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Tini a Tangaroa

# Characterisation and catch per unit effort of striped marlin in New Zealand.

New Zealand Fisheries Assessment Report 2018/30

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## EXECUTIVE SUMMARY

**Holdsworth J.C.; Kendrick, T.H.; Domeier, M. (2018) Characterisation and catch per unit effort of striped marlin in New Zealand.**

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This project updates the available data from commercial and recreational data for striped marlin caught in New Zealand waters. The total number of striped marlin landed or released by all fleets since 1979–80 ranges from 1400 to 2500 in most years. There are a few years with higher recorded catch and a period of low catches in the late 1980s and early 1990s. Since 1979 the average annual striped marlin catch reported in New Zealand has been 1804 (sd 693).

The commercial catch reporting data are incomplete due to inconsistent reporting by some of the foreign licenced surface longline vessels prior to 1980 and the requirement since 1988 for domestic vessels to release all striped marlin. The striped marlin catch which is largely a bycatch of bigeye and swordfish in the northern part of the New Zealand EEZ, has limited coverage in the observer database which is focused on the autumn and winter southern bluefin tuna fishery further south.

The New Zealand Sport Fishing Council (NZSFC) compiles annual sport fish tallies for the main sport fish species from 57 gamefishing clubs around New Zealand. These records contain a reasonably complete record of recreational striped marlin catch from a long-established target fishery and have therefore been used to provide an estimate of the national recreational landed catch. However, under-reporting also affects these data, particularly in the last 10 years. The New Zealand Gamefish Tagging Programme database was used to provide the number of striped marlin recorded as tagged and released from the recreational fishery.

The individual weights of recreationally caught marlin are recorded by gamefish clubs, with some records going back to the start of the fishery in the 1920s. Prior to 1988 a high proportion of the recreational catch was landed and accurately weighed. Since the early 1990s 60% of all striped marlin caught by recreational anglers have been tagged and released. Recreational fishers estimate weight for fish brought alongside the boat and the accuracy of these estimates cannot be assured. The average annual striped marlin weights for three of the oldest deep sea angling clubs has declined since the late 1950s.

There have been 24 393 striped marlin tagged and released in New Zealand waters since 1975. Of these 82 have complete release and recapture records, with most reported within a few months of release by sport fishers in New Zealand. To date 28 striped marlin have been recaptured outside New Zealand waters, with all but one from surface longline vessels. Recapture locations are spread across the southwest Pacific Ocean and Tasman Sea but not beyond. Electronic tags have been deployed on 61 striped marlin around New Zealand, with a high proportion of the daily location data from the first and second quarter (January to June). The dispersal of striped marlin from conventional and electronic tags is similar, with movement from New Zealand across the subtropical southwest Pacific Ocean from Australia to French Polynesia.

Recreational charter boat catch and effort information was collected using an annual postal survey of East Northland charter boat skippers from 1974–75 to 2005–06. The national Billfish Logbook Programme has collected daily catch and effort information since 2006–07. A subset of the logbook data has been used to extend the East Northland CPUE series since 2007.

Recreational CPUE was standardised using a negative binomial model, fitted to all data including zero catches. Fishing year was forced as the first variable but nevertheless explained most of the variance in the catch (35.5%). The effort term *days fished* entered the model second, explaining an additional 26% of the variance and was followed by *vessel* (13%). Overall there is an increasing trend in CPUE following the introduction of the billfish moratorium in 1987 to the mid-1990s and a decreasing trend since then.

A similar negative binomial model was used to standardise the 11 years of billfish logbook data. There were more explanatory variables available and fishing year explained just 3% of the variance in the catch. Vessel was the most influential variable, explaining an additional 23.4% of the variance and was followed by fishing area (*zone* 4.8%) and *hours fished* (1.5%). The final model explained 33.4% of the variance and the standardised CPUE index showed similar trends to the East Northland charter boat index.

While the recreational indices show trends in abundance and availability of striped marlin in New Zealand they suffer from limited spatial coverage of the data and a limited number of records. There are some quite large changes in availability of striped marlin from year to year which appear in all indices. These may be indicative of changes in abundance or recruitment in some part of the south western Pacific stock but the scale may be amplified by annual variability in oceanographic conditions.

# 1. INTRODUCTION

## 1.1. Objectives

Overall objectives:

1. To determine the feasibility of using CPUE from the recreational fishery to develop an index of relative abundance for striped marlin in New Zealand waters.

Specific objectives:

1. To characterise the recreational fishery for striped marlin in NZ waters.
2. To carry out unstandardised and standardised CPUE analyses of catch and effort data from the recreational striped marlin fishery in NZ waters

## 1.2. Overview

Striped marlin (*Kajikia audax*) (Philippi, 1887), is a highly migratory species widely distributed through the Pacific and Indian Oceans. It is one of five species of istiophorid billfish in the Pacific Ocean and all five of these occur in New Zealand waters where striped marlin is most common (Roberts et al. 2015). Collette et al. (2006) revised the generic classification for striped marlin and phylogeny of the billfishes. The revised classification places white marlin and striped marlin together in a single genus (*Kajikia*), which reflects the close evolutionary relationship between the two species (Graves & McDowell 2003). The former genus classification of striped marlin (*Tetrapturus*) is now applicable only to the spearfishes.

Based on the observed distribution of larval striped marlin, spawning occurs in spring in the southwest Pacific Ocean (10–30ºS), mainly in November and December (Nakamura 1985). Striped marlin display very high initial growth rates in the southwestern Pacific, with fish attaining 70–75% of their maximum length by the second year of life (Kopf et al. 2011) and mature at around 140–180 cm eye fork length (EFL) and 27–40 kg (Skillman & Yong 1976, Nakamura 1985, Kopf 2011). Females in the Coral Sea release multiple batches of up to 4.1 million hydrated oocytes per spawning event or about 29.7 ± 8 oocytes per gram of body weight (Kopf et al. 2012).

The spatial distribution of spawning striped marlin was significantly different from mature resting individuals which suggests that striped marlin have discrete spawning grounds. After spawning in the Coral Sea during the fourth quarter of the year, mature fish migrate south to more productive sub-tropical waters while juveniles generally stay in warmer subequatorial waters. Tagging with conventional and electronic tags in the SWPO has mostly occurred in the summer foraging grounds off New Zealand and New South Wales (Holdsworth et al. 2009, Holdsworth et al. 2016, Pepperell 1990). New Zealand tagged fish have been recaptured widely throughout the southwest Pacific Ocean, but not beyond. A third of all recaptures have been made 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.

Unvalidated maximum age estimates for striped marlin have ranged from 8 in New Zealand (Davie & Hall 1990) to 11 and 12 years in Mexico (Melo-Barrera et al. 2003) and Hawaii (Skillman & Yong 1976) respectively. Estimated ages of striped marlin from New Zealand ranged from 2 to 8 years in fish ranging in length from 2000 mm to 2871 mm LJFL. (Kopf et al. 2011).

The accuracy of historical catch statistics for striped marlin worldwide is uncertain because istiophorid billfishes have frequently been grouped together, without individual species recognition (Bromhead et al. 2004). The commercial longline catch of striped marlin in the southwest Pacific Ocean (SWPO) peaked at over 12 000 t a year in the 1950s. It has since declined to less than 2500 t annually since the

1980s. Striped marlin is also an important recreational species throughout the region (Bromhead et al. 2004, Holdsworth & Kopf 2011).

### 1.3. Description of the fishery

New Zealand has a long established and internationally recognised recreational fishery for large striped marlin from January to May. Recreational sport fishing clubs have kept detailed catch records for pelagic gamefish for many years, in some cases since 1924–25 (using a July to June fishing year). Recreational charter boats have been the mainstay of the fishery for many years, with competition to be the top boat for the season providing an incentive to record all caught marlin.

The New Zealand Sport Fishing Council (NZSFC) publishes annual tallies of landed gamefish from 57 affiliated sport fishing clubs. Since 1975 New Zealand anglers have been encouraged to tag and release striped marlin as part of a Ministry coordinated research project. For the last 25 years 59% of all striped marlin recorded by sport fishing clubs have been tagged and released. The tagging database contains a good record of where and when these fish were tagged but only estimated weights are available for these fish. In New Zealand no recreational catch can be sold but landed striped marlin are utilized as food for family and friends.

Recreational fishers target marlin around the North Island from Taranaki on the west coast to Poverty Bay on the east coast. However, the most concentrated effort is expended off Northland, including the banks around the Three Kings Islands in the Far North (Figure 1). The Three Kings area, north of mainland New Zealand, has been developed as a productive fishery, since the late-1980s, and in some years has contributed over half of the national catch of striped marlin (Holdsworth & Kopf 2005). It is accessed by long-distance charter and private vessels operating out of east Northland ports. In recent years the number of large charter boats has declined and the number of trailer boats engaged in the fishery has increased dramatically.

Japanese surface longline vessels began targeting pelagic species, including striped marlin, north of New Zealand in the late 1950s. Large numbers of vessels were attracted to New Zealand waters during the 1960s to catch southern bluefin tuna (*Thunnus maccoyii*). During the 1970s some of the fleet along with vessels from Korea took up licences to fish part of the year in northern New Zealand waters where bigeye and albacore tuna were the main target species.

After three very poor years in the recreational striped marlin fishery, regulations and foreign licence conditions were passed in 1987 prohibiting commercial vessels from retaining billfish caught in the Auckland Fisheries Management Area (referred to as the Billfish Moratorium). In 1991 the Billfish Moratorium was replaced with amendments to the regulations that allowed commercial vessels to retain broadbill swordfish, but prohibited the retention of istiophorid billfish on commercial vessels throughout the EEZ.

There was a rapid expansion New Zealand domestic surface longline effort in the 1990s. Tuna fisheries in New Zealand were the last significant fisheries with unrestricted entry and outside the Quota Management System (QMS). Tunas and swordfish, except for southern bluefin tuna, were not subject to any catch restrictions up to October 2004. All retained catch from surface longlining was required to be reported on Tuna Longline Catch Effort Returns (TLCER). A requirement to report marlin caught and released by commercial vessels was introduced in the mid 1990s. Despite this, striped marlin have been under-reported by some commercial fishers (Francis et al. 2000, Holdsworth & Kendrick 2012).

In October 2004, bigeye, Pacific bluefin, southern bluefin, and yellowfin tunas, and swordfish were introduced into the QMS, with swordfish changing from a by-catch only to a legitimate target species. Following the introduction of quotas the number of surface longline vessels declined markedly. By 2008 the number of longline vessels operating in New Zealand had declined to 35 from around 150 in 2002.

# 2. DATA SOURCES AND METHODS

## 2.1. Recreational catch, effort and CPUE

The recreational catch of striped marlin has been recorded by gamefish clubs and published in their annual reports for many years. 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 and weights for disqualified fish are also recorded. The New Zealand Sport Fishing Council (NZSFC) is an umbrella group for gamefish clubs and produces a yearbook with New Zealand line class records and catch tallies for all affiliated clubs. These records are used as the best estimate of national recreational landed catch for billfish.

The Bay of Islands has been a highly regarded tourist and sport fishing area for many years. The Bay of Island Swordfish Club has published annual catch records since 1925. Records from 1926 and 1928 have been lost and there are gaps in the early 1930s (Great Depression) and the early 1940s (World War II). Individual catch records have also been captured from Whangaroa Big Gamefish Club since 1927, Whangarei Deep Sea Anglers Club since 1955, and Tauranga Game Fishing Club since 1972. The electronic database includes individual fish weights, date of capture and name of vessel, and in recent years fishing area and fish tagged and released. The New Zealand Gamefish Tagging Programme was initiated in 1975 and the database includes all fish reported as tagged and released. Catch in numbers of fish and weight have been summarised by year for striped marlin inside New Zealand fisheries waters (200 n. miles).

The Ministry of Agriculture and Fisheries conducted an annual postal survey of East Northland charter boat skippers between 1977 and 1996. This survey 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. With support from various organisations including the Ministry of Fisheries and the New Zealand Marine Research Foundation the postal survey was continued for a further 11 years. In 2006–07 a national billfish logbook scheme was introduced to collect daily catch and effort information as well as detailed location and environmental data. A subset of logbook records came from East Northland charter skippers some of whom had been involved in the previous postal survey (Holdsworth et al. 2007). Core vessels with five or more years of data were selected and their catch and effort data for the East Northland survey area extracted. These criteria resulted in a core fleet size of 51 vessels which took 85% of the surveyed catch. A negative binomial model was fitted to all data including zero catches, with a forward stepwise selection of model terms made on the basis of the Akaike Information Criterion (AIC) using year, vessel, vessel type, and home port as potential explanatory variables.

The Billfish Logbook Programme enlists private and charter skippers from all regions who target marlin 10 days or more per year. Daily catch and hours fished is collected along with location and environmental variables. This analysis is the first to model the daily CPUE on it own. There are 11 years of data and the core fleet was defined as those vessels that had fished for at least 10 trips in each of at least 5 years. This resulted in a core fleet size of 31 vessels which took 72% of the logbook catch. A negative binomial model was fitted to all data including zero catches, with a forward stepwise selection of model terms made on the basis of the Akaike Information Criterion (AIC) using year, month, area fished, vessel, fleet (charter or private), target species, hours fished, and noon sea surface temperature as potential explanatory variables.

The effect of the variables accepted into the two models is examined with the aid of Coefficient-Distribution-Influence (CDI) plots (Bentley et al. 2011). These plots consider the combined effect of the coefficients for each level of the factor and the distribution of the underlying data across time to calculate the influence of a variable on moving the standardised index away from the nominal CPUE.

## 2.2. Commercial catch

Commercial catch reported by fleet and year is taken from the New Zealand country report to the WCPFC. Landed and discarded fish are reported separately. Various catch and effort forms have been used over the years to collect landed catch. The Billfish Moratorium introduced in 1987 and subsequent regulations in 1991 prohibit commercial vessels from retaining istiophorid billfish. A requirement to report marlin caught and released on domestic commercial vessel was introduced in the mid 1990s. Despite this, striped marlin have been under-reported by some commercial fishers (Francis et al. 2000, Holdsworth & Kendrick 2012). Almost all striped marlin by-catch is taken on surface longlines with a few fish reported each year from purse seine vessels.

## 2.3. Tagging data

The New Zealand Gamefish Tagging Programme (NZGTP ) was initiated by the Ministry of Agriculture and Fisheries in 1975 following requests from gamefish clubs. Fishers are supplied with numbered spaghetti tags to implant in caught fish prior to release. Several tag types have been used. Floy and Hallprint SSD tags have stainless steel tag heads capable of being implanted with the same slotted stainless steel applicator. Since 2005 Hallprint PIMA (plastic head intra-muscular) tags with a nylon double barbed anchor have been made available for tagging billfish. Programme coordinators provide guidance on the main species to tag and how to return catch details to their club or to the address printed on the back of the tag card. More striped marlin have been tagged in the NZGTP than any other species. The programme coordinator maintains a database of all the release and recapture information. When a recapture is reported this is matched with the release information and the fishers involved in release and recapture in formed abut time at liberty, movement and growth.

Generally, cooperative tagging programmes aim to provide basic information on movement and migration patterns; in some instances, age, growth, and longevity; and stock structure for defining management units (Ortiz et al. 2003). These programmes have gained widespread support from recreational anglers and often provide the only logistically and economically feasible way to tag large numbers of billfish (Pepperell 1990).

Over the last 15 years there have been several projects in the South Western Pacific that deployed satellite linked electronic tags. Data from three sources are compiled and summarised in this report. The New Zealand Marine Research Foundation, New Zealand Sport Fishing Council, Stanford University, Massey University and University of Auckland funded several projects between 2003 and 2008 with data received from 30 striped marlin tagged in New Zealand. Light level geolocation estimates and sea surface temperatures (SST) reported by the pop-up archival transmitting (PAT) tags were used as inputs into ukfsst, a Kalman filter developed by Lam et al. (2008). In addition 22 fish also had a smart position or temperature (SPOT) tag attached to the caudal fin. Both types of tag were manufactured by Wildlife Computers (Redmond, WA, USA). All fish were caught on lures using a rod and reel. Only fish in good condition were selected for tagging.

The Marine Conservation Science Institute led by Michael Domeier provided data from 41 PAT tags from striped marlin tagged in 2004 and 2005 in Australia and New Zealand.

Data from a further three striped marlin tagged in New Zealand as part of the IGFA great marlin race in 2017 are also included. Tag attachment and retention are a significant problem for achieving successful long-term deployments on striped marlin

## 2.4. Biological data

Club weigh stations in New Zealand are useful locations to collect biological samples. This has included length, weight, and sex information, collection of hard parts for ageing studies and tissue samples for genetic and stable isotope studies. We compile and summarise the available striped marlin length, weight, and sex data collected in New Zealand.

Several studies record striped marlin stomach contents (Morrow 1953, Baker 1966, Saul 1984, Kopf 2005) and these are compiled into a single table showing the number of each species observed and the proportion of striped marlin stomachs containing that species.

## 3. RESULTS

### 3.1. Striped marlin catch

The annual catch of striped marlin reported by all methods in New Zealand fisheries waters from 1979–80 onwards range from a low of 771 in 1987–88, the first year of the Billfish Moratorium, to 4006 in 1998–99 (Table 1). Prior to this, the best information available comes from the catch records for the foreign licenced Japanese surface longline fleet holding southern licences. These licences covered all New Zealand waters (including around the South Island) for southern bluefin tuna (Haddon 1990) (Table 2). Catch records for these vessels are considered to be reliable, but records for the Japanese northern licenced vessels (restricted to north of 34° S on the east coast and 38° S on the west coast) were of low to moderate reliability (Haddon 1990). There were fewer northern licence vessels and they arrived after the summer season, mainly targeting bigeye tuna and swordfish.

The total number of striped marlin landed or released in New Zealand waters since 1979–80 shows no obvious trend with most years in the range 1400 to 2500 fish per year (Figure 2). The mean catch for the 37 years to 2015–16 is 1804 fish (sd 693). Two high catch years were in the summer of 1982 and 1999. Lower catches were reported in the late 1980s and early 1990s following the introduction of the billfish moratorium which closed the northern surface longline fishery in the Auckland Fisheries Management Area to all foreign licenced vessels from 1 October to 31 May each year.

There has been a structural change in the recreational sport fishery in the last 10 years. The number of large long range charter boats which record all their catch has declined. The number of well-appointed trailer boats targeting pelagic gamefish has increased. These can launch at a wide variety of locations and are less likely to be affiliated to a club than owners of vessels moored at one port. As non-members they may still choose to weigh their fish at a club, where these fish will be recorded. Anecdotally, however, there have been a lot of new entrants to the gamefish fishery and the unreported billfish landed catch has increased (Holdsworth & Saul 2017a).

Striped marlin weigh station catch records from three long established East Northland sport fishing clubs have been summarised by year in Table 3. Prior to 1988 almost all weights are for landed fish. In 1988 clubs introduced a voluntary minimum weight of 90 kg to promote tag and release. Anglers estimate the weight of fish in the water prior to release. There is increased uncertainty in these estimates, but they are included in overall estimates of mean weight (Table 3) as a higher proportion of small fish are released (Figure 3).

Striped marlin catch in New Zealand are large by international standards and 20 of the 22 International Gamefish Association (IGFA) line weight records are for fish caught in New Zealand waters. The average weight of striped marlin reported by the three East Northland clubs shows a decline from about 120 kg in the 1920s and 1930s to about 90 kg in the late 1990s. Over the last 15 years annual average weights have mostly been about 100 kg (Table 3). Possibly most fishing was in cooler coastal waters in the early years of this fishery and a higher proportion of large striped marlin are caught in cooler water (Ghosn et.al 2012). In some warm years there are more smaller fish in the catch and this tends to increase the number available to fishers and the average weight dips– as it did in 1989 and 1999.

## 3.2. Striped marlin CPUE

Surveys of recreational striped marlin catch and effort have been conducted since 1977. Initially these were simple, low cost, annual postal surveys of East Northland charter boat skippers. They provided catch and effort on a coarse scale (striped marlin catch and vessel days per year) and in a limited area from North Cape to Bream Bay, effectively New Zealand fisheries Statistical Areas 002, 003 and 004. This excluded catch and effort from the productive Three Kings fishery which started in the early 1990s in the Far North region of New Zealand (Figure 1). A national billfish logbook programme was designed with input from charter boat organisations and experienced private skippers in 2006 (Holdsworth et al. 2007) which has replaced the postal survey.

A total of 6017 stiped marlin were recorded in surveys of East Northland charter boat skippers from 1974–75 to 2005–06 and a further 2538 were recorded in the national Billfish Logbook Programme between 2006–07 to 2016–17 (Table 4).

### East Northland charter CPUE standardisation

A general linear model (GLM) was used to standardise annual striped marlin CPUE from East Northland charter boats using the postal survey data and a matching subset of data from the Billfish Logbook Programme. The core fleet was defined as those vessels that had fished at least once in at least five years.

A negative binomial model was fitted to all data including zero catches, with a forward stepwise selection of model terms made on the basis of the Akaike Information Criterion (AIC). The maximal set of model terms offered to the stepwise selection algorithm was:

~ *fyear + area + vessel + hulltype + poly(log(days), 3) + poly(log(length), 3)*

with the term *fyear* forced into the model. *Area* denotes the home port of the vessel, *hulltype* differentiates between vessels with planing hulls and displacement hulls, *length* is a polynomial term for the length of the vessel. Terms were only added to the model if they increased the percent deviance explained by at least 0.1%. Table 5 provides a summary of the changes in the deviance explained and in AIC as each term was added to the model. The final model formula was

~ *fyear + poly(log(days), 3) + vessel*

### National billfish logbook CPUE standardisation

For the GLM the core fleet was defined as those vessels that had fished for at least 10 trips in each of at least 5 years. This resulted in a core fleet size of 31 vessels which took 72% of the catch.

A negative binomial model was fitted to all data including zero catches, with a forward stepwise selection of model terms made on the basis of the Akaike Information Criterion (AIC). The maximal set of model terms offered to the stepwise selection algorithm was

~ . *fyear + month + zone + vessel + fleet + target + poly(log(duration), 3) + poly(temp, 3)*

with the term *fyear* forced into the model, *zone* split the North Island into four fishing areas (Figure 1), *fleet* separated charter from private vessels, *target* is the main target species, *duration* is hours fished per day, and *temp* is the sea surface temperature at noon. Terms were only added to the model if they increased the percent deviance explained by 0.1 %. Table 6 provides a summary of the changes in the deviance explained and in AIC as each term was added to the model. The final model formula was

*~ fyear + vessel + zone + poly(log(duration), 3) + poly(temp, 3) + month*

The annual East Northland charter index shows an increasing trend in standardised CPUE following the introduction of the billfish moratorium in 1987 to the mid-1990s and a decreasing trend back toward the long-term average (Figure 4, Table A1). There have been several relatively poor years since 2013–14. A number of long term East Northland charter operators are leaving the industry and new entrants and more private vessels have been recruited to the logbook scheme. Over the time series since 1975 there has been a strong decline in the number of days fishing for marlin per season across the fleet of East Northland charter boats - most obvious in the influence plot of the effort variable in Appendix A (Figure A3). The CPUE index based on daily billfish logbook data shows similar trends to the charter index over the last 11 years (Figure 4, Appendix B).

### 3.3. Striped marlin tagging and movement

The New Zealand Gamefish Tagging Programme contains data on 24 279 striped marlin tagged in New Zealand waters between 1980 and 2017 (Table 1). Details of methods and results are described in a number of Fisheries Assessment Reports (Holdsworth et al. 2016, Holdsworth & Saul 2014, 2017b). Most striped marlin tagged in New Zealand were caught between 33° S and 39° S between January and May. Small numbers have been tagged from surface longline vessels in winter months. Recaptures at lower latitudes are mainly from May to November (Holdsworth et al. 2016).

The first recapture reported was from a Japanese longliner in February 1989 from the north of the Marquesas Group. This 75 kg fish had been at liberty for 8 months and the displacement distance was 3200 nautical miles. There are 82 striped marlin with complete release and recapture records. Most recaptures from New Zealand are reported within a few months of release by sport fishers, with only 9% from recaptures made in a subsequent season.

There are 28 records of recaptures of striped marlin outside New Zealand waters with all but one from surface longline vessels. Recapture locations are spread across the southwest Pacific Ocean and Tasman Sea between 2° S and 37° S (Figure 5). So far no striped marlin tagged in the southwest Pacific have been recaptured beyond the southwest Pacific or Tasman Sea. Most striped marlin were recaptured within 10 months of release. Tag shedding is a problem with this species and this may be the reason for the short duration of most recaptures (Ortiz et al. 2003). Spawning is known to occur in the Coral Sea, in the Fiji Basin and in French Polynesia (Kopf et al. 2012) Recaptures of tagged striped marlin from the NZGTP have occurred in all three of these areas (Figure 5).

Electronic tags capable of transmitting to satellites can provide information on migratory pathways and potentially residence times in different regions of the southwestern Pacific and Tasman Sea. Daily locations are estimated where data is sufficient. For double tagged fish preference is given to daily locations estimated by the satellite-linked radio transmitting tail tags as these are more accurate than PSAT location estimates on the same day (Holdsworth et al. 2009). Tagging was carried out from 2003 to 2017 in the summer and autumn when striped marlin are available to the recreational fisheries in New Zealand and Australia. A total of 61 usable data sets are available for striped marlin tagged in New Zealand and 13 data sets from Australia. Most of the location data collected is from the first and second quarter and spread over several years (Table 7). Very few PSAT tags programmed to be deployed for 10 months or more made transmissions. As a result, location information for the third and fourth quarters is under represented. The general pattern is for striped marlin tagged in New Zealand and New South Wales is to migrate north during the second quarter and to be north of 30° S in the third quarter with some movement south again in December (Figure 6) (Chambers et al. 2013, Sippel et al. 2011).

### 3.4. Biological data

The average weight of striped marlin reported landed or tagged by the three East Northland clubs shows a decline from about 115 kg average in the 1950s to about 90 kg in the late 1990s (Figure 3). Since 1988–89 a high proportion of striped marlin have been tagged and released with weight estimated by the crew when the fish is alongside the boat. Undoubtedly this will have reduced the accuracy of the mean weights calculated from club records. Prior to 1989 fish were almost all weighed on certified scales by club weigh masters. NZSFC introduced a voluntary minimum size for striped marlin in 1988 to encourage fishers to tag and release 50% of the recreational catch. Consequently, more small marlin are tagged and the annual average weights of tagged fish from the three East Northland clubs is usually smaller than the average weight of landed fish (Figure 3, Table 3). The proportion of marlin tagged has decreased over the last ten years. A structural change in the fleet has contributed to this, with a shift away from long range charter boats tagging large numbers of marlin at the Three Kings toward many new entrants to the fishery in trailer boats that catch one or two fish per year.

Catch sampling at fishing club weigh stations has collected 800 striped marlin length weight and sex records since 1985 (Table 8). The smallest was a fish with 1760 mm lower jaw fork length (LJFL) and a greenweight of 33 kg. The largest was a fish with 2720 mm LJFL and a greenweight of 179 kg. Most striped marlin sampled in New Zealand are mature fish with immature fish more likely to be caught in the warmest years (Kopf 2005, Kopf et al. 2012). The length weight relationship derived from these data was published in 2005. There was no difference in L-W coefficients between sexes (P = .07), which resulted in the single negative allometric L-W equation: $W = 2E\text{-}08\ LJFL^{2.88}$ where LJFL is in millimetres (Kopf et al. 2005) (Figure 7). However, there is sexual dimorphism in striped marlin. Females display a larger average weight compared to males (Kopf et al. 2005) but the difference is not as prominent as seen in blue or black marlin. The proportion of females increases significantly with length class in striped marlin caught in the southwest Pacific Ocean.

Saury and squid (arrow squid and unidentified squid) were the most frequent food items observed in striped marlin stomachs, although overall a wide variety of mainly pelagic species were found (Morrow 1953, Baker 1966, Saul 1984, Kopf 2005). Saury was found in 47% of stomachs with food items, while 19% contained jack mackerel and 14% contained pilchards (Table 9). Arrow squid was found in 33% of stomachs with food items and unidentified squid beaks in 17% of fish, though there may be some overlap.

## 4. ACKNOWLEDGMENTS

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**Table 1: Commercial landings and discards of striped marlin (number of fish) in the New Zealand EEZ reported by fishing nation (CELRs and TLCERs), and recreational landings and number of fish tagged, by fishing year (1 October to 30 September).**

| Fishing | Japan | Japan | Korea | Philippine | Australia | NZ commercial | NZ Recreational | | Total |
|---|---|---|---|---|---|---|---|---|---|
| Year | Landed | Discarded | Landed | Discarded | Discarded | Discarded | Landed | Tagged | |
| 1979–80 | 659 | | | | | | 692 | 17 | 1 368 |
| 1980–81 | 1 663 | | 46 | | | | 792 | 2 | 2 503 |
| 1981–82 | 2 796 | | 44 | | | | 704 | 11 | 3 555 |
| 1982–83 | 973 | | 32 | | | | 702 | 6 | 1 713 |
| 1983–84 | 1 172 | | 199 | | | | 543 | 9 | 1 923 |
| 1984–85 | 548 | | 160 | | | | 262 | | 970 |
| 1985–86 | 1 503 | | 19 | | | | 395 | 2 | 1 919 |
| 1986–87 | 1 925 | | 26 | | | | 226 | 2 | 2 179 |
| 1987–88 | 197 | | 100 | | | | 281 | 136 | 714 |
| 1988–89 | 23 | | 30 | | | 5 | 647 | 408 | 1 113 |
| 1989–90 | 138 | | | | | 1 | 463 | 367 | 969 |
| 1990–91 | | 1 | | | | 6 | 532 | 232 | 771 |
| 1991–92 | | 17 | | | | 1 | 519 | 242 | 779 |
| 1992–93 | | | | | | 7 | 608 | 386 | 1 001 |
| 1993–94 | | | | | | 59 | 663 | 929 | 1 651 |
| 1994–95 | | | | | | 182 | 910 | 1 206 | 2 298 |
| 1995–96 | | | | | | 456 | 705 | 1 104 | 2 265 |
| 1996–97 | | | | | | 441 | 619 | 1 302 | 2 362 |
| 1997–98 | | | | | | 445 | 543 | 898 | 1 886 |
| 1998–99 | | | | | | 1 642 | 823 | 1 541 | 4 006 |
| 1999–00 | | 2 | | | | 798 | 398 | 791 | 1 989 |
| 2000–01 | | | | | | 527 | 422 | 851 | 1 800 |
| 2001–02 | | | | | | 225 | 430 | 771 | 1 426 |
| 2002–03 | | 3 | | 7 | | 205 | 495 | 671 | 1 381 |
| 2003–04 | | 1 | | | | 423 | 592 | 1 051 | 2 067 |
| 2004–05 | | | | | | 307 | 834 | 1 348 | 2 489 |
| 2005–06 | | | | | | 203 | 630 | 923 | 1 756 |
| 2006–07 | | | | | 9 | 152 | 688 | 964 | 1 813 |
| 2007–08 | | 1 | | | | 231 | 485 | 806 | 1 523 |
| 2008–09 | | | | | | 242 | 731 | 1 058 | 2 030 |
| 2009–10 | | | | | | 195 | 607 | 858 | 1 660 |
| 2010–11 | | | | | | 269 | 607 | 731 | 1 607 |
| 2011–12 | | | | | | 241 | 635 | 663 | 1 539 |
| 2012–13 | | 1 | | | | 227 | 744 | 858 | 1 830 |
| 2013–14 | | | | | | 202 | 620 | 519 | 1 341 |
| 2014–15 | | | | | | 371 | 696 | 1 086 | 2 153 |
| 2015–16 | | | | | | 562 | 900 | 1644 | 3 106 |
| Total | 11 597 | 26 | 656 | 7 | 9 | 8 063 | 22 143 | 24 393 | 67 456 |

**Table 2: Commercial landings from the Japanese southern licence fleet and landings and releases from four large sport fishing clubs by calendar year. Landings from Japanese northern licence fleet and other New Zealand sport fishing clubs are not available.**

| | Japan southern licence | New Zealand recreational | |
|---|---|---|---|
| | Landed | Landed | Tagged |
| 1967 | 467 | 149 | |
| 1968 | 230 | 160 | |
| 1969 | 1 846 | 202 | |
| 1970 | 2 021 | 75 | |
| 1971 | 6 186 | 82 | |
| 1972 | 1 791 | 158 | |
| 1973 | 934 | 88 | |
| 1974 | 2 991 | 209 | |
| 1975 | 2 568 | 242 | |
| 1976 | 3 364 | 284 | 3 |
| 1977 | 889 | 334 | 2 |
| 1978 | 594 | 452 | 7 |
| 1979 | 80 | 565 | 18 |

**Table 3: Striped marlin number, weight and mean weight for landed or released fish from the oldest three East Northland sport fishing clubs.**

| Year | Club catch numbers | Club total weight | Club mean weight | Year | Club catch numbers | Club total weight | Club mean weight |
|---|---|---|---|---|---|---|---|
| 1925 | 84 | 10 419 | 124.0 | 1972 | 119 | 12 874 | 108.2 |
| 1926 | | | | 1973 | 76 | 8 105 | 106.7 |
| 1927 | 143 | 17 006 | 118.9 | 1974 | 184 | 17 366 | 94.4 |
| 1928 | 22 | 2 608 | 118.6 | 1975 | 211 | 21 715 | 102.9 |
| 1929 | 135 | 15 682 | 116.2 | 1976 | 255 | 25 223 | 98.9 |
| 1930 | 194 | 22 610 | 116.5 | 1977 | 288 | 32 235 | 111.9 |
| 1931 | 38 | 4 683 | 123.2 | 1978 | 309 | 34 696 | 112.3 |
| 1932 | 23 | 2 626 | 114.2 | 1979 | 523 | 54 373 | 104.0 |
| 1933 | | | | 1980 | 652 | 68 311 | 104.8 |
| 1934 | 107 | 12 246 | 114.4 | 1981 | 597 | 59 157 | 99.1 |
| 1935 | 82 | 8 987 | 109.6 | 1982 | 673 | 73 476 | 109.2 |
| 1936 | 87 | 10 486 | 120.5 | 1983 | 659 | 71 230 | 108.1 |
| 1937 | 313 | 36 909 | 117.9 | 1984 | 510 | 50 058 | 98.2 |
| 1938 | 95 | 11 342 | 119.4 | 1985 | 217 | 21 371 | 98.5 |
| 1939 | 0 | | | 1986 | 325 | 32 526 | 100.1 |
| 1940 | 78 | 9 220 | 118.2 | 1987 | 210 | 21 518 | 102.5 |
| 1941 | 57 | 6 906 | 121.2 | 1988 | 346 | 36 281 | 104.9 |
| 1942 | | | | 1989 | 700 | 58 875 | 84.1 |
| 1943 | | | | 1990 | 727 | 67 671 | 93.1 |
| 1944 | | | | 1991 | 546 | 51 722 | 94.7 |
| 1945 | 108 | 12 762 | 118.2 | 1992 | 566 | 59 954 | 105.9 |
| 1946 | 78 | 8 690 | 111.4 | 1993 | 707 | 70 304 | 99.4 |
| 1947 | 196 | 22 077 | 112.6 | 1994 | 1175 | 108 495 | 92.3 |
| 1948 | 410 | 45 109 | 110.0 | 1995 | 1472 | 138 387 | 94.0 |
| 1949 | 618 | 65 947 | 106.7 | 1996 | 1133 | 105 874 | 93.4 |
| 1950 | 341 | 37 858 | 111.0 | 1997 | 941 | 94 298 | 100.2 |
| 1951 | 329 | 34 959 | 106.3 | 1998 | 863 | 80 654 | 93.5 |
| 1952 | 287 | 33 389 | 116.3 | 1999 | 1055 | 90 837 | 86.1 |
| 1953 | 335 | 39 887 | 119.1 | 2000 | 599 | 55 001 | 91.8 |
| 1954 | 259 | 30 326 | 117.1 | 2001 | 696 | 64 614 | 92.8 |
| 1955 | 298 | 34 925 | 117.2 | 2002 | 749 | 77 389 | 103.3 |
| 1956 | 276 | 31 848 | 115.4 | 2003 | 760 | 77 277 | 101.7 |
| 1957 | 278 | 32 654 | 117.5 | 2004 | 953 | 94 487 | 99.1 |
| 1958 | 402 | 46 816 | 116.5 | 2005 | 974 | 96 948 | 99.5 |
| 1959 | 186 | 21 414 | 115.1 | 2006 | 787 | 75 443 | 95.9 |
| 1960 | 164 | 18 279 | 111.5 | 2007 | 1028 | 99 283 | 96.6 |
| 1961 | 319 | 33 852 | 106.1 | 2008 | 590 | 58 483 | 99.1 |
| 1962 | 105 | 11 753 | 111.9 | 2009 | 1128 | 112 993 | 100.2 |
| 1963 | 122 | 12 575 | 103.1 | 2010 | 739 | 74 380 | 100.6 |
| 1964 | 122 | 13 599 | 111.5 | 2011 | 683 | 65 572 | 96.0 |
| 1965 | 145 | 16 418 | 113.2 | 2012 | 504 | 48 767 | 96.8 |
| 1966 | 124 | 13 346 | 107.6 | 2013 | 666 | 68 951 | 103.5 |
| 1967 | 74 | 8 460 | 114.3 | 2014 | 398 | 40 942 | 102.9 |
| 1968 | 96 | 10 305 | 107.3 | 2015 | 562 | 52 823 | 94.0 |
| 1969 | 140 | 15 554 | 111.1 | 2016 | 906 | 86 315 | 95.3 |
| 1970 | 46 | 4 992 | 108.5 | 2017 | 367 | 37 661 | 102.6 |
| 1971 | 47 | 4 176 | 88.8 | | | | |

**Table 4: The number of striped marlin recorded as landed or tagged in New Zealand and the number of stiped marlin recorded in surveys of East Northland charter boat skippers from a postal survey 1974–75 to 2005–06 and the national Billfish Logbook Programme 2006–07 to 2016–17.**

| | Number of striped marlin | | | |
|---|---|---|---|---|
| Fishing Year | New Zealand recreational catch | East Northland postal survey | National billfish logbook scheme | Proportion of catch surveyed |
| 1974–75 | 242 | 4 | | 0.02 |
| 1975–76 | 284 | 11 | | 0.04 |
| 1976–77 | 334 | 140 | | 0.42 |
| 1977–78 | 452 | 70 | | 0.15 |
| 1978–79 | 565 | 150 | | 0.27 |
| 1979–80 | 709 | 136 | | 0.19 |
| 1980–81 | 794 | 84 | | 0.11 |
| 1981–82 | 715 | 127 | | 0.18 |
| 1982–83 | 708 | 126 | | 0.18 |
| 1983–84 | 552 | 149 | | 0.27 |
| 1984–85 | 262 | 66 | | 0.25 |
| 1985–86 | 397 | 67 | | 0.17 |
| 1986–87 | 228 | 51 | | 0.22 |
| 1987–88 | 417 | 165 | | 0.4 |
| 1988–89 | 1 055 | 407 | | 0.39 |
| 1989–90 | 830 | 308 | | 0.37 |
| 1990–91 | 764 | 181 | | 0.24 |
| 1991–92 | 761 | 197 | | 0.26 |
| 1992–93 | 994 | 226 | | 0.23 |
| 1993–94 | 1 592 | 438 | | 0.28 |
| 1994–95 | 2 116 | 510 | | 0.24 |
| 1995–96 | 1 809 | 489 | | 0.27 |
| 1996–97 | 1 921 | 116 | | 0.06 |
| 1997–98 | 1 441 | 116 | | 0.08 |
| 1998–99 | 2 364 | 451 | | 0.19 |
| 1999–00 | 1 189 | 206 | | 0.17 |
| 2000–01 | 1 273 | 267 | | 0.21 |
| 2001–02 | 1 201 | 96 | | 0.08 |
| 2002–03 | 1 166 | 142 | | 0.12 |
| 2003–04 | 1 643 | 206 | | 0.13 |
| 2004–05 | 2 182 | 181 | | 0.08 |
| 2005–06 | 1 553 | 134 | | 0.09 |
| 2006–07 | 1 640 | | 270 | 0.16 |
| 2007–08 | 1 291 | | 316 | 0.24 |
| 2008–09 | 1 799 | | 384 | 0.21 |
| 2009–10 | 1 465 | | 276 | 0.19 |
| 2010–11 | 1 338 | | 185 | 0.14 |
| 2011–12 | 1 298 | | 176 | 0.14 |
| 2012–13 | 1 602 | | 243 | 0.15 |
| 2013–14 | 1 139 | | 206 | 0.18 |
| 2014–15 | 1 782 | | 209 | 0.12 |
| 2015–16 | 2 430 | | 207 | 0.09 |
| 2016–17 | 970 | | 66 | 0.07 |
| Total | 49 267 | 6 017 | 2 538 | |

**Table 5: Summary of stepwise selection for the East Northland charter vessel model. Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.**

| Term | DF | Log likelihood | AIC | Deviance pseudo-$R^2$ (%) | Nagelkerke pseudo-$R^2$ (%) | |
|---|---|---|---|---|---|---|
| fyear | 43 | -1 626 | 3 338 | 35.48 | 37.88 | * |
| poly(log(days), 3) | 46 | -1 481 | 3 055 | 61.53 | 63.25 | * |
| vessel | 96 | -1 367 | 2 926 | 74.50 | 75.79 | * |

**Table 6: Summary of stepwise selection for the daily billfish logbook vessel model. Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.**

| Term | DF | Log likelihood | AIC | Deviance pseudo-$R^2$ (%) | Nagelkerke pseudo-$R^2$ (%) | |
|---|---|---|---|---|---|---|
| fyear | 11 | -3 935 | 7 892 | 2.84 | 2.19 | * |
| vessel | 41 | -3 485 | 7 053 | 26.24 | 21.28 | * |
| zone | 44 | -3 376 | 6 840 | 31.00 | 25.48 | * |
| poly(log(duration), 3) | 47 | -3 341 | 6 777 | 32.45 | 26.78 | * |
| poly(temp, 3) | 50 | -3 330 | 6 760 | 32.93 | 27.20 | * |
| month | 57 | -3 317 | 6 748 | 33.44 | 27.69 | * |

**Table 7: Number of daily locations from striped marlin carrying electronic tags in the southwest Pacific Ocean and Tasman Sea by country of release, year and quarter (Quarter 1 = Jan-Mar).**

| Release location and year | | Quarter | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | Total |
| Australia | | | | | | |
| | 2003 | | 17 | | | 17 |
| | 2004 | 72 | 381 | 66 | 17 | 536 |
| | 2005 | | 143 | | | 143 |
| Total | | 72 | 541 | 66 | 17 | 696 |
| | | | | | | |
| New Zealand | | | | | | Total |
| | 2003 | 79 | 19 | | | 98 |
| | 2004 | 572 | 715 | 328 | 59 | 1 674 |
| | 2005 | 41 | 214 | 2 | | 257 |
| | 2006 | 183 | 297 | 25 | | 505 |
| | 2007 | 129 | 61 | | | 190 |
| | 2008 | 51 | 49 | | | 100 |
| | 2017 | 31 | 88 | | | 119 |
| Total | | 1 086 | 1 443 | 355 | 59 | 2 943 |

**Table 8: Length, weight and sex data collected from striped marlin caught in the New Zealand recreational fishery by year.**

| Year | Female | Male | Blank | Total |
|---|---|---|---|---|
| 1985 | 11 | 9 | | 20 |
| 1986 | 2 | 9 | | 11 |
| 1987 | 17 | 13 | | 30 |
| 1988 | 67 | 28 | | 95 |
| 1989 | 75 | 84 | | 159 |
| 1992 | 48 | 32 | | 80 |
| 1993 | 63 | 47 | | 110 |
| 1994 | 71 | 46 | | 117 |
| 2004 | 17 | 22 | 2 | 41 |
| 2006 | 56 | 28 | 3 | 87 |
| 2007 | 33 | 12 | | 45 |
| 2008 | 3 | 2 | | 5 |
| Total | 463 | 332 | 5 | 800 |

**Table 9: Number of stomachs and percent of striped marlin stomachs containing each prey item from four stomach contents analysis projects in New Zealand.**

| Common name | Scientific name | Baker (1966) (N=38) | | Kopf 2005 (N=20) | | Morrow (1953) (N=38) | | Saul (1983) (N=147) | | Overall (N=243) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | No. | % | No. | % | No. | % | No. | % | No. | % |
| 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 & Trachurus novaezelandiae* | 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 |

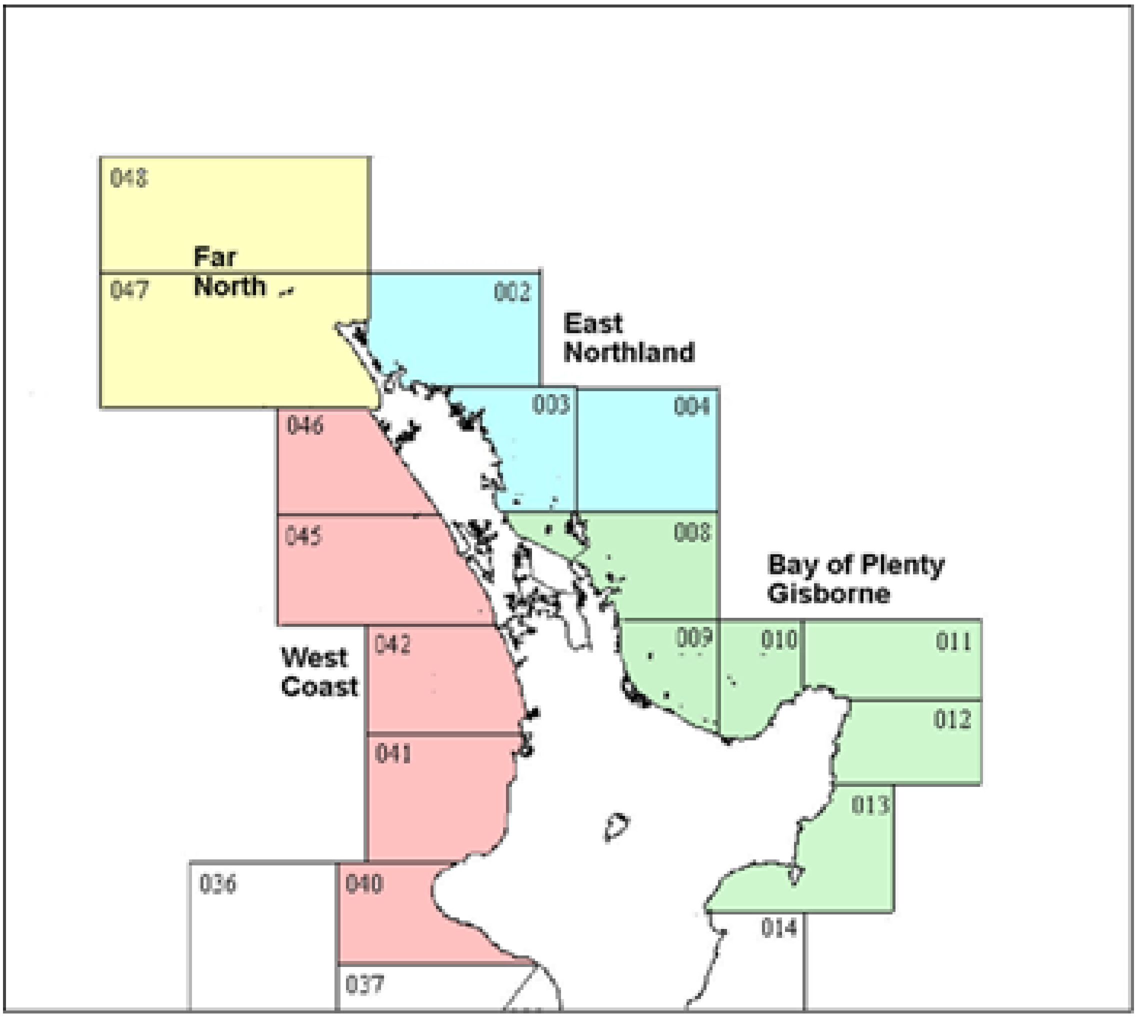


**Figure 1: The four regions and corresponding fisheries statistical areas in Northern New Zealand used in this report.**

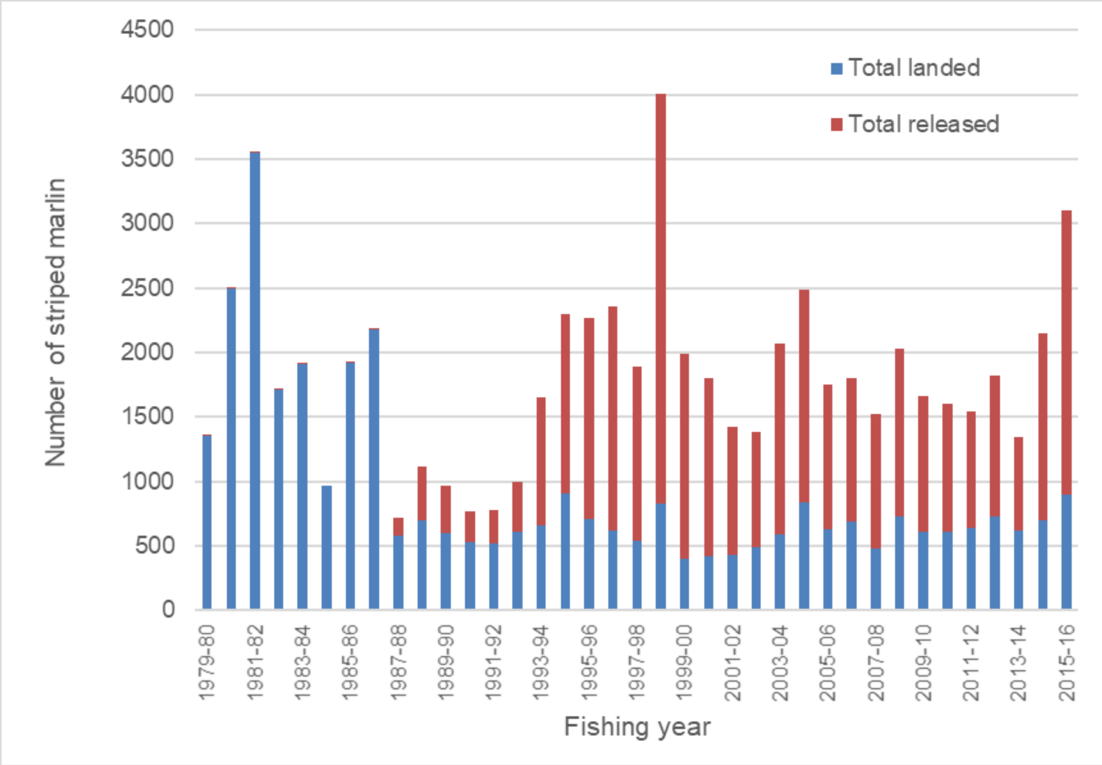


**Figure 2: The number of striped marlin from commercial and recreational records of fish landed and released from New Zealand waters.**

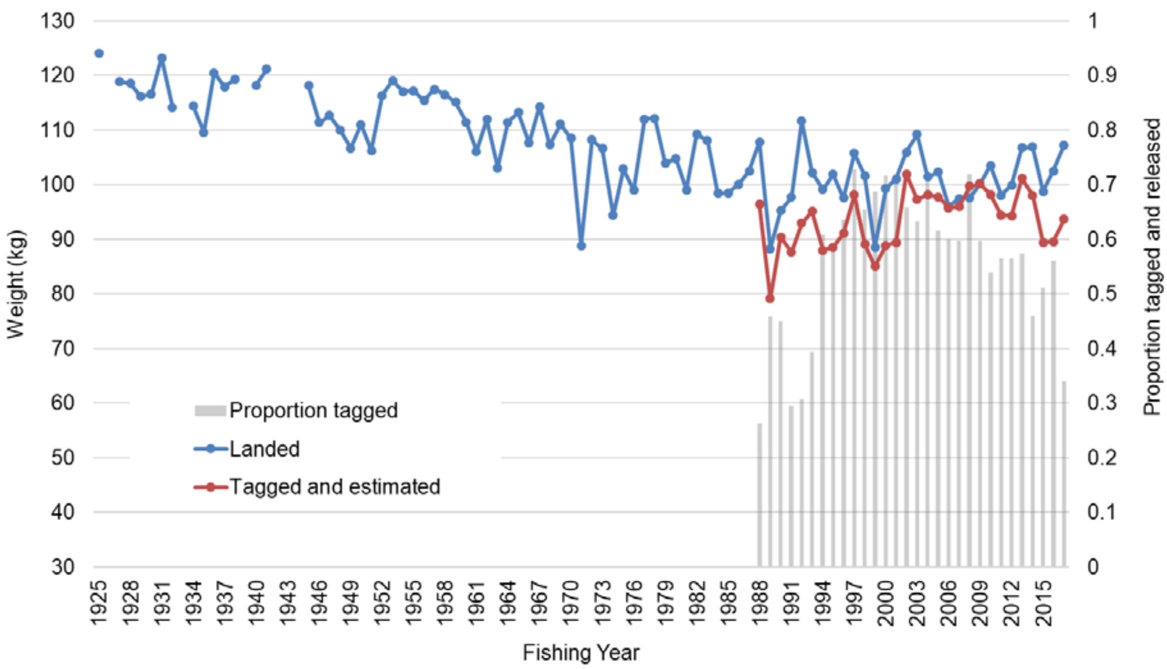


**Figure 3: The annual average weight of striped marlin landed or tagged and released by sport fishers from three East Northland clubs and the proportion of striped marlin tagged and released.**

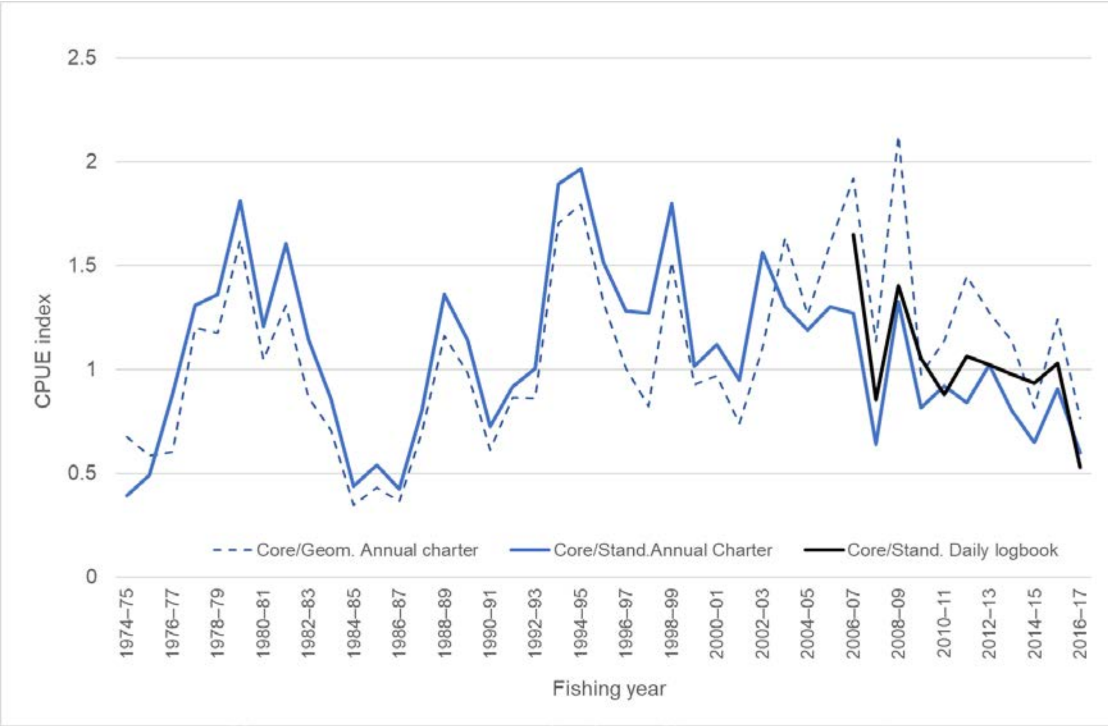


**Figure 4: Comparison between the negative binomial model of annual East Northland recreational charter boat CPUE and billfish logbook daily CPUE since 2006–07.**

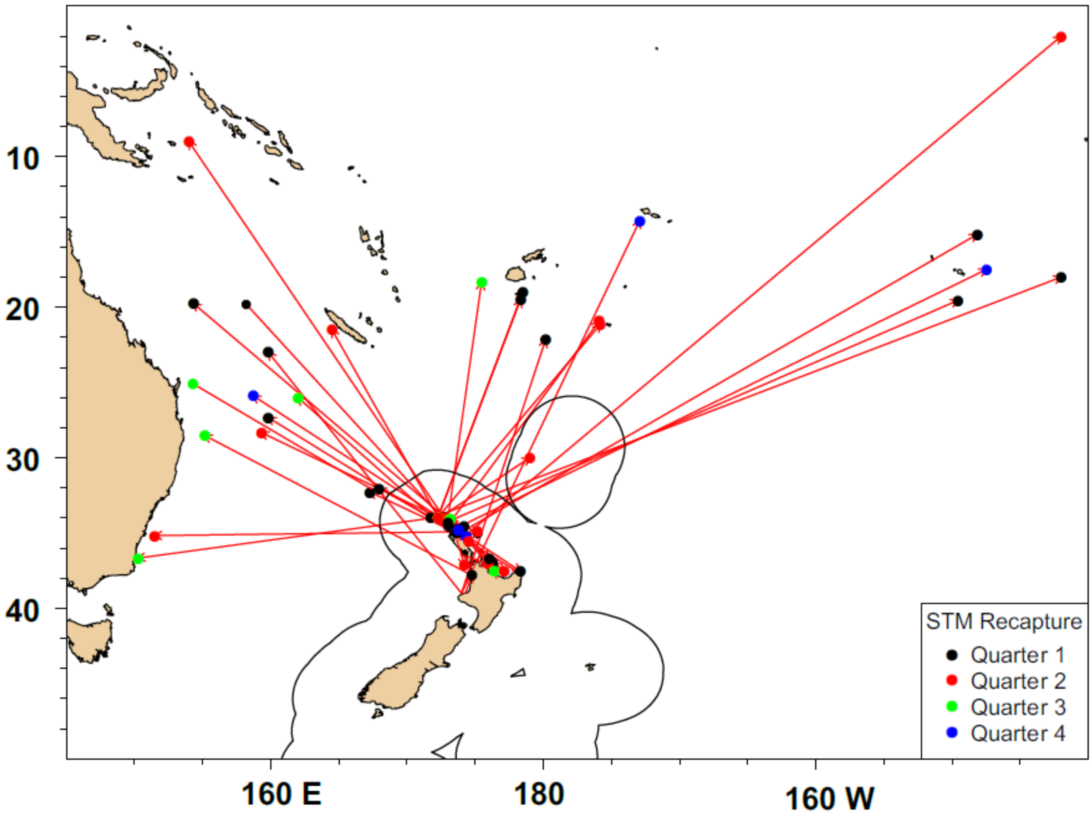


**Figure 5: Long distance movements of striped marlin in the New Zealand gamefish tagging programme, 1988–2016 with recapture location colour coded by quarter (Quarter 1 = Jan-Mar).**

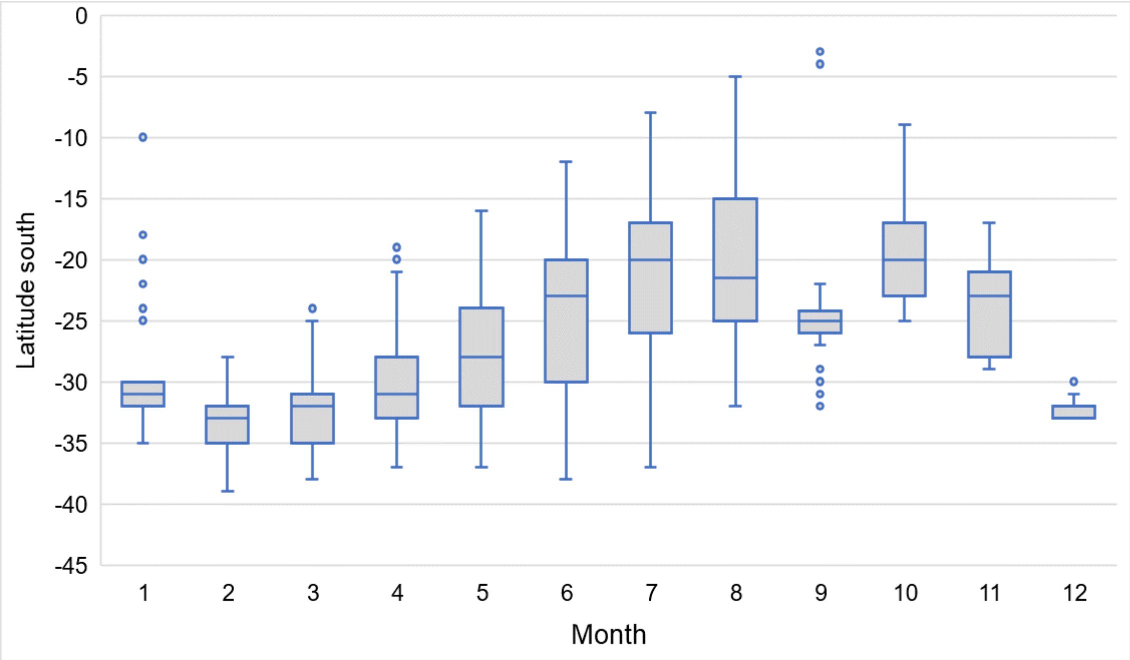


**Figure 6: Box plot distribution of daily latitude by month estimated from electronic tag data.**

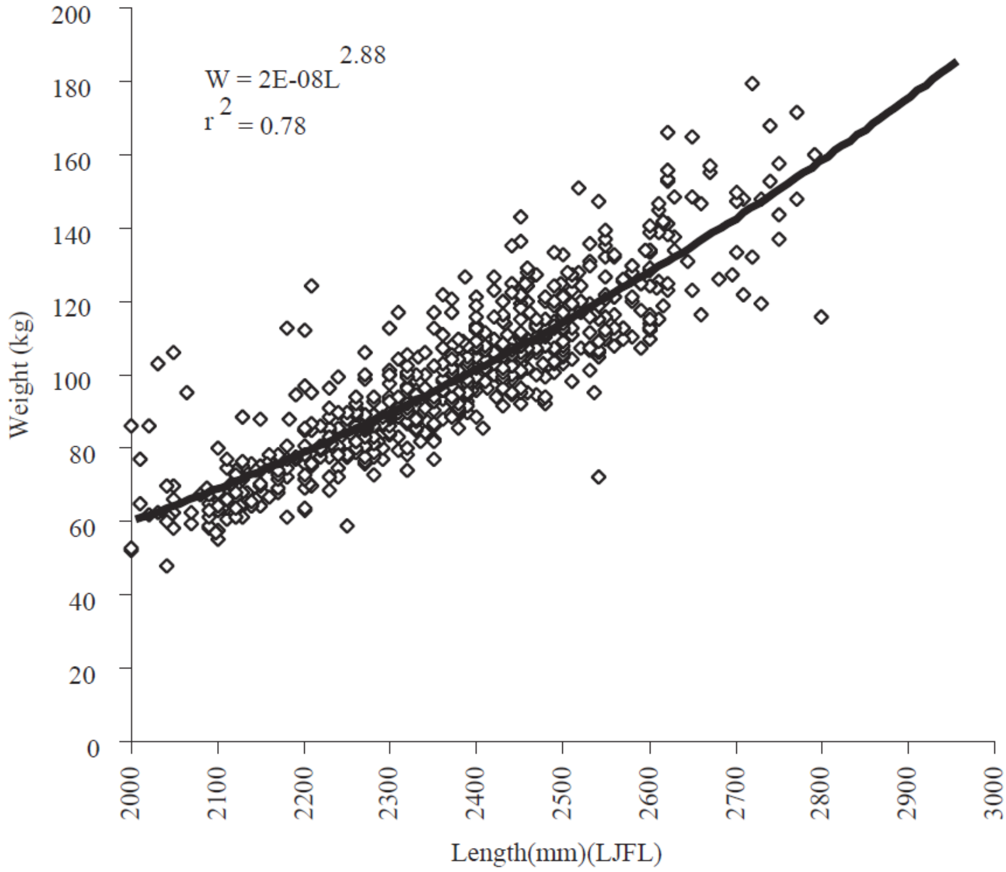


**Figure 7: Length weight relationship for striped marlin caught in the New Zealand recreational fishery, truncated at 2000 mm (from Kopf et al. 2005)**

# 6. APPENDIX A. EAST NORTHLAND CHARTER VESSEL MODEL OUTPUTS

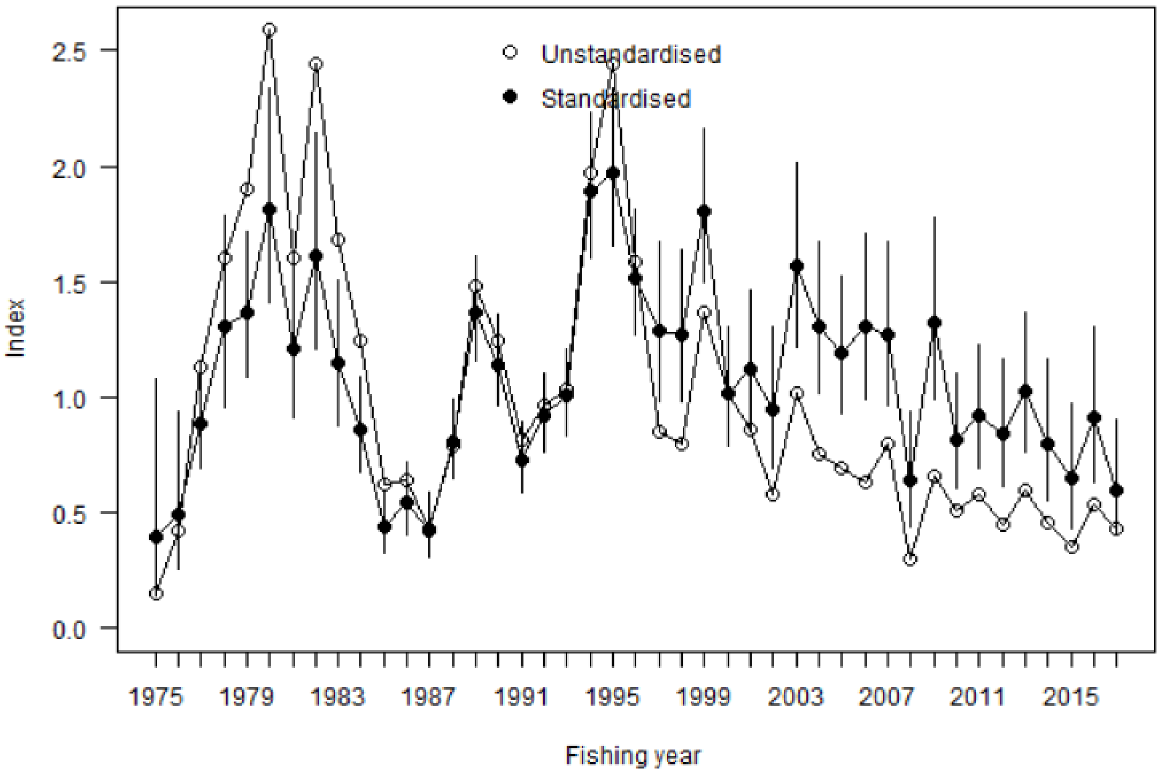


**Figure A1: Overall standardization effect of the East Northland charter vessel model. The unstandardised index is based on the geometric mean of the catch per year and is not adjusted for effort.**

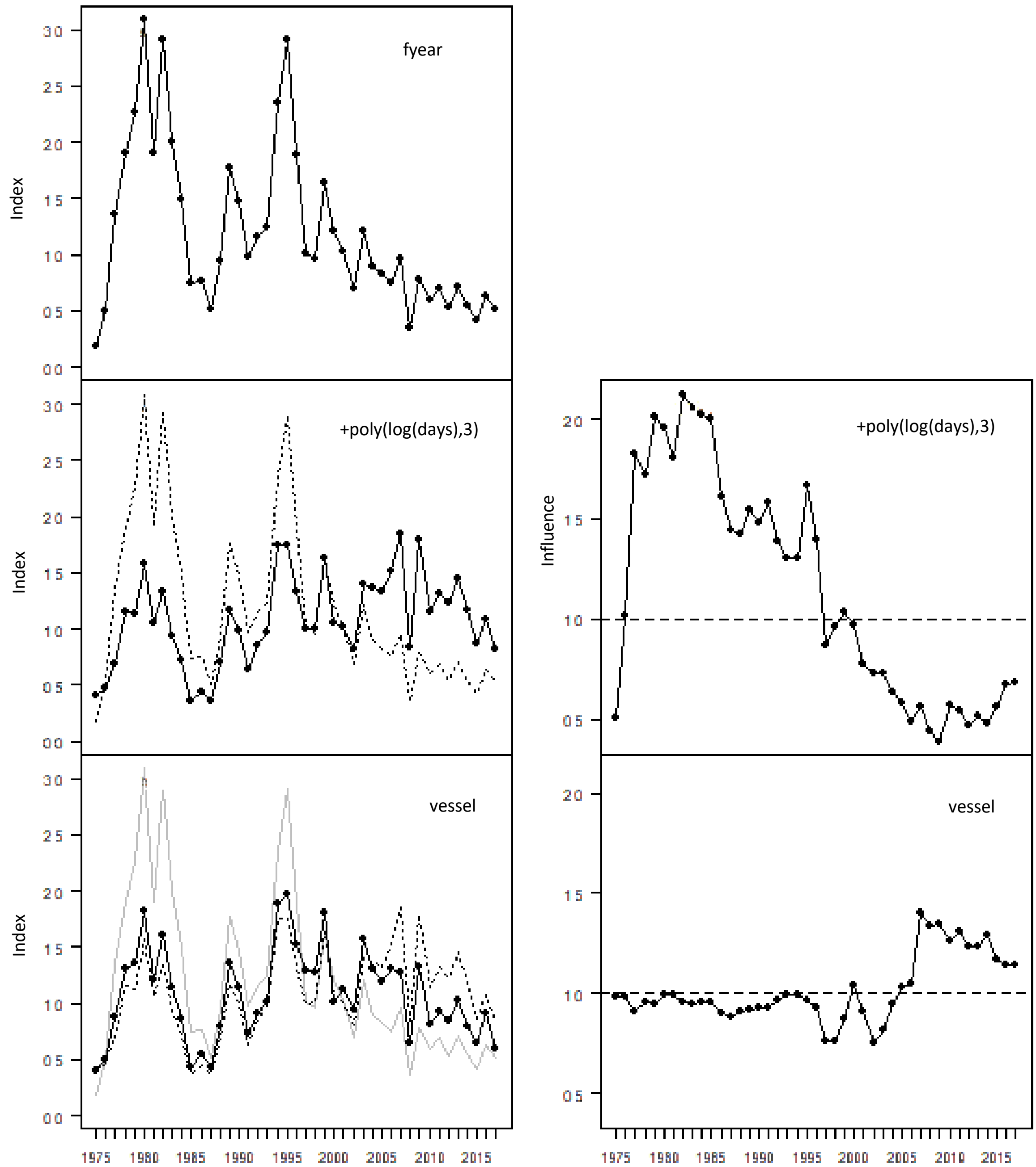


**Figure A2: Step and influence plot for the East Northland charter vessel model.**

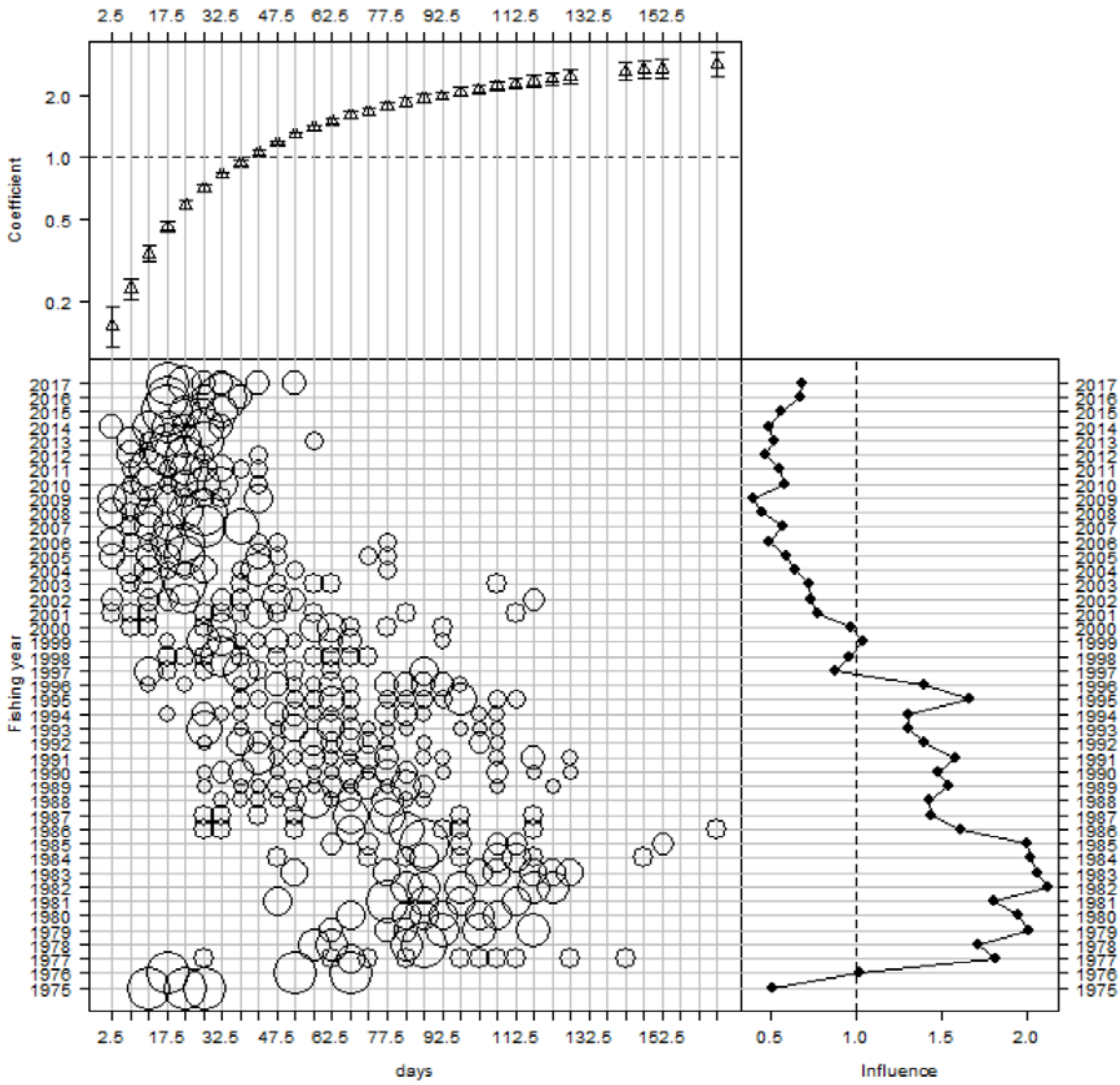


**Figure A3: Coefficient-distribution-influence plot for *poly(log(days), 3)* for the East Northland charter vessel model.**

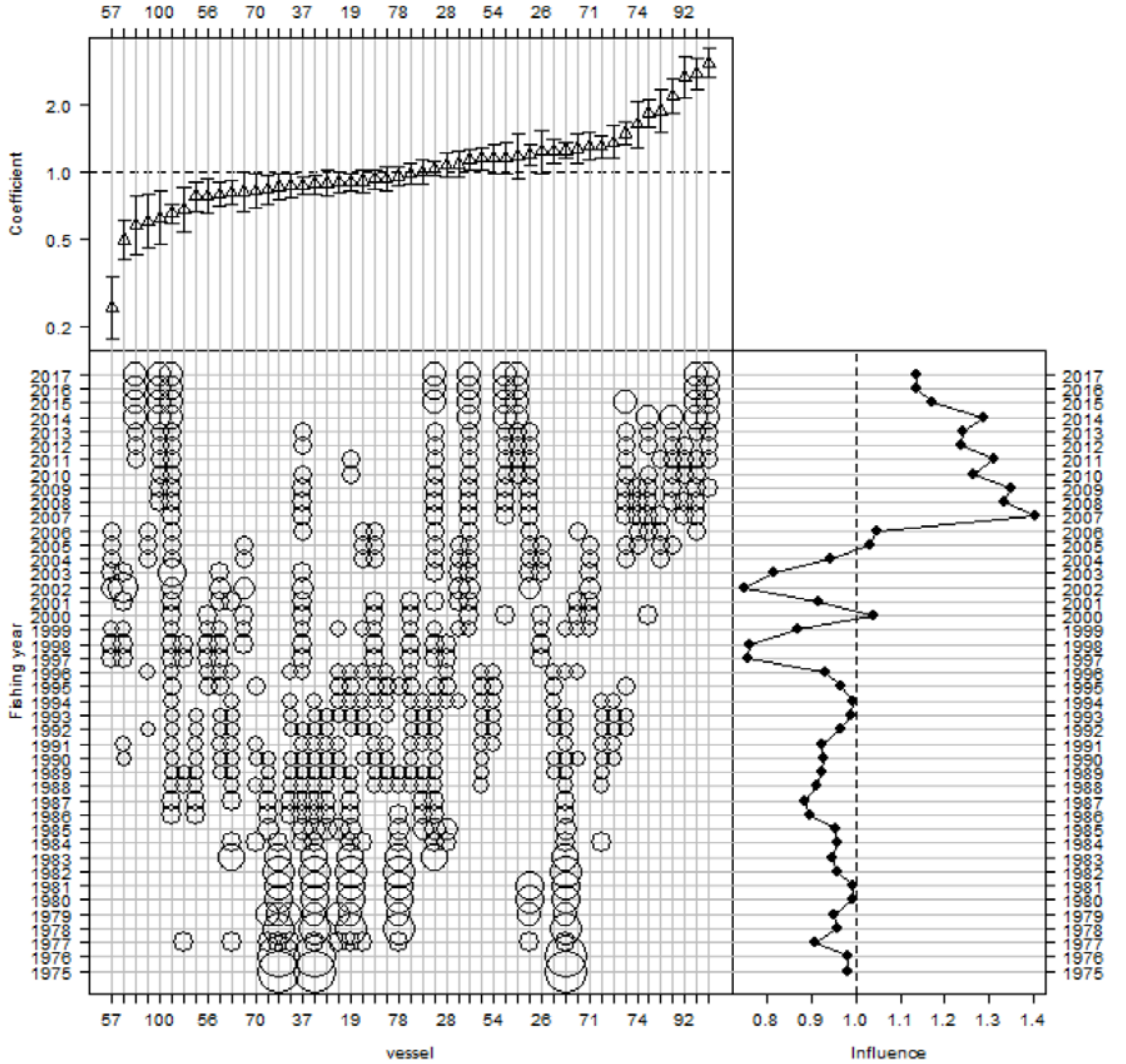


**Figure A4: Coefficient-distribution-influence plot for *vessel* in the East Northland charter vessel model.**

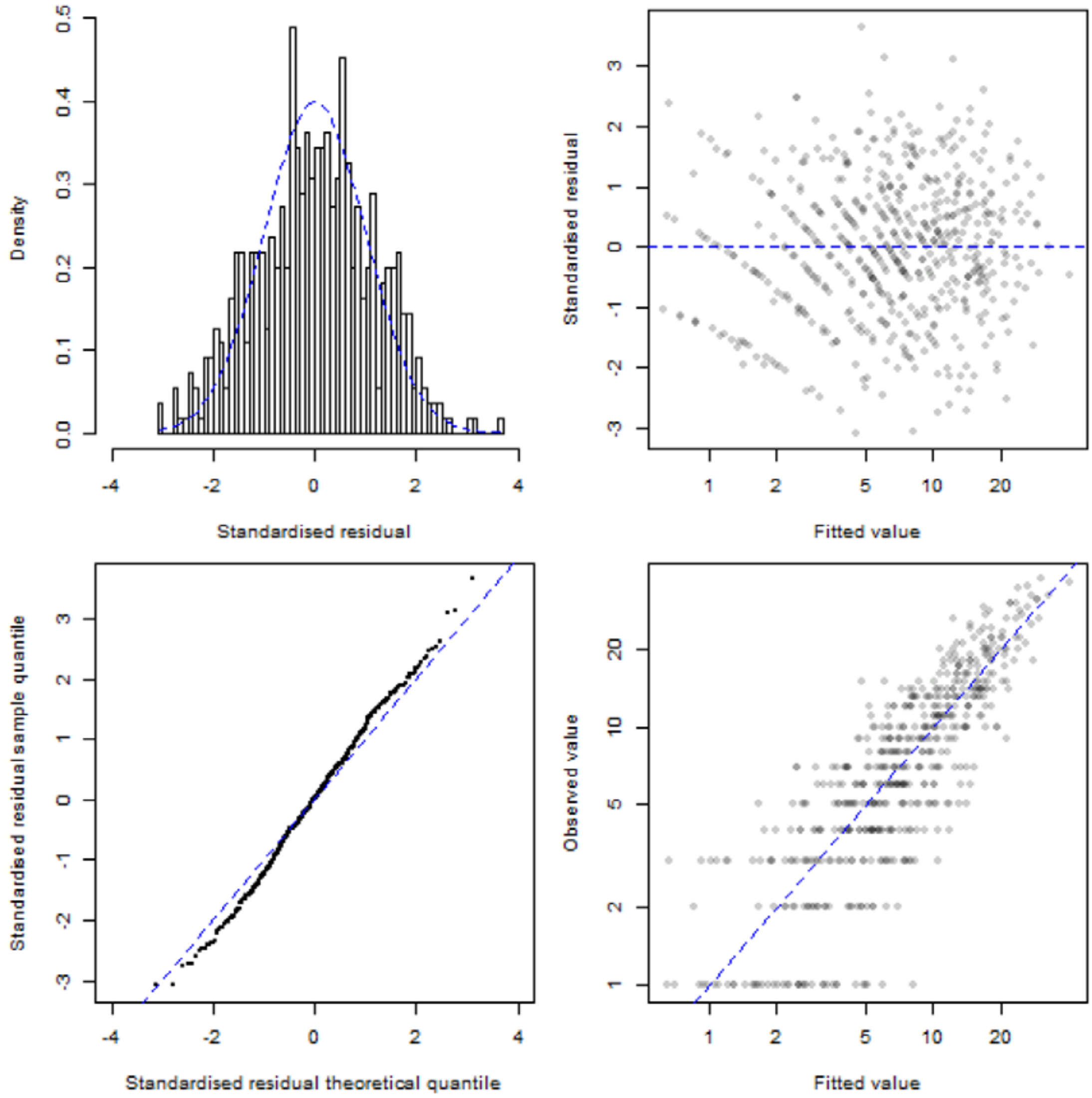


**Figure A5: Residual diagnostics. Top left: histogram of standardised residuals compared to standard normal distribution.', Bottom left: quantile-quantile plot of standardised residuals. Top right: fitted values versus standardised residuals. Bottom right: observed values versus fitted values for the East Northland charter vessel model.**

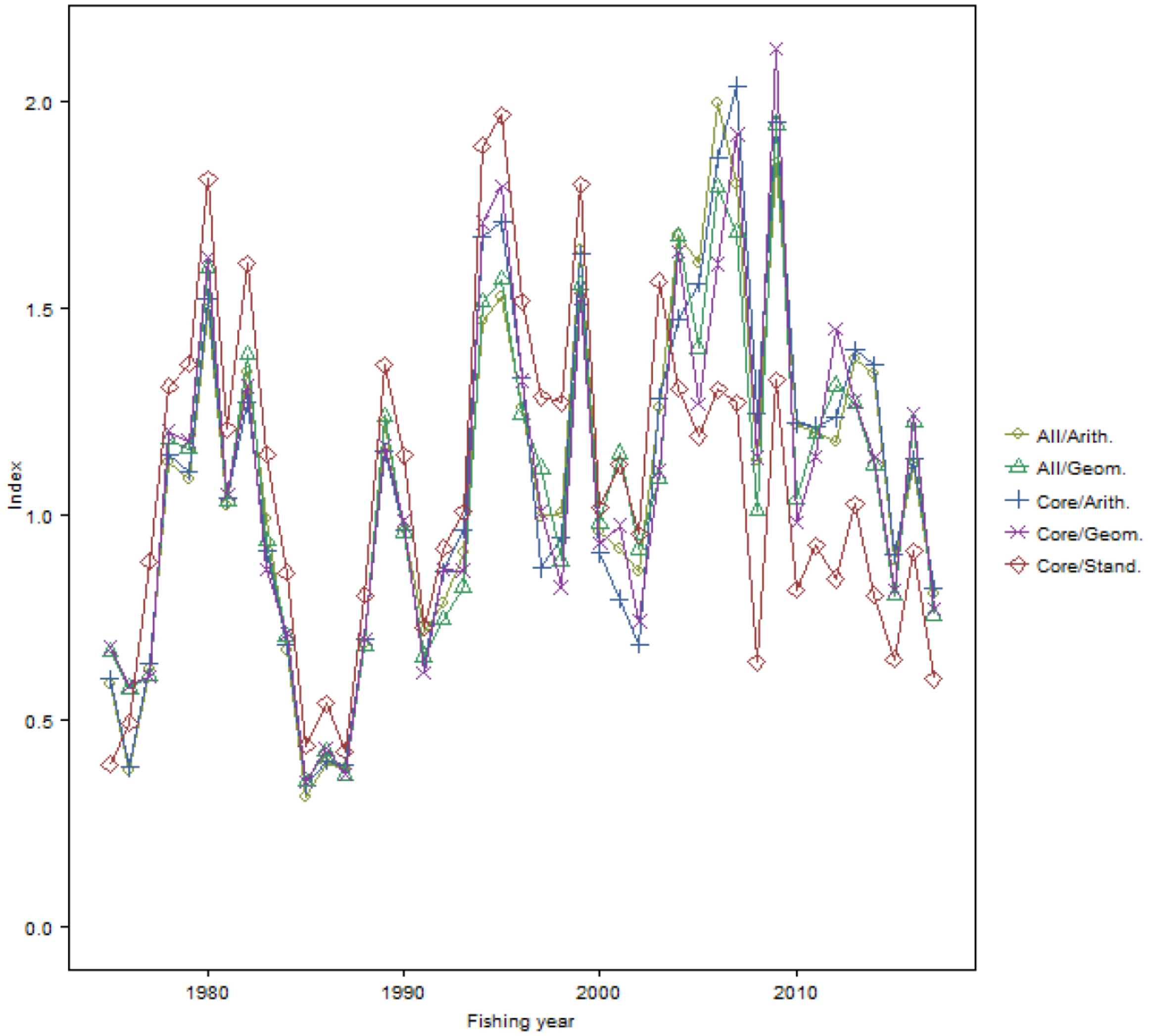


**Figure A6: Standardised and unstandardised CPUE indices. All: all vessels, Core: core vessels, Geom.: geometric mean, Arith: arithmetic mean, Stand.: standardised using GLM for the East Northland charter vessel model.**

**Table A1. Standardised and unstandardised CPUE indices for the East Northland charter vessel model. Fishing year labelled by later calendar year e.g. 1990=1989/90. All: all vessels, Core: core vessels, Geom.: geometric mean, Arith: arithmetic mean, Stand.: standardised using GLM, SE: standard error.**

| Fishing year | All/Arith. | Core/Arith. | Core/Geom. | Core/Stand. | Core/Stand. SE |
|---|---|---|---|---|---|
| 1975 | 0.5886 | 0.5988 | 0.6769 | 0.3931 | 0.50285 |
| 1976 | 0.3777 | 0.3843 | 0.5857 | 0.4920 | 0.32482 |
| 1977 | 0.6244 | 0.6352 | 0.6046 | 0.8841 | 0.11931 |
| 1978 | 1.1240 | 1.1434 | 1.2002 | 1.3086 | 0.15643 |
| 1979 | 1.0854 | 1.1041 | 1.1776 | 1.3636 | 0.11529 |
| 1980 | 1.4966 | 1.5224 | 1.6242 | 1.8127 | 0.12691 |
| 1981 | 1.0202 | 1.0378 | 1.0467 | 1.2073 | 0.14253 |
| 1982 | 1.3431 | 1.2697 | 1.3110 | 1.6073 | 0.14393 |
| 1983 | 0.9903 | 0.9091 | 0.8647 | 1.1459 | 0.13606 |
| 1984 | 0.6697 | 0.6824 | 0.7092 | 0.8586 | 0.11722 |
| 1985 | 0.3155 | 0.3418 | 0.3486 | 0.4378 | 0.14828 |
| 1986 | 0.3936 | 0.4004 | 0.4310 | 0.5404 | 0.14156 |
| 1987 | 0.3840 | 0.3887 | 0.3673 | 0.4241 | 0.16226 |
| 1988 | 0.6842 | 0.6986 | 0.6980 | 0.8026 | 0.10386 |
| 1989 | 1.2198 | 1.1525 | 1.1641 | 1.3627 | 0.08310 |
| 1990 | 0.9640 | 0.9634 | 0.985 | 1.1426 | 0.08650 |
| 1991 | 0.7150 | 0.6432 | 0.6143 | 0.7246 | 0.10346 |
| 1992 | 0.7825 | 0.8602 | 0.8661 | 0.9177 | 0.09328 |
| 1993 | 0.9074 | 0.9620 | 0.8628 | 1.0068 | 0.09325 |
| 1994 | 1.4681 | 1.6720 | 1.7067 | 1.893 | 0.08250 |
| 1995 | 1.5262 | 1.7088 | 1.7951 | 1.9683 | 0.08617 |
| 1996 | 1.2576 | 1.3323 | 1.3246 | 1.5172 | 0.08874 |
| 1997 | 0.9930 | 0.8698 | 1.0053 | 1.2835 | 0.13205 |
| 1998 | 1.0005 | 0.9445 | 0.8230 | 1.2698 | 0.12751 |
| 1999 | 1.6421 | 1.6299 | 1.5216 | 1.8003 | 0.09246 |
| 2000 | 0.9559 | 0.9054 | 0.9286 | 1.0149 | 0.12495 |
| 2001 | 0.9146 | 0.7941 | 0.9719 | 1.1207 | 0.13226 |
| 2002 | 0.8626 | 0.6836 | 0.7399 | 0.9499 | 0.15863 |
| 2003 | 1.2593 | 1.2811 | 1.1057 | 1.5642 | 0.12547 |
| 2004 | 1.6789 | 1.4731 | 1.637 | 1.3035 | 0.12578 |
| 2005 | 1.6074 | 1.5600 | 1.2657 | 1.1894 | 0.12372 |
| 2006 | 1.9985 | 1.8638 | 1.6072 | 1.3028 | 0.13603 |
| 2007 | 1.8023 | 2.0390 | 1.9222 | 1.2700 | 0.13653 |
| 2008 | 1.1313 | 1.2439 | 1.1367 | 0.6416 | 0.18896 |
| 2009 | 1.8512 | 1.9495 | 2.1282 | 1.3261 | 0.14553 |
| 2010 | 1.2150 | 1.2213 | 0.9793 | 0.8166 | 0.15206 |
| 2011 | 1.2005 | 1.2131 | 1.1382 | 0.9228 | 0.14139 |
| 2012 | 1.1745 | 1.2342 | 1.4483 | 0.8426 | 0.16136 |
| 2013 | 1.3749 | 1.3992 | 1.2736 | 1.0237 | 0.14544 |
| 2014 | 1.3386 | 1.3617 | 1.1385 | 0.8023 | 0.18806 |
| 2015 | 0.8872 | 0.9025 | 0.8163 | 0.6475 | 0.20186 |
| 2016 | 1.1142 | 1.1334 | 1.2425 | 0.9090 | 0.18225 |
| 2017 | 0.8047 | 0.8186 | 0.7683 | 0.6006 | 0.20320 |

# 7. APPENDIX B. NATIONAL BILLFISH LOGBOOK MODEL OUTPUTS

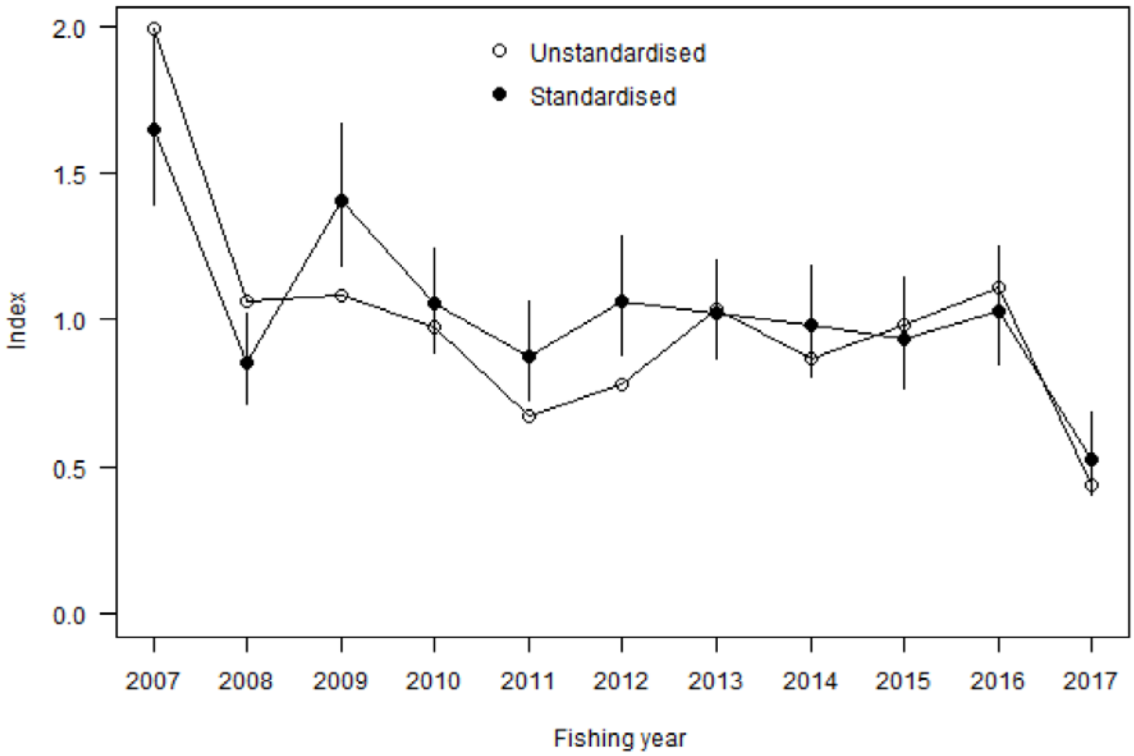


**Figure B1: Overall standardization effect from the billfish logbook model. The unstandardised index is based on the geometric mean of the catch per year and is not adjusted for effort.**

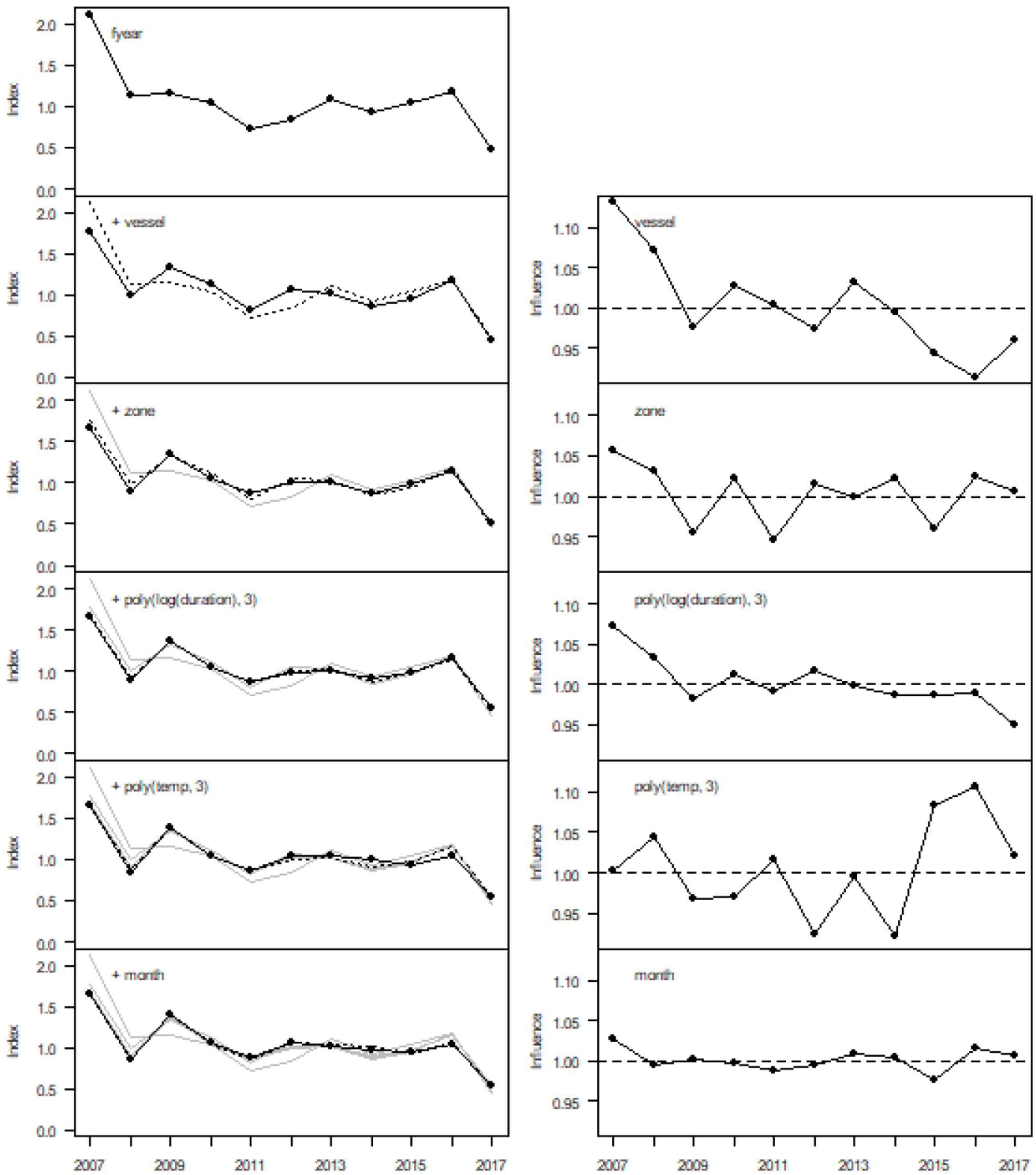


**Figure B2: Step and influence plot from the billfish logbook model.**

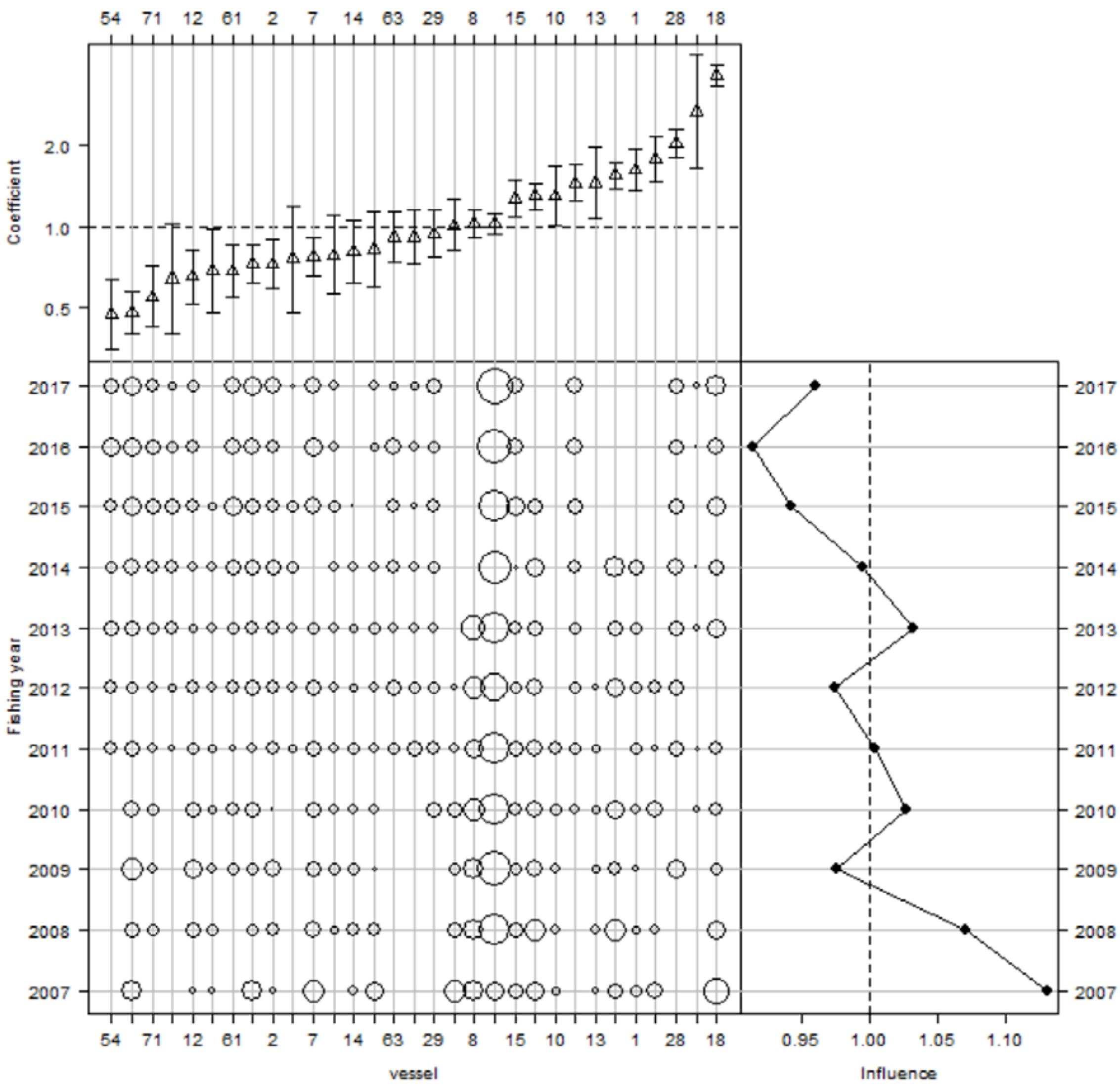


**Figure B3: Coefficient-distribution-influence plot for *vessel* from the billfish logbook model.**

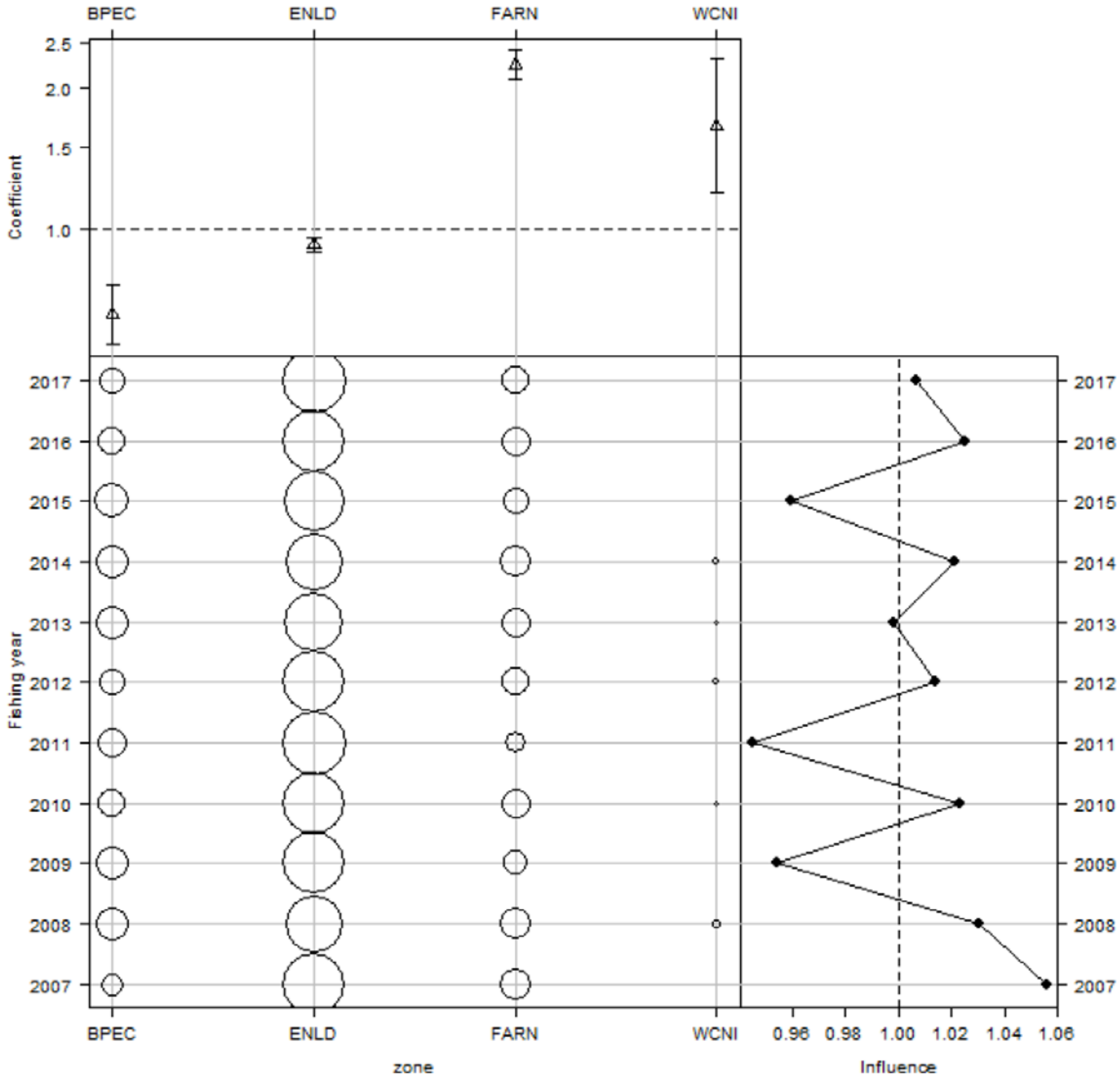


**Figure B4: Coefficient-distribution-influence plot for *zone* from the billfish logbook model.**

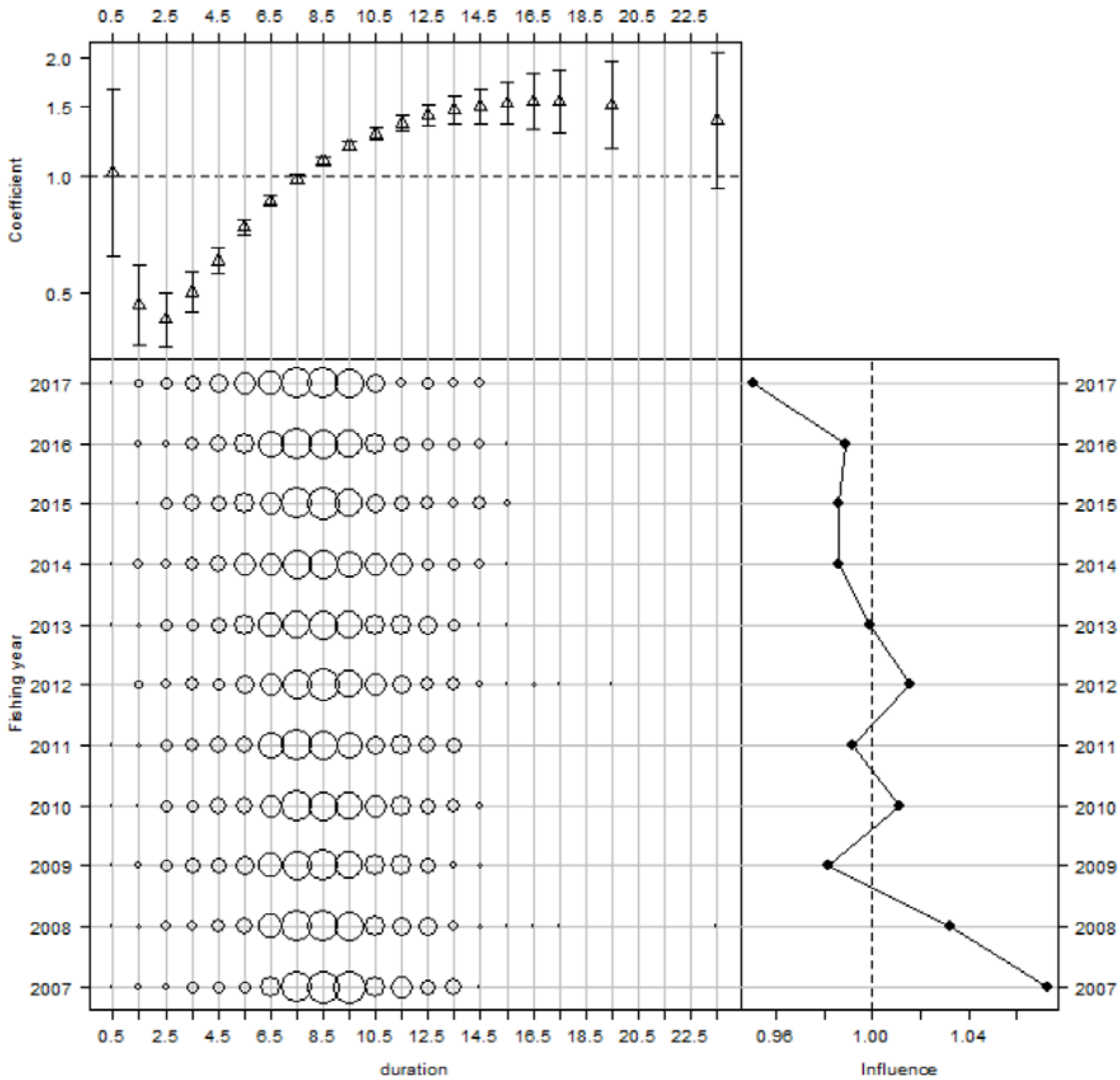


**Figure B5: Coefficient-distribution-influence plot for *poly(log(duration), 3)* from the billfish logbook model.**

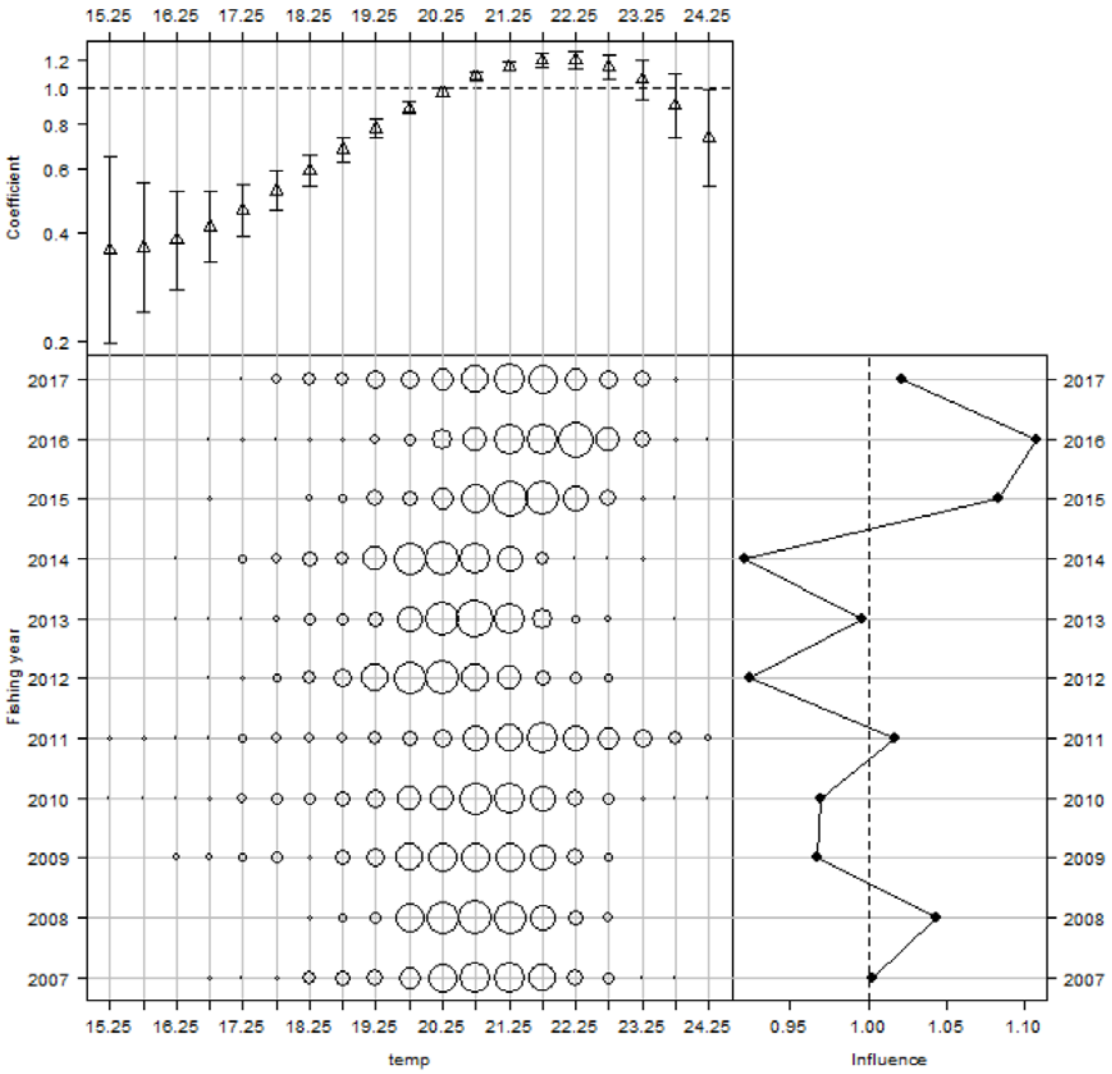


**Figure B6: Coefficient-distribution-influence plot for *poly(temp, 3)* from the billfish logbook model.**

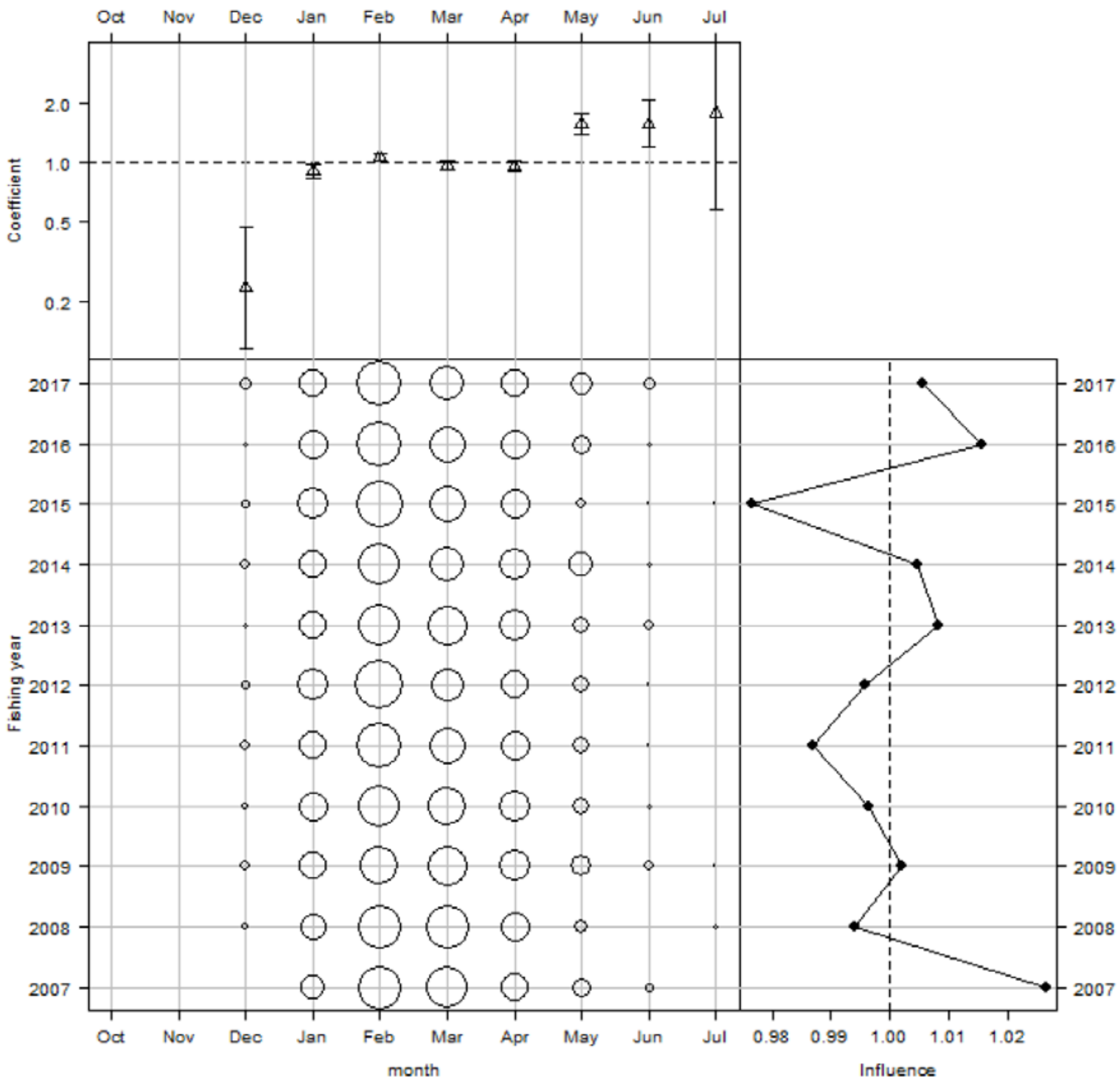


**Figure B7: Coefficient-distribution-influence plot for *month* from the billfish logbook model.**

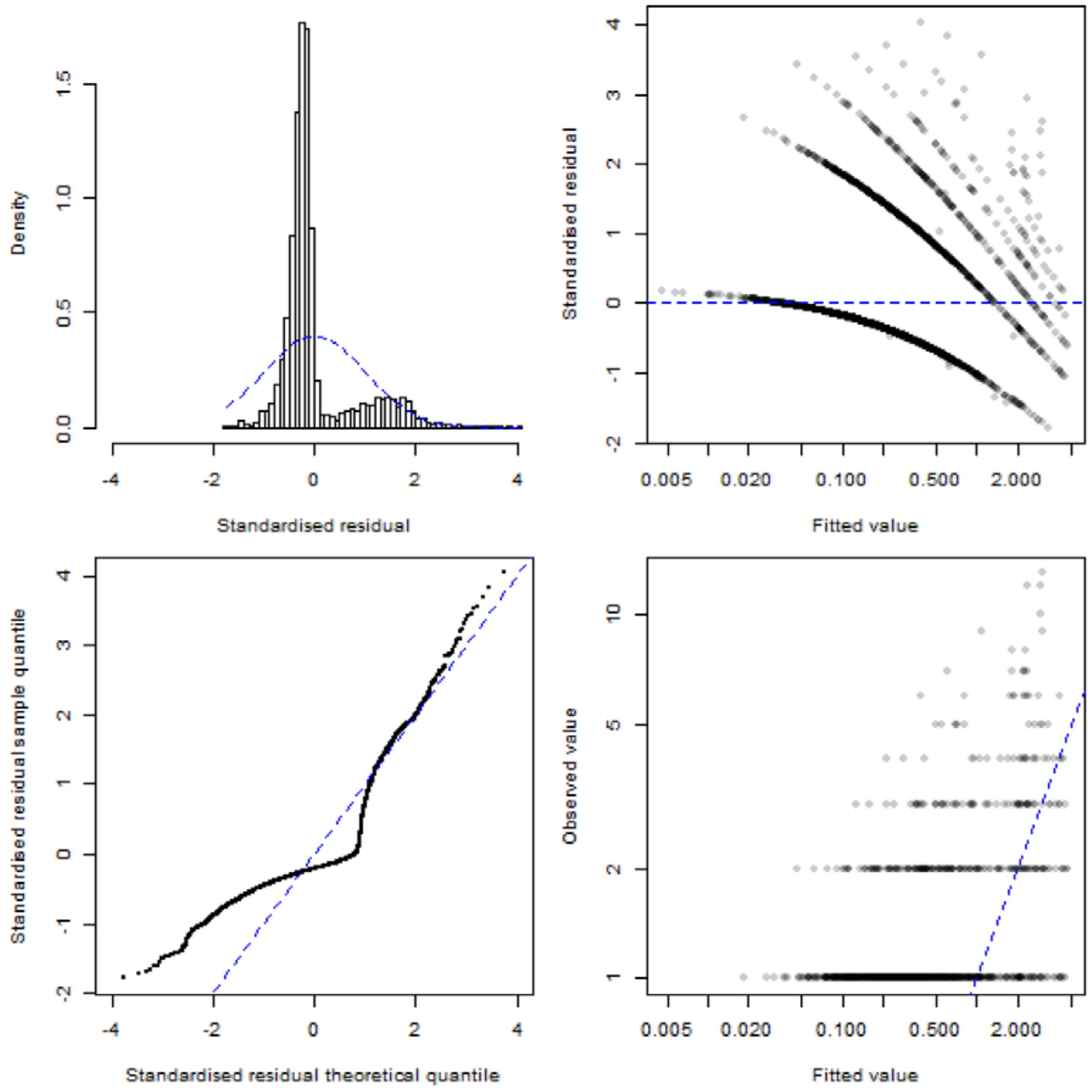


**Figure B8: Residual diagnostics. Top left: histogram of standardised residuals compared to standard normal distribution.', Bottom left: quantile-quantile plot of standardised residuals. Top right: fitted values versus standardised residuals. Bottom right: observed values versus fitted values from the billfish logbook model.**

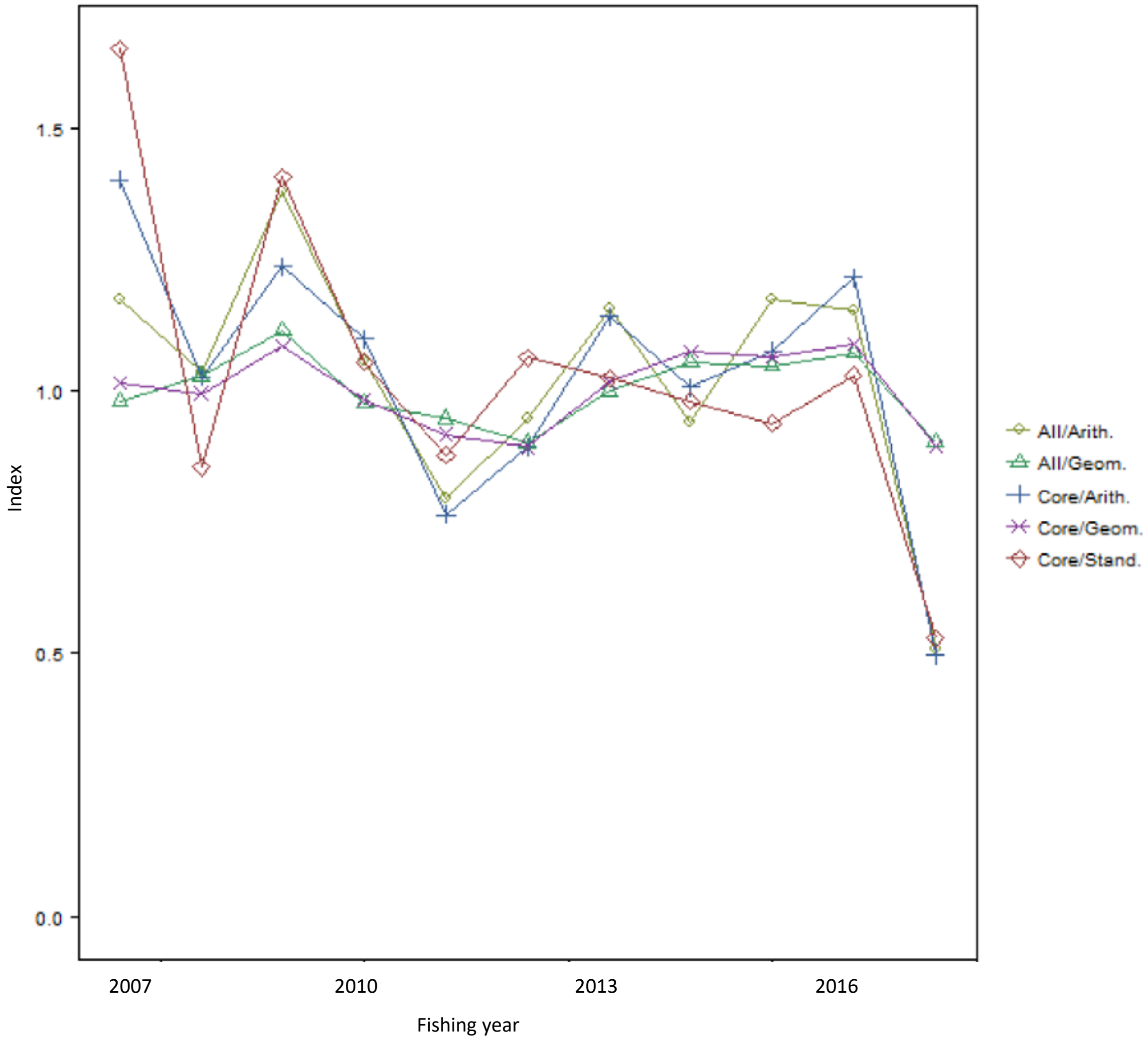


**Figure B9: Standardised and unstandardised CPUE indices from the billfish logbook model. All: all vessels, Core: core vessels, Geom.: geometric mean, Arith: arithmetic mean, Stand.: standardised using GLM.**

**Table A2: Standardised and unstandardised CPUE indices from the billfish logbook model. Fishing year labelled by later calender year e.g. 1990=1989/90. All: all vessels, Core: core vessels, Geom.: geometric mean, Arith: arithmetic mean, Stand.: standardised using GLM, SE: standard error.**

| Fishing year | All/Arith. | Core/Arith. | Core/Geom. | Core/Stand. | Core/Stand. SE |
|---|---|---|---|---|---|
| 2007 | 1.1743 | 1.4020 | 1.0158 | 1.6510 | 0.08593 |
| 2008 | 1.0366 | 1.0269 | 0.9952 | 0.8552 | 0.08983 |
| 2009 | 1.3802 | 1.2369 | 1.0857 | 1.4058 | 0.08480 |
| 2010 | 1.0562 | 1.0983 | 0.9824 | 1.0537 | 0.08379 |
| 2011 | 0.7943 | 0.7636 | 0.9168 | 0.8782 | 0.09596 |
| 2012 | 0.9486 | 0.8942 | 0.8928 | 1.0639 | 0.09415 |
| 2013 | 1.1569 | 1.1409 | 1.0168 | 1.0244 | 0.08084 |
| 2014 | 0.9416 | 1.0066 | 1.0753 | 0.9794 | 0.09619 |
| 2015 | 1.1749 | 1.0766 | 1.0640 | 0.9373 | 0.09970 |
| 2016 | 1.1511 | 1.2164 | 1.0893 | 1.0294 | 0.09676 |
| 2017 | 0.5077 | 0.4979 | 0.8942 | 0.5287 | 0.13289 |