Population characteristics and biology of striped marlin, *Tetrapturus audax* in the New Zealand fishery

A thesis presented in partial fulfillment of the requirements for the degree of Master of Science (MSc) in Physiology at Massey University, Palmerston North, New Zealand.

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Abstract

Striped marlin (*Tetrapturus audax*) are apex predators in the pelagic ecosystem and are seasonally abundant in the off-shore waters of New Zealand during December through May. Data presented in this thesis were derived from a variety of fishing databases from New Zealand, Australia and United States as well as biological samples collected from east Northland New Zealand. This thesis may be used to help answer questions about growth and size structure, factors influencing conventional tag recoveries, and the trophic dynamics of striped marlin in the New Zealand fishery.

Results show that the average weight of striped marlin in the New Zealand recreational fishery has declined between 1925-1944 (117.9 ± 0.6 kg) and 1985-2003 (96.6 ± 0.3 kg) (Means ± S.E.). The root causes of this average size decline are unknown but appear to be related to the expansion of a surface longline fishery in the southwest Pacific Ocean during 1958. Despite the large average size (104.9 ± 0.2 kg) of striped marlin from New Zealand, parameters estimated in the von Bertalanffy growth model ($L\infty 3010$ mm, K=0.22 annual and t_0=-0.04) do not show higher growth rates compared to Hawaii or Mexico.

During their residency in the New Zealand Exclusive Economic Zone (EEZ) the condition Wr (relative weight) of striped marlin improves from 95.1 ± 1.2 to 109.4 ± 3.4 and average weight increases from 98.1 ± 2.0 kg to 114.6 ± 0.4 kg. These data imply that striped marlin migrate to New Zealand in order to take advantage of the abundant food resources and to improve condition after spawning in warmer waters to the north. Arrow squid (*Nototodarus* spp.), jack mackerel (*Trachurus murphyi*) and saury (*Scomberesox saurus*) comprised a large portion of the diet from (n=20) striped marlin stomachs during March of 2004. Additionally, with a consumption rate of 0.962 to 1.28 kg of prey per day, striped marlin may consume the equivalent of 2.8-3.5% of New Zealand's current commercial catch of arrow squid and jack mackerel respectively.

With concerns about declining pelagic fish stocks, tag-and-recovery programmes have become increasingly popular and over 50% of recreationally captured marlin in New Zealand are tagged and released annually. However, low tag recovery rates (<1.0%) have hindered progress in understanding growth, stock structure and migration patterns important for managing this species. Data from this study suggests that tag returns from striped marlin would increase if more fish were captured and released in less than 39 min and a greater number of small (< 89 kg) individuals were released. Tag recoveries and presumably post-release survivorship of striped marlin was reduced by increasing capture time and fish size. Rates of injury were lowest during capture times ranging from 20-29 min and in fish weighing 60-89 kg.

Preface

Billfishes (marlins, sailfishes, spearfishes, and swordfish) are large, aggressive, relatively rare, highly migratory and inhabit an expansive pelagic environment. These characteristics make management and scientific study difficult and are the root causes for the paucity of biological information about these fishes. The large gap in our knowledge of billfishes fosters a high level of uncertainty about the sustainability of current fishing practices and demands immediate attention.

The 1972, 1988, and 2001 Billfish Symposia are the most significant works published about management and scientific study of these fishes (Shomura & Williams 1974; Stroud 1989; JMFR 2003). Related works by Bromhead et al. (2004); Hinton & Maunder (2003); Hinton & Bayliff (2002) and; Nakamura (1985) are specific to striped marlin biology and fisheries. As the need for international cooperation in billfish management and research persists, more information will be disseminated during the Fourth International Billfish Symposium held in Avalon, Santa Catalina Island, California, in 2005. Research presented in this thesis attempts to address some of the fundamental questions about billfish biology and fisheries which were posed in the previously cited symposia and literature.

In order to provide a more robust investigation, new data presented in this report were supplemented with data sets from the Bay of Islands Swordfish Club and from three of the world's largest Conventional Cooperative Billfish Tagging Programmes. The goals of this thesis were to review and consolidate the scientific literature on striped marlin (Chapter 1); provide information about growth and size structure (Chapter 2); determine factors influencing conventional tag recoveries (Chapter 3); and describe the diet of striped marlin while in the New Zealand fishery (Chapter 4). Chapter 5 provides an overall discussion of the results and summarises the main findings from Chapters 1-4.

Recently, there has been considerable debate about the animal welfare implications associated with fishing and recreational game fishing has been the focus of much attention in New Zealand. At the present time, very little information exists informing anglers on how to improve the welfare of fish which they catch. Anglers may be forced to change their methods of capture and it is up to the scientific community to provide objective evaluations to inform the procedures on how to improve the treatment of fish during capture. Appendix D is a manuscript submitted to the Journal of Fish Biology which addresses this issue by evaluating some of the behavioural and physiological impacts of capture by hook-and-line.

Acknowledgements

I am particularly grateful to my friend and advisor Dr. Peter Davie who gave me the opportunity pursue my passion for pelagic fish research and has made my studies in New Zealand a life changing experience. His encouragement, hospitality and guidance throughout my studies will not be forgotten.

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I thank Nick and Julie Du Pain of Saint Paul Cannery in Whangaroa for their hospitality and kindness for allowing me to stay at their home and interfere with their business in order to collect stomach contents which are reviewed in Chapter 4.

I thank Cathy Davidson, Des Waters and Tim Sippel for their friendship and help during my studies at Massey. Additionally, I thank Massey University for financial assistance which has permitted me to conduct this research.

Lastly, I would like to thank my family for their encouragement and support throughout my studies and in particular my lovely wife Stacey. I am thankful for the sacrifices that she has made in order to supported me emotionally and financially and for her love I am eternally grateful.

Table of Contents

Chapter 1:

Review of striped marlin biology, ecology and fisheries

Chapter 2:

Size trends and growth of striped marlin in the New Zealand recreational fishery

Chapter 3:

Impacts of capture time, body mass and injury on conventional tag recoveries from striped marlin

Chapter 4:

Diet and feeding ecology of striped marlin off the coast of New Zealand

Chapter 5:

List of Tables

Chapter 2

Chapter 3

Chapter 4

List of Figures

Chapter 1

Chapter 2

Chapter 3

Chapter 4

List of Appendices

Chapter 1

Review of striped marlin biology, ecology and fisheries

1.1 Systematics

The striped marlin, *Tetrapturus audax* (Philippi, 1887) is one of eight billfishes in the family Istiophoridae, which encompasses marlins (*Tetrapturus* spp. and *Makaira* spp.), sailfishes (*Istiophorus* spp.) and spearfishes (*Tetrapturus* spp.) (Bromhead et al. 2004). The total number of Istiophorid billfishes is unclear because there is considerable uncertainty about recognition several species of spearfish and differentiating Atlantic and Indo-Pacific blue marlin and sailfish (Graves & McDowell 1995; Graves & McDowell 2003). In contrasts to popular beliefs, molecular evidence suggests that Istiophorids are not in the same suborder as tunas and mackerels (Scombrodei), rather they are members of the suborder Xiphioidei (Finnerty & Block 1995). The suborder Xiphioidei includes marlins, sailfishes, spearfishes and broadbill swordfish (*Xiphias gladius*).

All five of the Istiophorid species that occur in the Pacific and Indian Oceans have been recorded in New Zealand waters but striped marlin are most common. Of the billfishes occurring in the Pacific and Indian Oceans, striped marlin are most closely related to shortbill spearfish (*T. angustirostris*) and share classification at the genus level (Nakamura 1985). Mitochondrial DNA research indicates that white marlin (*T. albidus*) in the Atlantic Ocean and striped marlin are separated by nearly the same level of genetic diversity as blue marlin species of the Atlantic and Pacific Oceans. However, white marlin and striped marlin are separate lineages (Graves & McDowell 2003).

1.2 Identification

Striped marlin have two dorsal (first is 37-42 rays, second is 5-6 rays) and anal fins (first anal fin is 13-18 second 5-6 rays). The second dorsal fin is positioned slightly behind the second anal fin and there is a pair of notched lateral keels on the caudal peduncle. Pectoral fins are long (18-22 rays) and can be pressed against the body and are similar in length to ventral (single spine) pelvic fins. The upper jaw (bill) extends nearly twice the length of the lower jaw and is round in cross section with small sand paper like teeth (Preceding paragraph from Nakamura 1985; Figure 1.1).

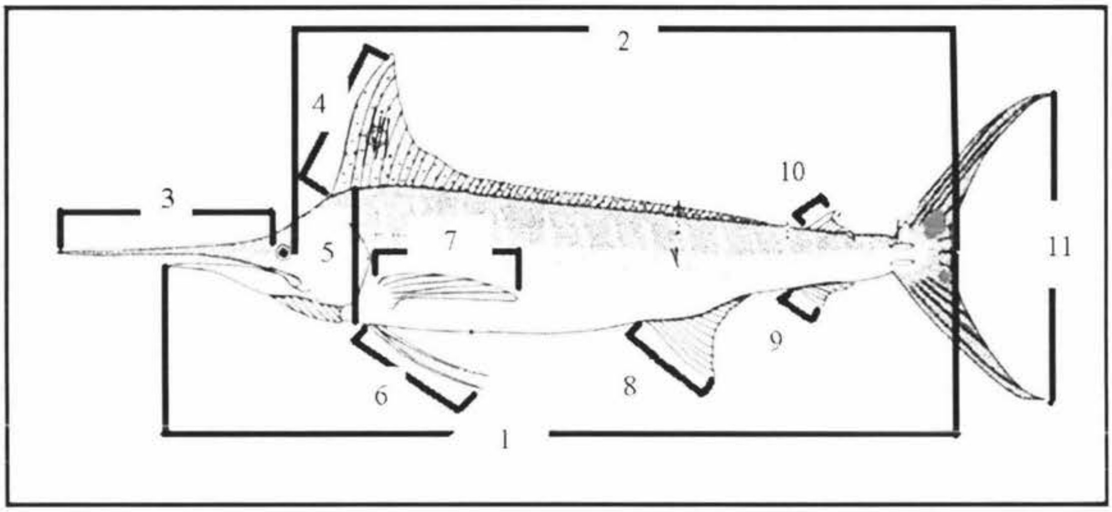

Figure 1.1 External features of striped marlin showing common morphological measurements cited throughout text. 1) Lower jaw-fork length; 2) Eye-fork length; 3) Bill length; 4) First dorsal fin height; 5) Body depth; 6) Pelvic fin length; 7) Pectoral fin length; 8) First anal fin height; 9) Second anal fin height; 10) Second dorsal fin height; 11) Caudal spread.

Striped marlin can most easily be distinguished from blue and black marlin (*M. nigricans* and *indica)* by the height of the first dorsal fin. The 1st and possibly 2nd or 3rd dorsal fin spine in striped marlin is nearly equal to or greater in height than straight line body depth. The height of the first dorsal fin in blue and black marlin is distinctly less than body depth (Figure 1.1). Blue and black marlin have more robust bodies and steeply sloped foreheads compared to striped marlin. The ability of striped marlin to fold pectoral fins against the body also 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. Colour during life is metallic blue with 10-15 prominent vertical stripes that remain present several hours after death. Metallic stripes in blue marlin usually fade soon after death (Paul 2000).

1.3 Distribution and Habitat Preferences

Striped marlin are widely distributed throughout pelagic ecosystems, inhabiting tropical and temperate waters throughout the Pacific and Indian Oceans. Commercial longline catch rates show a horseshoe shaped distribution pattern in the Pacific and a latitudinal range of 45° N to 45 ° S in the Indian and Pacific Oceans (Nakamura 1985; Figure 1.2)

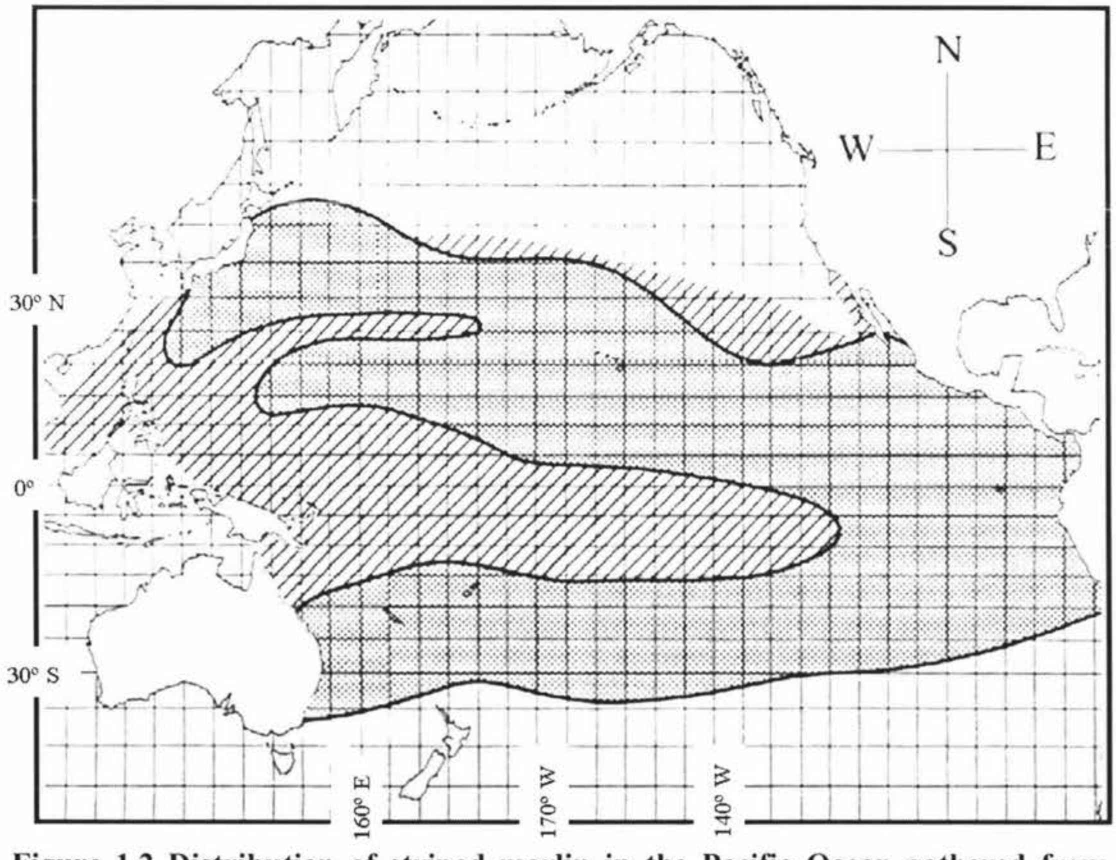

Figure 1.2 Distribution of striped marlin in the Pacific Ocean gathered from Japanese longline records (1964-69). Shaded areas indicate moderate to high catch rates. Cross hatched areas represent lower catch rates. * Striped marlin also occur approximately 10° north and south of shaded areas and in the Indian Ocean. Reproduced from Squire & Suzuki (1990).

Striped marlin occur in the widest range (15.2 ° - 30.5 ° C) of sea surface temperatures of all Istiophorid species (Bromhead et al. 2004). Catch rates show that juveniles are more abundant in warmer equatorial waters while adults frequently penetrate higher latitudes and cooler waters during the summer months in both hemispheres. Squire (1974) found that striped marlin were most frequently captured in the eastern Pacific at water temperatures ranging from 16.1° to 22.8 °C and Bromhead et al. (2004) cite that 97% of striped marlin near Australia are caught at sea surface temperatures ranging from 18 ° to 27 ° C. The absolute water temperatures in which striped marlin can survive is unknown but there appears to be is a limiting rate of water temperature change that influences the ability for deep dives (≈ 8-10 °C) (Holts & Bedford 1990; Sippel et al. unpublished).

Satellite and acoustic tags have shown that striped marlin regularly make short dives to depths exceeding 100 m but most time is spent in the upper 10 m of the water column (Holts & Bedford 1990; Domeier et al. 2003). The deepest dive recorded for striped marlin is 180 m and longlines rarely catch striped marlin deeper than 150 m (Boggs 1992; Brill et al. 1993). However, in a satellite tagging study from New Zealand, Sippel et al. (unpublished) recorded a striped marlin dive of 310 m. At night striped marlin spend approximately 78% of their time in the upper 5 m of the water column and during the day spend they spend 65% of their time in the upper 5 m (Sippel et al. unpublished).

1.4 Migration and Stock Structure

Fine scale seasonal movements of striped marlin are unclear but appear to be driven by changes in water temperature, food availability and reproduction. Tag recoveries from conventional tagging programmes reveal that striped marlin a capable of long distance migrations and the longest straightline distance recorded is 6713 km (Ortiz et al. 2003; *see* Chapter 3). Satellite tags have recorded a striped marlin which traveled an average of 58 km per day for 33 days migrating from the King Bank off the coast of New Zealand to Vanuatu, 2140 km north (Sippel et al. unpublished). Despite their extensive movements, striped marlin appear to be less migratory than the blue and black marlin, which have both had tag recoveries with net displacements exceeding 14,000 km (Ortiz et al. 2003).

Currently, striped marlin in the Pacific are considered a single stock but investigations into Mitochondrial DNA suggest significant heterogeneity between samples from Australia, Hawaii, Ecuador and Mexico (Graves & McDowell 1994). Interestingly, other highly migratory and pelagic fish species such as yellowfin tuna (*Thunnus albacares*) and black marlin show no heterogeneity in genotype samples from the same areas in which striped marlin were sampled (Graves & McDowell 1994). Population structuring of striped marlin may be facilitated by multiple spawning areas throughout the Pacific Ocean, while black marlin who exhibit no Pacific wide heterogeneity are known to spawn only in one region which is near the Great Barrier Reef (Graves & McDowell 1994). However, the two most likely theories regarding stock structure of striped marlin are: 1) Single unit-stock or 2) Two stocks, one in the north and south Pacific, roughly divided by the equator (Hinton & Bayliff 2002).

Catch rates, tag recoveries and modal shifts in size classes show there are several regions in the Pacific where striped marlin make cyclic annual migrations but there is also significant population mixing throughout the ocean (Squire & Suzuki 1990). In the southwest Pacific, striped marlin migrate south to New Zealand during the austral summer and are most abundant in January through April (Figure 1.3). In May or June, striped marlin migrate north, away from New Zealand to a wide variety of locations in the tropics and then many migrate to the Coral Sea of Australia where spawning is known to take place during September-December (Hanamoto 1977; Figure 1.3). In December or January striped marlin migrate south and return once again to New Zealand waters. However, conventional tag recoveries span a wide spread throughout the southwest Pacific and indicate potential population mixing with other regions (Figure 1.4).

In the eastern Pacific, evidence suggests that there is transequatorial exchange from South America (Ecuador) to Mexico and southern California (Ortiz et al. 2003). However, striped marlin off the coast of South America are also known to migrate northwest toward the central Pacific during the winter and return with warmer waters during the summer (Squire & Suzuki 1990). The region surrounding Hawaii also appears to be a central location for striped marlin migrating from northeast and northwest Pacific during cooler seasons of the year and is also in close proximity to known spawning grounds.

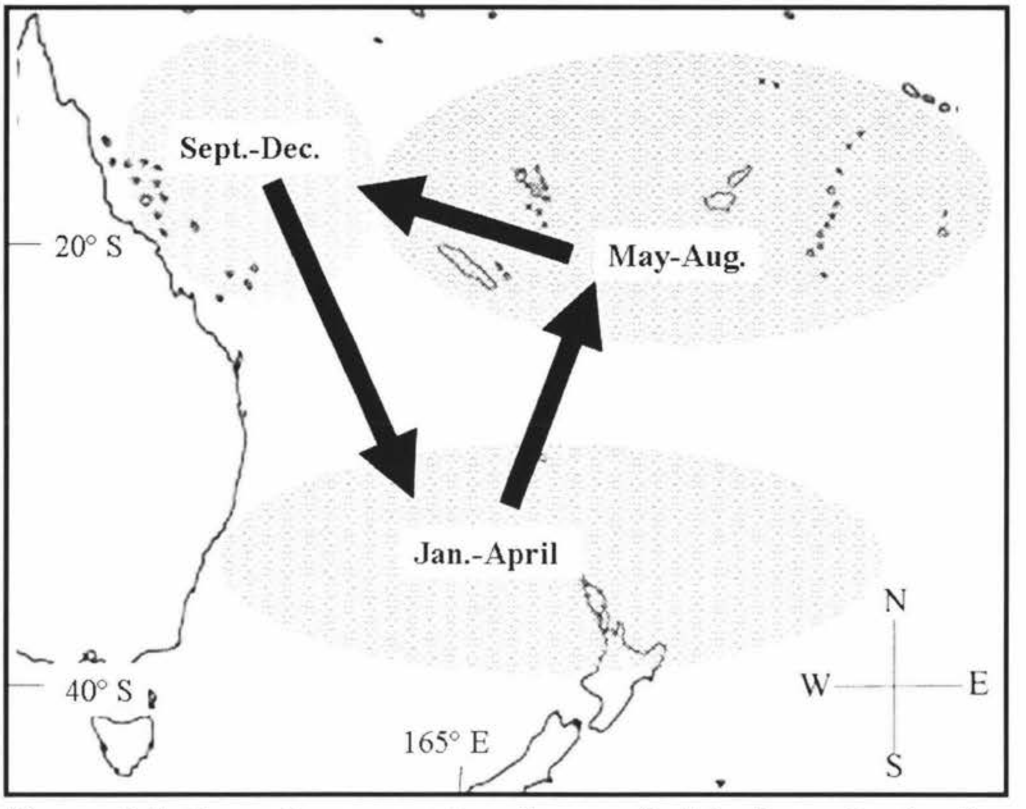

Figure 1.3 General movement patterns of striped marlin in the southwest Pacific Ocean derived from longline catch records adapted from Hanamoto (1977) and Squire & Suzuki (1990).

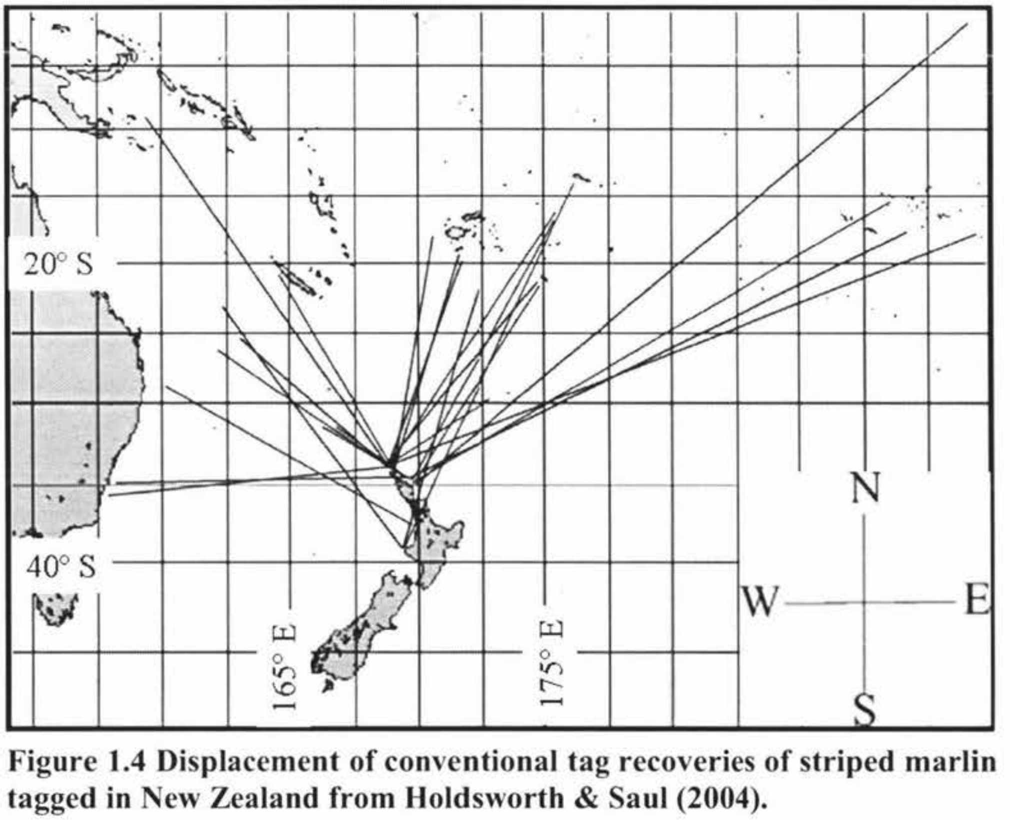

Figure 1.4 Displacement of conventional tag recoveries of striped marlin tagged in New Zealand from Holdsworth & Saul (2004).

1.5 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 likely 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 fecundity is highly dependent on female size (Eldridge &Wares 1974). Fertilisation is external and eggs are approximately 1-1.5 mm diameter. There is no parental care and survival of young is dependent upon on current, predators, and food supply.

Spawning behaviour is not well documented but striped marlin have been observed swimming in close pairs during known spawning periods and may remain together even when one fish is hooked (Eldrige & Wares 1974). Literature suggests that spawning occurs once annually but recent research on white marlin indicates that spawning may occur several times per year (Bromhead et al. 2004). Striped marlin exhibit a low degree of sexual dimorphism but females are generally larger than males but not to the same extent as blue marlin and black marlin (*see* Chapter 2).

Water temperature may influence the location of spawning grounds as most larvae are collected in sea surface temperatures $\geq 24^{o}$C (Ueyanagi & Wares 1975). The majority of larvae recoveries occur in off shore waters between 25 and 27^{o}C and during the summer in both hemispheres (Gonzalez-Armas et al. 1999). However, Gonzalez-Armas et al. (1999) recovered striped marlin larvae in the coastal waters of the mouth of the Gulf of California and Leis et al. (1987) collected istiophorid larvae from inshore waters near reefs in the Coral Sea region of Australia. Larvae are usually collected in the upper 5 m of the water column but distribution changes between night and day and ontogenetic development (Leis et al. 1987; Ueyanagi 1974).

Spawning areas have been identified in the southwest Pacific (Hanamoto 1977); west-central Pacific (Ueyanagi 1974); eastern Pacific (Kume & Joseph 1969 and Gonzalez-Armas et al. 1999); and through out the Indian Ocean (Nakamura 1985). The contribution of individual spawning grounds to the total population unclear but the abundance of juveniles in the north-central to western Pacific suggests this is a major spawning ground (Squire & Suzuki 1990). There is no evidence of striped marlin reproduction near mainland New Zealand. However, one of the closest recorded striped marlin spawning grounds to New Zealand occurs in the Coral Sea near Australia. Female ovaries start to mature in this region during late September or early October (Hanamoto 1977). Spawning peaks in November and December as 60-70% of fish are mature.

The minimum size of mature fish recorded in the Coral Sea is estimated at 1430 mm (eye-fork length) or approximately 1700 mm (lower jaw-fork length) and 36 kg. Ueyanagi & Wares (1975) estimate maturity in the central Pacific Ocean at approximately 1600 mm (lower jaw-fork length). The striped marlin fishing season in New Zealand begins in December and coincides with the end of recorded spawning time in the Coral Sea near. Striped marlin captured in New Zealand are rarely less than 2000 mm (lower jaw-fork length) suggesting that these fish are mature. Age at maturity is unclear but by applying age at length data to size at maturity data it is probable that fish become reproductively active between ages 2 and 4 (Davie & Hall 1990; Skillman & Yong 1976; Ueyanagi & Wares 1975).

1.6 Growth, Size and Age

Striped marlin grow to a larger size than shortbill spearfish but are the smallest and most slender of the three species of marlin occurring in the Pacific and Indian Oceans. Few studies on striped marlin recognize significant sexual dimorphism but some suggest that females may grow to a larger size than males (Pillai & Ueyanagi 1978). Sexual dimorphism for weight and length is apparent in New Zealand's recreational fishery as females are on average 10% longer and 16% heavier than males. Females in New Zealand averaged 106 kg and 2399 mm LJFL in length while males averaged 90 kg and 2305 mm LJFL (*see* Chapter 2). New Zealand is renown for large striped marlin and average weight (104 kg) is significantly greater than commercial and recreational catches from Hawaii (31.9 kg), Mexico (54.7 kg), the Indian Ocean (65.0 kg) and southern California (68 kg) (Squire 1983; van der Elst 1990; Dalzell & Boggs 2003; Ortega-Garcia et al. 2003). The world record striped marlin was caught in New Zealand and weighed 224 kg (IGFA 2004). However, a positively identified striped marlin weighing 243 kg was also weighed in New Zealand but the method of recreational capture did not meet the International Game Fish Association (IGFA) rules and thus was disqualified.

Conventional tagging programs have provided insight on age and growth of many pelagic fishes but striped marlin have one of the lowest recovery rates of all billfishes (Ortiz et al. 2003; *see* Chapter 3). Age estimates have been made using growth rings in spines and otoliths or statistical modeling of length frequencies but these methods are not validated. Davie and Hall (1990) estimated the age of striped marlin in New Zealand using dorsal spine growth rings and found between 2 and 8 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. von

Bertalanffy growth models predict that striped marlin may grow up to 45% of their total length in the first year of life and weigh 100 kg by age 4 or 5 (Skillman & Yong 1976; Melo-Barrera et al. 2003; *see* Chapter 2).

1.7 Diet

Striped marlin frequently forage on schools of pelagic and epipelagic organisms ranging from squid and nautilus to mackerel and saury (Baker 1966; Morrow 1953; Saul 1983; *see* Chapter 4). Longline commercial fishing vessels have significantly higher catch rates of striped marlin at depths < 150 m, which suggests that feeding occurs most often in the upper level of the water column (Boggs 1992). Although striped marlin are primarily epipelagic predators, benthic and demersal prey items such as rays (Batoidea spp.) are occasionally consumed (Abitia-Cardenas et al. 1997; Baker 1966). Little research has been conducted on the behaviour of striped marlin during feeding but they are believed to be highly visual and solitary predators but have been observed feeding in small groups. Crystalline deposits in iridophores cause an iridescent "lighting up" in the lateral stripes of striped marlin during feeding and may work to disorient prey (Davie 1990).

Striped marlin are opportunistic feeders that rely on food availability rather than on specific prey items. The opportunistic nature of striped marlin is exhibited in stomach contents analysis from New Zealand, which record over 28 fish and 4 cephalopod species. Off the coast of New Zealand the most frequent prey items of striped marlin are saury (*Scomberesox saurus*) and arrow squid (*Nototodarus spp.*) followed by jack mackerel (*Trachurus murphyi*) (Baker 1966; Morrow 1953; Saul 1984). Saul (1983) found a small variety of prey species in individual striped marlin stomachs from New Zealand, 73% of 147 stomachs contained one or two prey species. This data suggests that feeding occurs during short intense events rather than continuously through out 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).

1.8 Anatomy and Physiology

Striped marlin are large, highly athletic predators which migrate thousands of kilometers each year and their anatomy and physiology have unique attributes which support this demanding life style. Marlin body mass is made up of 57-65 % muscle which is supplied with blood from a four chambered heart consisting of a sinus venosus, atrium, ventricle and bulbus arteriousus (Davie 1990). Striped marlin use ram ventilation to oxygenate their gills which means that water is propelled through the gills as the fish as it swims forward (rather than using the gills to pump water) (Davie 1990). They are designed for fast efficient swimming whereby propulsive thrusts of the axial musculature and caudal fin can propel some Istiophorids as fast as 75 kph (Walters 1962).

Despite the faith of many anglers there exists a large debate on weather or not billfish see colour. Fritsches (2004) identified three visual pigments in striped marlin that provide the "hardware" for colour vision. However, without the ability to study live specimens the question remains unanswered. Striped marlin spend the majority of their time in the light rich pelagic ecosystem and for this reason it is reasonable to assume that striped marlin can see colour. Another intriguing aspect of the eyes of marlin is the presence of a heater organ. The heater organ is also present in the brain of marlin and is made up of highly modified muscle cells that produce heat by ATP hydrolysis (Block 1986). The function of the eye and brain heaters are not fully understood but probably allow marlin to occupy regions of cooler water and exploit prey items that do not possess such physiological attributes.

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. Occasionally, marlin that undergo rapid changes in depth from deep to shallow water will evert their stomach because of an expansion in the swim bladder. The ability of marlin to evert their stomach may be an adaptation to expel unwanted items such as squid beaks (Davie 1990).

Another area of interest in marlin anatomy is the bill and its use during feeding. Reports of marlin moving their head and bill from side to side in a slashing motion 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 1983). Numerous researchers have documented marlin with broken bills and none has identified fish 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.

1.9 Commercial Fisheries

Striped marlin are commercially fished throughout most of their distribution but commercial fishing for marlin has been prohibited in New Zealand since 1987 (Holdsworth et al. 2003). Striped marlin are caught as bycatch in New Zealand but all must be released dead or alive. Surface longlining is the primary method of capture but purse seining and gill netting account for a small proportion of catch (Bromhead et al. 2004). Striped marlin are regularly targeted by Japanese, Korean and Taiwanese fleets mainly in the east central and northwest Pacific Ocean (Bromhead et al. 2004) However, countries like the United States, Belize, South Africa and Australia have also developed longline fisheries for tuna and swordfish in which striped marlin are caught.

Striped marlin is more valuable than blue or black marlin in the sashimi markets of Japan but yields a lower price than other fish such as the southern bluefin tuna (*Thunnus maccoyii*). The global catch of striped marlin peaked during the late 1960's at over 20,000 metric tonnes but has decreased to around 12,000 metric tonnes per annum since 1990 (FAO 2004). Underreporting of catch and grouping all billfish into one catch statistic has created a great deal of concern about the validity of information provided by commercial fishers. The uncertainty about catch statistics also causes concern about the status of the population and at present time the sustainability of the Pacific Ocean fishery is unknown.

Commercial longlining began in the southwest Pacific around 1952 as Japanese fleets targeted albacore (*T. alalunga)* and yellowfin tuna *(T. albacares)*. Fleets soon moved south targeting bluefin and bigeye tuna (*T. obesus*) and the first record of longlining in New Zealand's present day exclusive economic zone (EEZ) was 1955. Fishing effort for striped marlin in the southwest Pacific Ocean approached 30 million hooks per year by 1960 and nearly 175 million hooks per year by 2001 (Figure 1.5). The catch per unit effort (CPUE) in the southwest Pacific, however shows a declining trend from 3-6 striped marlin per 1000 hooks in the 1950's down to less than 0.5 during the 1990's until present (Figure 1.6). CPUE and overall effort in New Zealand's EEZ show a similar declining trend but there is more variability between years (Figure 1.7; 1.8). The variability may due to differences in striped marlin abundance but are likely also related to their seasonal availability.

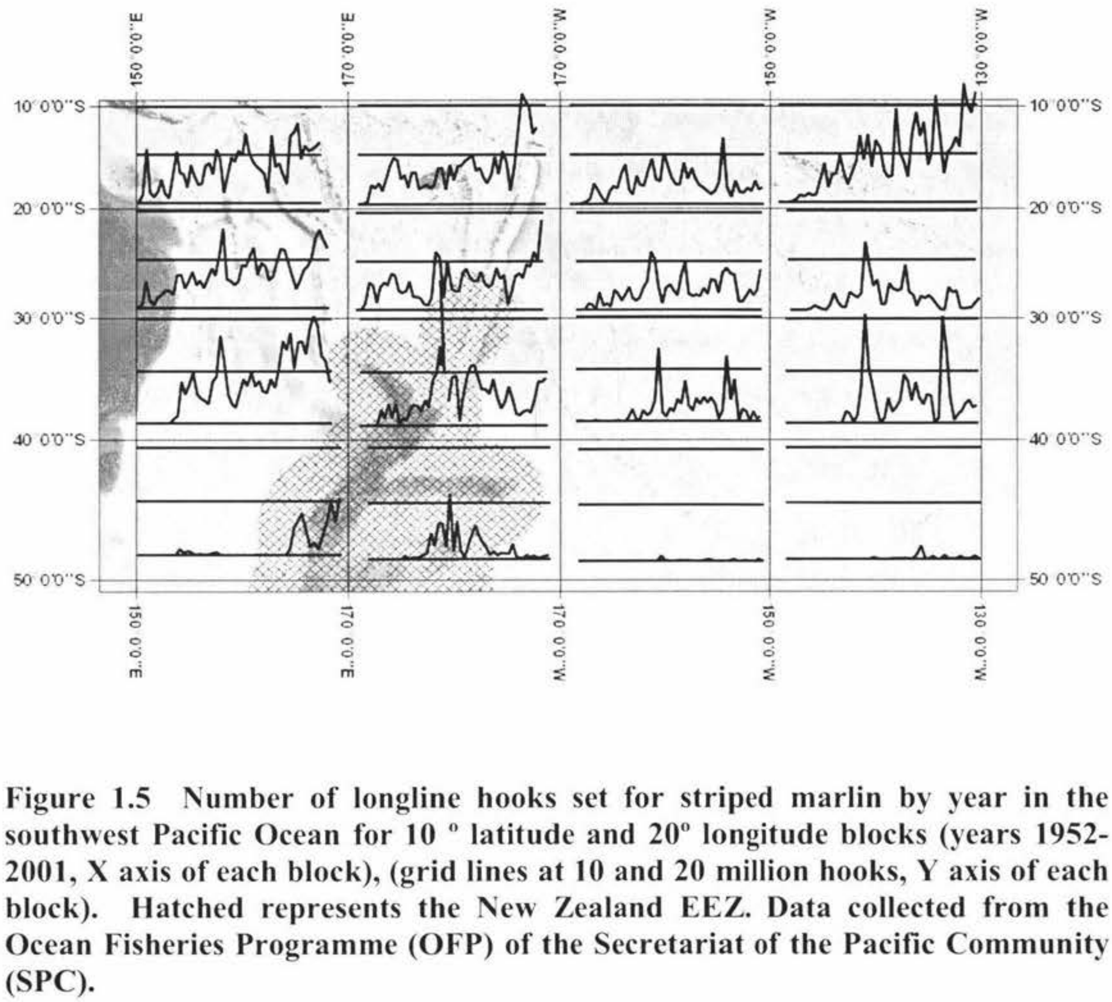

Figure 1.5 Number of longline hooks set for striped marlin by year in the southwest Pacific Ocean for 10 ° latitude and 20° longitude blocks (years 1952-2001, X axis of each block), (grid lines at 10 and 20 million hooks, Y axis of each block). Hatched represents the New Zealand EEZ. Data collected from the Ocean Fisheries Programme (OFP) of the Secretariat of the Pacific Community (SPC).

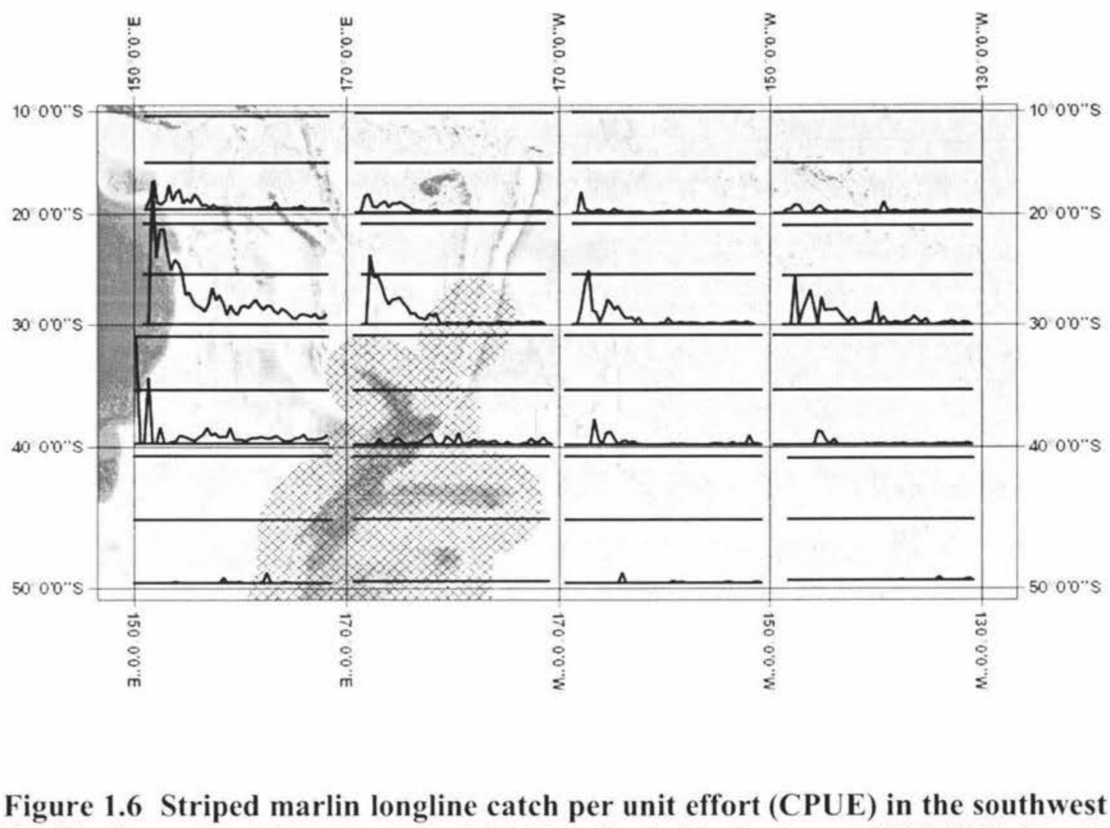

Figure 1.6 Striped marlin longline catch per unit effort (CPUE) in the southwest Pacific Ocean for 10 ° latitude and 20 ° longitude blocks (years 1952-2001, X axis of each block), (grid lines at 3 and 6 per fish per 1000 hooks, Y axis of each block). Hatched area represents the New Zealand EEZ. Data collected from the Ocean Fisheries Programme (OFP) of the Secretariat of the Pacific Community (SPC).

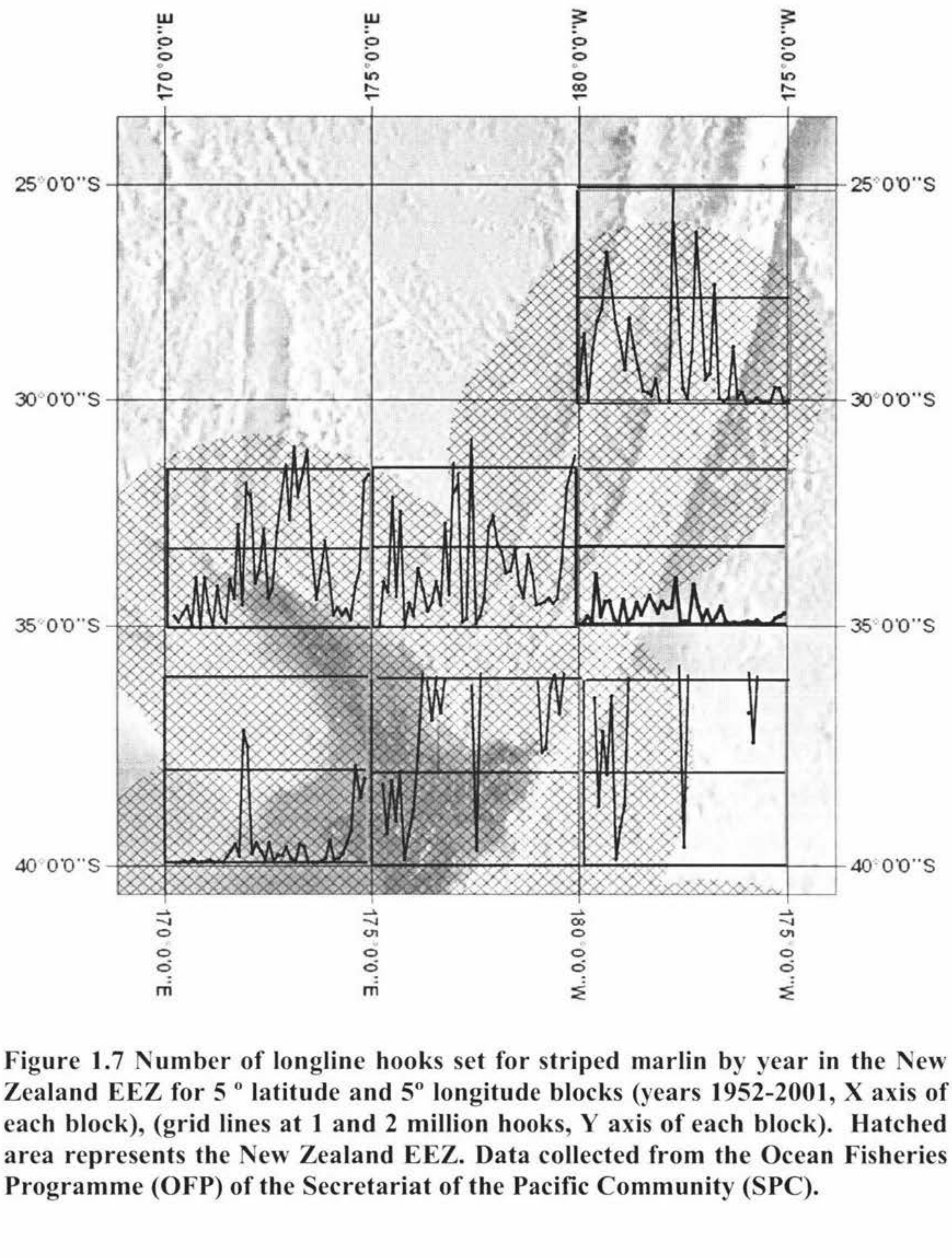

Figure 1.7 Number of longline hooks set for striped marlin by year in the New Zealand EEZ for 5 ° latitude and 5° longitude blocks (years 1952-2001, X axis of each block), (grid lines at 1 and 2 million hooks, Y axis of each block). Hatched area represents the New Zealand EEZ. Data collected from the Ocean Fisheries Programme (OFP) of the Secretariat of the Pacific Community (SPC).

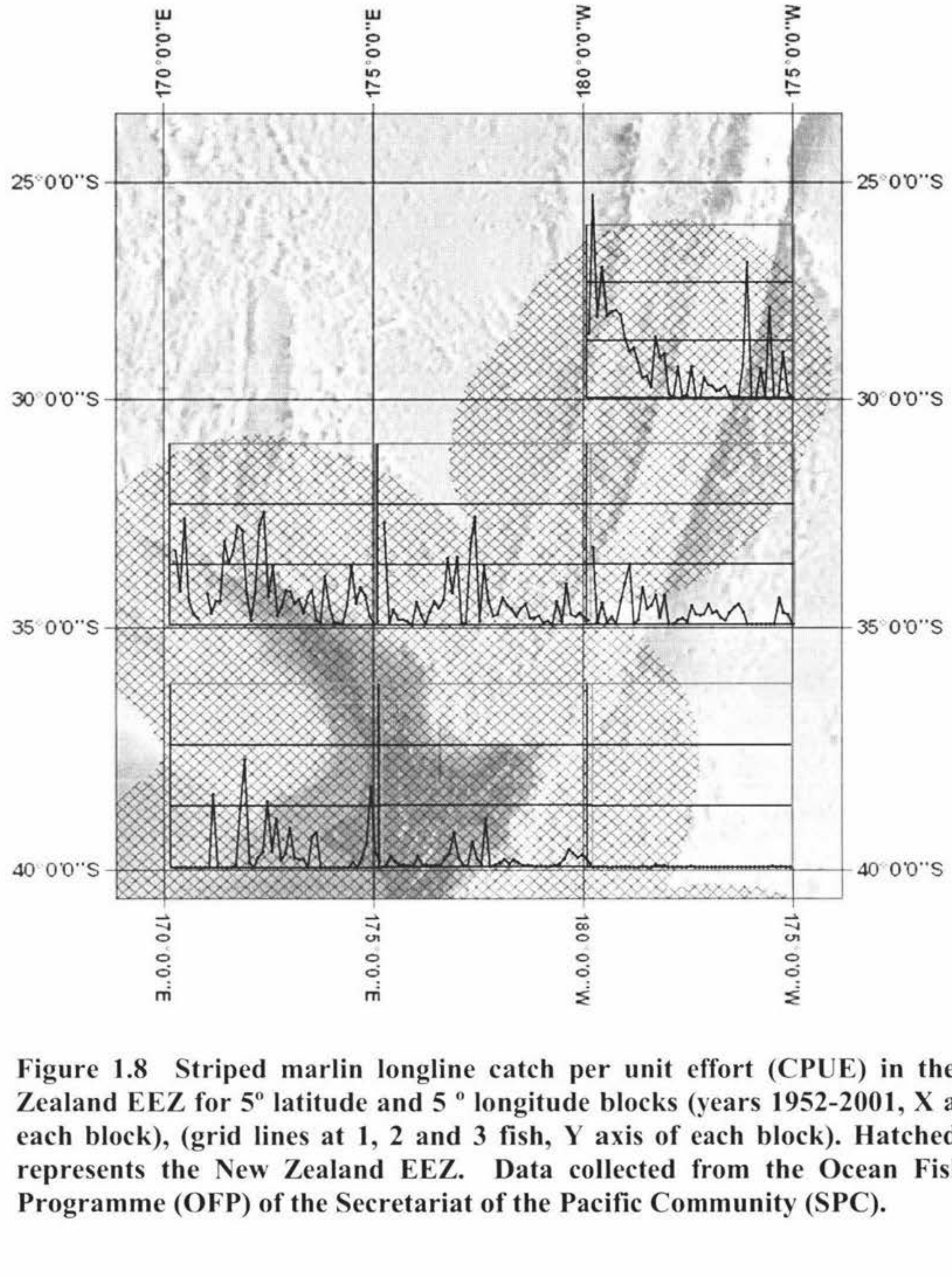

Figure 1.8 Striped marlin longline catch per unit effort (CPUE) in the New Zealand EEZ for 5° latitude and 5 ° longitude blocks (years 1952-2001, X axis of each block), (grid lines at 1, 2 and 3 fish, Y axis of each block). Hatched area represents the New Zealand EEZ. Data collected from the Ocean Fisheries Programme (OFP) of the Secretariat of the Pacific Community (SPC).

1.10 Recreational Fisheries

Striped marlin are one of the worlds most sought after big game fishes and are targeted by sport fishers throughout the Pacific and in several locations of the Indian Ocean (van der Elst 1990; Whitelaw 2003; Kopf et al. unpublished). Major recreational fisheries exist in northern New Zealand; Cabo San Lucas, Mexico; Hawaii, United States; southern California, United States and New South Wales, Australia. Most fisheries are seasonal with peak catches occurring during the summer in both hemispheres. The New Zealand striped marlin fishery is unique because it is a recreational fishery only as commercial catch of marlin has been prohibited since 1987, and all commercial fishers must release marlin dead or alive within the EEZ.

The New Zealand fishery generally extends 25 km offshore while most fishing occurs within 16 km of the coast (Saul 1983). The first recorded striped marlin catch by rod and reel in New Zealand occurred in 1915 and by 1924 a marlin fishing club (The Bay of Islands Swordfish and Mako Shark Club) was established (Saul 1983). The fishery gained worldwide recognition by visits from the American author and fisherman, Zane Grey who deemed New Zealand the "Anglers Eldorado". This fishery consistently produces some of the worlds largest striped marlin and is the location of 16 of the 22 line class world records (IGFA 2004; *see* Chapter 2).

Until the late 1970's the primary method of capture was drifting or trolling baits but has subsequently changed to trolling surface lures at speeds of 4 to 10 knots (Holdsworth & Saul 2004). Tag-and-release programmes in which fishers tag, release and most importantly recover striped marlin have been adopted by most major recreational fisheries including New Zealand. However, recovery rates of striped marlin are among the lowest of all pelagic fishes and are less than 1% (183/25,555) (*see* Chapter 3). The New Zealand tagging programme has been in place since 1974 and approximately 68 striped marlin have been recovered while 12, 418 have been released. In 2004, 1019 striped marlin were tagged and released which accounts for approximately 65% of the recreational catch (Holdsworth & Saul 2004).

The New Zealand recreational fishing season begins in December and persists through until May. The number of reported striped marlin catches in New Zealand's recreational fishery generally ranges from 1200 to 2000 per annum but has a high seasonal variability. The catch rate in New Zealand's recreational fishery ranges from 0.053 to 0.269 striped marlin per charter boat day (Holdsworth et al. 2003). The exact number of private boats which fish for marlin is unknown but there are approximately 100 professionally licensed vessels between 11 and 18 metres in length (Kingett-Mitchell 2002). This fishery generated an estimated $17 million NZD in gross output during the year 2000-2001 in which spending was negatively affected by poor weather (Kingett-Mitchell 2002).