al. 1996). Since 1988 there has been significant under-reporting of striped marlin returned to the sea by domestic vessels, but this appears to be changing. An estimate of domestic longline discards in 1997–98 was 930 – more than twice the number reported on TLCERs (Francis et al. 2000). There are also anecdotal reports from some domestic surface longline skippers that they do not report tagged marlin they recapture.

Striped marlin is the main target species in the northern gamefish fishery. Total recreational striped marlin catch is well captured in club records as there is a strong culture of weighing landed fish and reporting tag and release. The recreational catch has increased significantly from a few hundred fish per season in the 1960s and 1970s – with a low of 82 fish in 1970–71 – to over 1500 per season in the mid to late 1990s. The total recreational catch recorded in club records peaked in 1999 at 2368 striped marlin. The total weight of catch that year is estimated to be 210 t, but 67% of these were tagged and released.

Gamefish club records also provide individual fish weights. The Bay of Island Swordfish Club records contain good information on the weight distribution of striped marlin in New Zealand since the 1920s. Since 1960 there has been greater interannual variability in average weight, and there has been a significant declining trend in mean weight from about 120 kg to 95 kg. A much higher proportion of the recreational catch is small and medium sized fish (less than 100 kg) and that trend appears to be continuing. Techniques for targeting marlin have changed over the years and the area fished has expanded, but these changes occurred in the 1980s and 1990s (Peter Saul, president Whangarei Deep Sea Angers Club, pers. comm.). Changes in fishing area may have an effect on the size of fish caught. For instance larger striped marlin may be caught in cooler coastal waters while smaller fish are more likely to be taken from warmer offshore waters. As yet there are no data to support this assumption.

Since 1990, most of the recreational catch has been tagged and released. The estimated weight on release is recorded in club records. Some data are available on the accuracy of weight estimates from recaptures of tagged fish. Fishers appear to estimate fish around the voluntary minimum size of 90 kg quite well, but over-estimate larger fish (Holdsworth & Saul 2004). Therefore, mean weights from the BOISC records over the last 14 years are less precise and may be biased high.

If surface longlining was impacting on the abundance of striped marlin in the southwest Pacific, particularly the larger older fish, then we would expect the size composition of the population to change. The size composition of striped marlin in the BOISC records appears to start changing in the late 1950s, at the same time surface longline CPUE was declining.

There is also evidence from BOISC records of a sharp decline in the incidence of multiple captures by one boat on a single day. Before 1958–59, 36% of striped marlin were taken in multiple captures and in some seasons close to 60% of all striped marlin caught were landed as part of a multiple capture. From 1960 to 1987, the proportion dropped to a mean of 13% and seldom exceeded 20%. There is a higher proportion of multiple captures since 1988 (mean 30% of total catch), but many of these can be attributed to boats fishing the banks north of the Three Kings Islands. The reason fishers travel that distance and endure the rough seas is that catch rates are generally higher than on the coast, where all fishing was located in the early years. If the proportion of multiple captures is used as a measure of the quality of the recreational striped marlin fishing over a period of relatively stable fleet size and similar fishing methods, then the fishery was nearly three times better in the 1940s and 1950s than it was in the 1960s and 1970s. Changes in the number of multiple catches per boat day in the New Zealand recreational fishery may not be reflected in CPUE from other fisheries and there is no simple way to translate the index into one that may relate to relative abundance.

The changes in average size and recreational fishing success occur 4 or 5 years after large numbers of striped marlin were first caught in the southwest Pacific and 2 or 3 years after Japanese longliners started fishing extensively in the area to the north of New Zealand. There is no doubt that fishing decreases the abundance of fish populations. The abundance and size structure of the striped marlin population available to recreational fishers in New Zealand has been affected by surface longlining in the southwest Pacific since the late 1950s.

Following the introduction of the billfish moratorium, CPUE in the recreational fishery has improved from the very low levels of the mid 1980s. For the 8 years between 1993–94 and 2000–01, CPUE in the recreational charter boat fishery was above the long-term (27 year) mean. However, during the best fishing years in the 1990s CPUE was equivalent to the best years in the early 1980s on the Northland east coast (0.25 striped marlin per charter boat day averaged over the whole season).

Some data for charter boats that predominantly fish at the Three Kings Islands have been excluded from the CPUE index. The main attraction of this remote location is higher striped marlin catch rates than on the coast, although the fishery can be mercurial. Recreational boats have caught up to 15 striped marlin per day on the banks to the north of the Three Kings and charter boat CPUE is often more than 0.5 striped marlin per charter boat day averaged over the whole season in this fishery.

Recreational charter boat striped marlin CPUE has been found to be positively correlated with longline CPUE from the southwest Pacific. This correlation may be attributed to changes in the general abundance of striped marlin in the region. Other influences on recreational CPUE are longline catch in New Zealand fisheries waters (negative correlation) and possibly habitat preference. The presence of warm oceanic water is often associated with higher recreational catch rates, but the poor seasons in the mid 1980s were warmer than normal (Holdsworth et al. 2003).

In 2001, 570 anglers were surveyed to estimate the economic contribution of the recreational billfish fishery in New Zealand. A question was asked about billfish not recorded in club records. It was estimated that 7% of billfish were not recorded in club records. This may be an under-estimate as the face to face interviews were conducted at the main fishing ports only. That year gamefish club records recorded the proportion of billfish catch as: 84% striped marlin; 12% blue marlin; 2% swordfish; 2% shortbill spearfish, and a few black marlin (Boyd et al. 2002).

The 2000–01 billfishery generated significant economic benefits for New Zealand, both regionally and nationally. Total expenditure by billfishers in 2000–01 was $65 million, of which $13 million was by overseas fishers. The billfish fishery has its greatest economic impact in Northland and the Bay of Plenty. Expenditure by billfishers in Northland was $34 million, and in the Bay of Plenty $27 million. There was total expenditure of $3 million in the billfishery in other regions (Boyd et al. 2002).

The additional economic activity generated by the billfishery is also significant. On a nationwide basis, and taking into account indirect production effects and induced consumption effects, the economic contribution of the billfishery is estimated to generate $17 million in gross output, 151 full time equivalent jobs and a further $8.4 million in value added (Boyd et al. 2002).

Tagging data, both conventional and electronic, show that striped marlin leaving New Zealand spread widely around the southwest Pacific, but not beyond. Occasionally a tagged fish is recaptured the following season back in New Zealand waters. Striped marlin seem to shed tags more easily than other billfish, with very few recaptures longer than a year at liberty and bio-fouling by gooseneck barnacles appears to be a problem. The longest term striped marlin recapture recorded in any tagging programme was 2 years 10 months for a fish tagged at the King Bank which was recaptured off Bermagui, southern New South Wales, Australia.

Electronic tags have evolved into a useful tool for collecting biological and movement data continuously for individual fish. They also are difficult to anchor, but have successfully captured and reported data on striped marlin for up to nine months (Michael Domeier, President Pfleger Institute of Environmental Research, pers. comm.). The New Zealand Marine Research Foundation project in 2003 was the first to use the pop-up satellite archive tags on striped marlin in the South Pacific. Five of the six tags reported information and these five fish all survived capture and release. All were tagged in the far north of New Zealand, and while they moved around quite extensively, they all stayed north of North Cape, the same area where commercial catches have been greatest. Two fish moved away, one to the northeast in mid April and the other over 2000 km north in May. Clearly, these fish forage successfully in oceanic waters and are not reliant on school fish over the continental shelf or particular submarine structures for food.

2003 was not a particularly warm year and temperature preference may have influenced the movement of these fish. In a warmer year they may have moved further down the coast. Temperature appears to influence the southern boundary of striped marlin distribution. It is plausible that if global warming results in warmer sea temperatures, striped marlin may range further south and the fishing season may become longer.

The recently established Western Central Pacific Fisheries Commission will provide a management framework for highly migratory species in the region. The focus of that body will initially be on the large fisheries for tuna, but will eventually turn to striped marlin as a major bycatch and high value commercial and recreational species. The New Zealand catch of striped marlin is a small but significant component of the total southwest Pacific catch. There is a well developed, valuable recreational fishery in northern New Zealand and the detailed catch records spanning the last 80 years have contributed to an understanding of the fishery.

The New Zealand fishery tends to catch large striped marlin and is on the southern boundary of their distribution. Sound international management of this species is therefore very important for New Zealand, as increased fishing pressure may affect this fishery the most.

10. ACKNOWLEDGMENTS

We acknowledge the Secretariat of the Pacific Community, Ocean Fisheries Programme, for surface longline catch and effort data, athe Ministry of Fisheries for providing New Zealand commercial catch and effort data, and the N.Z. Big Game Fishing Council for providing recreational catch tallies. We also thank the Bay of Islands Swordfish Club, particularly John Chibnall and Stewart Hunter, for providing access to their catch records. We also thank Dr Peter Davie for providing access to the records of his ageing study and Massey University for their assistance. Many thanks to Peter Saul for his advice and editorial comments. Thanks to Dr Julian Pepperell (Pepperell Research & Consulting, Australia) for reviewing this paper. This study was funded by the Ministry of Fisheries under contract STM2003-01.

11. REFERENCES

Bailey, K.; Williams, P.G.; Itano, D. (1996). By-catch and discards in western pacific tuna fisheries: A review of SPC data holdings and literature. *Oceanic Fisheries Programme Technical Report 34.* 171 p.

Boyd, R; Holdsworth, J; Saul, P. (2002). The economic contribution of the New Zealand recreational billfish fishery in 2000–2001. Unpublished report held by NZ Marine Research Foundation, PO Box 93 Whangarei. 57 p.

Baker, A.N. (1966). Food of marlins from New Zealand waters. *Copeia 4*: 818-822.

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

Brill, R.W.; Holts, D.B.; Chang, R.K.C.; Sulivan, S.; Dewar, H.; Carey, F.G. (1993). Vertical and horizontal movements of striped marlin (Tetrapturus audax) near the Hawaiian Islands, determined by ultrasonic telemetry, with simultaneous measurement of oceanic currents. *Marine Biology 117(4)*: 567–574.

Bromhead, D.; Pepperell, J.; Wise, B.; Findlay, J. (2004). Striped marlin: biology and fisheries. Bureau of Rural Sciences. Canberra. 260 p.

Davie, P.S.; Hall, I. (1990). Potential of dorsal and anal spines and otoliths for assessing age structure of the recreational catch of striped marlin. In: R.H. Stroud (ed.). Proceedings of the second international billfish symposium, Kailua-Kona, Hawaii, 1988 Part 2, pp 287–294.

Davie, P.S. (1990). Pacific marlins: anatomy and physiology. Massey University and Simon Print, Palmerston North, N.Z. 88 p.

Domeier, M.L.; Dewar, H.; Nasby-Lucas, N. (2003). Post-release mortality rate of striped marlin caught with recreational tackle. *Marine and Freshwater Research 54*: 435–445.

Ehrhardt, N.M. (1992). Age and growth of swordfish in the northwestern Atlantic. *Bulletin of Marine Science* 50(2): 299–301.

Eldridge, M.B.; Wares, P.G. (1974). Some biological observations of billfishes taken in the eastern Pacific Ocean, 1967–1970. In: Shomura, R.S.; Williams, F., (eds.) Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9–12 August 1972. Part 2. Review and Contributed Papers. pp 89–101.

Finnerty, J.R.; Block, B.A. (1995). Evolution of cytochome B in the Scombroidei: molecular insights into billfish (Istiophoridae and Xiphiidae) relationships. *Fishery Bulletin 93*: 78–96.

Francis, M.P.; Griggs, L.H.; Baird, S.J.; Murrey T.E.; Dean, H.A. (1999). Fish bycatch in New Zealand tuna longline fisheries. *NIWA Technical Report 55.* 70 p.

Francis, M.P.; Griggs, L.H.; Baird, S.J.; Murrey, T.E.; Dean, H.A. (2000). Fish bycatch in New Zealand tuna longline fisheries, 1988–89 to 1997–98. *NIWA Technical Report 76*. 79 p.

Francis, M.P.; Griggs, L.H.; Baird, S.J. (2004). Fish bycatch in New Zealand tuna longline fisheries, 1998–99 to 1999–2000. *New Zealand Fisheries Assessment Report 2004/22*. 62 p.

Gibson, D. (1982). The Japanese tuna longline fishery in New Zealand. Catch '82 9 (6): 27–28.

Gonzalez-Armas, R.; Sosa-Nishizaki, O.; Funes-Rodriguez R.; Levy-Perez, A. (1999). Confirmation of the spawning area of the striped marlin, *Tetrapturus audax*, in the so-called core area of the eastern tropical Pacific off Mexico. *Fisheries Oceanography 8(3)*: 238–242.

Graves, J.E.; McDowell, J.R. (2003). Stock structure of the world's istiophorid billfishes: a genetic perspective. *Marine and Freshwater Research 54*: 287–298.

Hamilton, A,; Mackay, J. (1908). Fishing and sea-foods of the ancient Maori. *Dominion Museum-Bulletin No. 2*. Wellington, Government Printer.

Hanamoto, E. (1977). Fishery oceanography of striped marlin. Part 2: Spawning activity of the fish in the southern Coral Sea. SO - *Nippon Suisan Gakkaishi-Bulletin of the Japanese Society of Scientific Fisheries 43(11)*: 1279–1286.

Hanamoto, E. (1978). Fishery oceanography of striped marlin. Part 3: Relation between fishing ground of striped marlin and submarine topography in the southern Coral Sea. *Nippon Suisan Gakkaishi-Bulletin of the Japanese Society of Scientific Fisheries 44*: 19–26.

Hill, K.T. (1986). Age and growth of the Pacific blue marlin: a comparison of growth zones in otoliths, vertebrae, and dorsal and anal fin spines. Unpublished MSc. thesis, California State University, Stanislaus.

Holdsworth, J.; Saul, P. (2004). New Zealand billfish and gamefish tagging, 2002–03. *New Zealand Fisheries Assessment Report 2004/50*. 27 p.

Holdsworth, J.; Saul, P.; Browne, G. (2003). Factors affecting striped marlin catch rate in the New Zealand recreational fishery. *Marine and Freshwater Research 54*: 473–481.

Holts, D.; and Bedford, D. (1990). Activity patterns of striped marlin in the southern California Bight. In R.H. Stroud (ed.). Proceedings of the second international billfish symposium, Kailua-Kona, Hawaii, 1988 Part 2, pp 67–80.

IGFA (2004). 2004 world record game fishes. Published by International Game Fish Association. Florida.

Kopf, R.K. (2005). Population characteristics and biology off striped marlin, *Tetrapturus audax* in the New Zeaqland fishery. Unpublished MSc thesis, Massey University.

Melo-Barrera, F.N.; Uraga-Felix, R.; Velazquez-Quinonez, C. (2003). Growth and length-weight relationship of the striped marlin in Cabo San Lucas, Baja California Sur, Mexico. *Ciencias Marinas 29(3)*: 305–313.

Morrow, J. (1951). A striped marlin without a spear. *Copeia 4*: 303–304.

Morrow, J. (1953). Food of striped marlin *Makaira mitsukurii* from New Zealand. *Copeia 3*: 143-145.

Mossman, S. (2002). Serious about gamefishing: bluewater techniques for New Zealand. Bateman. Auckland. 208 p.

Myers, R.A. & Worm, B. (2003). Rapid worldwide depletion of predatory fish communities. *Nature 423*: 280–283

Nakamura, I. (1985). FAO species catalogue, Vol. 5. Billfishes of the world. An annotated and illustrated catalogue of marlins, sailfishes, spearfishes and swordfishes known to date, Rome 5.

New Zealand Fishing News. April 1999. World's most southern marlin? p 7–8.

Ortiz, M.; Prince, E.; Serafy, J.; Holts, D.; Davy, K.; Pepperell, J.; Lowery, M.; Holdsworth, J. (2003). A global overview of the major constituent-based billfish tagging programs and their results since 1954. *Marine and Freshwater Research 54*: 489–508.

Pepperell, J.G. (2001). Fish tales. Random House, Australia. 207 p.

Pepperell, J.G.; Grewe, P. (2001). A field guide to the Indo-Pacific billfishes. CSIRO, Australia. 17 p.

Ricker, W.E. (1975). Computation and interpretation on biological statistics of fish population. *Bulletin of Fisheries Research Board Canada 191*: 1–392.

Saul, P.J. (1984). Review of the catch of big gamefish from the Bay of Islands, New Zealand, 1925–1983. Massey University Press, Palmerston North, N.Z. 45 p.

Saul, P.; Holdsworth, J. (1992). Cooperative gamefish tagging in New Zealand waters, 1975–90. *New Zealand Fisheries Technical Report No. 33*. 24 p.

Sharples, P.; Brogan, D.; Williams, P. (2000) A preliminary summary of (i) species identification problems,(ii) discarding practices and (iii) the life status if billfish taken in longline fisheries of the western and central Pacific Ocean, according to information collected by observers and logbook data. Working Paper BBRG – 15. Thirteenth Meeting of the Standing committee on Tuna and Billfish (SCTB13). 5–12 July 2000. Noumea, New Caledonia.

Sippel, T. (2005). Movements and environmental preferences of striped marlin (*Tetrapturus audax*) tagged in New Zealand with satellite transmitting archival tags. Unpublished MSc thesis, Massey University.

Skillman, R.A.; Yong, M.Y.Y. (1976). Von Bertalanffy growth curves for striped marlin *Tetrapturus audax* and blue marlin *Makaira nigricans* in the central north Pacific Ocean. *Fishery Bulletin 74(3)*: 553–566.

Speare, P. (2003). Age and growth of black marlin (*Makaira indica*), in east coast Australian waters. *Marine and Freshwater Research 54*: 307-314.

Squire, J.L.; Suzuki, Z. (1990). Migration trends of striped marlin (*Tetrapurus audax*) in the Pacific Ocean. In R.H. Stroud (ed.). Proceedings of the second international billfish symposium, Kailua-Kona, Hawaii, 1988, Part 2, pp 51–66.

Ueyanagi, S. (1974). A review of the world commercial fisheries for billfishes. In: Shomura, R.S. and Williams, F. (Eds.). Proceedings of the international billfish symposium, Kailua-Kona, Hawaii, 9–12 August 1972. *NOAA Technical Report SSRF-675 (2)*: 1-11.

Ueyanagi, S.; Wares, P.G. (1975). Synopsis of biological data on striped marlin, Tetrapturus audax (Philippi, 1887). In: Shomura, R.S. and Williams, F. (Eds.) Proceedings of the international billfish symposium, Kailua-Kona, Hawaii, 9-12 August 1972, Part 3. Species synopses. pp 132–159.

Ueyanagi, S.; Shomura, R.S.; Watanabe, Y.; Squire, J.L. (1989) Trends in the fisheries for billfishes in the Pacific. In: Stroud, R.H. (Ed) Proceedings of the second international billfish symposium, Kailua-Kona, Hawaii, 1988 Part 1, pp 31–45.

Table 1: Number of surface longline vessels operating in New Zealand fisheries waters by year from New Zealand fisheries reporting forms TLCERs and CELRs.

Year	Japan	Korea	New Zealand	Philippines	USA	Total vessels
1980	86					86
1981	85	11				96
1982	73	4				77
1983	56	4				60
1984	36	18				54
1985	37	13				50
1986	42	6				48
1987	54	8				62
1988	58	14				72
1989	37	6	7			50
1990	44		19			63
1991	51		31			82
1992	35		34			69
1993	26		49		1	76
1994	8		60		1	70
1995	7		94		1	102
1996			87			87
1997	5		64			69
1998	5		81			86
1999	5		86			91
2000	4		109			113
2001	4		130			134
2002	4		149			153
2003	4		125	2		131

Table 2: Number of striped marlin caught by commercial fleet by fishing season (1 Oct to 30 Sept) (from TLCERs and CELRs) and by recreational fishers by fishing season (1 July to 30 June) (from New Zealand Big Game Fishing Council records and tagging database).

Fishing Year	Japan landed	Japan discarded	Korea landed	Domestic discarded	USA discarded	NZ recreational landed	NZ recreational tagged	Total
1979–80	592					692	17	1301
1980–81	1 677		41			792	2	2512
1981–82	2 799		22			704	11	3536
1982–83	980		33			702	6	1721
1983–84	1 176		215			543	9	1943
1984–85	552		163			262		977
1985–86	1 711		19			395	2	2 127
1986–87	1 755		27			226	2	2 010
1987–88	167		105			281	136	689
1988–89	31		30			647	408	1 116
1989–90	123					463	367	953
1990–91		1				532	232	765
1991–92		13				519	242	774
1992–93		1		6		608	386	1 001
1993–94				32	27	663	929	1 651
1994–95				175	4	910	1 206	2 295
1995–96				462		705	1 104	2 271
1996–97		12		392		619	1 302	2 325
1997–98				385		543	898	1 826
1998–99				1 546		823	1 541	3 910
1999–00		2		782		398	791	1 973
2000–01				477		422	851	1 750
2001–02				216		430	751	1 397
Total	11 563	29	655	4 473	31	12 879	11 193	40 823

Table 3: Conversions for length and weight derived from striped marlin measured caught by recreational fishers in New Zealand (LJFC=Lower jaw-fork curve).

DESCRIPTION	EQUATION
Male, lower jaw-fork (curve,mm) to weight (kg)	$W = .00000002L^{2.88}$
Female, lower jaw-fork (curve,mm) to weight (kg)	$W = .00000002L^{2.90}$
Either sex, lower jaw-fork (curve, mm) to weight (kg)	$W = .00000002L^{2.90}$
Lower jaw-fork (curve,mm) to age (years)	$Age = -.04 - (1/.22) \times \ln (1 - (LFFC/3010)$

Table 4: Age and mean lower jaw -fork lengths (mm, curved) estimated from von Bertalaffy growth models from different regions of the Pacific Ocean.

Age	Kopf (2005) New Zealand LJFC mm	Melo_Barrera et al. (2003) Mexico LJFC mm	Skillman & Yong (1976) Hawaii LJFC mm
1	616	995	1 321
2	1 088	1 244	2 001
3	1 468	1 443	2 389
4	1 772	1 600	2 619
5	2 017	1 726	2 758
6	2 213	1 825	2 845
7	2 370	1 904	2 900
8	2 497	1 967	2 937
9	2 598	2 017	2 961
10	2 679	2 057	2 978

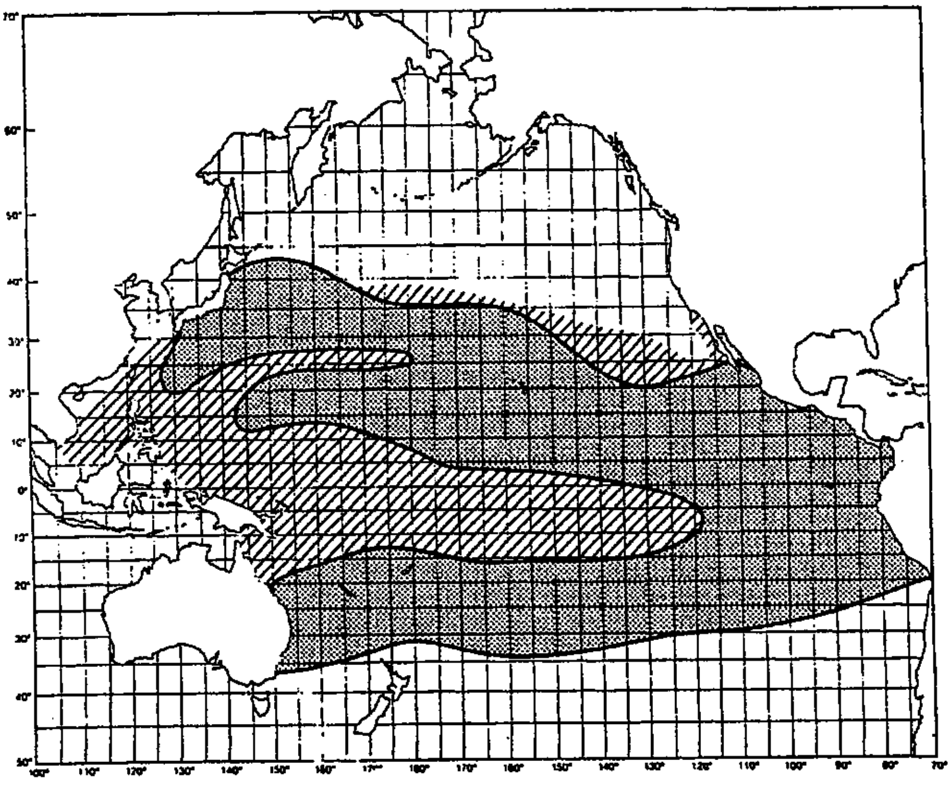


Figure 1: Distribution of striped marlin catch from Japanese longline records (1964-69). Grey stippled areas indicate areas of moderate to high catch rates. Cross-hatched areas represent lower catch rates. Actual distribution extends approximately 5-10° south and north. Reproduced from Squire & Suzuki (1990) with permission from NCMC.

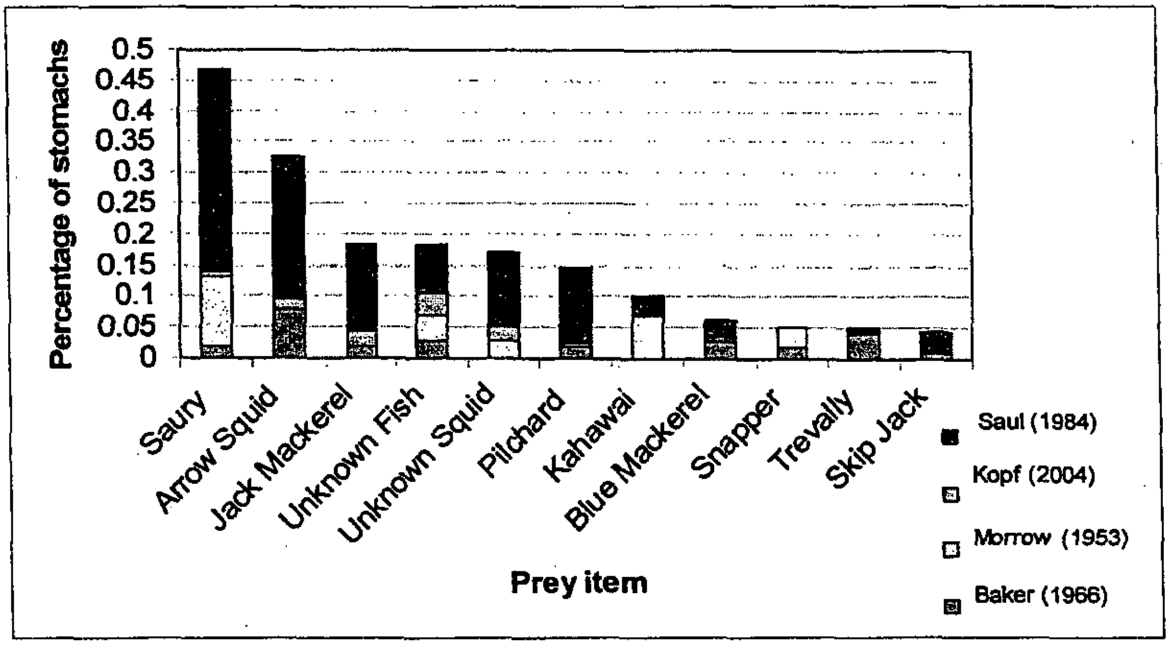


Figure 2: Percentage of striped marlin stomachs (≥.05%) containing prey items from four stomach contents analysis in New Zealand.

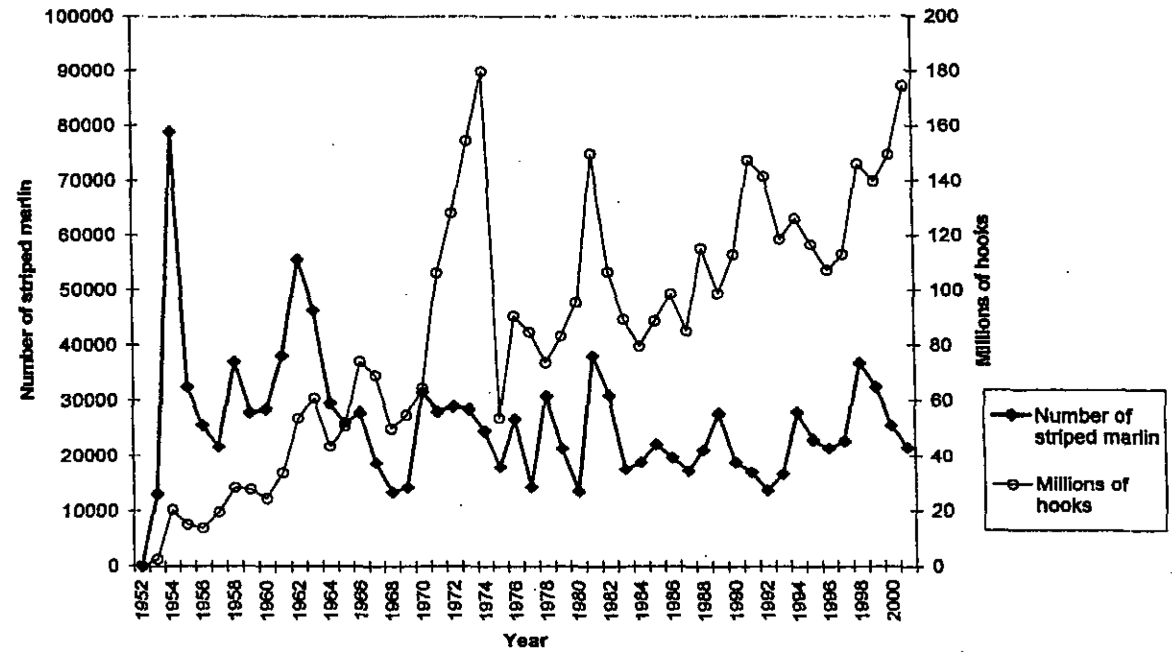


Figure 3: Number of striped marlin landed and number of hooks set by surface longline vessels in the southwest Pacific Ocean (10° S – 50° S 140° E – 130° W) from Ocean Fisheries Programme data.

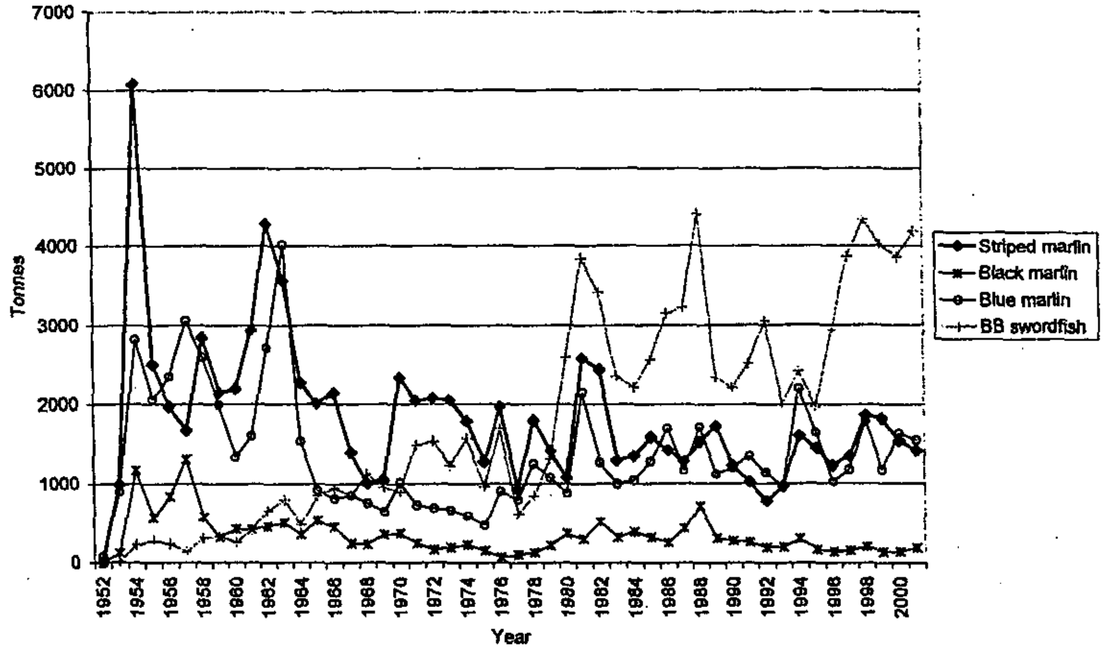


Figure 4: Longline billfish landed catch by weight in the southwest Pacific Ocean from OFP data.

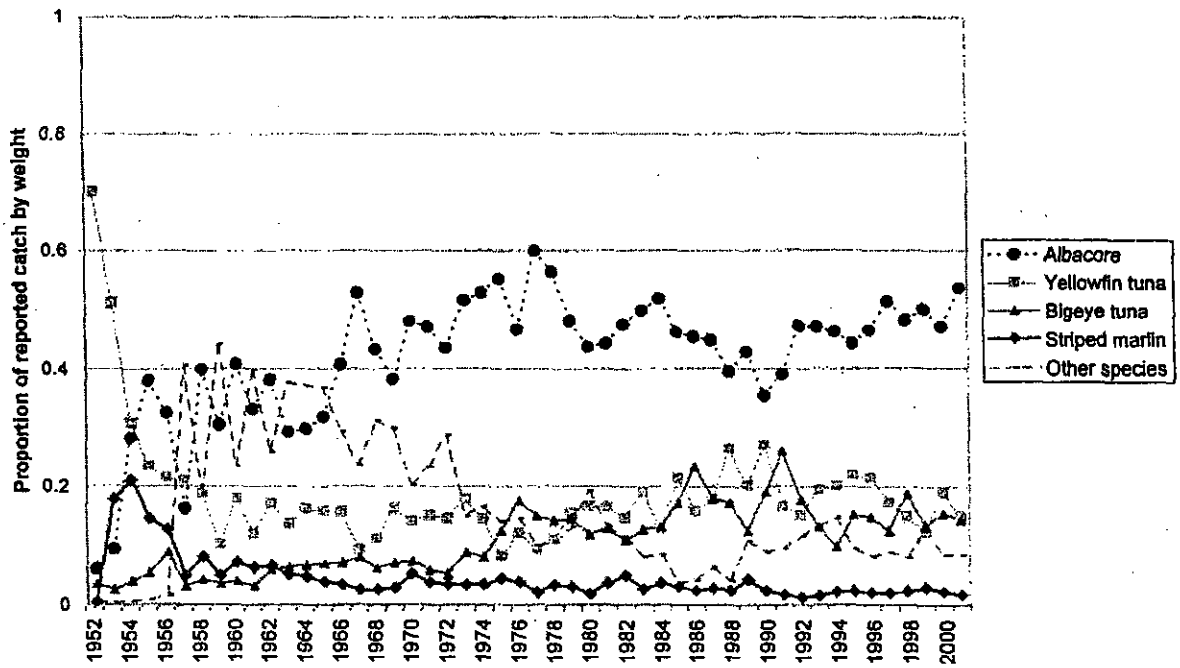


Figure 5: The proportion of reported longline landed catch by weight for striped marlin and the main tuna species in the southwest Pacific by year.

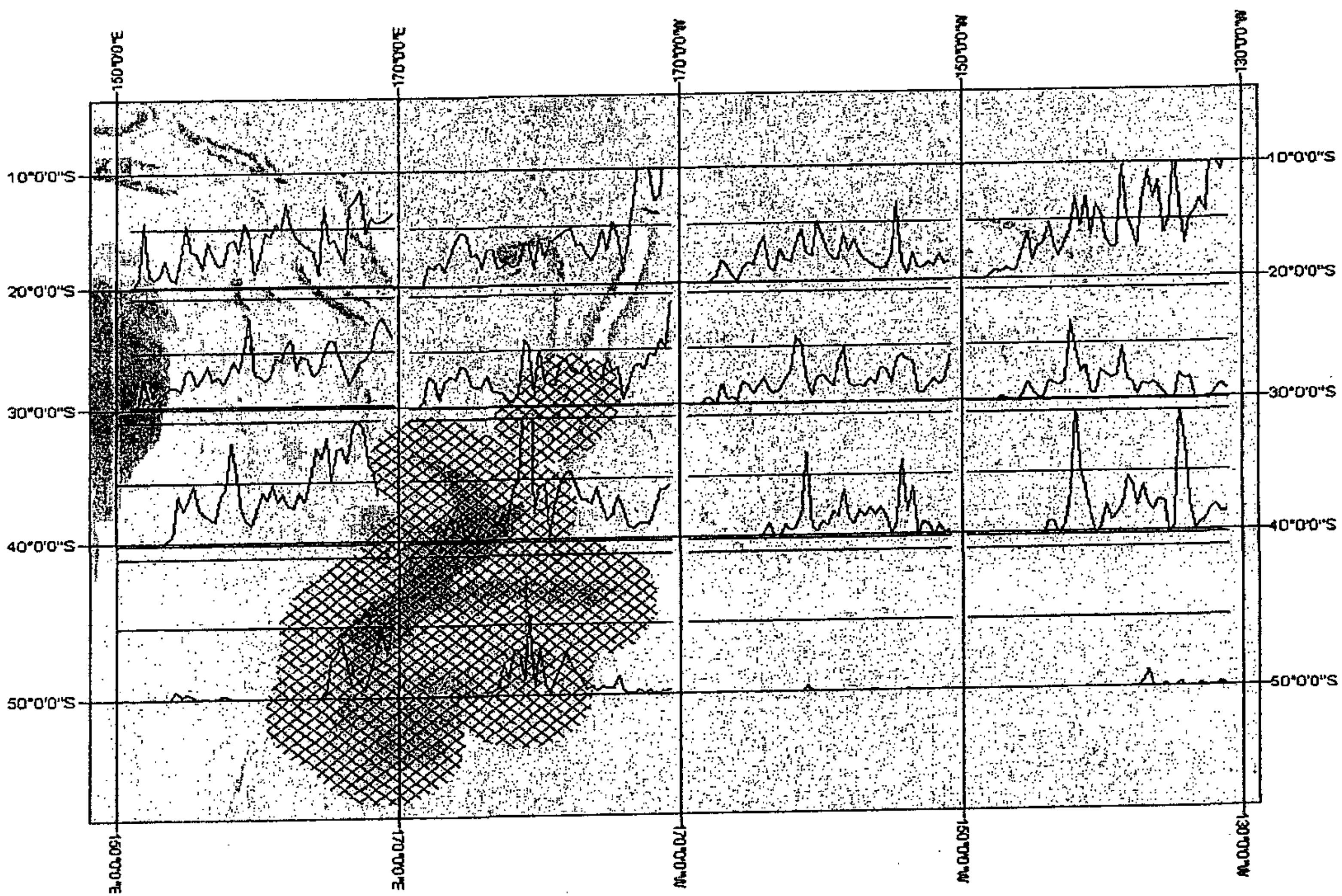


Figure 6: Striped marlin longline hooks set by season for 10° latitude and 20° longitude blocks (1952–2001, X axis of each block), (grid lines at 10 and 20 million hooks, Y axis of each block).

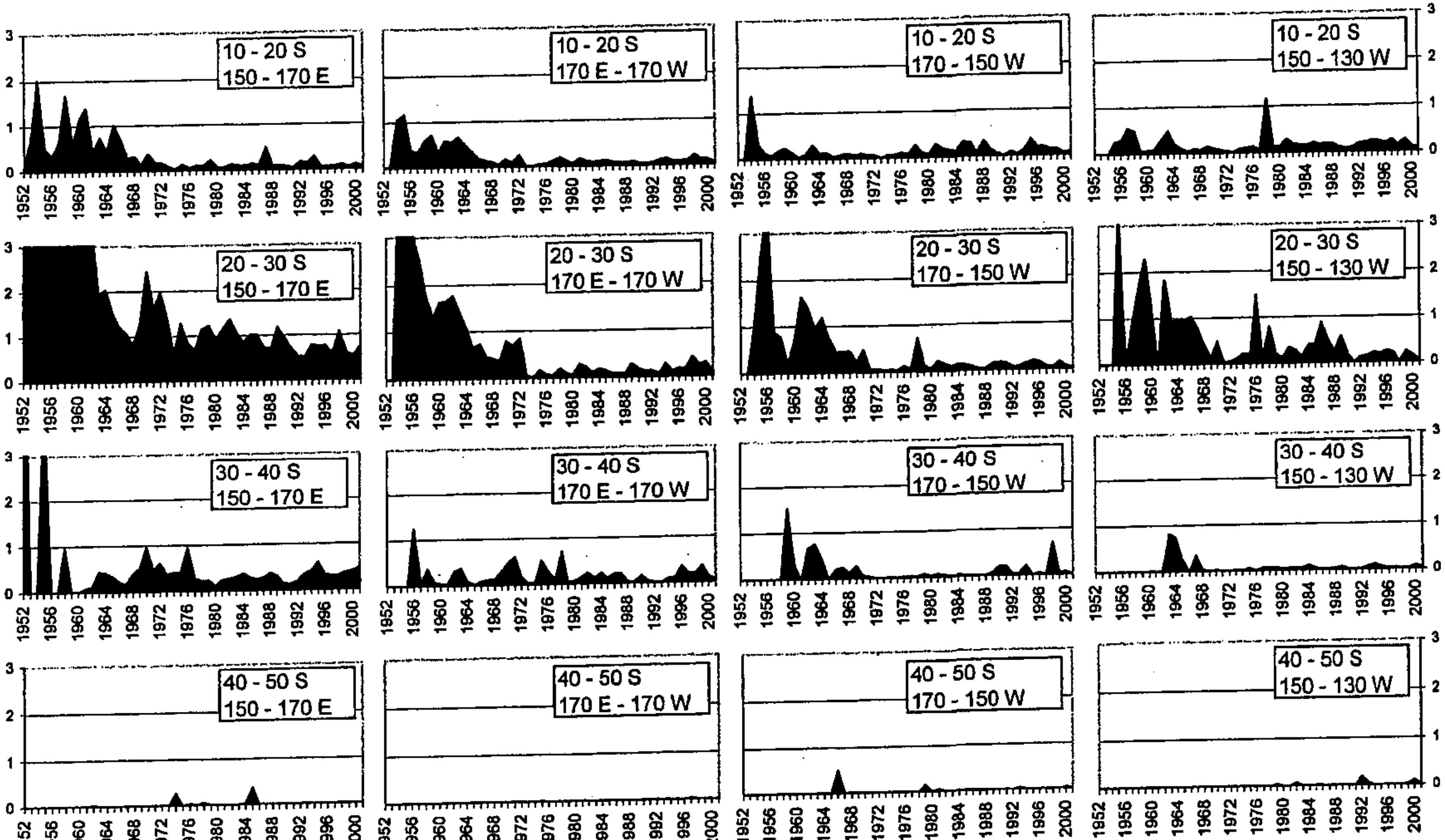


Figure 7: Striped marlin longline CPUE number of fish per 1000 hooks by season for 10° latitude and 20° longitude blocks as depicted in Figure 6, (1952–2001, X axis), (0–3 striped marlin / 1000 hooks, Y axis) (OFP data).

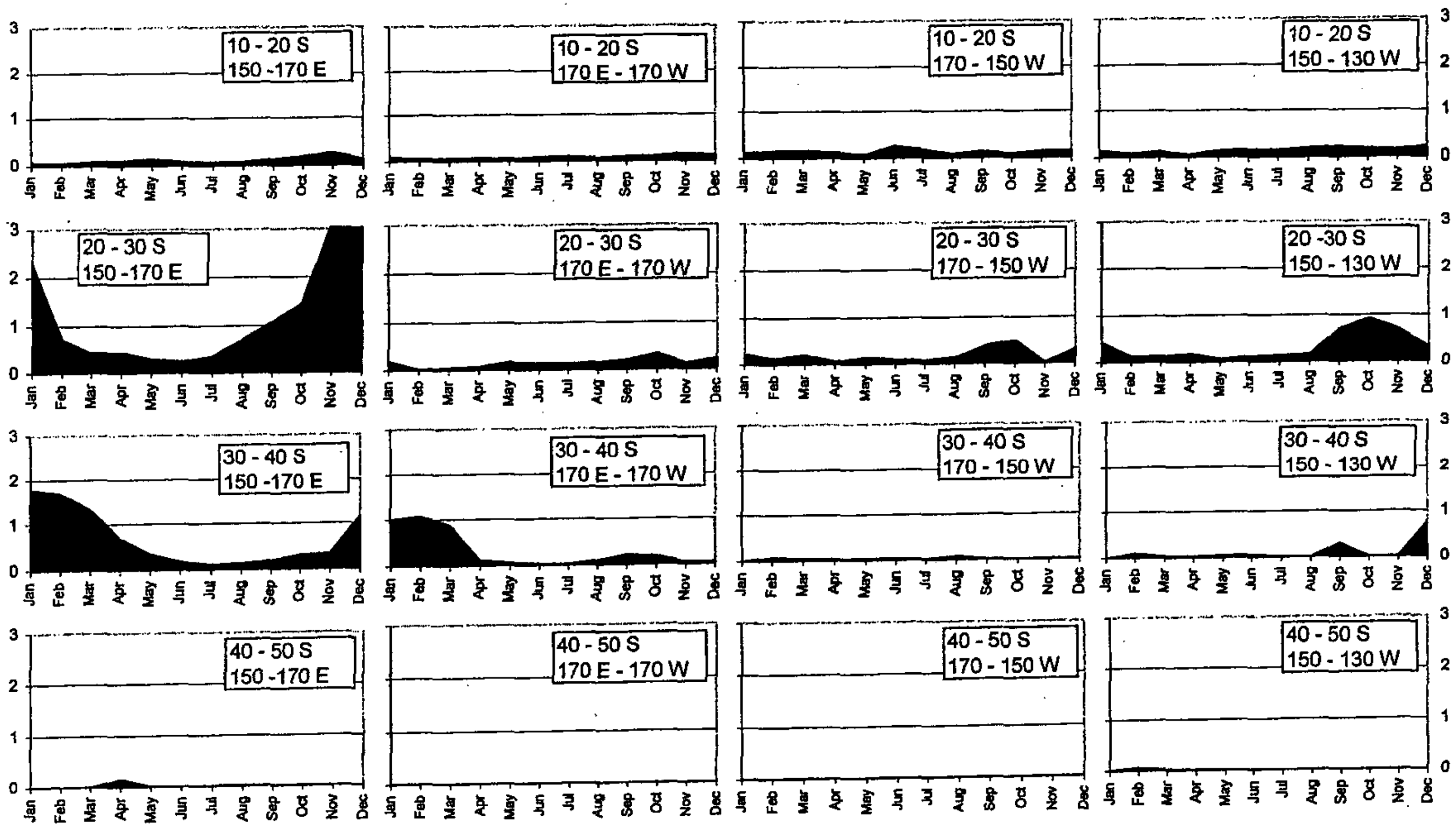


Figure 8:* Mean striped marlin longline CPUE number of fish per 1000 hooks by month for the years 1970 to 1987 in 10° latitude and 20° longitude blocks as depicted in Figure 6, (Jan.-Dec., X axis), (0–3 striped marlin/1000 hooks, Y axis) *(OFP data).

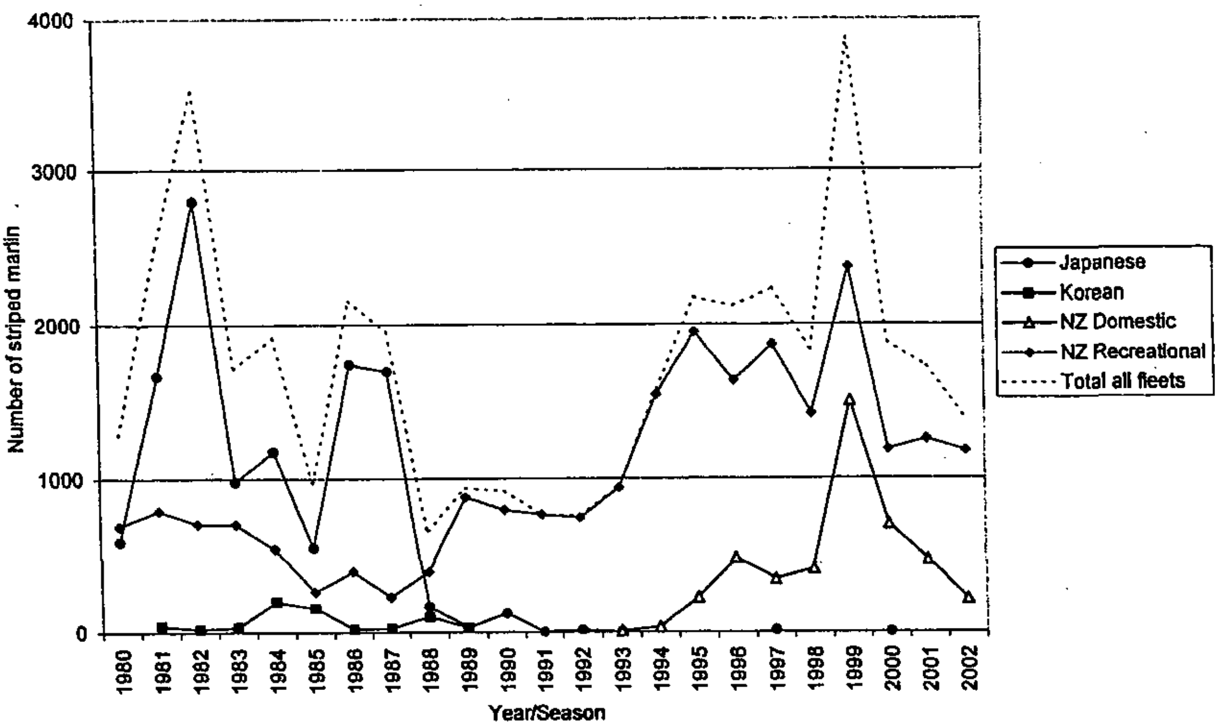


Figure 9: Total number of striped marlin landed in the New Zealand EEZ for longline vessels by nationality by calendar year and recreational catch (landed and tagged combined) by fishing season.

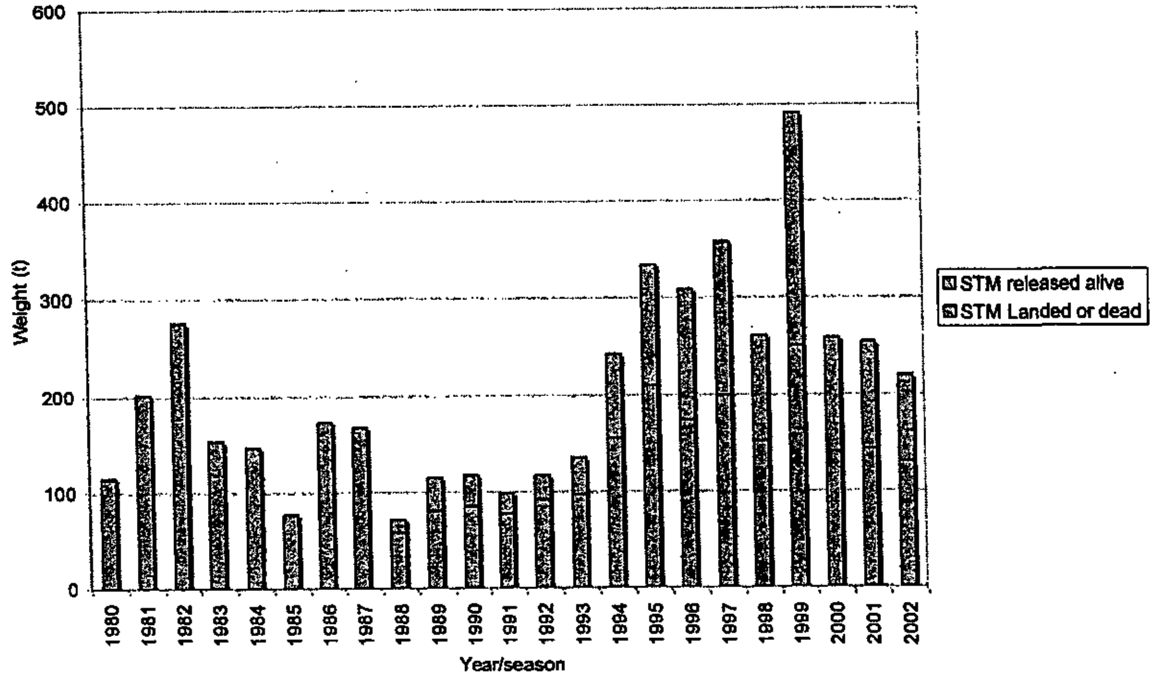


Figure 10: Estimated weight of striped marlin landings and released dead by commercial and recreational methods combined (grey) and the estimated weight of live commercial discards and recreational fish tagged and released (hatched) by year in New Zealand.

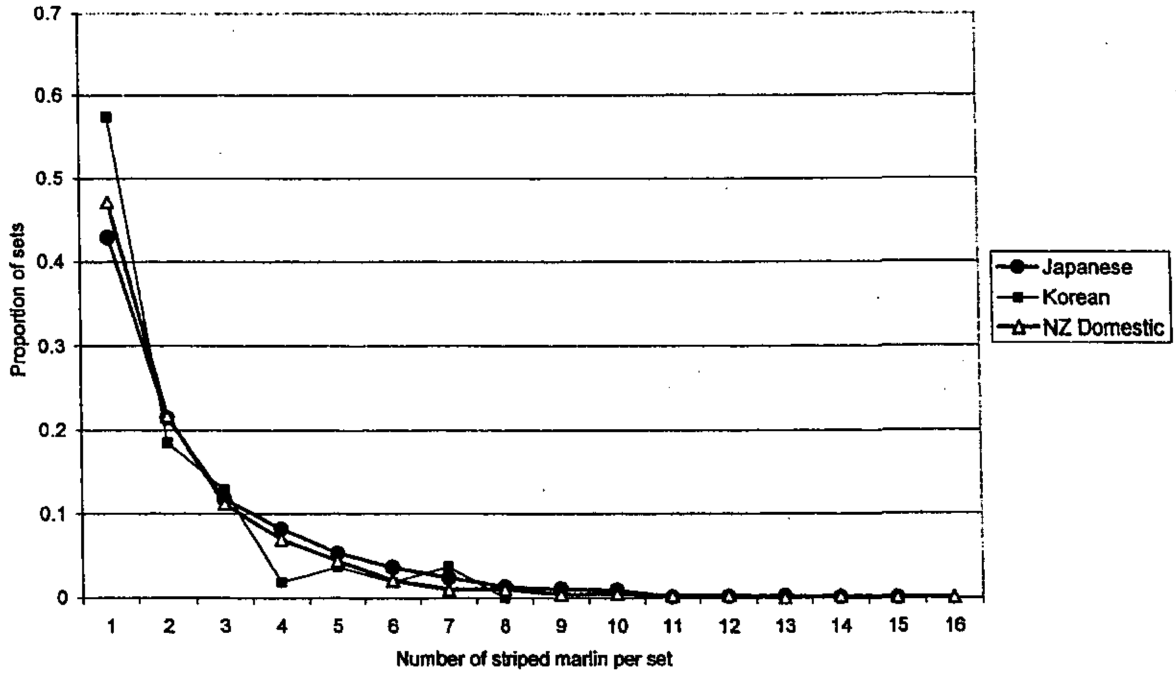


Figure 11: The number of striped marlin caught per longline set in the New Zealand EEZ by fleet.

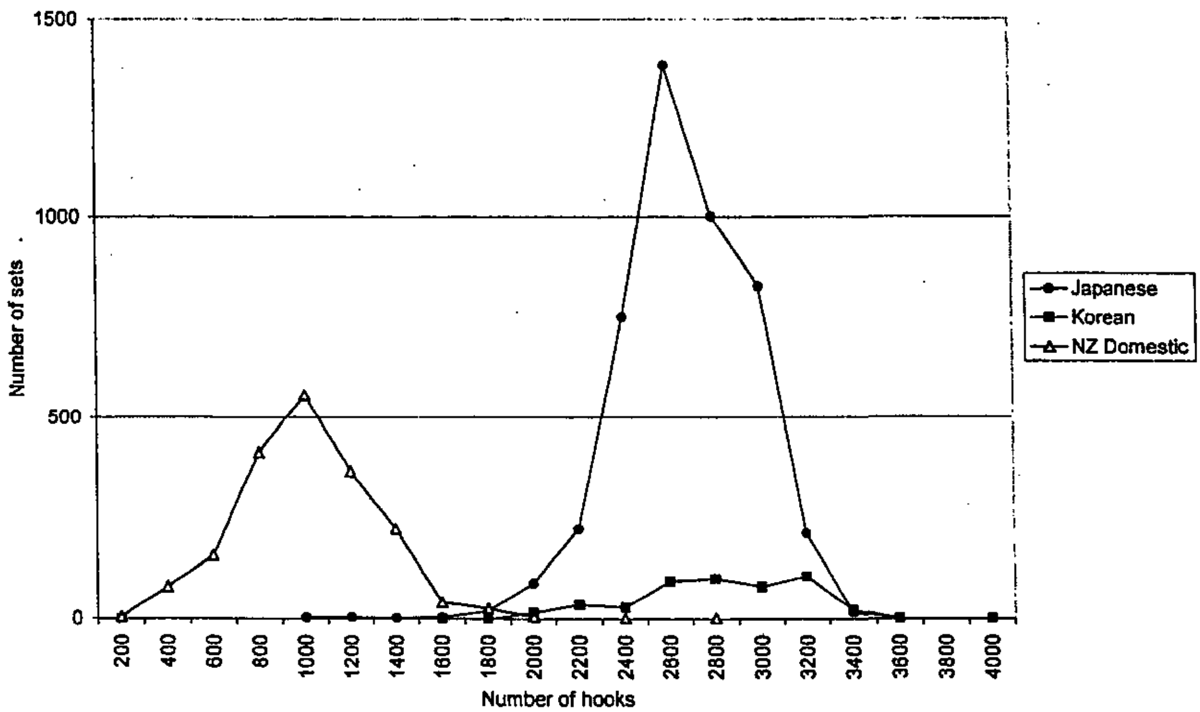


Figure 12: The number of hooks in each set by longline vessels by fleet in the New Zealand EEZ.

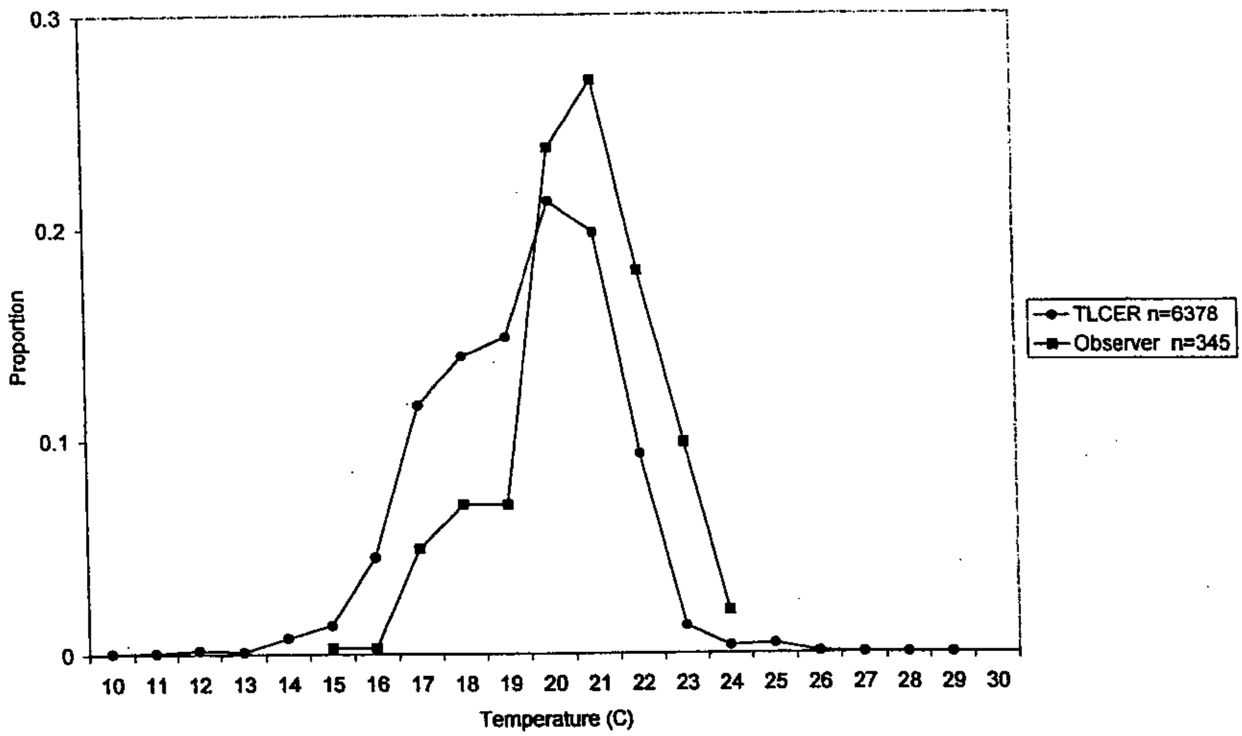


Figure 13: The sea surface temperature recorded at the start of sets catching striped marlin from tuna longline catch effort returns (TLCER) and scientific observer records.

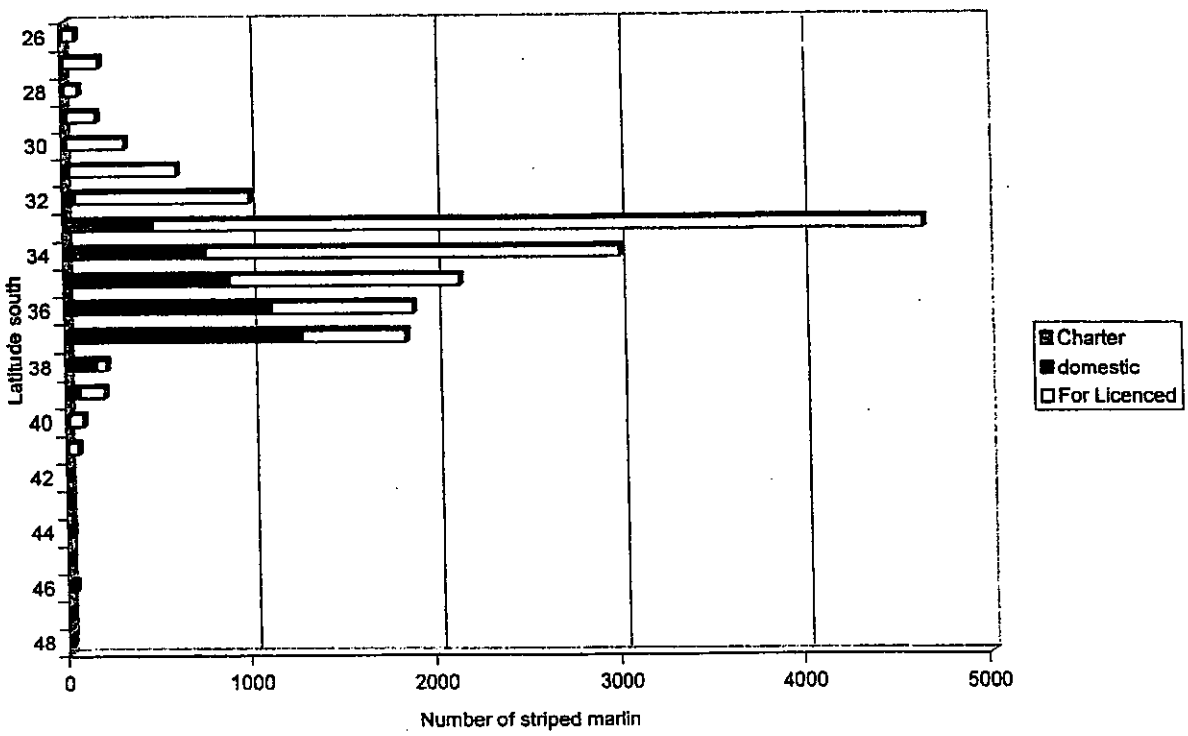


Figure 14: The number of striped marlin caught (landed and reported discards) by whole latitude at the start of set in the New Zealand EEZ by longline fleet.

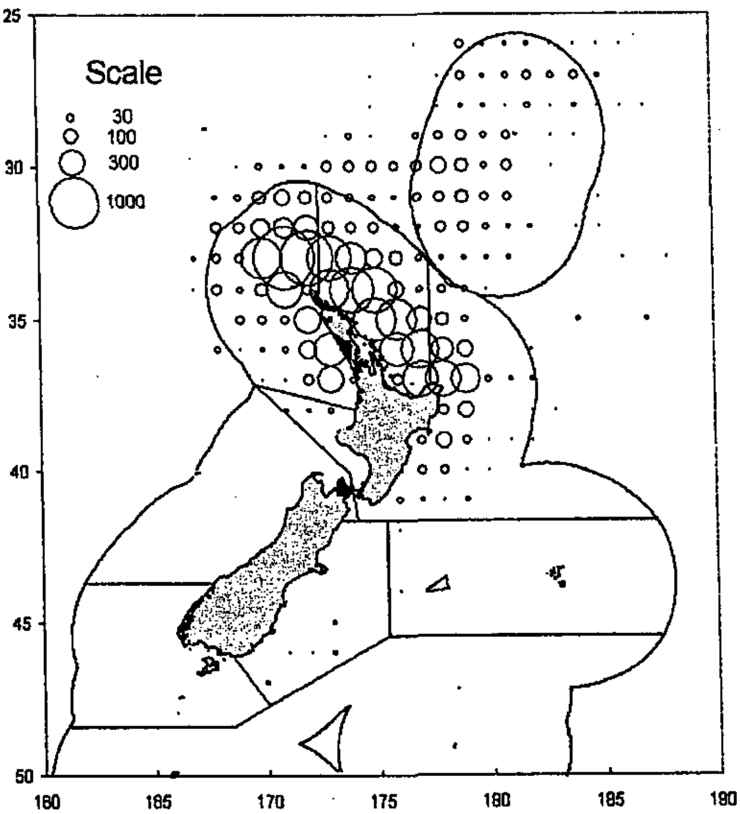


Figure 15: Striped marlin landings and reported discards (TLCERs) by 1 degree square for 1980–2002 combined.

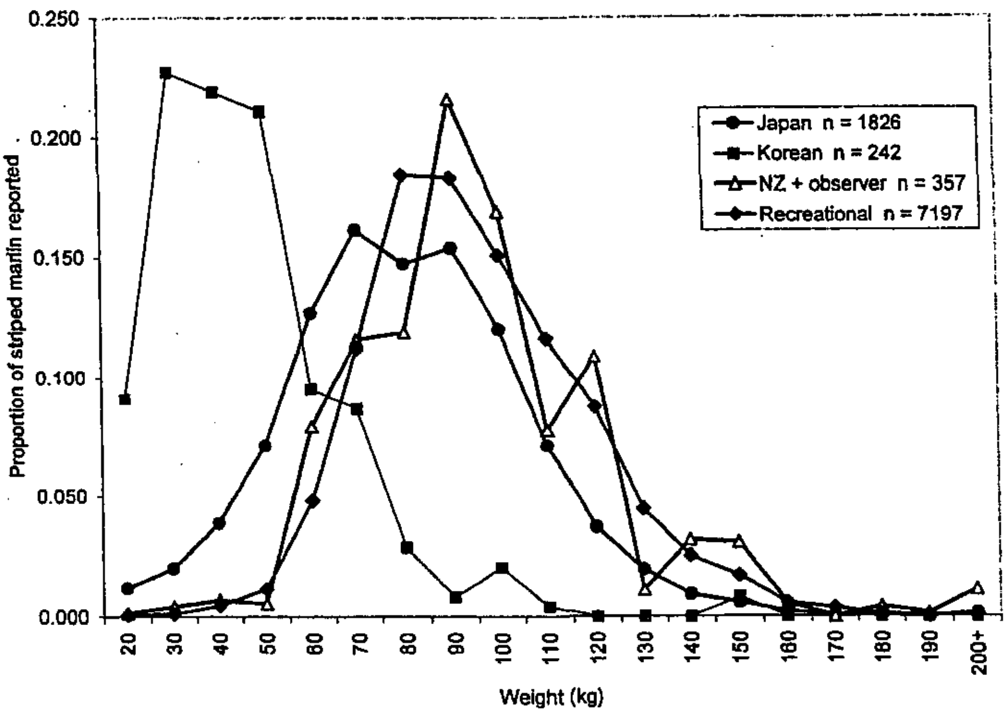


Figure 16: Weight distribution of striped marlin reported catch in the New Zealand EEZ by fleet.

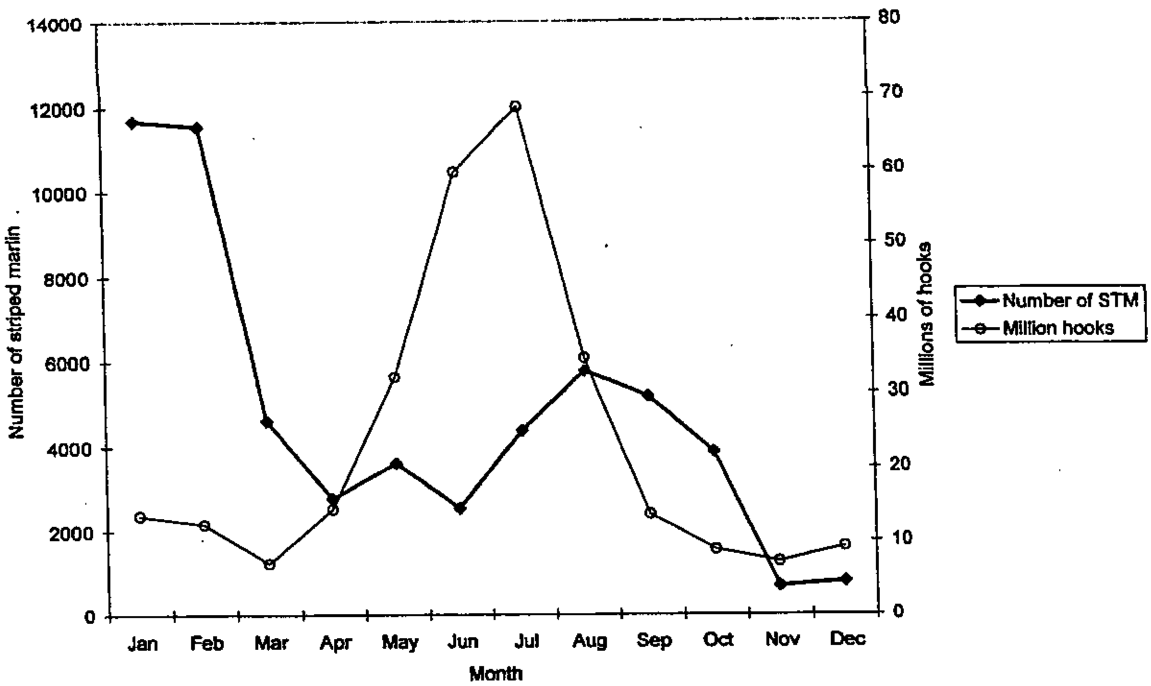


Figure 17: Total striped marlin longline landings and effort by month for 5 degree squares around northern New Zealand (as depicted in Figure 18), for 1952 to 2001 from OFP data (all fleets).

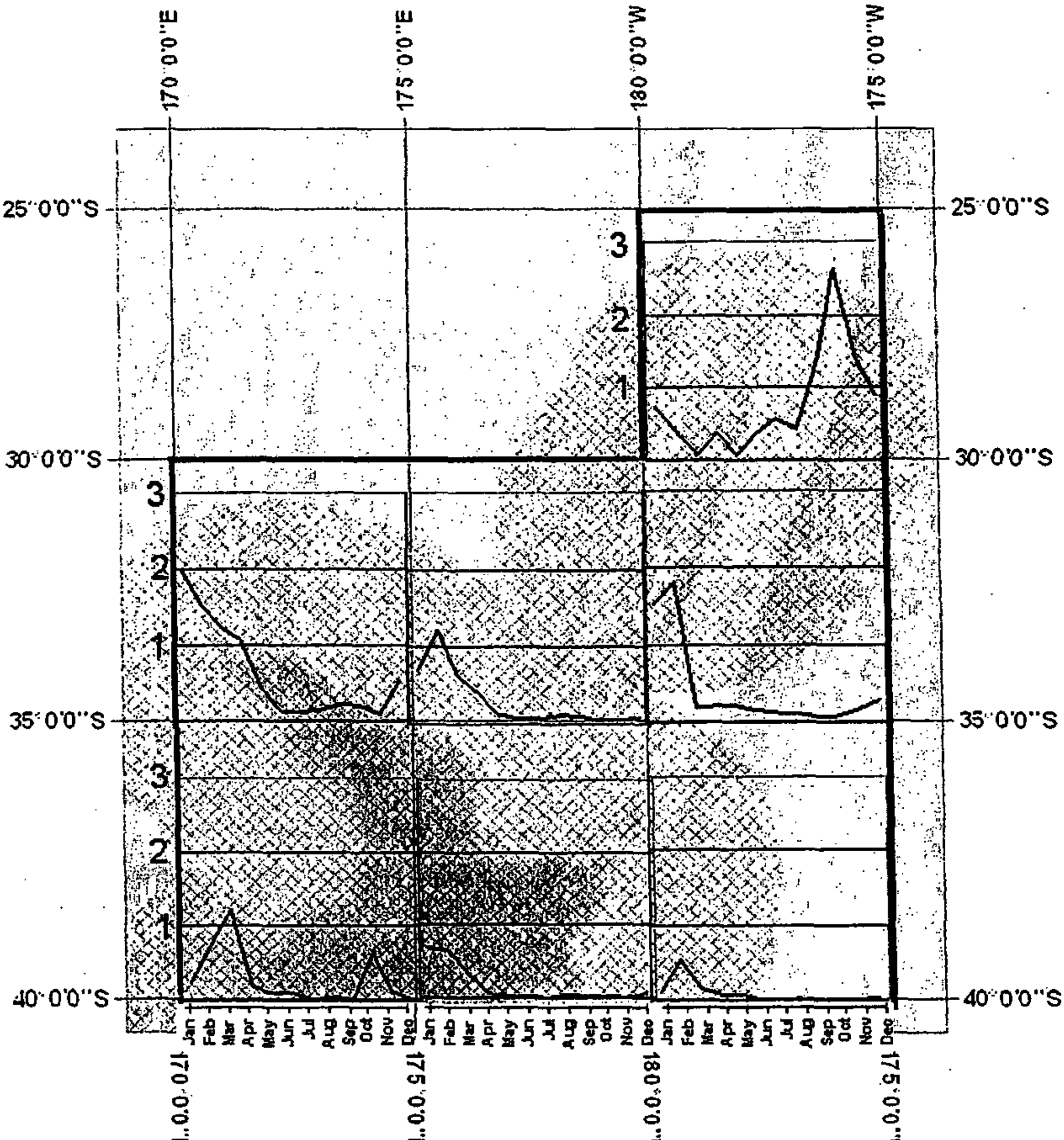


Figure 18: Striped marlin longline CPUE (number of fish per 1000 hooks) by fishing month. New Zealand EEZ hatched (Jan.-Dec., X axis), (Grid lines at 0–3 striped per 1000 hooks) (OFP data).

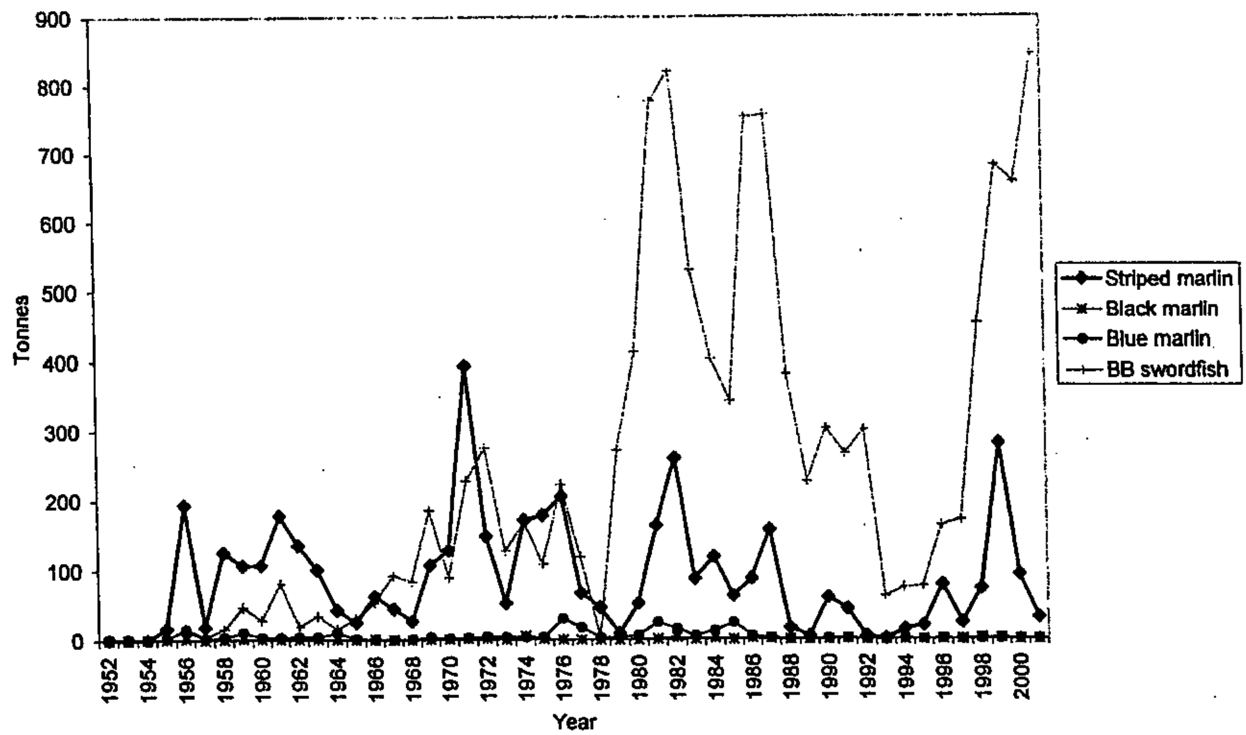


Figure 19: Longline billfish reported landings from all fleets by weight around northern New Zealand by year from OFP data

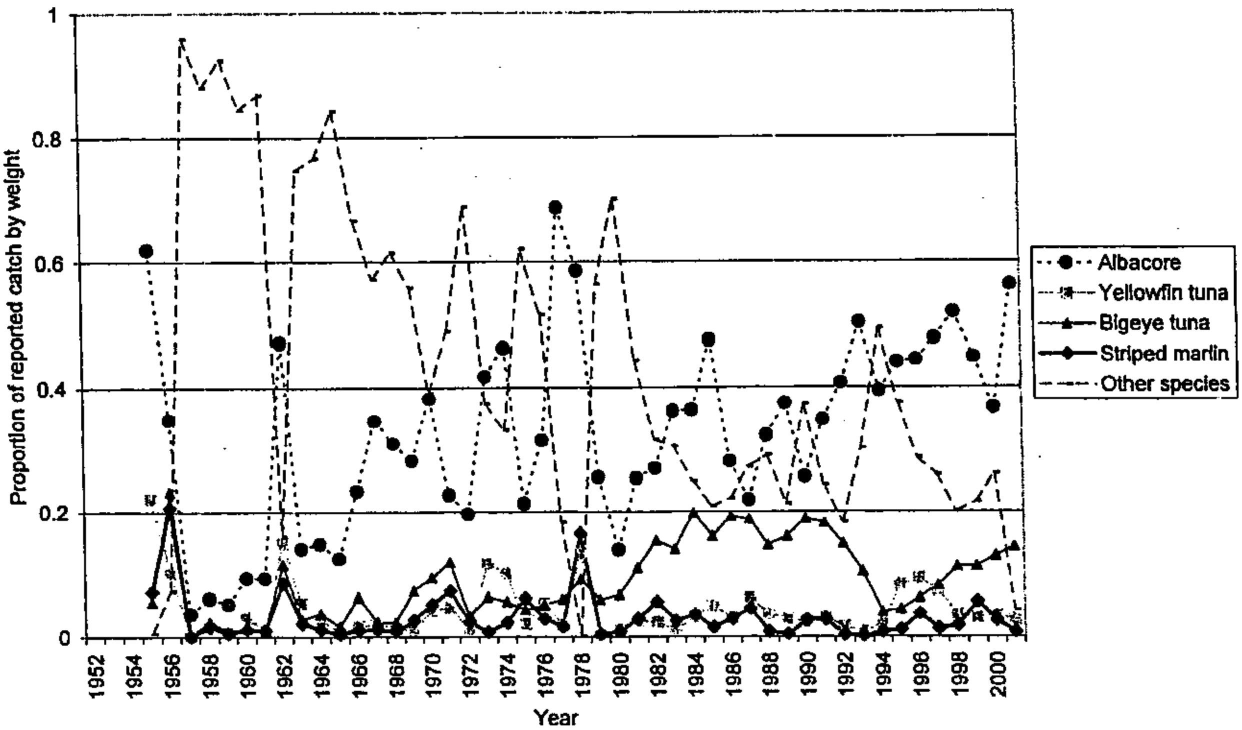


Figure 20: The proportion of longline landings from all fleets by weight for striped marlin and the main tuna species around northern New Zealand by year from OFP data.

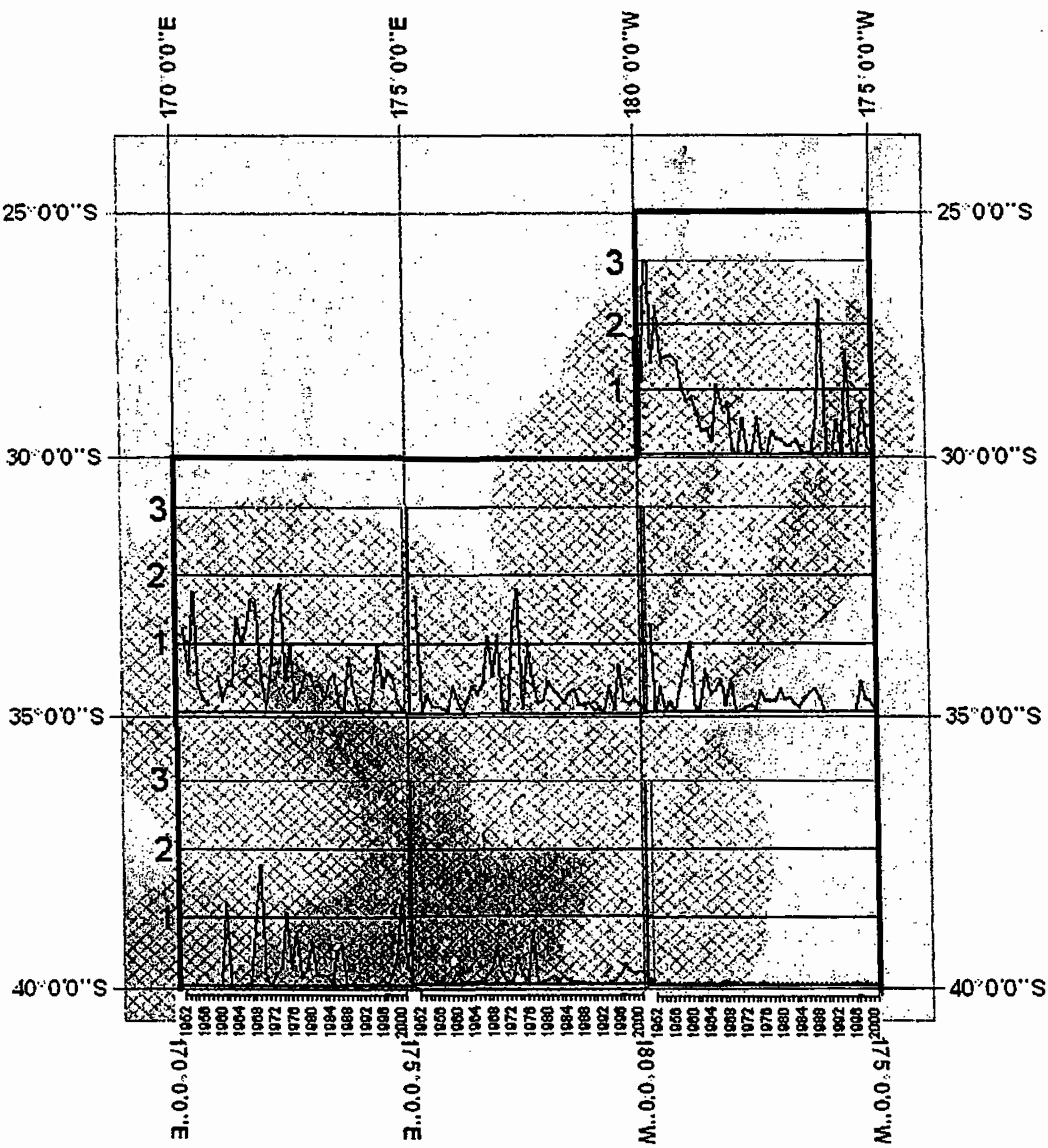


Figure 21: Striped marlin reported CPUE (number of fish per 1000 hooks) by year (1952–2001, X axis), (0–3 striped marlin per 1000 hooks, Y axis) for all fleets from OFP data.

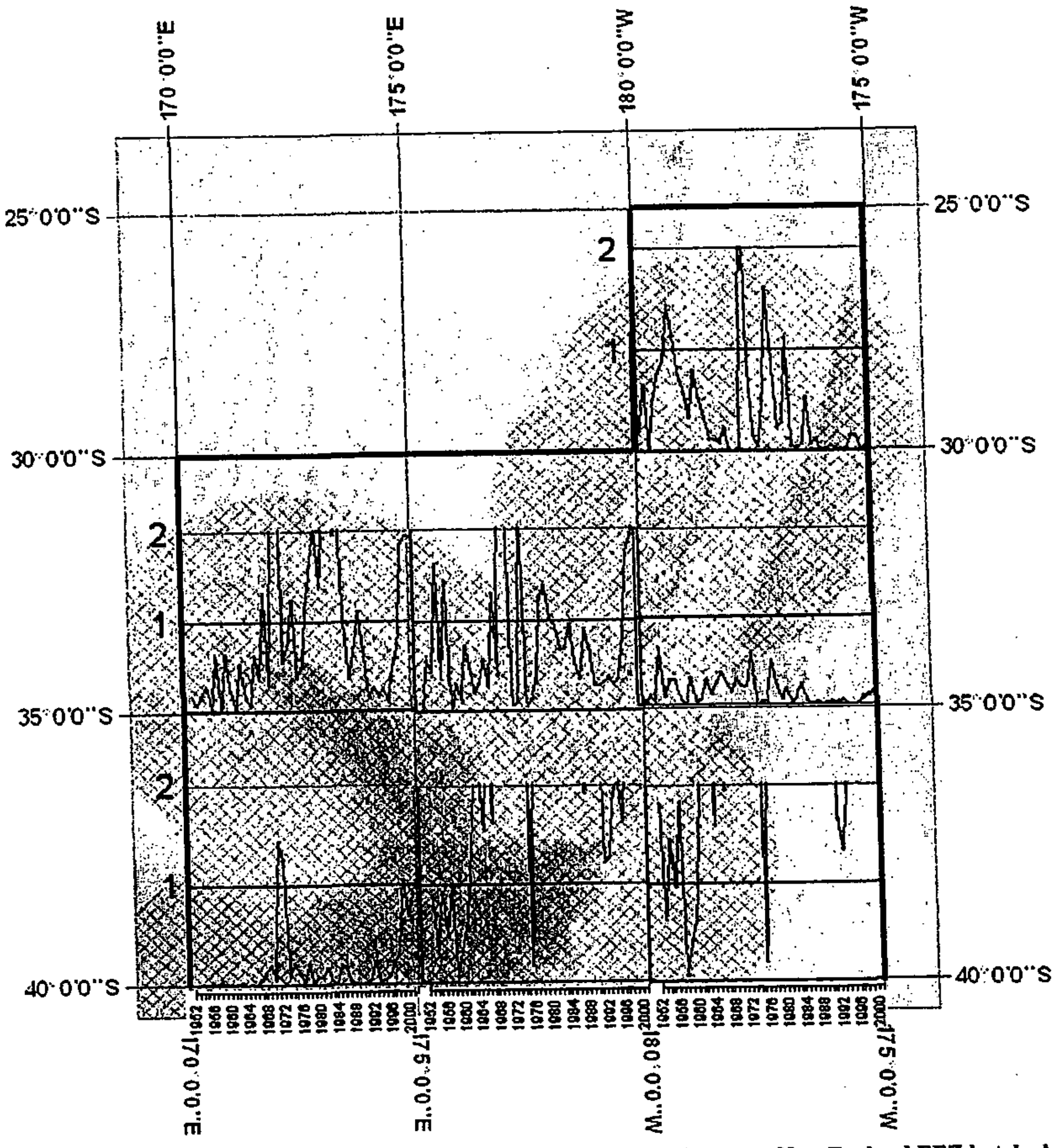


Figure 22: Surface longline fishing effort in 5 degree squares by fishing year. New Zealand EEZ hatched (1952–2001, X axis), (Grid lines at 1 million and 2 million hooks, Y axis).

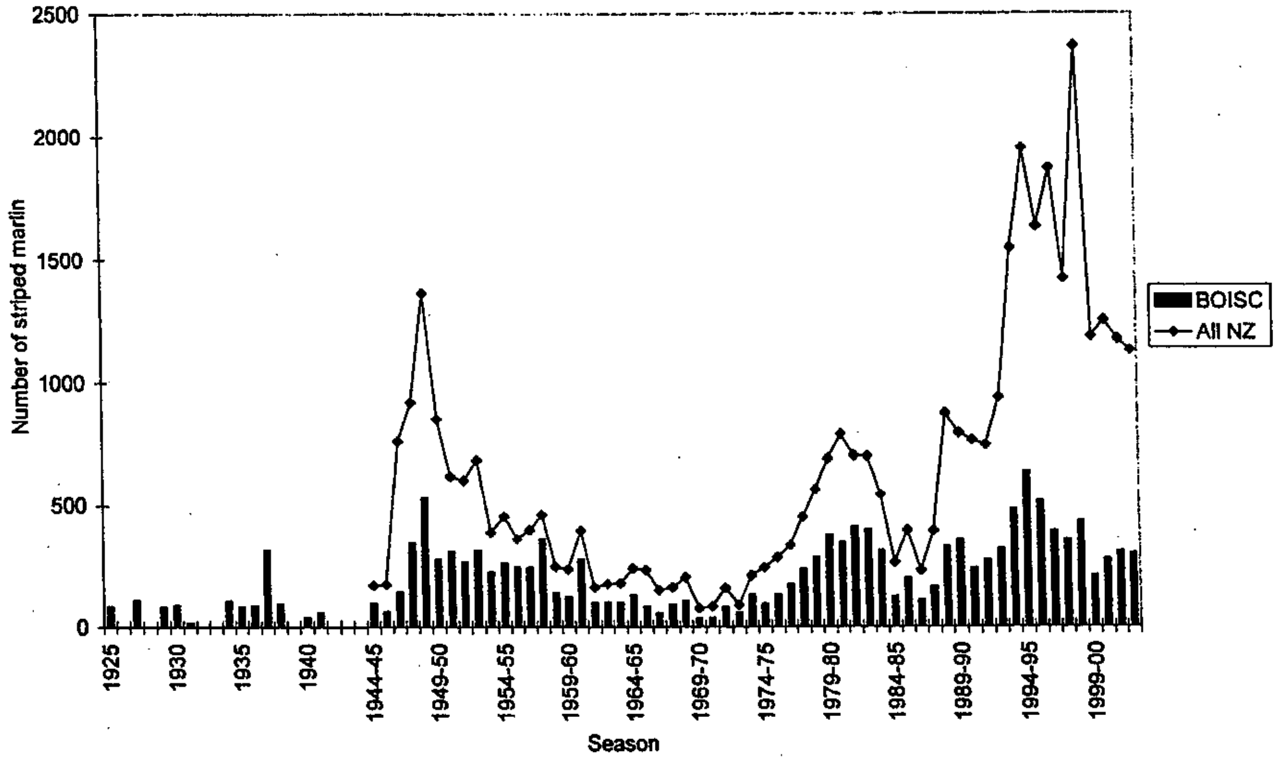


Figure 23: Recreational striped marlin catch (landed and tagged) for all New Zealand recorded by the New Zealand Big Game Fishing Council (line) and for Bay of Islands Swordfish Club (BOISC) (columns).

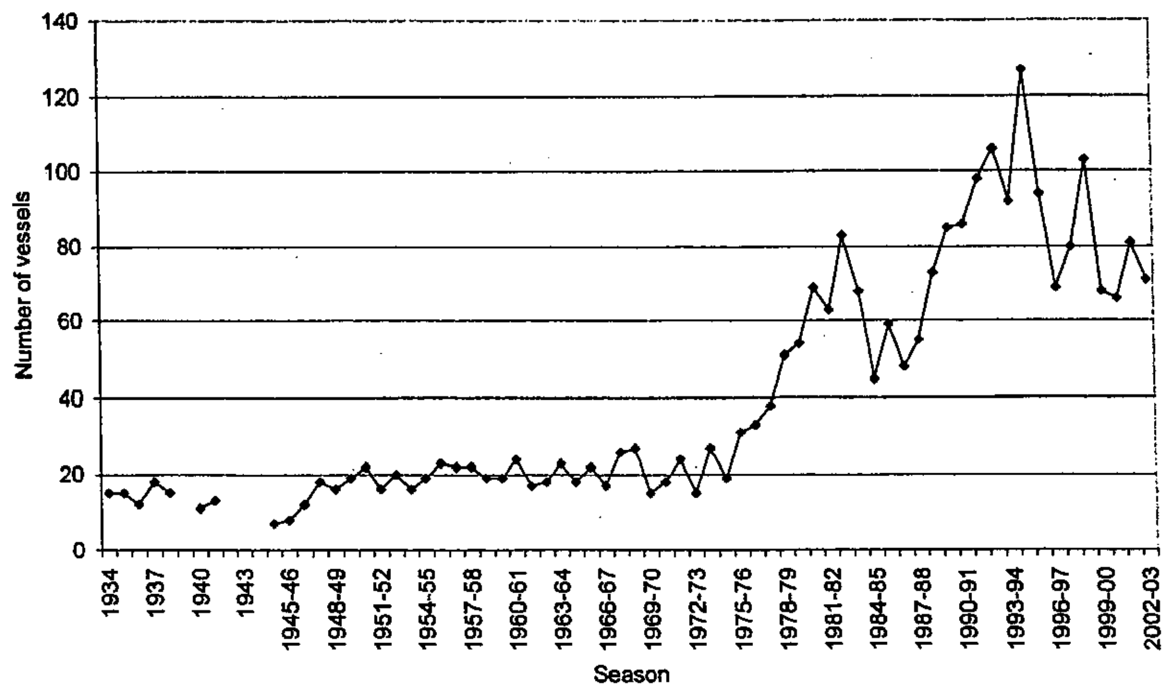


Figure 24: Number of recreational boats catching one or more striped marlin in a season from BOISC records.

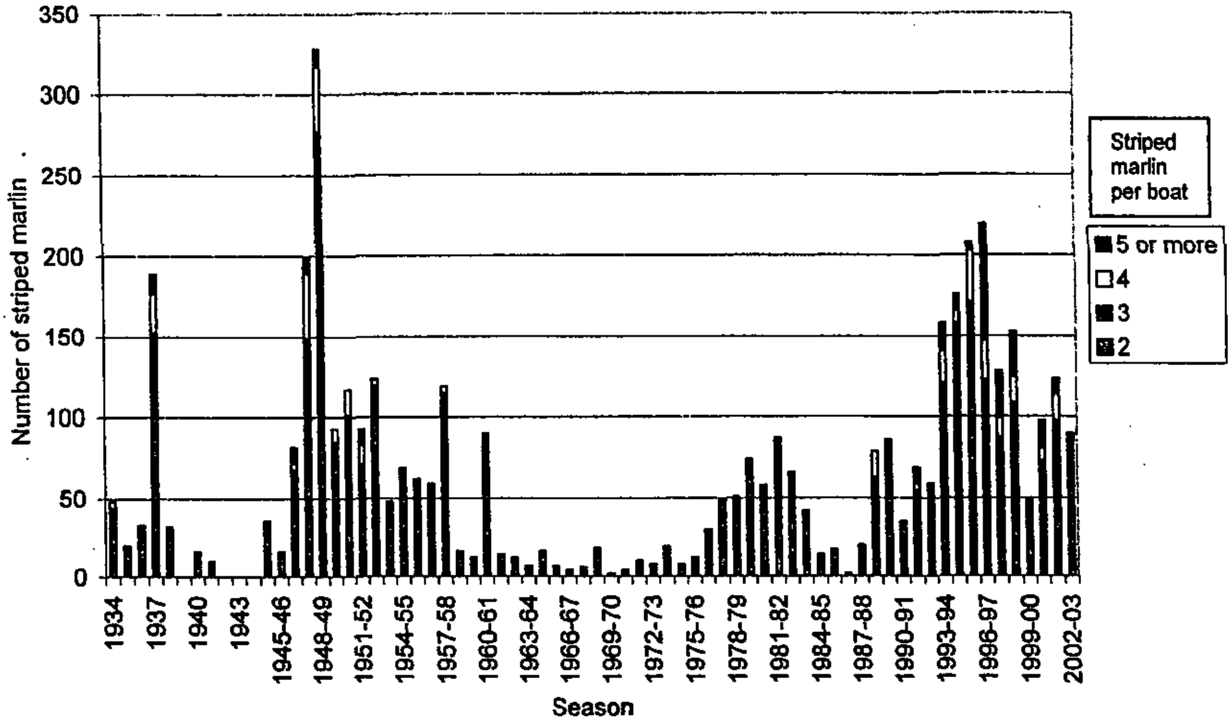


Figure 25: The number of striped marlin caught in multiple captures (2 or more fish on the same date for a single boat) by season from BOISC records.

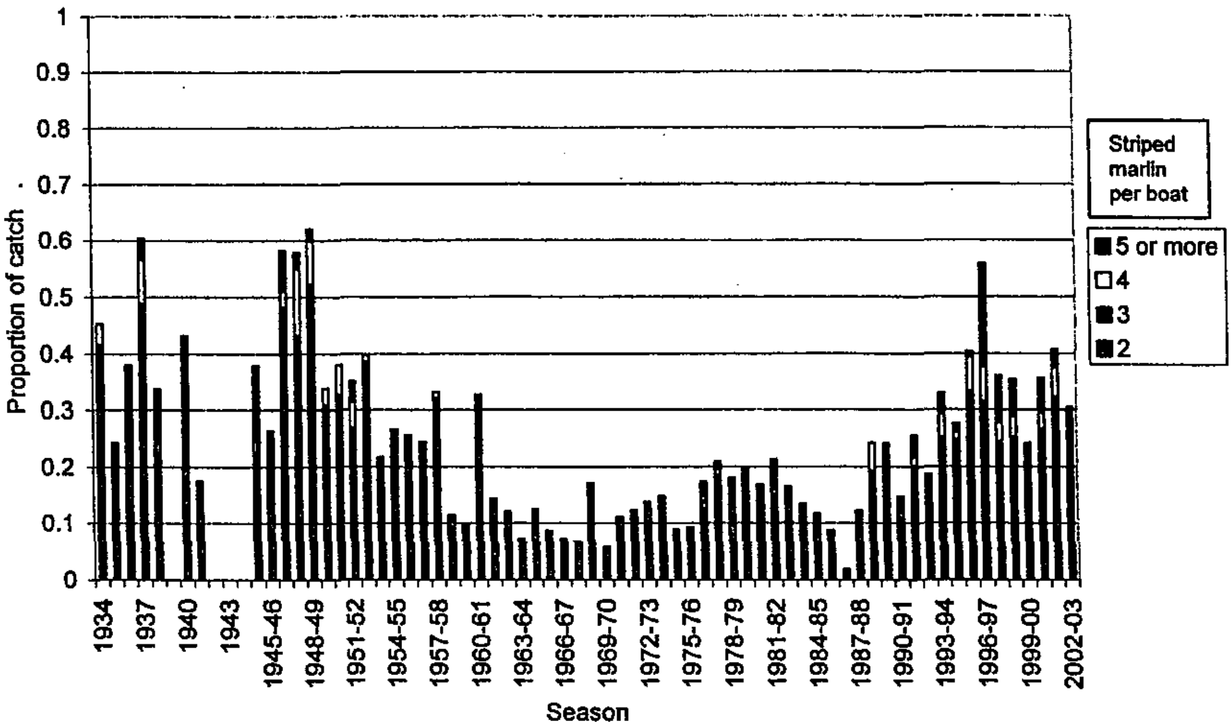


Figure 26: The proportion of catch by season recorded as multiple captures (2 or more fish on the same date for a single boat) from BOISC records.

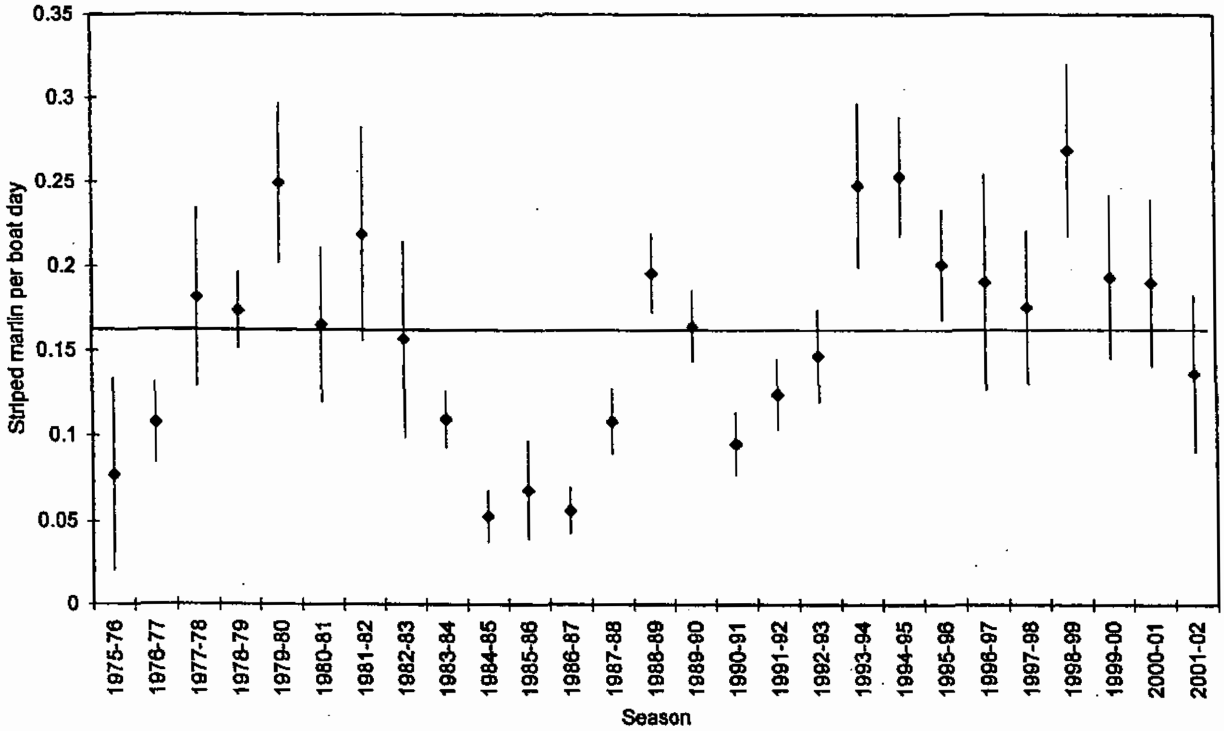


Figure 27: Recreational CPUE (striped marlin per charter boat day) from east Northland with the overall mean at 0.162 (line).

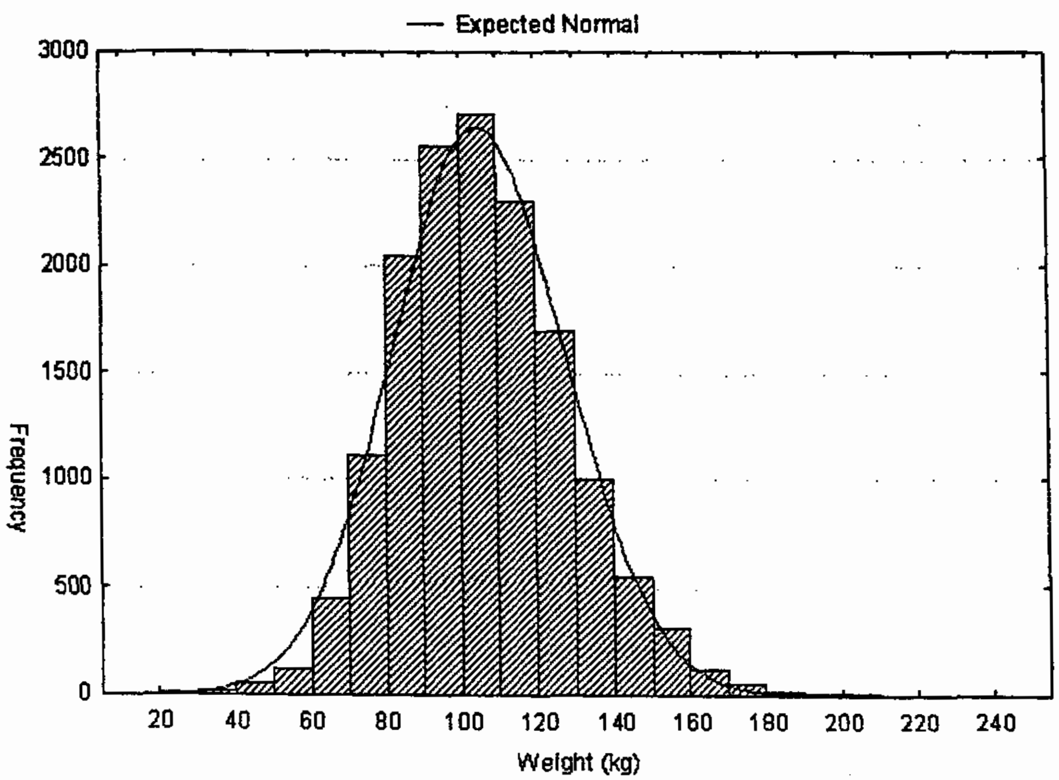


Figure 28: Striped marlin weight distribution of all marlin recorded by the BOISC 1925 to 2003 (n =15 127).

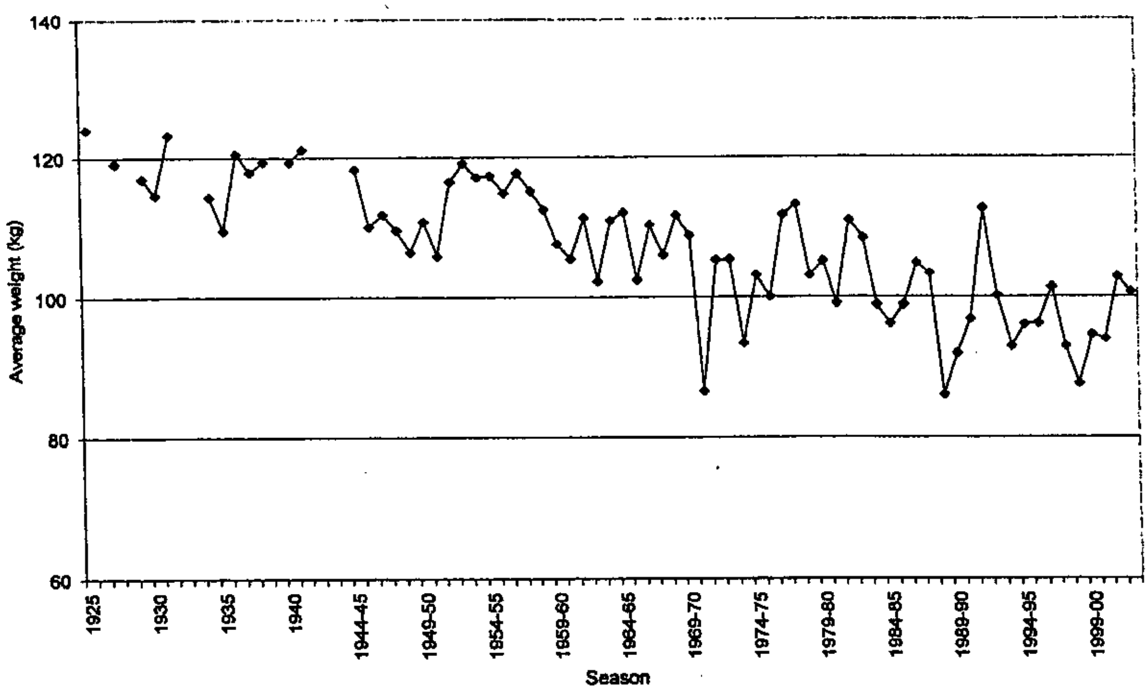


Figure 29: Striped marlin average weight (landed and tagged) by season from the BOISC records.

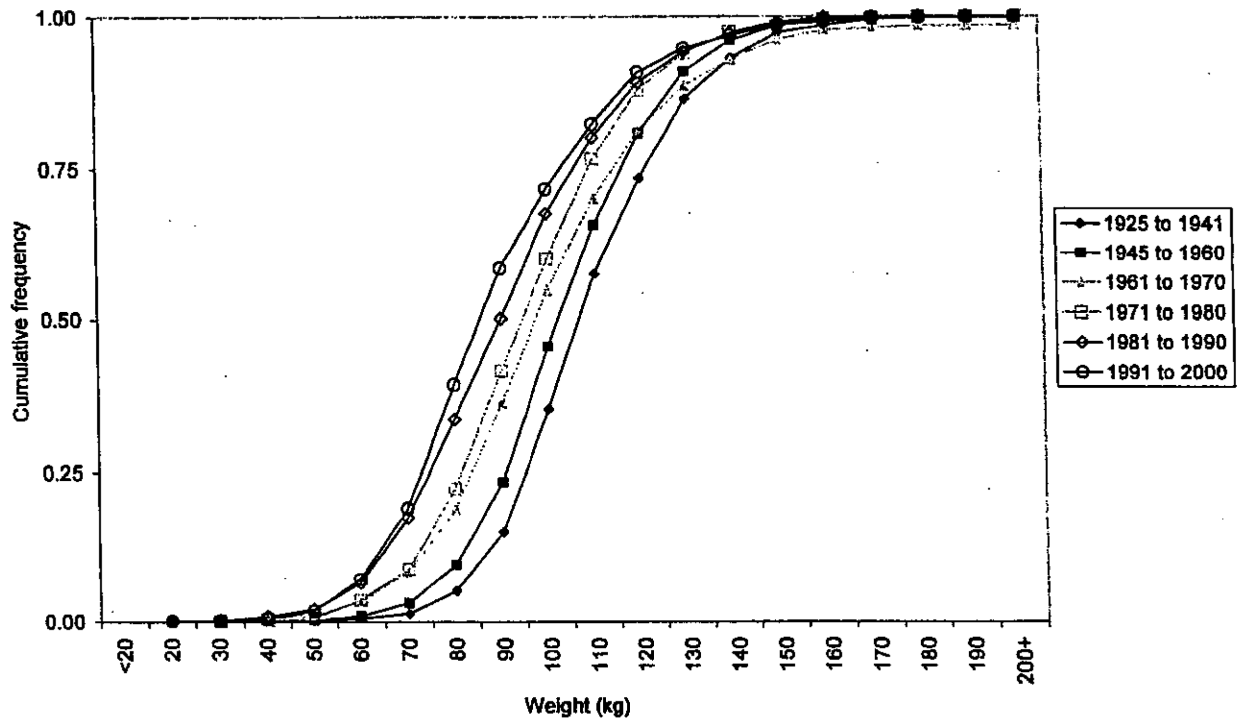


Figure 30: Striped marlin cumulative weight frequency (landed and tagged) by 10 to 16 year blocks from the BOISC records.

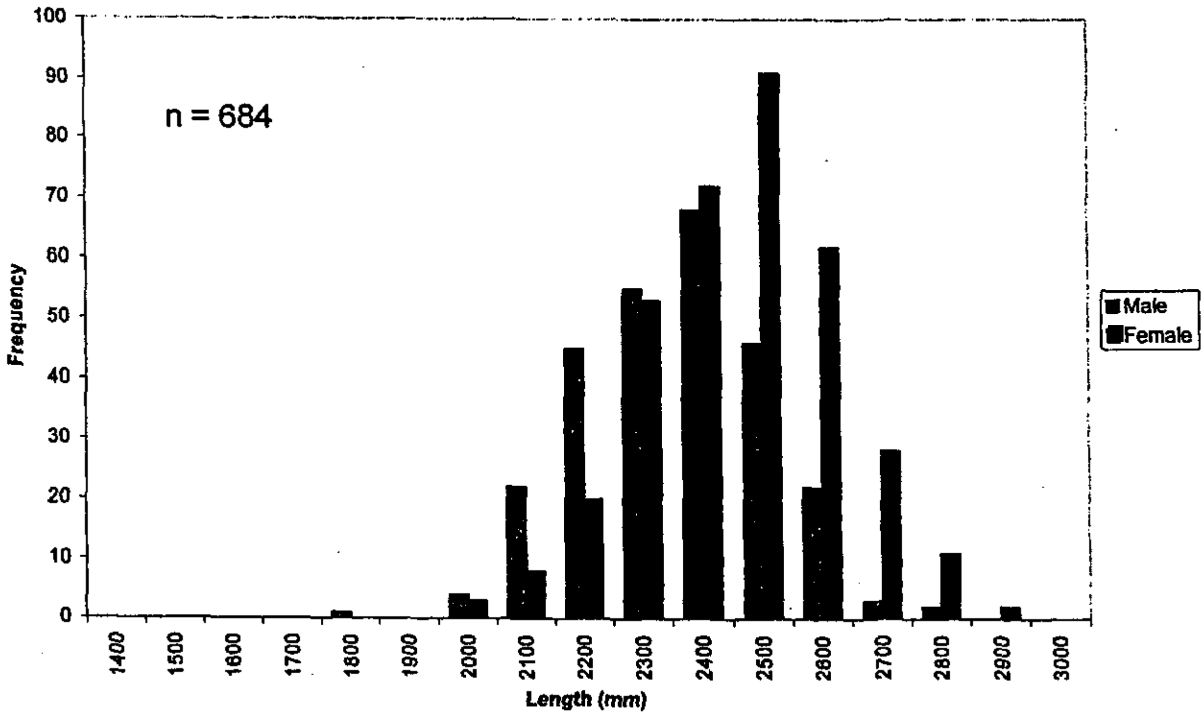


Figure 31: Striped marlin lower jaw-fork lengths by sex from Northland clubs, 1985–94.

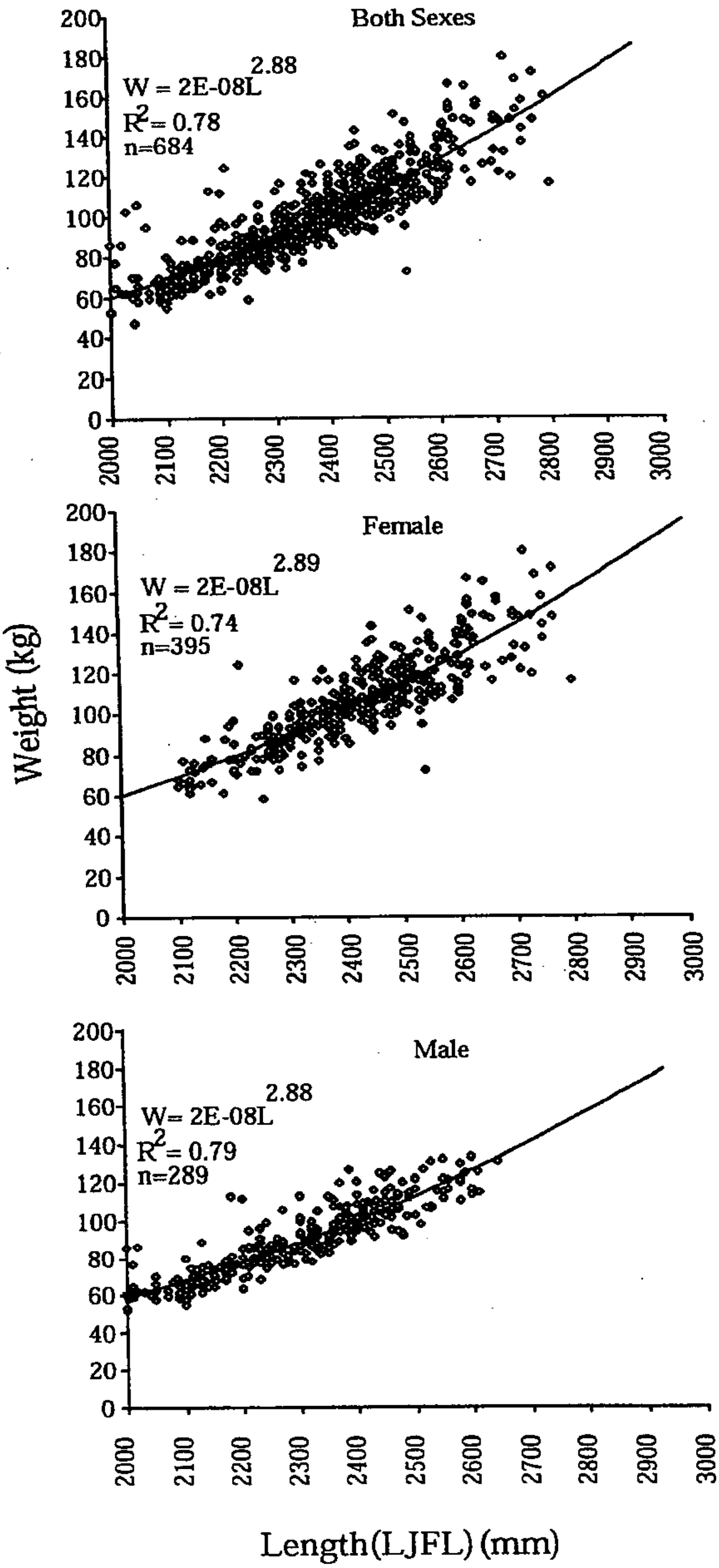
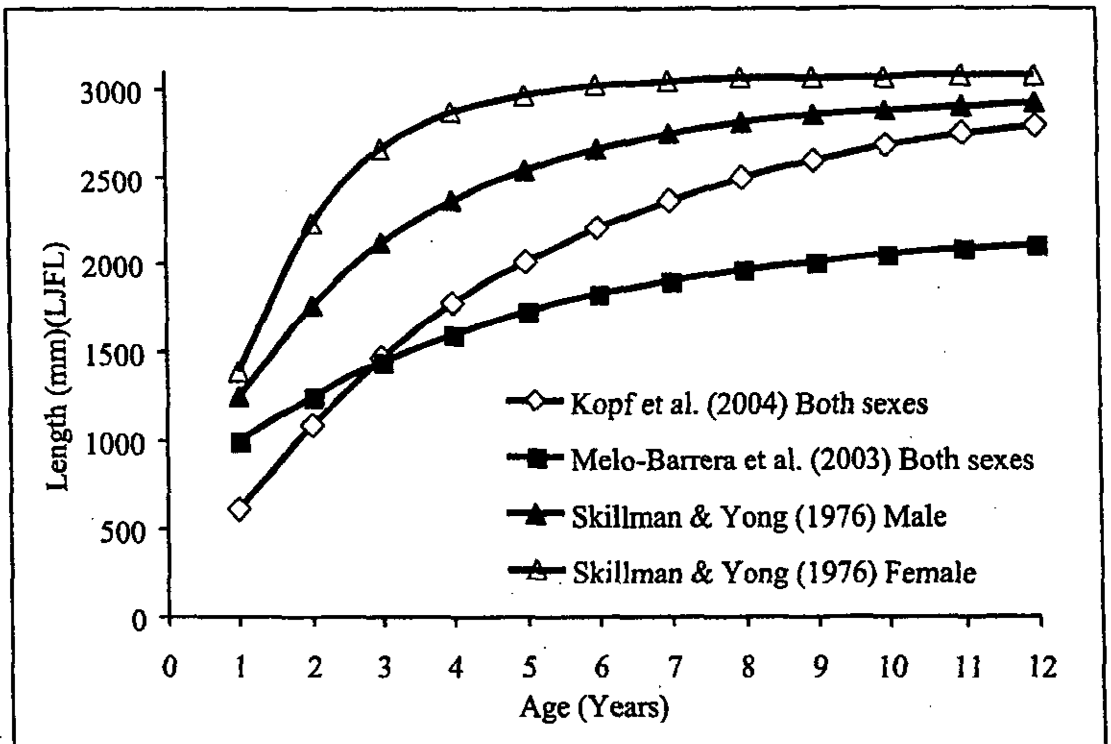


Figure 32: Length weight scatter plots and regression curves for striped marlin landed by recreational fishers in New Zealand by sex and combined.



Reference	Location	n	Sex	L Inf. LJFL (mm)	to (years)	k (annual)	Mode Age	Max Age
Kopf et al. (2004)	New Zealand	94	M-F	3010 ± 253	-0.04 ± 0.03	0.22 ± 0.12	7	8
Melo-Barrera et al. (2003)	Mexico	399	M-F	2210	-1.6	0.23	7	11
Skillman & Yong (1976)	Hawaii	-	M	2774 - 3144	-0.521	.315-.417	-	12
Skillman & Yong (1976)	Hawaii	-	F	2887 - 3262	0.136	.696 - .709	-	11

Figure 33: Comparison of von Bertalanffy growth curves from the Pacific Ocean (LJFL, mm, curved) and estimated parameters projected to 10 years.

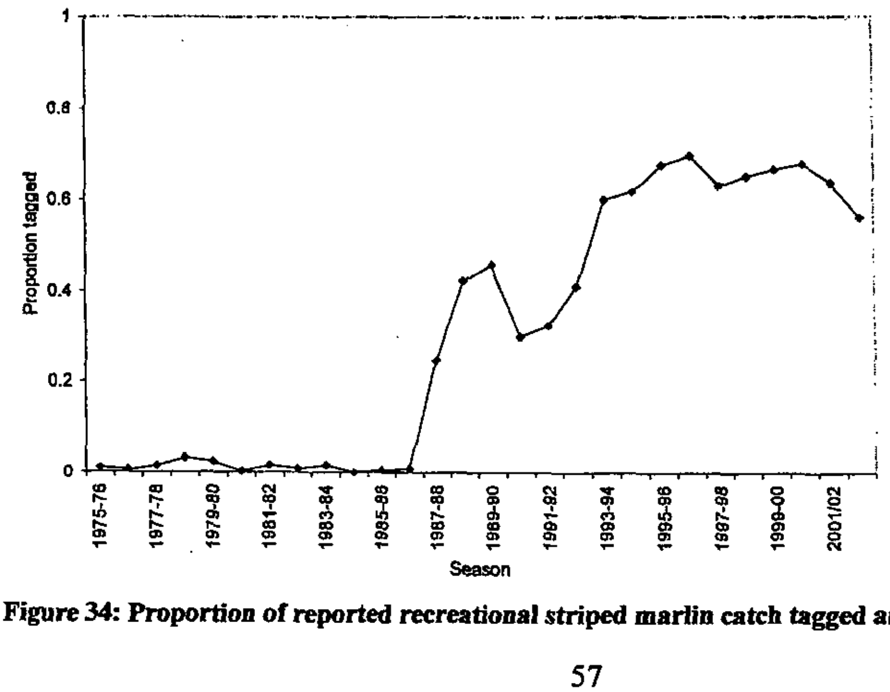


Figure 34: Proportion of reported recreational striped marlin catch tagged and released by season.

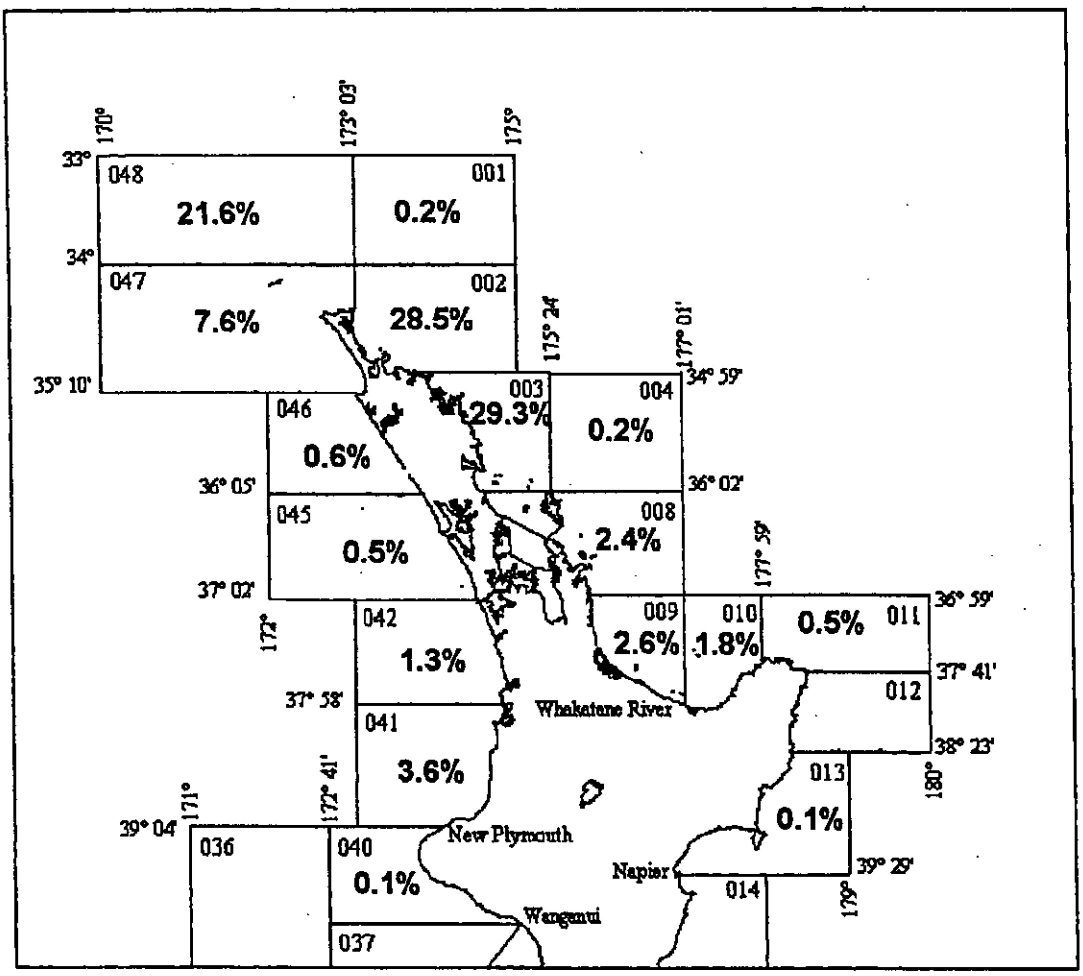


Figure 35: Percentage of striped marlin tagged and released by statistical area, 1976 to 2002.

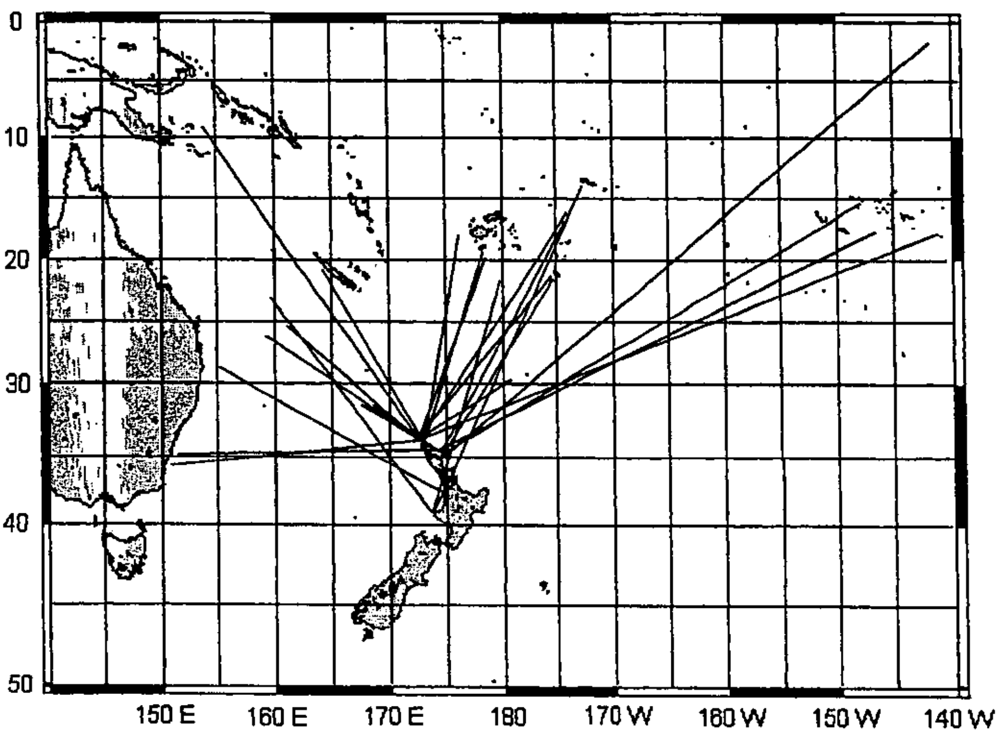


Figure 36: Long distance movements of striped marlin tagged in New Zealand waters, 1976 to 2003.

Appendix 1: Common and scientific names for species cited in text

Common name	Scientific name
albacore tuna	*Thunnus alalunga*
arrow squid	*Nototodarus sloanii*
bigeye tuna	*Thunnus obesus*
black marlin	*Makaira indica*
blue marlin	*Makaira nigricans*
broadbill swordfish	*Xiphias gladius*
jack mackerel	*Trachurus declivis, T. novaezelandiae, T. murphyi*
kahawai	*Arripis trutta*
mako shark	*Isurus oxyrinchus*
nautilus	*Argonauta spp.*
sailfish	*Istiophorus platypterus*
saury	*Scomberesox saurus*
shortbill spearfish	*Tetrapturus angustirostris*
snapper	*Pagrus auratus*
southern bluefin tuna	*Thunnus maccoyii*
striped marlin	*Tetrapturs audax*
white marlin	*Tetrapturus albidus*
yellowfin tuna	*Thunnus albacares*

Appendix 2: Number of stomachs and percent of striped marlin stomachs containing prey items from four stomach contents analysis in New Zealand

Common name	Scientific name	Baker (1966) (N=38) No	Baker (1966) %	Kopf (2005) (N=20) No	Kopf (2005) %	Morrow (1953) (N=38) %	No	Saul (1963) (N=147) %	No	Overall (N=243) No	Overall %
Saury	*Scomberesox saurus*	5	13	2	1	27	71	81	55	115	47
Arrow squid	*Nototodarus sloanii*	20	53	4	20	0	0	57	39	81	33
Jack mackerel	*Trachurus declivis, T. novaezelandiae, T. murphyi*	5	13	6	30	0	0	34	23	45	19
Unknown fish	Teleost	7	18	8	40	10	26	20	14	45	19
Unknown squid	Nototodarus and Loligo spp.	0	0	5	25	8	21	29	20	42	17
Pilchard	*Sardinops neopilchardus*	5	13	1	0.05	0	0	29	20	35	14
Kahawai	*Arripis trutta*	1	2	0	0	17	45	7	5	25	10
Blue mackerel	*Scomber australasicus*	8	21	1	0.05	0	0	8	5	17	7
Snapper	*Pagrus auratus*	6	15	0	0	7	18	0	0	13	5
Trevally	*Caranx georgianus*	9	24	0	0	0	0	2	1	11	5
Skipjack	*Katsuwonus pelamis*	3	7	1	.05	0	0	8	5	12	5
Yellowtail kingfish	*Seriola lalandi*	1	2	0	0	0	0	8	5	9	4
Butterfly perch	*Caesioperca lepidoptera*	3	7	0	0	4	11	0	0	7	3
Anchovy	*Engraulis australis*	1	2	0	0	0	0	6	4	7	3
Koheru	*Decapterus koheru*	3	7	1	0.05	0	0	2	1	6	2
Nautilus spp.	*Argonauta spp.*	1	2	0	0	1	3	2	1	4	2
Jack family	*Carangidae*	0	0	0	0	4	11	0	0	4	2
Porcupine fish	*Allomycterus jaculiferus*	1	2	0	0	1	3	1	1	3	1
Blue maomao	*Scorpis violaceus*	3	7	0	0	0	0	0	0	3	1
Green puffer	*Sphoeroides hamiltoni*	0	0	0	0	0	0	3	2	3	1
Barracouta	*Thyrsites atun*	1	2	0	0	1	3	1	1	3	1
Rays bream	*Brama brama*	0	0	0	0	0	0	2	1	2	1
Pink maomao	*Caprodon longimanus*	0	0	0	0	1	3	1	1	2	1
Dolphin fish	*Coryphaena hippurus*	0	0	0	0	0	0	2	1	2	1
Mako shark	*Isurus oxyrhinchus*	0	0	0	0	0	0	2	1	2	1
Frostfish	*Lepidopus caudatus*	0	0	0	0	0	0	2	1	2	1
Leatherjacket	*Parika scaber*	1	2	0	0	0	0	1	1	2	1
Broad squid	*Sepioteuthis bilineata*	0	0	0	0	0	0	2	1	2	1
Louvar	*Luvarus imperialis*	0	0	1	0.05	0	0	0	0	1	0
Ray sp.	Batoidea spp	1	2	0	0	0	0	0	0	1	0
Golden snapper	*Centroberx affinis*	0	0	0	0	0	0	1	1	1	0
Garfish	*Hyporamphus intermedius*	0	0	0	0	1	3	0	0	1	0
Blue shark	*Prionace glauca*	0	0	0	0	0	0	1	1	1	0
Hammerhead shark	*Sphyrna zygaena*	0	0	0	0	0	0	1	1	1	0

Appendix 3: Frequency of single and multiple captures per vessel day, BOISC

Season	Number of striped marlin recorded per vessel on a single date									
	1	2	3	4	5	6	7	8	9	12
1934	58	16	4	1						
1935	62	7	2							
1936	54	12	3							
1937	124	60	11	6		2				
1938	63	13	2							
1939										
1940	21	5				1				
1941	47	5								
1942										
1943										
1944										
1944-45	59	12	4							
1945-46	45	8								
1946-47	59	22	8	1	2					
1947-48	145	46	19	10	2					
1948-49	201	83	37	10	1	1				
1949-50	182	38	3	2						
1950-51	191	34	11	4						
1951-52	172	28	5	3	2					
1952-53	187	48	8	1						
1953-54	173	21	2							
1954-55	191	30	3							
1955-56	181	25	4							
1956-57	182	28	1							
1957-58	241	44	9	1						
1958-59	122	8								
1959-60	110	6								
1960-61	186	36	6							
1961-62	83	7								
1962-63	87	6								
1963-64	91	2	1							
1964-65	112	8								
1965-66	75	2	1							
1966-67	52	2								
1967-68	72	3								
1968-69	87	6	2							
1969-70	32	1								
1970-71	32	2								
1971-72	71	5								
1972-73	50	4								
1973-74	109	8	1							
1974-75	83	4								
1975-76	118	6								
1976-77	143	15								
1977-78	185	23	1							
1978-79	232	18	5							
1979-80	302	31	4							
1980-81	286	26	2							
1981-82	321	33	7							
1982-83	333	30	2							
1983-84	268	21								
1984-85	105	7								
1985-86	180	7	1							
1986-87	104	1								
1987-88	143	10								
1988-89	246	27	3	4						
1989-90	269	26	3		2	1			1	
1990-91	202	16	1							
1991-92	203	23	3	1	2					
1992-93	257	28	1							
1993-94	323	47	9	5	2		1			
1994-95	461	61	12	2	2					
1995-96	307	57	19	8	1					
1996-97	173	24	25	6	6	1	1	1	1	1
1997-98	227	33	7	3	3		2			
1998-99	279	41	9	4	3	1	1			
1999-00	156	13	6			1				
2000-01	177	20	11	2	1	2				
2001-02	180	31	12	4	2					
2002-03	206	29	8					1		

Appendix 4: Survey responses and CPUE from the east Northland charter boat skippers by season

Season	Number of responses	Striped marlin caught	Total days fishing	Raw CPUE	Standard deviation
1975-76	3	11	143	0.077	0.0291
1976-77	14	140	1 301	0.108	0.0123
1977-78	5	70	385	0.182	0.0271
1978-79	9	150	862	0.174	0.0118
1979-80	6	136	545	0.250	0.0244
1980-81	6	84	508	0.165	0.0234
1981-82	6	127	580	0.219	0.0324
1982-83	8	126	802	0.157	0.0297
1983-84	14	149	1 361	0.109	0.0084
1984-85	13	66	1 247	0.053	0.0079
1985-86	12	67	982	0.068	0.0148
1986-87	13	51	905	0.056	0.0071
1987-88	24	163	1 505	0.108	0.0099
1988-89	30	401	2 049	0.196	0.0122
1989-90	28	301	1 830	0.164	0.0110
1990-91	21	149	1 563	0.095	0.0095
1991-92	26	197	1 586	0.124	0.0107
1992-93	26	226	1 538	0.147	0.0141
1993-94	25	356	1 435	0.248	0.0252
1994-95	20	384	1 516	0.253	0.0182
1995-96	20	275	1 367	0.201	0.0169
1996-97	14	116	608	0.191	0.0328
1997-98	15	116	660	0.176	0.0235
1998-99	20	255	948	0.269	0.0262
1999-00	14	124	640	0.194	0.0249
2000-01	25	168	882	0.190	0.0254
2001-02	12	61	446	0.137	0.0238

Appendix 5: Recreationally captured striped marlin measured in 2004 (n=35), sex, weight (kg), straight and curved lower jaw fork length and eye fork length (mm)

Sex	Weight (kg)	Length (mm, LJFL-straight)	Length (mm, LJFL-curve)	Length (mm, eye-fork)
M	72.8	2 150	2 170	1 810
M	75		2 040	1 721
M	76.6	2 289	2 357	1 973
F	76.8	2 157	2 191	1 831
F	77.8	2 164	2 191	1 842
M	80.6	2 187	2 220	1 892
M	82.6	2 182	2 220	1 871
F	84.4	2 282	2 311	1 956
M	84.4	2 281	2 319	1 966
F	88	2 141	2 185	1 842
F	88.2	2 210	2 260	1 910
M	88.8	2 325	2 381	2 004
F	89.2	2 289	2 339	1 971
M	90.4	2 370	2 394	2 010
F	91.4	2 310	2 350	2 010
M	92.8	2 368	2 409	2 039
M	95.4	2 275	2 296	1 937
M	96.6	2 281	2 320	2 001
F	99.2	2 442	2 466	2 008
M	99.8	2 250	2 315	1 973
M	100.4	2 375	2 413	2 025
F	102.6	2 390	2 440	2 050
M	103.8	2 417	2 475	2 108
M	107.6	2 419	2 442	2 064
M	109	2 394	2 412	2 049
M	110.2	2 336	2 439	2 024
M	111.4	2 323	2 385	2 020
F	111.6	2 389	2 422	2 030
M	116.4	2 388	2 356	2 015
M	119	2 460	2 535	2 101
F	121	2 488	2 546	2 163
F	124.2	2 547	2 585	2 167
F	125.2	2 432	2 491	2 106
M	131.6	2 390	2 379	2 001
F	132.4	2 450	2 503	2 165
F	146.6	2 582	2 656	2 190