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Striped marlin catch and CPUE in the New Zealand sport fishery 2016–17 to 2018–19

New Zealand Fisheries Assessment Report 2019/74

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Holdsworth, J.C.; Saul, P.J. (2019). Striped marlin catch and CPUE in the New Zealand sport fishery 2016–17 to 2018–19.

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Striped marlin is the main billfish species available to sport fishers in New Zealand over the austral summer months, with a long-established international reputation for large fish. Two fishing clubs on the northeast coast have near continuous records of landed fish weights since 1925. An annual postal survey of charter boat operators started collecting striped marlin catch and effort information from the target fishery in East Northland in 1975.

The New Zealand billfish Logbook programme took over from the postal survey in 2006–07 to collect daily catch and effort data from charter operators and experienced private skippers wherever they fished. It is a voluntary programme aimed at those people willing to keep a complete and accurate fishing record while targeting billfish.

Billfish catch records from sport fishing clubs and striped marlin CPUE are updated and summarised in this report. Over the fishing years 2016–17 to 2018–19 307 striped marlin were reported in logbooks from 1687 days fished. Fishing clubs affiliated to New Zealand Sport Fishing Council (NZSFC) reported 2900 striped marlin caught with 60 % of these tagged and released. Commercial fishers have been required to release all marlin caught for the last 30 years and there is little overlap between the sport fishery and the surface longline fishery.

Annual striped marlin catch and effort is standardised using a negative binomial model that includes zero catches for both the annual East Northland charter boat series and the daily billfish logbook series. Overall CPUE was relatively high in the late 1970s and early 1980s. There were three years of low CPUE in the mid-1980s followed by an increasing trend to the mid-1990s and a variable but decreasing trend since then. The 2016–17 to 2018–19 seasons were relatively poor years for the recreational striped marlin fishery.

This report also summarises the combined catch from 56 sport fishing clubs affiliated to the New Zealand Sport Fishing Council. This includes fish landed at club weigh stations and fish tagged and released. Fishers who are not members of clubs may choose to weigh their fish at a weigh station (where they can also arrange for it to be smoked). The details of these fish may also be recorded by clubs.

For many years club records have been considered a reasonably complete record of billfish and large pelagic shark landings in the sport fishery. However, over the last few years there has been an increase in new entrants to the fishery who are less inclined to join a club or weigh their marlin. Future estimates of landed striped marlin catch from the New Zealand recreational fishery provided to Fisheries New Zealand and the WCPFC could include an allowance for unaccounted catch.

1 INTRODUCTION

Of the five billfish species reported from New Zealand waters striped marlin (*Kajikia audax*) are the most abundant and main species of the recreational gamefish fishery in northern New Zealand. Broadbill swordfish (*Xiphias gladius*) are increasingly targeted by recreational fishers with deep set baits during the day and by commercial fishers with night set surface longlines. Other billfish occasionally caught by recreational and commercial fishers are blue marlin (*Makaira nigricans*), black marlin (*Makaira indica*), and shortbilled spearfish (*Tetrapturus angustirostris*). The marlins and spearfish are most abundant in summer and autumn around northern New Zealand. Swordfish are caught year round in New Zealand, with the main season for recreational fishers being between March and July (Holdsworth et al. 2016).

Striped marlin in the southwest Pacific grow rapidly and enter the New Zealand recreational fishery as 3 or 4 year olds and are sexually mature (Kopf et al. 2011, Kopf et al. 2012).

Regulations in New Zealand have prohibited commercial vessels from retaining marlins and spearfish caught in New Zealand fisheries waters. Although required to report marlin caught and released, commercial operators have not kept complete records of marlin species that they cannot land (Francis et al. 2000). Many sport fishers are willing to report their catch and fishing effort to help monitor trends in abundance and availability of billfish in New Zealand.

Recreational sport fishing clubs have kept catch records for pelagic gamefish for many years. The Bay of Islands Swordfish Club (BOISC) and Whangaroa Sport Fishing Club have published yearbooks with detailed catch records since 1925. These contain the date, weight and vessel name for each fish recorded. For many years these records contained an almost complete record of billfish caught by charter boats and skippers who had the specialist knowledge and fishing tackle to target marlin. Since 1990 there has been a significant increase in the number of private launches and trailer boats targeting marlin (Holdsworth & Kopf 2005).

The New Zealand Gamefish Tagging Programme has operated since 1975. This project is supported by Fisheries New Zealand and NZSFC and encourages anglers to tag and release billfish, tuna and sharks to aid research and conservation. The tagging database contains a good record of where and when these fish were released but only estimated weights are available for these fish.

A 44 year time series of striped marlin CPUE data has been collected from gamefish charter skippers fishing the northeast coast of New Zealand. It started as a simple, low cost, annual postal survey. However, it only provided catch and effort on a coarse scale (fish and vessel days per vessel per season) and in a limited area (North Cape to Cape Rodney). The postal survey was last used to collect striped marlin CPUE in east Northland for the 2005–06 season (Holdsworth et al. 2007). Since then the Billfish Logbook Programme has collecting daily information on billfish catch, hours fished and environmental variables from private and charter skippers in all areas fished (Holdsworth & Saul 2017).

Recreational charter boat operators have been required to report their fishing activity since November 2010 under MPI's Amateur Fishing Charter Vessel (AFCV) requirements. Subsequently, they have also had to report area of operation and the catch of certain species. There will unavoidably be some duplication of data reporting between the two reporting schemes but as no billfish are required to be reported under the AFCV scheme, the overlap between the two projects is limited to the effort section. There has been a sharp decline in the number of charter boats targeting billfish over the last six years due to changes in the tax provisions and maritime safety regulations.

Specific Objectives for Project STM2016-01:

1. To update time series of catches, landings, and size composition data collected from recreational sources for the 2016–17, 2017–18 and 2018–19 fishing years.

2. To undertake a logbook programme for striped marlin for the recreational fishery for the 2016–17, 2017–18 and 2018–19 fishing years.

2 METHODS

2.1 Catches, landings and size composition

The number of billfish, shark and tuna landed by recreational fishers and weighed by fishing clubs is collated annually by the New Zealand Sport Fishing Council (NZSFC) and published in their yearbook. The New Zealand Gamefish Tagging Programme collects tag and release details from clubs and individuals. Annual catches of fish landed or tagged are summarised and plotted by species. The fishing year used by NZSFC and in this report is 1 July to 30 June.

Catch records from club weigh stations and tag cards are requested at the end of each year from the main North Island clubs. Data from within the New Zealand EEZ were separated into landed fish and released fish and summarised by species, fishing year and club.

Average annual weights are plotted with available data from the three Northland clubs with the longest time series. Where fewer than 10 striped marlin were landed by a club in a season the average weight was not plotted.

2.2 Logbook programme

The main objective of this logbook scheme is to collect data on striped marlin CPUE. However, data on other New Zealand gamefish species is also requested. These are blue marlin, black marlin, shortbill spearfish, swordfish, yellowfin tuna (*Thunnus albacares*), bigeye tuna (*Thunnus obesus*), southern bluefin tuna (*Thunnus maccoyii*) and shortfin mako shark (*Isurus oxyrinchus*). The logbook forms were designed with input from charter boat organisations and experienced private skippers as part of MPI project STM2005/01 (Holdsworth et al. 2007) and reviewed by the Highly Migratory Species Working Group. Data collected includes target species; hours fished per day; fishing method; location at noon; primary target species; water temperature at noon; a record of billfish strikes; wind speed and direction; and precise locations for fish caught. Distribution of logbooks has focused on charter vessels and private boats that target billfish more than 10 days per season. Fishing effort is measured as vessel days or vessel hours targeting billfish as the number of lines set or number of anglers on board does not effectively increase fishing power.

Most skippers or owners were recruited in December and January 2006–07, but new volunteers have been actively sought and accepted in subsequent seasons. Regular contact with participants is maintained including in-season newsletters. Free nylon (PIMA) billfish tags are provided to logbook participants during the year and a free logbook shirt is provided to each skipper if they return their logbook at the end of the season.

A database with a 3-tier architecture built in Microsoft .NET Framework 2.0 is used to store the information. The first tier is the front-end or presentation layer which uses Windows Forms created in Microsoft Visual Studio 2008. The middle tier contains all the business rules for the system which check the data before it is inserted into the database. The final tier is the data access layer which handles all the database access. The data model adopts the table and field names of the Fisheries New Zealand **rec_data** database with the addition of several tables and fields required to support functionality in the application. Summary tables were exported into MS Excel for analysis and plotting.

2.3 Catch per unit effort

The gamefish logbook scheme has been running for 13 years (2006–07 to 2018–19) and collects data on catch and effort from charter and private vessels from around New Zealand. A subset of data was selected to match the previous East Northland postal survey (1974–75 to 2005–06) so that the East Northland charter boat CPUE time series now extends over 44 years. It excludes catch and effort from the productive Three Kings fishery which started in the early 1990s north of New Zealand. For trends in CPUE to be comparable across the whole time series it is important to standardise the fishing area and methods where

possible. Effectively the survey area is covered by Fisheries New Zealand General Statistical Areas 002, 003 and 004.

Standardisation of CPUE was undertaken on core vessels in the fleet. These were vessels that had provided at least five years of data. Vessel characteristics such as length and hull type have also been compiled. A negative binomial model was fitted to all data including zero catches in GLM runs undertaken using R software (Bentley et al. 2012).

3 RESULTS

3.1 Catch trends from fishing club records

Striped marlin has been the main large pelagic species targeted and caught in the New Zealand gamefish fishery over the last 18 years (Figure 1). Details of landed catch comes from all fishing clubs affiliated to the New Zealand Sport Fishing Council. For many years this has been a reasonably complete record of billfish and large pelagic shark landings. Clubs also record fish taken by non-members who may choose to weigh their fish at a club and have it processed or smoked. A record number of striped marlin (2471) were landed or tagged by sport fishers in the 2015–16 fishing year and this was followed by a poor year with 1071 striped marlin landed or tagged (Figure 1).

Yellowfin tuna were a major component of catch in the mid-1990s, but by 2008–09 they were effectively absent from the gamefish fishery (Figure 1). In 2014–15 some, mainly small, yellowfin were caught and in 2015–16 over 550 were landed or tagged. Many yellowfin weighed by clubs were in the 25 to 35 kg range.

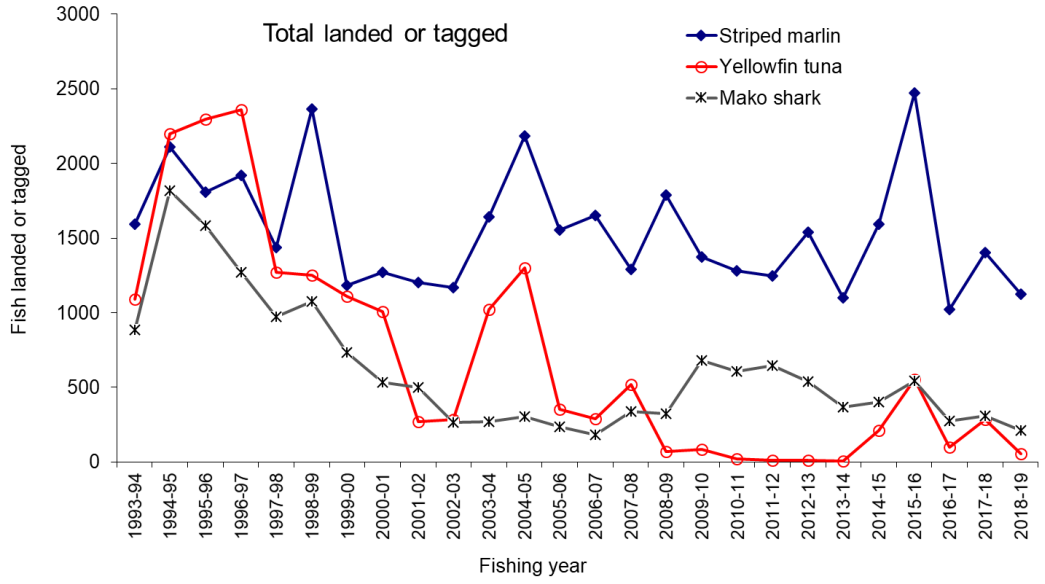


Figure 1: The total of landed or tagged fish by year for the main billfish, tuna and shark species in the New Zealand gamefish fishery.

The number of mako sharks recorded has also declined since the mid-1990s (Figure 1), in part because of a shift in fisher attitudes. Fishing tournaments now discourage landing of sharks and over 95% of recorded mako catch is tagged and released. The NZSFC clubs have minimum weights for landed pelagic sharks of 40 kg and some clubs have increased this to 70 kg or do not recognise landed sharks at all.

Blue marlin are at times a dominant component of the catch of the other billfish caught in New Zealand waters, with occasionally over 150 blue marlin landed and 50 tagged and released (Figure 2 and Figure

3). Swordfish catch has increased over the last 10 years to over 80 fish landed and 40 tagged and released per year but the numbers have started to decline. The number of shortbill spearfish landed has been increasing over the last five or six years. Black marlin are caught in low numbers, generally between 5 and 15 each year (Figure 2, Figure 3).

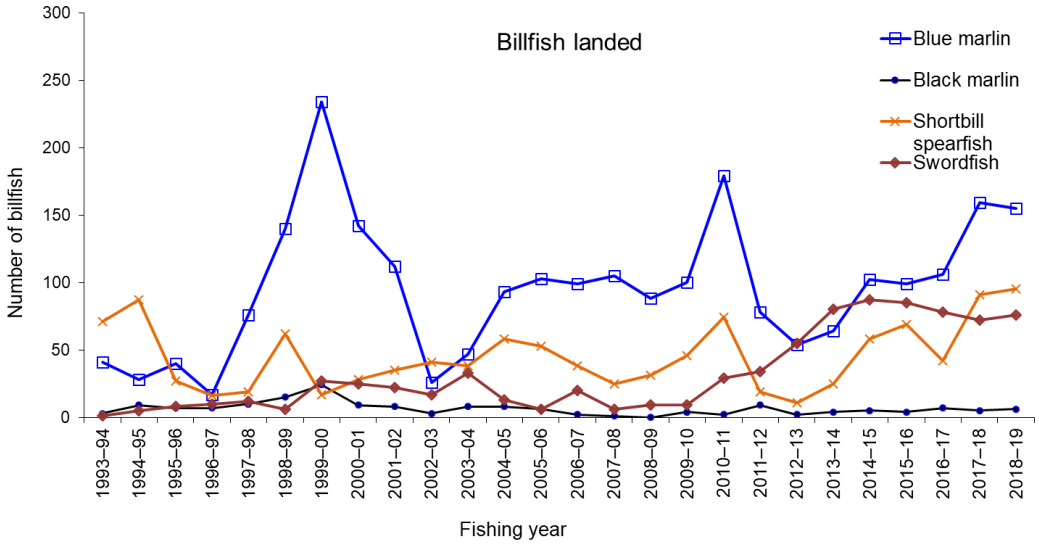


Figure 2: Total number of billfish, other than striped marlin, landed by year in New Zealand from New Zealand Sport Fishing Council records.

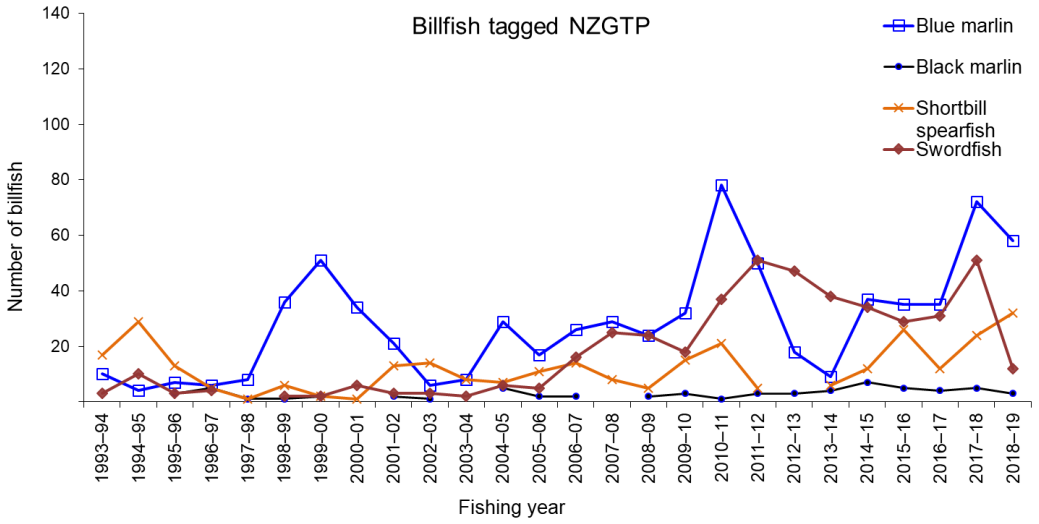


Figure 3: The number of tagged billfish per year, other than striped marlin, in the New Zealand gamefish tagging programme.

The number of striped marlin caught by sport fishers in New Zealand has increased significantly since the early 1970s (Figure 4). The majority of striped marlin caught in the first half of the time series came from the charter fleet in East Northland. In 2016–17 a record number of 2471 striped marlin were reported from the recreational fishery. The catch and club landed weight data are important inputs to the 2019 stock assessment for striped marlin in the southwest Pacific (Ducharme-Barth et al. 2019).

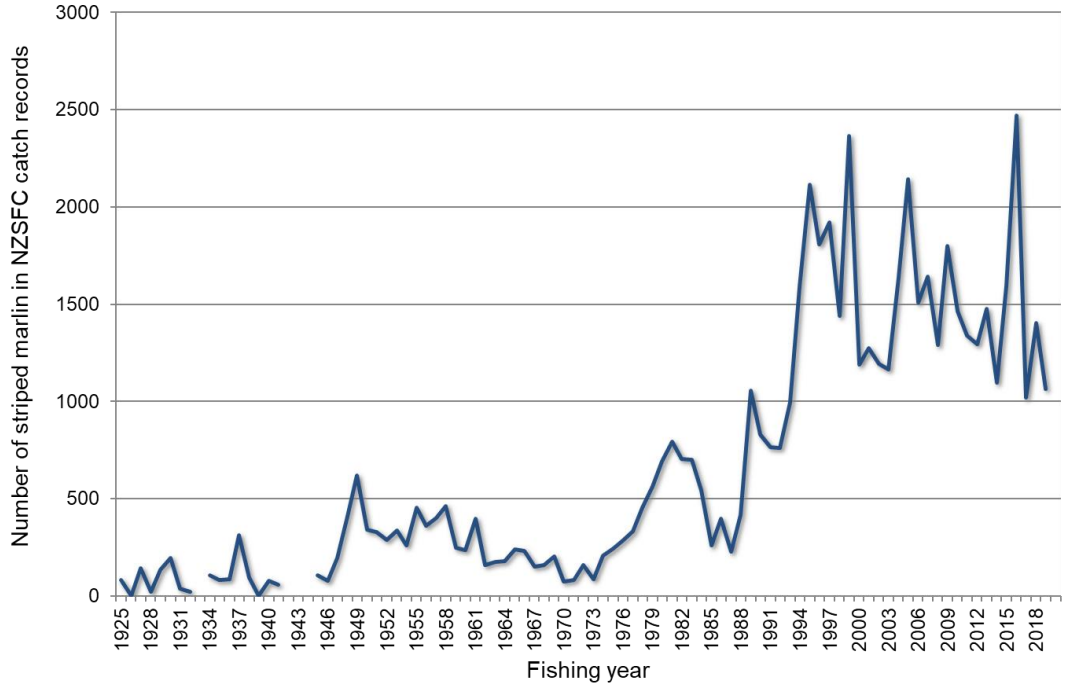


Figure 4: The number of striped marlin landed or tagged in NZSFC club records by fishing year. Fishing years are labelled by the later calendar year e.g. 2018 is 2017–18.

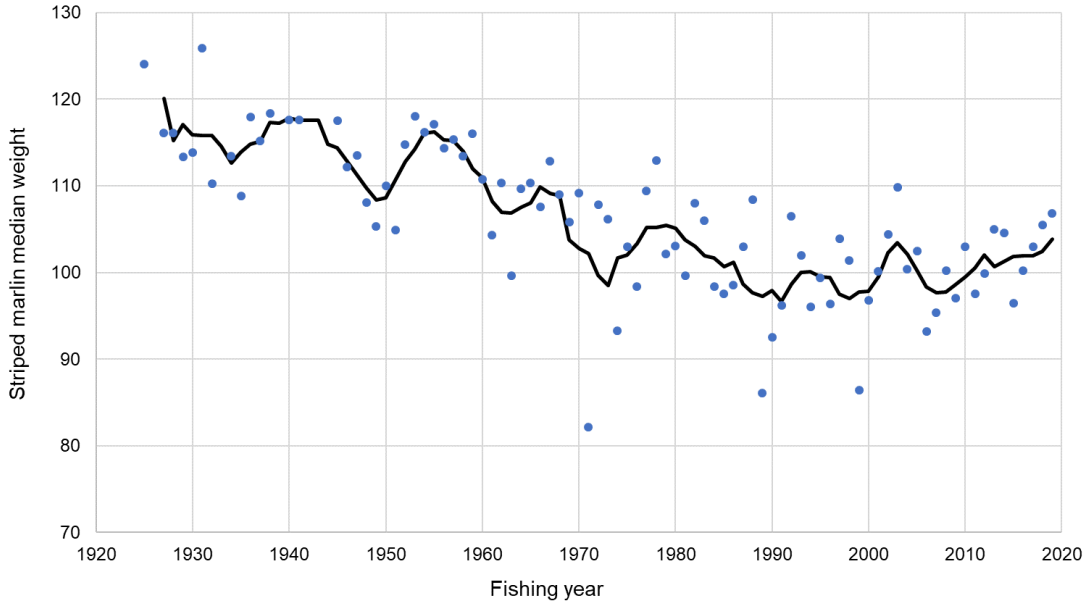


Figure 5: The median weight of landed striped marlin from NZSFC clubs and the five year rolling average by fishing year.

The median weight of landed striped marlin reported shows a decline from about 115 kg average prior to 1950 to about 100 kg since the mid 1980s (Figure 5). Over the last 10 years annual median weight has been increasing. NZSFC introduced a voluntary minimum weight of 90 kg 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 average weight of landed fish is higher than that of the total recreational catch in most years (Figure 6). 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.

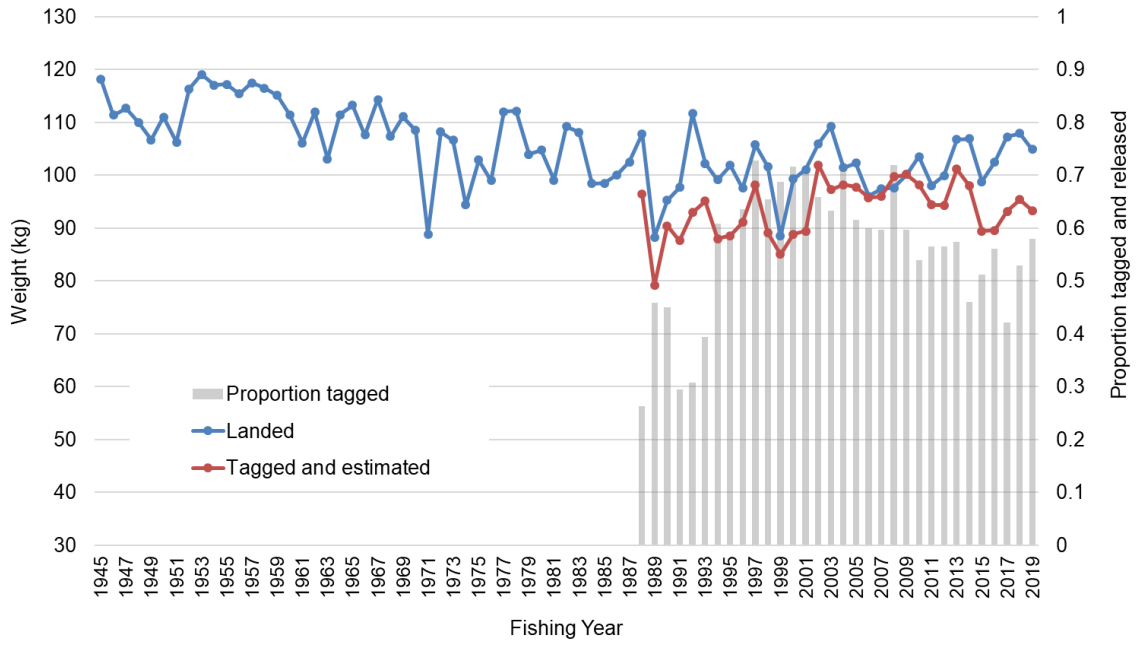


Figure 6: Average weight of landed striped marlin and tagged striped marlin from NZSFC clubs and the proportion tagged and released by fishing year.

3.2 Billfish logbook CPUE

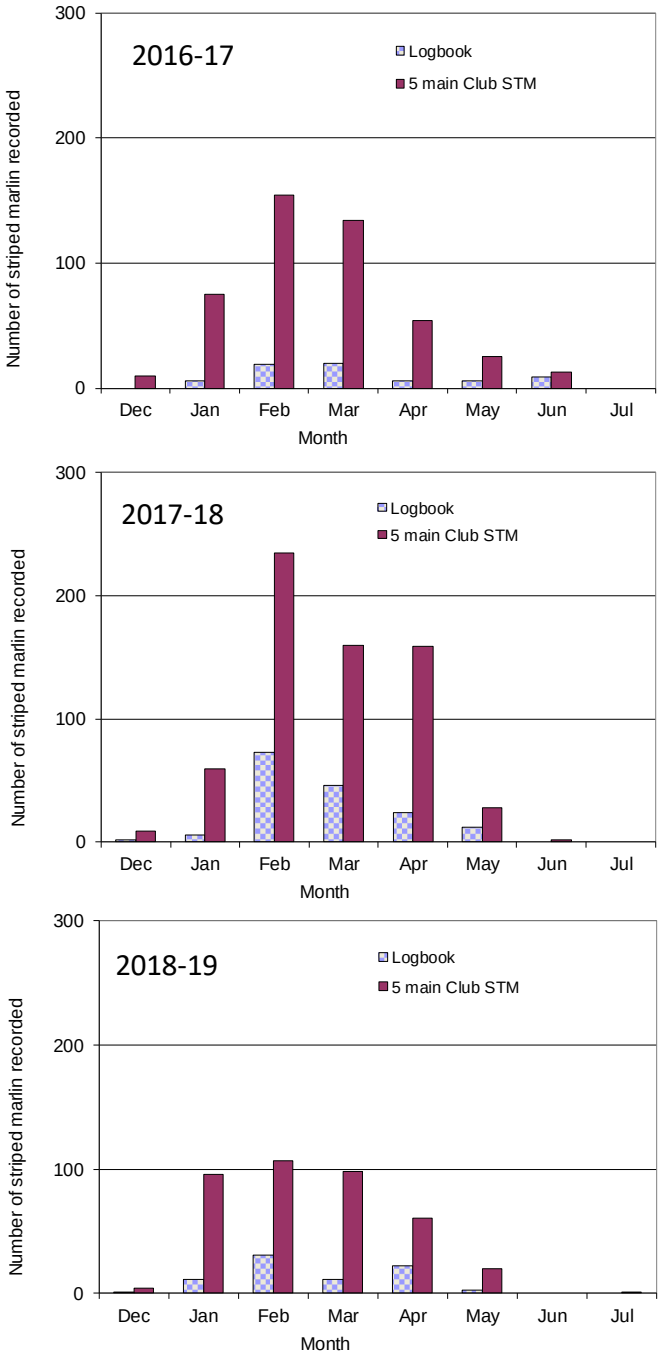
The billfish logbook programme has collected 13 years of data with an average of 214 (sd = 87.8) striped marlin recorded per year. The annual catch of striped marlin by sport fishers in New Zealand has been quite variable in recent years. It ranged from 970 in 2016–17 to 2430 in 2015–16 (Table 1). The average annual reported total catch is 1493 (sd = 393.3) over the last 13 years. For many years the charter boat skippers were the main participants in the billfish postal surveys that make up much of this time series. The number of charter boats engaged in the billfish fishery and the number of days fished per year has declined in recent years.

A subset of logbook data can be used to extend the existing time series of East Northland charter catch and effort. From 2016–17 to 2018–19 there were 673 logbook days targeting billfish and 94 striped marlin caught by charter vessels in General Statistical Areas 002, 003 and 004 (Figure 7). This includes days fished under charter and days when the boat was fished privately.

Table 1: Number of landed striped marlin recorded in club records and number tagged from the gamefish tagging programme. Also totals from two catch effort surveys of skippers, the East Northland charter boat postal survey 1974–75 to 2005–06 and the national Billfish Logbook Programme 2006–07 to 2018–19.

Fishing	NZ recreational striped marlin		Total	East Northland	NZ billfish	Proportion of
Year	Landed	Tagged		charter survey STM	logbook STM	catch surveyed
1974–75	242	0	242	4		0.02
1975–76	281	3	284	11		0.04
1976–77	332	2	334	140		0.42
1977–78	445	7	452	70		0.15
1978–79	547	18	565	150		0.27
1979–80	692	17	709	136		0.19
1980–81	792	2	794	84		0.11
1981–82	704	11	715	127		0.18
1982–83	702	6	708	126		0.18
1983–84	543	9	552	149		0.27
1984–85	262		262	66		0.25
1985–86	395	2	397	67		0.17
1986–87	226	2	228	51		0.22
1987–88	281	136	417	165		0.4
1988–89	647	408	1 055	407		0.39
1989–90	463	367	830	308		0.37
1990–91	532	232	764	181		0.24
1991–92	519	242	761	197		0.26
1992–93	608	386	994	226		0.23
1993–94	663	929	1 592	438		0.28
1994–95	910	1206	2 116	510		0.24
1995–96	705	1104	1 809	489		0.27
1996–97	619	1302	1 921	116		0.06
1997–98	543	898	1 441	116		0.08
1998–99	823	1541	2 364	451		0.19
1999–00	398	791	1 189	206		0.17
2000–01	422	851	1 273	267		0.21
2001–02	430	771	1 201	96		0.08
2002–03	495	671	1 166	142		0.12
2003–04	592	1 051	1 643	206		0.13
2004–05	834	1 348	2 182	181		0.08
2005–06	630	923	1 553	134		0.09
2006–07	675	965	1 640		270	0.16
2007–08	485	806	1 291		316	0.24
2008–09	741	1058	1 799		384	0.21
2009–10	607	858	1 465		276	0.19
2010–11	607	731	1 338		185	0.14
2011–12	635	663	1 298		176	0.14
2012–13	744	858	1 602		243	0.15
2013–14	620	520	1 139		206	0.18
2014–15	696	1 088	1 782		209	0.12
2015–16	900	1 658	2 430		207	0.09
2016–17	516	517	970		66	0.07
2017–18	544	711	1 161		163	0.14
2018–19	446	579	1 025		78	0.08
Total	25 047	25 669	50 428	6 017	2 779	

The main season for striped marlin is from January to May and the number of fish recorded in logbooks is spread across the season in a similar way to fishing club data (Figure 7). Generally, February and March are the months with the highest catch. Club catches remained high in April 2018 and all months were relatively poor in 2018–19 (Figure 7).



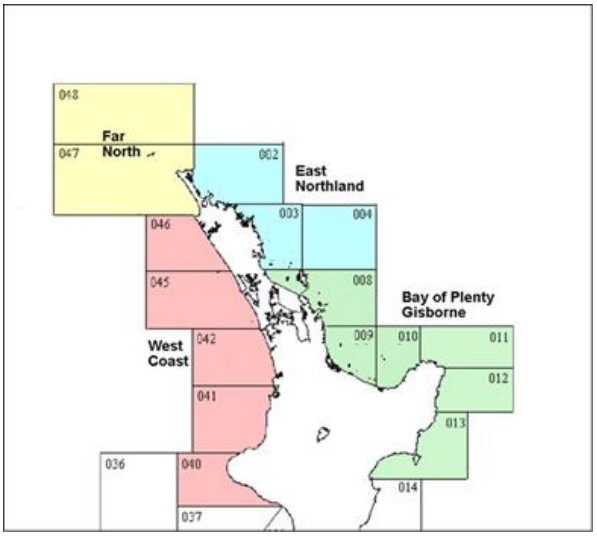


Figure 7: Striped marlin catch by month recorded by five large fishing clubs in East Northland and Bay of Plenty and recorded in billfish logbooks (left). General Statistical Areas and the regional boundaries used in this report (right).

Billfish logbook data for 2016–17 to 2018–19 by month and region shows most catch coming from east Northland. Striped marlin catch in the far north area is often high, but variable. February 2018 was the month with highest catch recorded in logbooks with 56 striped marlin caught in the Far North alone (Figure 8).

The overall distribution of logbook days fished shows a similar monthly trend in each year with peak effort in February, tapering off to June (Figure 8).

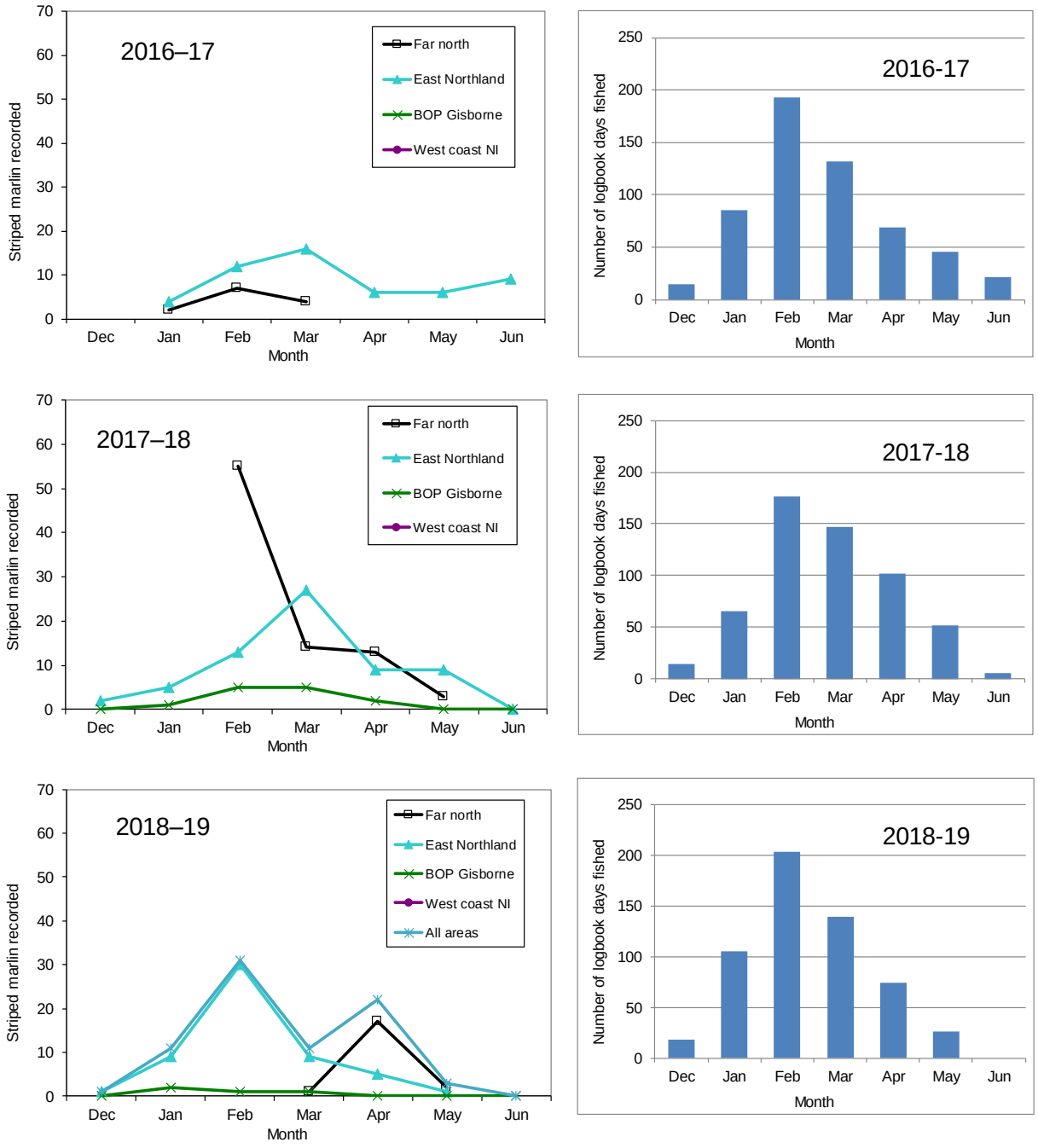


Figure 8: Logbook reported striped marlin catch by region and month for 2016–17 to 2018–19 (left) and total logbook days fished targeting billfish by month (right).

Striped marlin and blue marlin catch and billfish strikes by week are shown in Figure 9. A strike is when a bait or lure is taken by a billfish. This does not always result in a hook up or capture and it can be hard to determine the species if the fish is not seen. The number of marlin caught was most consistent in 2017–18 for both species (Figure 9). The last week of February is when the New Zealand Sport Fishing Council run their six day Nationals Tournament. There tends to be a spike in catch for many species at this time.

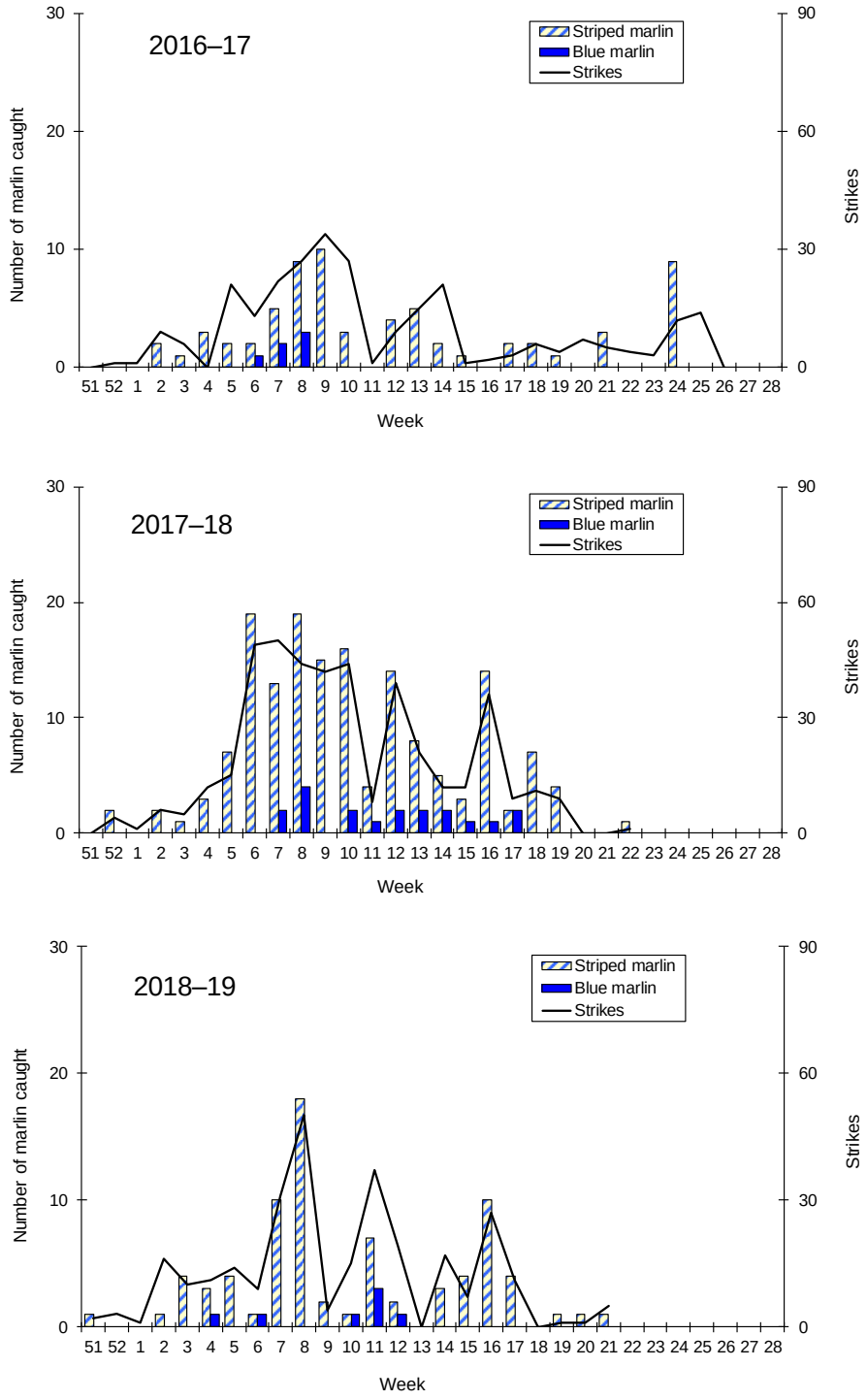


Figure 9: The number of striped or blue marlin caught by week and the number of strikes per week (right axis) 2016–17 to 2018–19. Week 0 starts 24 December.

Catch rates of striped marlin per vessel day have been consistently low across the main fishing areas from 2016–17 to 2018–19, at or below 0.2 fish per day. The Far North, which includes the Three Kings area, generally has higher catch rates than other areas, but the number of fishable days and the distance from port limits fishing effort (Figure 10). Late season catch rates can rise but this is based on limited data from a few days fishing.

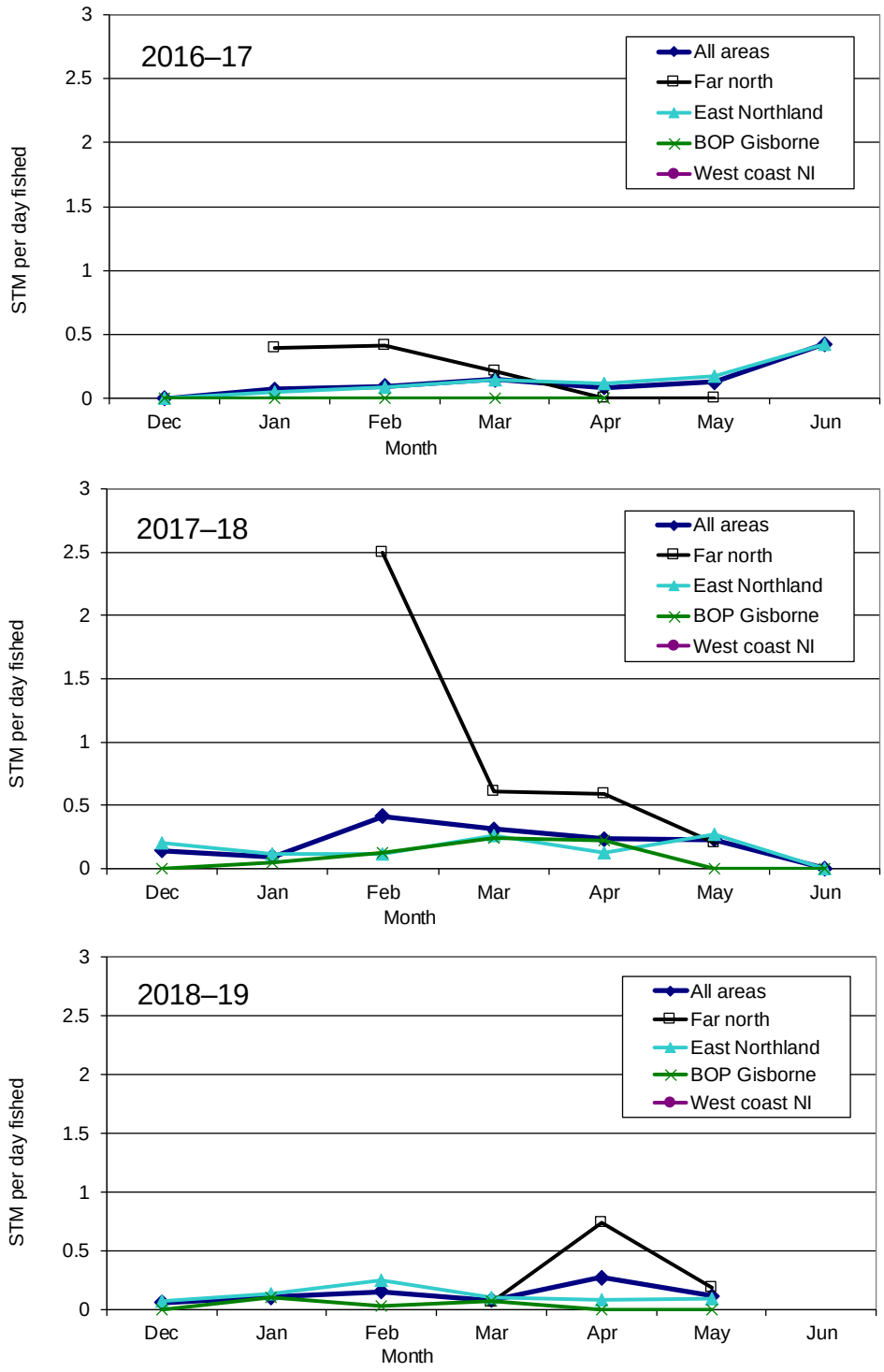


Figure 10: Striped marlin catch per vessel day by area and month from logbook data for 2016–17 to 2018–19.

Average summer monthly sea surface temperatures (SST) from logbook records during 2018 and 2019 were warmer than the overall average since 2007 (Table 2). These temperatures were similar or slightly higher than the summer of 2016 which recorded high striped marlin catches by most clubs. No strong correlation was found between summer sea surface temperatures and overall striped marlin or blue marlin catch by year. While most of the best fishing years were warm, there are other factors that affect abundance and availability of marlin in New Zealand waters.

Table 2: Average monthly SST January to May by fishing year from logbook data all regions combined, highest monthly average per year in bold.

All regions	Mean sea surface temperature by month				
Fishing year	Jan	Feb	Mar	Apr	May
2006–07	20.88	**21.12**	21.01	19.75	19.2
2007–08	20.72	**21.05**	20.99	20.87	19.33
2008–09	20.68	**21.46**	20.79	20.54	18.67
2009–10	20.35	**21.47**	21.00	20.02	18.32
2010–11	21.46	**22.43**	21.55	20.11	17.92
2011–12	20.14	**20.85**	19.98	19.92	18.57
2012–13	20.46	**21.37**	20.76	20.14	19.43
2013–14	20.21	20.33	**20.57**	20.02	18.95
2014–15	**21.50**	21.44	21.33	20.54	18.93
2015–16	21.74	**22.13**	21.86	20.93	20.43
2016–17	20.18	21.46	**21.75**	21.03	19.60
2017–18	21.72	**22.67**	22.04	21.00	19.82
2018–19	21.71	**22.41**	21.92	20.60	19.32
Overall mean	20.90	21.55	21.20	20.42	19.11

3.3 East Northland charter CPUE time series

CPUE data from 1974–75 to 2005–06 are available from the annual postal survey of charter skippers. A subset of logbook data from the gamefish logbook scheme has been used to extend the postal survey time series from 2006–07 to 2018–19. The data was restricted to recreational charter vessels, fishing in East Northland (General Statistical Areas 002, 003 and 004, Figure 7).

The data available is the total striped marlin catch and days fished targeting marlin by vessel and year. The core fleet was restricted to vessels that had fished for at least five years including years with zero catch. This resulted in a core fleet size of 52 vessels which took 85% of the catch from this dataset. A plot of the degree of overlap of core vessel fishing years is provided (Figure 11).

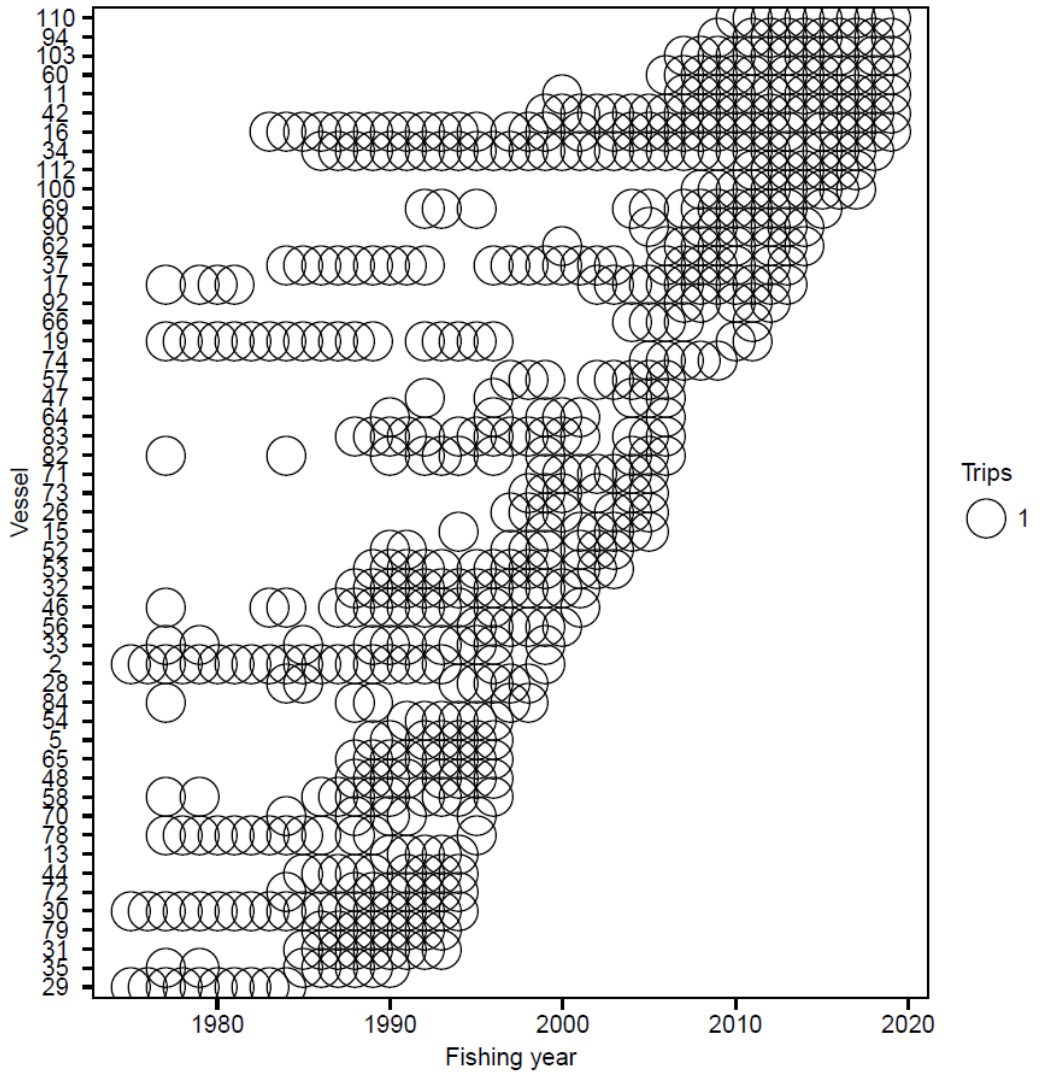


Figure 11: Participation of the core charter vessels used. Each observation summarises one year of fishing, whether or not successful with respect to striped marlin. Fishing years are labelled by the later calendar year e.g. 1990 = 1989–90.

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 1%. Table 3 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*

Table 3: 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-R2 (%)	Nagelkerke pseudo-R2 (%)	
fyear	45	-1 682	3 453	36.11	38.55	*
poly(log(days), 3)	48	-1 538	3 173	61.01	62.74	*
vessel	99	-1 414	3 027	74.58	75.84	*

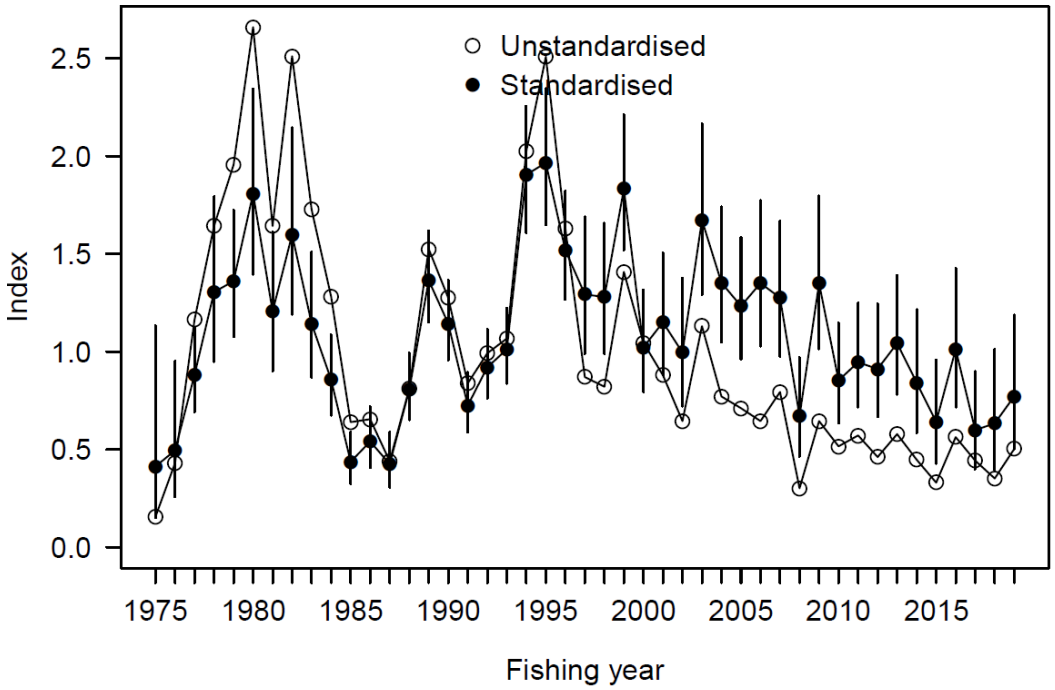


Figure 12: The effect of standardization on East Northland charter boat striped marlin catch. The unstandardised index is based on the geometric mean of the catch only and is not adjusted for effort. The standardised index is adjusted for fishing effort and vessel.

Standardised and unstandardised CPUE indices by year are presented in Appendix 2. The standardisation effect of the model was a tendency to reduce the index in the early years and lift the index since the late 1990s (Figure 12). The main driver for this was the effort term which shows a large and consistent trend toward fewer days fished by charter boats in East Northland between 1982 and 2009. The vessel effect pushed the index back down as a number of new high performing vessels entered the fishery in the mid-2000s (Figure 13). (See distribution and influence plots in Appendix 3).

The diagnostic plots of the residuals from the fit of this model to the data show an adequate fit to the negative binomial assumption (Figure 14).

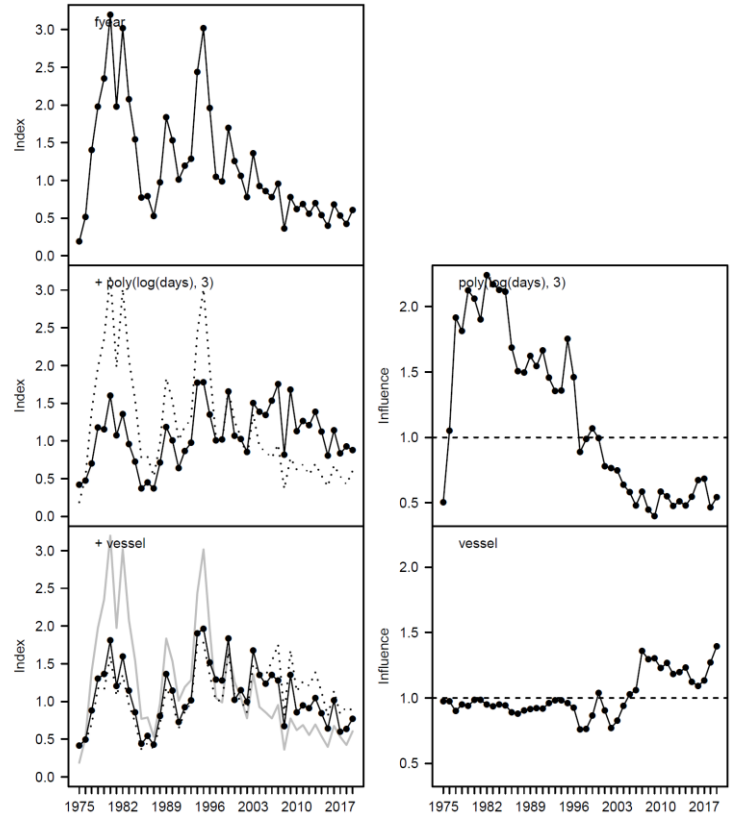


Figure 13: Step plot (left) and influence plots (right) with fishing year at the top, adding polynomial of days fished in the middle, and adding vessel at the bottom.

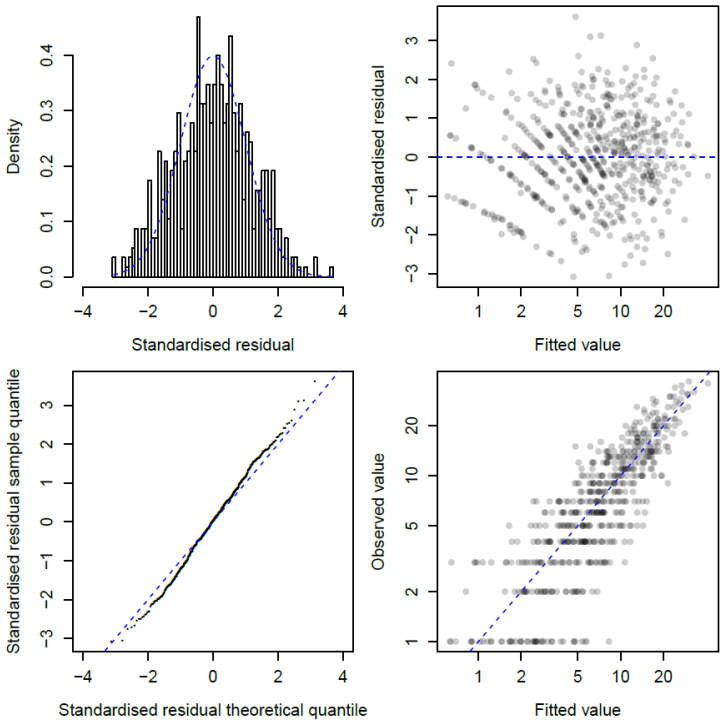


Figure 14: Residual diagnostics for the charter vessel model. Top left: histogram of standardised residuals compared to standard normal distribution. Bottom left: quantile-quantile plot of standardised residuals. Top right: fitted values versus standardised residuals. Bottom right: observed values versus fitted values.

3.4 Billfish logbook CPUE time series

The billfish logbook has been collecting daily catch effort and environmental data from participating fishers since 2006–07. Over these 13 years 92 boats have participated and reported 10 041 days targeting billfish for a catch of 2747 striped marlin and 188 blue marlin.

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 32 vessels which took 74% of the catch (Figure 15).

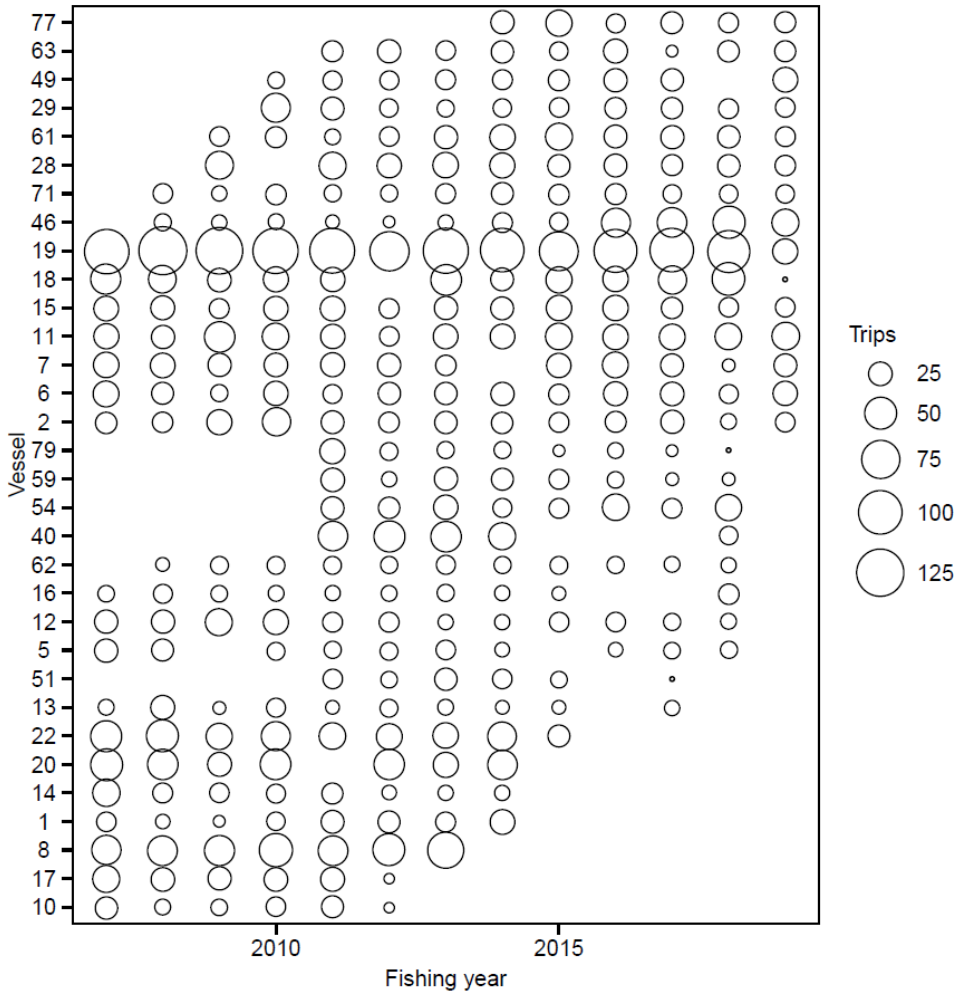


Figure 15: Participation of core vessels providing billfish logbook data by fishing year. The area of circles is proportional to the number of trips for a vessel in a fishing year.

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 7), *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 1%. Table 4 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)

Table 4: 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-R2 (%)	Nagelkerke pseudo-R2 (%)	
fyear	13	-4 424	8 873	2.83	2.12	*
vessel	44	-3 922	7 932	26.28	20.82	*
zone	47	-3 803	7 701	30.93	24.85	*
poly(log(duration), 3)	50	-3 764	7 629	32.37	26.13	*
poly(temp, 3)	53	-3 754	7 614	32.77	26.48	
month	60	-3 743	7 606	33.15	26.84	
target	67	-3 732	7 598	33.56	27.20	

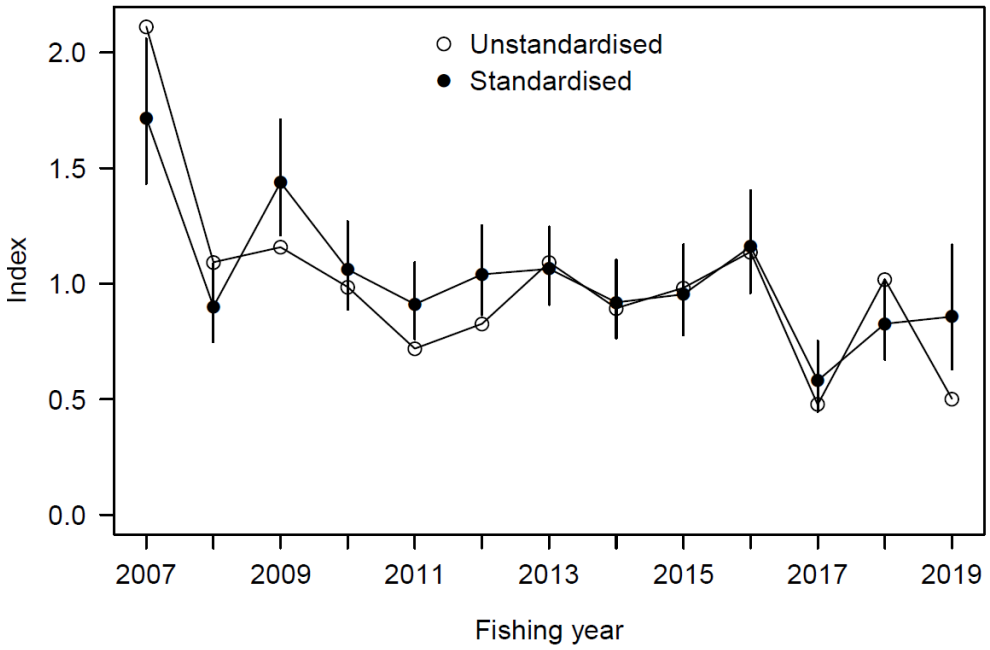


Figure 16: Overall standardisation effect from the billfish logbook model of striped marlin CPUE. The unstandardised index is based on the geometric mean of the catch per year and is not adjusted for effort. Fishing years are labelled by the later calendar year e.g. 2007 = 2006–07.

The CPUE index based on daily billfish logbook data shows a flat or slightly declining trend with a lower CPUE in 2017 and 2018 (Figure 16). Explaining most variance was the vessel effect which pushed the index down in the first few years and in the last year. The hours fished per day (duration) had a strong correlation with catch (See distribution and influence plots in Appendix 3) but did not show much of a trend over time to affect the CPUE index (Figure 17). Sea surface temperature and month did not explain more than 1% of the deviance after vessel and zone were included in the model.

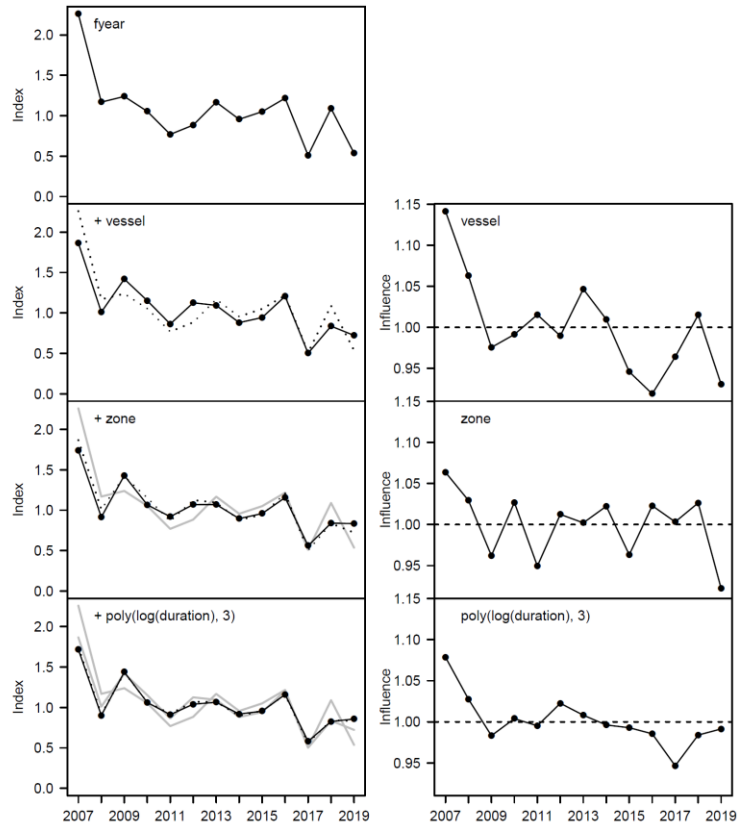


Figure 17: Step and influence plot from the billfish logbook model.

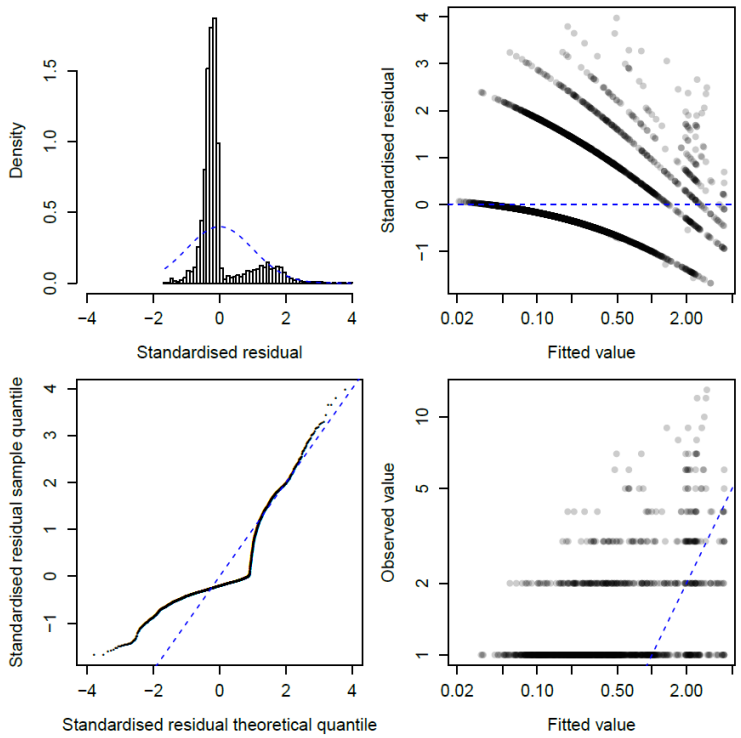


Figure 18: Residual diagnostics for the billfish logbook model. Top left: histogram of standardised residuals compared to standard normal distribution. Bottom left: quantile-quantile plot of standardised residuals. Top right: fitted values versus standardised residuals. Bottom right: observed values versus fitted values from the billfish logbook model.

Residual diagnostics for the billfish logbook model show a bimodal distribution of standardised residuals due to the high proportion of zero catch days (Figure 18).

The logbook and East Northland charter standardised CPUE indices show a similar pattern in the years where they overlap (Figure 19). This is expected as the charter catch and effort is a subset of the logbook data. Overall catch rates were relatively high in the late 1970s and early 1980s. There was an increasing trend in the CPUE index from the lows in the mid-1980s to highs in the mid-1990s and a variable but decreasing trend since then (Figure 19). The 2016–17 to 2018–19 seasons were relatively poor years for the recreational striped marlin fishery.

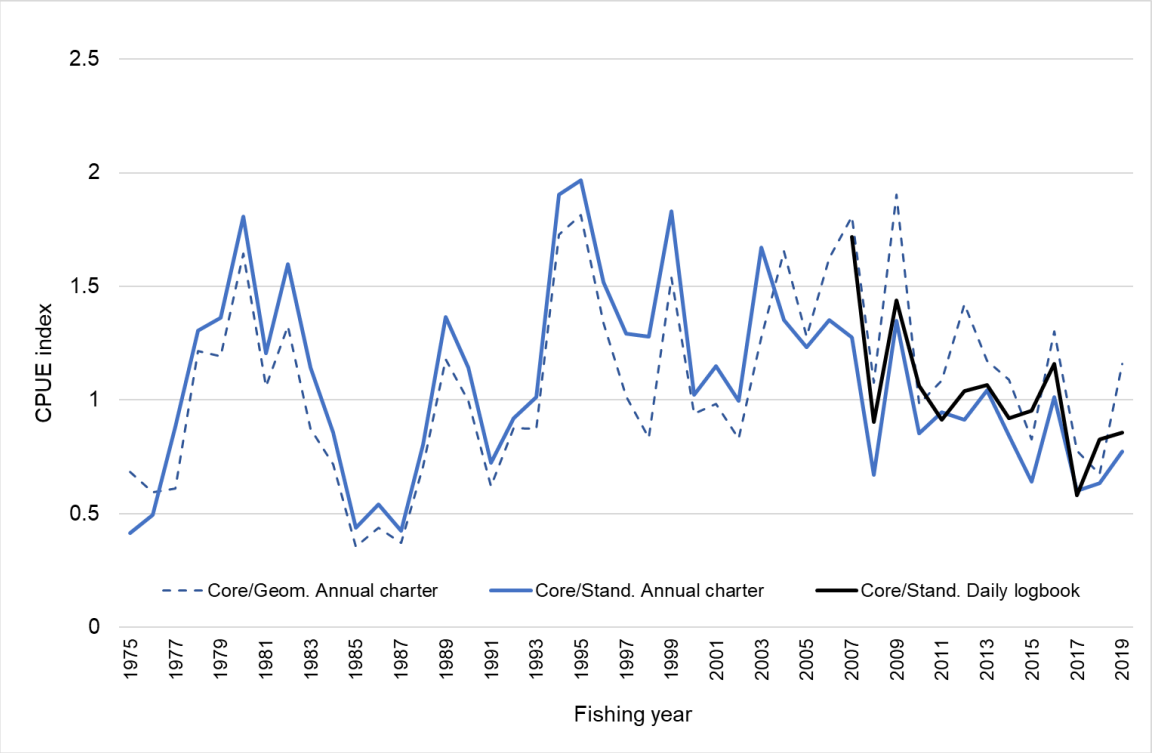


Figure 19: Comparison between the negative binomial model of East Northland recreational charter boat annual CPUE since 1975 (1974–75 fishing year) and billfish logbook daily CPUE since 2007.

4 DISCUSSION

The Billfish Logbook Programme collects details of daily fishing effort and catch from charter skippers and experienced private fishers. It is a voluntary scheme and it is preferable to collect data from active fishers who maintain a complete and accurate record of fishing effort and catch. For many years the most reliable participants were gamefish charter skippers. Changes to the maritime safety regulations and rules around claiming running costs from owning a charter boat against tax has reduced the number of dedicated billfish charter boats. In addition, a number of long term charter operators and participants in the logbook programme have retired over the last few years. The inclusion of fishers running private boats has helped maintain logbook coverage in the billfish fishery but turnover in participation is higher than in the core charter fleet. Two thirds of logbook participants over the three years of this project have been private fishers. In addition, there has been a significant decline in the number of days fishing for marlin per season across the fleet of East Northland charter boats - most obvious in the vessel distribution plot in Appendix 3 (Figure A1).

Fisheries New Zealand requires charter operators to register and report fishing effort and catch of selected species. There have been around 20 striped marlin reported voluntarily on the AFCV forms per year since 2016–17 along with effort and some location information. Fisheries New Zealand is currently reviewing the reporting requirements of the AFCV programme. Billfish are not included in the proposal for inclusion of new species that charter operators will be required to report.

Sport fishing clubs in New Zealand have traditionally kept detailed catch records of species, weight, date and vessel. The billfish logbook form collects important additional information on vessel size and power, target species, fishing effort, fishing method, wind strength, SST, and location fished (Appendix 4). Logbook data shows the variability in catch rates between areas and months and provides potential explanatory variables.

There are now 13 years of logbook data, sufficient to generate a standardised CPUE index based on daily catch and a range of potential terms in a general linear model. The vessel term explained most of the variance in the model, followed by the area fished (zone) and hours fished (duration). While fishers often seek out the warmest water when targeting billfish SST and month were not significant factors in the daily logbook CPUE standardisation. The East Northland charter series is now 45 years long and shows some large fluctuations in the 1980s and 1990s. Over the last 13 years the charter CPUE trend has been similar to the daily logbook data, in part because it is a subset of that data rolled up to annual catch and days fished, and because the model terms selected are similar.

Data from New Zealand striped marlin fisheries was documented and summarised for the pre-assessment workshop run by the Secretariat for the Pacific Community (SPC) (Holdsworth et al. 2019). The stock assessment for southwest Pacific striped marlin uses the long time series Japanese longline fishery in area 2 as the CPUE index fishery for the diagnostic (base) case (Ducharme-Barth et al. 2019). Area 2 is between 15°–30° S from Australia to Samoa. The fit of the New Zealand charter CPUE to the model prediction for this fishery was reasonably good, apart from for the last ten years where the New Zealand index declined while the model, and longline data from the distant water fleets, showed an increase.

As part of this project catch records of individual fish from New Zealand Sport Fishing Clubs were collected and added to the existing time series which in some cases goes back to 1925. Prior to 1988 most recreational striped marlin catch was weighed on certified scales by club weighmasters. The New Zealand sport fishing club catch records for landed striped marlin was one of the most influential data components in the stock assessment, as it provides a continuous record of catch-at-weight data (Ducharme-Barth et al. 2019). These data show a decline in median weight since the beginning of the assessment period in 1952, which the model attributed to fishing mortality. It is possible that since 1988, further decline in median weight has been masked by the New Zealand Sport Fishing Council's voluntary 90 kg minimum weight policy.

The stock assessment model shows a persistent decline in spawning biomass and increase in fishing mortality from the beginning of the model period, which is consistent with what was found in the previous assessment. Fishing mortality increased further in the 2000s to a peak at the beginning of the current decade (2010s) which also coincided with the lowest estimates of spawning biomass. Recent years show a slight improvement in stock status relative to the early 2010s. The assessment concludes that the southwest Pacific Ocean striped marlin stock is likely to be overfished, at about 20% of unfished spawning stock biomass in 2017 and that the total striped marlin biomass in the region is estimated to be about 7500 tonnes (Ducharme-Barth et al. 2019).

Over the last 10 to 15 years there has been an increase in the number of well-appointed trailer boats targeting pelagic gamefish in New Zealand. These can launch at a wide variety of locations and are less likely to be affiliated to a club. As non-members they may still choose to weigh their fish at a club, where it can be picked up and taken to a local smoke house. Anecdotally there are a large number of new entrants to the gamefish fishery, particularly when catch rates are high, and the unreported billfish catch has

increased. For many years club records have been considered a reasonably complete record of billfish and large pelagic shark landings in the sport fishery. Future estimates of landed striped marlin catch from the New Zealand recreational fishery provided to Fisheries New Zealand and the WCPFC could include an allowance for unaccounted catch.

The National Panel Survey (NPS) provides estimates of harvest by amateur fishers, although in specialist fisheries sample sizes are low and uncertainty is high. The estimated number of marlin retained by recreational fishers in the 2011–12 NPS was 985 (CV 0.65) (Wynne-Jones et al. 2014). The NZSFC recorded 722 across the three species of marlin that year. There were a few more sport fishers in the 2017–18 NPS and the estimated retained catch of marlin was 1168 (CV 0.31) (Wynne-Jones et al. 2019). The NZSFC recorded 782 marlin in the same year.

5 ACKNOWLEDGMENTS

Thanks to all those who participated in this programme and completed and returned billfish logbooks. The New Zealand Sport Fishing Council and all affiliated clubs are thanked for their cooperation and for providing detailed catch records. Many thanks to Terese Kendrick for undertaking the striped marlin CPUE analysis. This project was reviewed by the Highly Migratory Species Working Group chaired by Dr John Annala from Fisheries New Zealand. The Ministry for Primary Industries provided funding for this project STM2016-01, "Management of data from the gamefish tag recapture programme".

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7 APPENDIX 1. CATCH FROM NEW ZEALAND SPORT FISHING CLUBS

Table A1: Landed catch by species from New Zealand Sport Fishing Council club records since 1993–94.

	Striped marlin	Blue marlin	Black marlin	Shortbill spearfish	Broadbill swordfish	Albacore tuna	Yellowfin tuna	Mako shark	Blue shark	Hammerhead shark	Thresher shark
1993–94	663	41	3	71	1	703	996	220	96	57	6
1994–95	910	28	9	87	5	617	1 997	288	235	49	14
1995–96	705	40	7	27	8		2 187	424	198	44	5
1996–97	619	17	7	16	10	803	2 325	352	114	44	9
1997–98	543	76	10	19	12	993	1 268	455	177	47	13
1998–99	823	140	15	62	6	599	1 235	320	70	36	11
1999–00	398	234	24	17	27	453	1 085	338	79	50	11
2000–01	422	142	9	28	25	803	988	255	54	40	18
2001–02	430	112	8	35	22	576	262	155	100	39	14
2002–03	495	26	3	41	17	1 005	211	109	30	24	9
2003–04	592	47	8	38	33	789	838	82	18	12	4
2004–05	834	93	8	58	13	839	1 219	61	25	9	3
2005–06	630	103	6	53	6	868	346	44	30	7	5
2006–07	688	99	2	38	20	970	283	34	15	8	1
2007–08	485	105	1	25	6	1 189	496	45	12	7	2
2008–09	731	88	0	31	9	848	69	47	12	4	1
2009–10	607	100	4	46	9	794	59	51	13	4	0
2010–11	607	179	2	74	29	596	20	58	18	6	2
2011–12	635	78	9	19	34	535	10	40	15	4	2
2012–13	744	54	2	11	55	778	10	31	13	2	3
2013–14	620	64	4	25	80	592	8	24	6	11	1
2014–15	696	102	5	58	87	808	198	21	12	1	1
2015–16	900	99	4	69	85	877	492	24	8	9	1
2016–17	542	120	7	46	87	694	96	9	3	3	0
2017–18	618	159	5	91	72	731	274	8	10	2	1
2018–19	446	154	5	95	67	651	50	6	0	0	0
Total	16 383	2 500	167	1 180	825	19 111	15 803	3 501	1 363	519	137

Table A2: Striped marlin catch and average weight by year from three large East Northland clubs.

	Number		Average weight			Number		Average weight	
Year	landed	tagged	landed	tagged and estimated (kg)	Year	landed	tagged	landed	tagged and estimated (kg)
1945	108		118.17		1993	428	279	102.27	95.10
1946	78		111.41		1994	460	715	99.12	87.97
1947	196		112.64		1995	601	871	101.90	88.57
1948	410		110.02		1996	412	721	97.54	91.10
1949	618		106.71		1997	256	685	105.78	98.13
1950	341		111.02		1998	298	565	101.69	89.12
1951	329		106.26		1999	329	726	88.47	85.03
1952	287		116.34		2000	170	429	99.28	88.87
1953	335		119.06		2001	203	493	101.09	89.44
1954	259		117.09		2002	256	493	105.97	101.95
1955	298		117.20		2003	279	481	109.22	97.31
1956	276		115.39		2004	269	684	101.48	98.23
1957	278		117.46		2005	375	599	102.35	97.77
1958	402		116.46		2006	315	472	96.05	95.73
1959	186		115.13		2007	414	614	97.42	96.01
1960	164		111.46		2008	166	424	97.67	99.69
1961	319		106.12		2009	454	674	100.18	100.16
1962	105		111.93		2010	340	399	103.54	98.19
1963	122		103.08		2011	297	386	98.07	94.42
1964	122		111.47		2012	219	285	99.93	94.33
1965	145		113.23		2013	284	382	106.74	101.15
1966	124		107.63		2014	215	183	106.95	98.08
1967	74		114.32		2015	274	288	98.79	89.43
1968	96		107.35		2016	398	508	102.54	89.58
1969	140		111.10		2017	242	176	107.25	93.12
1970	46		108.52		2018	231	259	107.96	95.43
1971	47		88.84		2019	156	225	104.92	93.31
1972	119		108.19						
1973	76		106.65						
1974	184		94.38						
1975	211		102.91						
1976	254		99.03						
1977	284		112.01						
1978	305		112.20						
1979	515		103.99						
1980	647		104.78						
1981	597		99.09						
1982	668		109.25						
1983	657		108.11						
1984	501		98.44						
1985	217		98.48						
1986	325		100.08						
1987	209		102.50						
1988	255	91	107.88	96.40					
1989	379	321	88.31	79.15					
1990	400	327	95.25	90.43					
1991	385	161	97.69	87.64					
1992	392	174	111.67	92.98					

8 APPENDIX 2. TABLES OF CPUE INDICES

Table A3. 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	0.5956	0.6062	0.6847	0.4136	0.50394
1976	0.3822	0.3890	0.5924	0.4950	0.32751
1977	0.6317	0.6431	0.6115	0.8814	0.12145
1978	1.1372	1.1576	1.2140	1.3043	0.15923
1979	1.0982	1.1179	1.1911	1.3607	0.11771
1980	1.5143	1.5414	1.6429	1.8078	0.12975
1981	1.0323	1.0508	1.0588	1.2054	0.14516
1982	1.3590	1.2855	1.3261	1.5981	0.14700
1983	1.0021	0.9204	0.8746	1.1431	0.13861
1984	0.6777	0.6909	0.7174	0.8560	0.11937
1985	0.3193	0.3461	0.3526	0.4370	0.15006
1986	0.3983	0.4054	0.4359	0.5407	0.14335
1987	0.3885	0.3936	0.3715	0.4256	0.16374
1988	0.6923	0.7073	0.7060	0.8046	0.10553
1989	1.2342	1.1668	1.1774	1.3644	0.08508
1990	0.9754	0.9754	0.9963	1.1436	0.08843
1991	0.7235	0.6512	0.6213	0.7249	0.10516
1992	0.7917	0.8709	0.8760	0.9202	0.09501
1993	0.9182	0.9740	0.8727	1.0118	0.09502
1994	1.4854	1.6929	1.7263	1.9048	0.08454
1995	1.5443	1.7301	1.8157	1.9654	0.08830
1996	1.2724	1.3489	1.3398	1.5183	0.09082
1997	1.0048	0.8807	1.0169	1.2928	0.13399
1998	1.0123	0.9562	0.8324	1.2792	0.12920
1999	1.6615	1.6502	1.5390	1.8320	0.09399
2000	0.9672	0.9167	0.9392	1.0220	0.12641
2001	0.9254	0.8039	0.9831	1.1503	0.13391
2002	0.9173	0.7314	0.8303	0.9955	0.16179
2003	1.3657	1.3901	1.2767	1.6726	0.12864
2004	1.6987	1.4915	1.6558	1.3520	0.12669
2005	1.6264	1.5795	1.2802	1.2330	0.12464
2006	2.0221	1.8870	1.6256	1.3502	0.13645
2007	1.7603	1.9591	1.8089	1.2754	0.13365
2008	1.1084	1.2052	1.0748	0.6714	0.18418
2009	1.7935	1.8648	1.9026	1.3497	0.14288
2010	1.2087	1.2081	0.9830	0.8532	0.14803
2011	1.1752	1.1785	1.0848	0.9459	0.13900
2012	1.1713	1.2260	1.4201	0.9114	0.15627
2013	1.3274	1.3431	1.1719	1.0429	0.14388
2014	1.2846	1.3076	1.0879	0.8416	0.18352
2015	0.8161	0.8307	0.8257	0.6411	0.20085
2016	1.1686	1.1895	1.3006	1.0119	0.17207
2017	0.8142	0.8287	0.7771	0.5992	0.20371
2018	0.9166	0.9330	0.6722	0.6334	0.23439
2019	0.8164	0.8310	1.1602	0.7716	0.21571

Table A4. Standardised and unstandardised CPUE indices for the daily billfish logbook 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
2007	1.2127	1.4594	1.0141	1.7174	0.09101
2008	1.0695	1.0510	0.9957	0.9013	0.09371
2009	1.4360	1.3109	1.0774	1.4384	0.08665
2010	1.0875	1.1042	0.9797	1.0617	0.08918
2011	0.8341	0.8288	0.9207	0.9112	0.09100
2012	0.9866	0.9284	0.8668	1.0405	0.09251
2013	1.1852	1.1976	0.9969	1.0643	0.07891
2014	0.9756	1.0271	1.0577	0.9192	0.09214
2015	1.2391	1.0758	1.0559	0.9542	0.10223
2016	1.1885	1.2430	1.0736	1.1605	0.09533
2017	0.5056	0.5354	0.8734	0.5809	0.13033
2018	1.0352	0.9862	1.0689	0.8268	0.10357
2019	0.6730	0.6741	1.0536	0.8576	0.15489

9 APPENDIX 3. COEFFICIENT, DISTRIBUTION AND INFLUENCE PLOTS

East Northland charter vessels

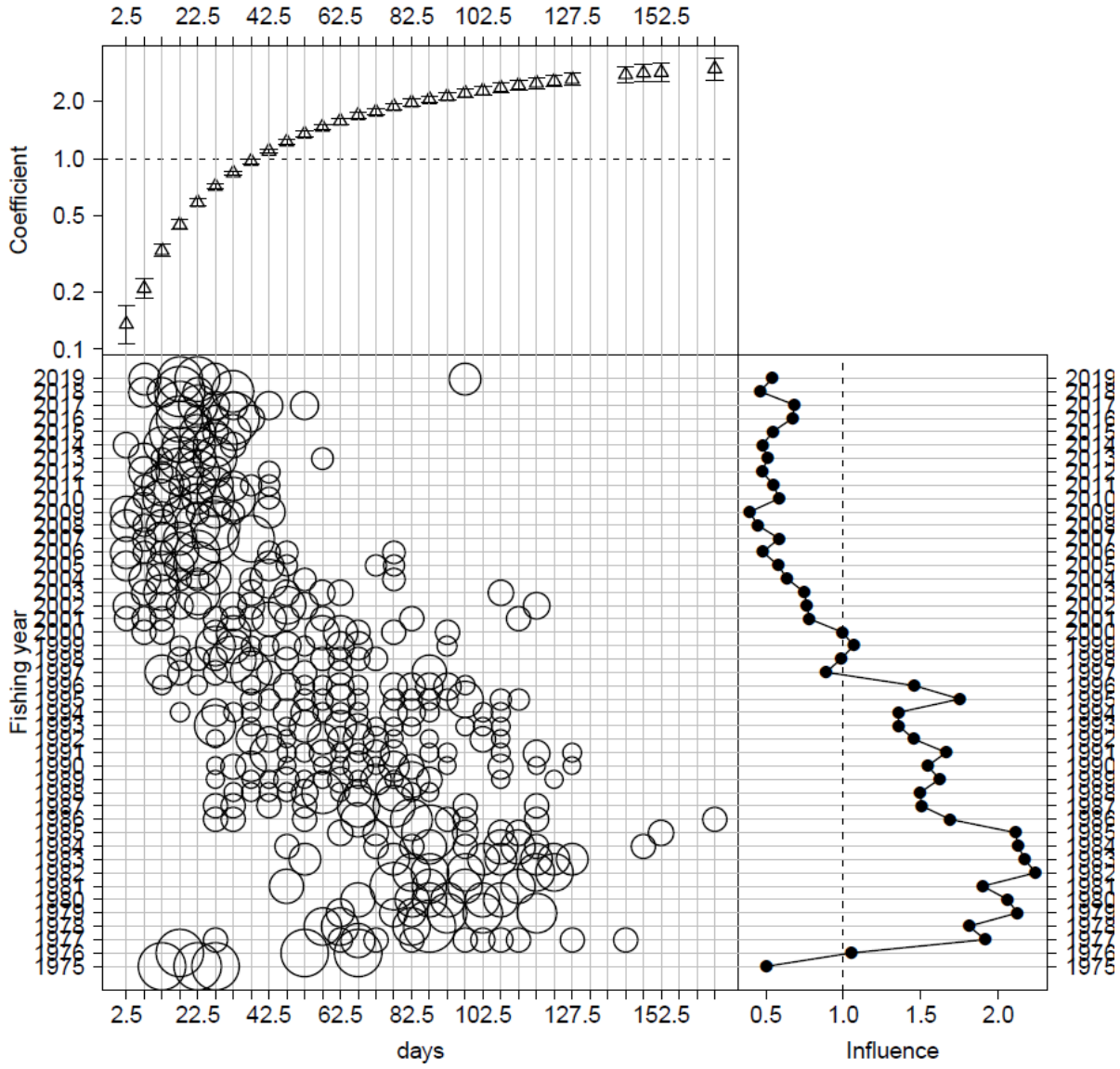

Figure A1: Coefficient-distribution-influence plot for *poly(log(days), 3)* for the East Northland charter vessel model.

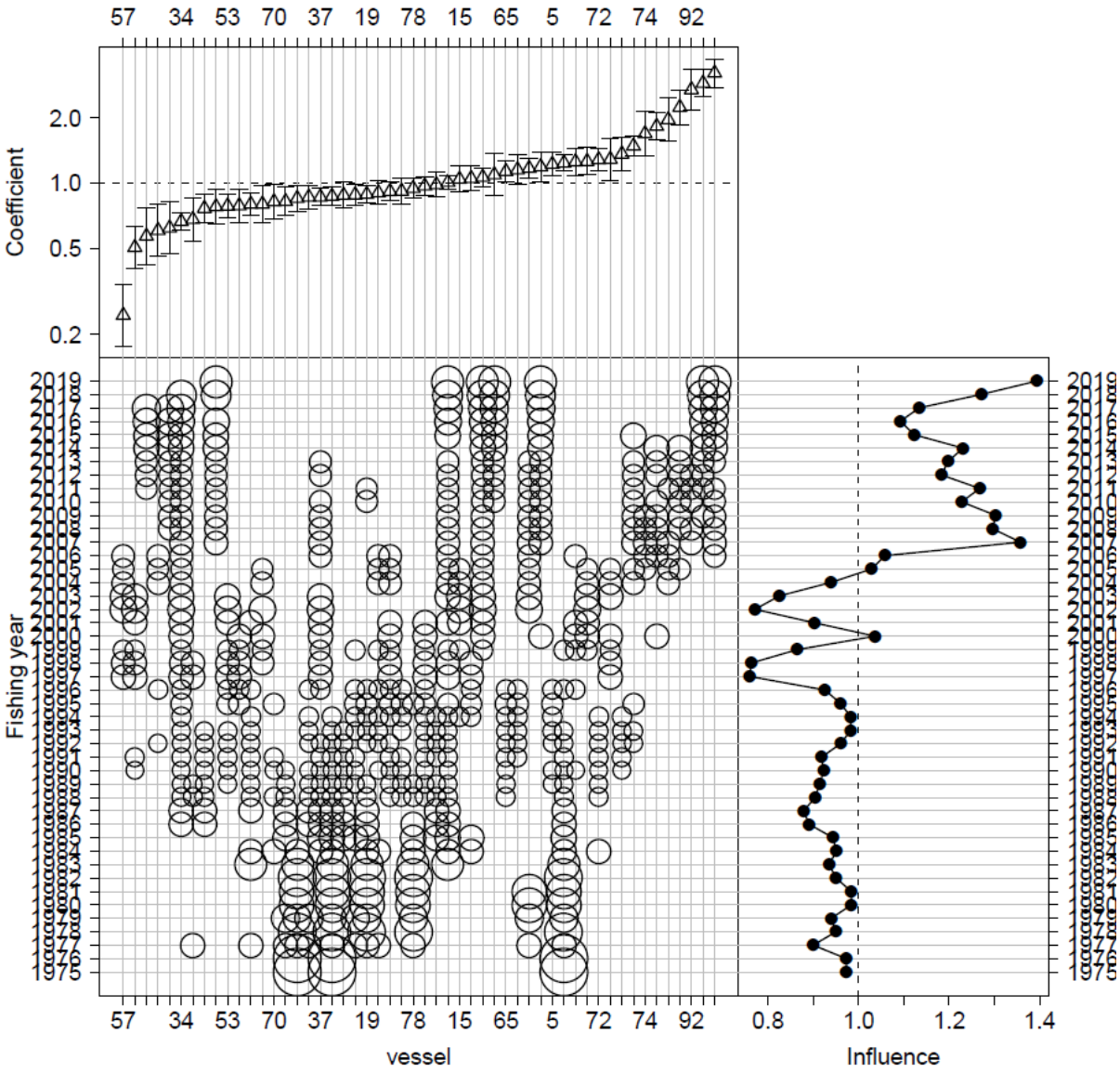

Figure A2: Coefficient-distribution-influence plot for *vessel* in the East Northland charter vessel model.

Billfish logbook vessels

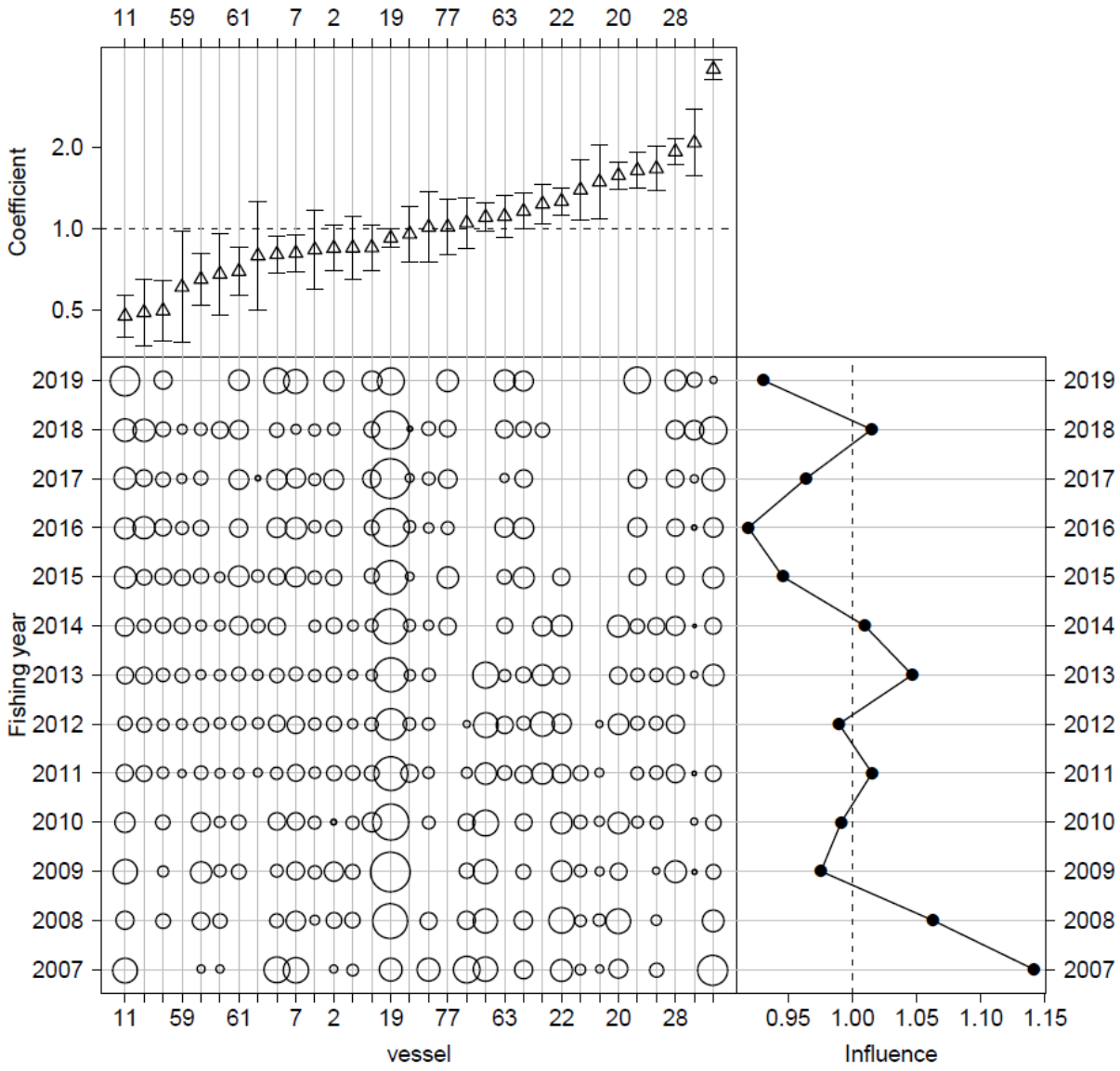

Figure A3: Coefficient-distribution-influence plot for *vessel* from the billfish logbook model.

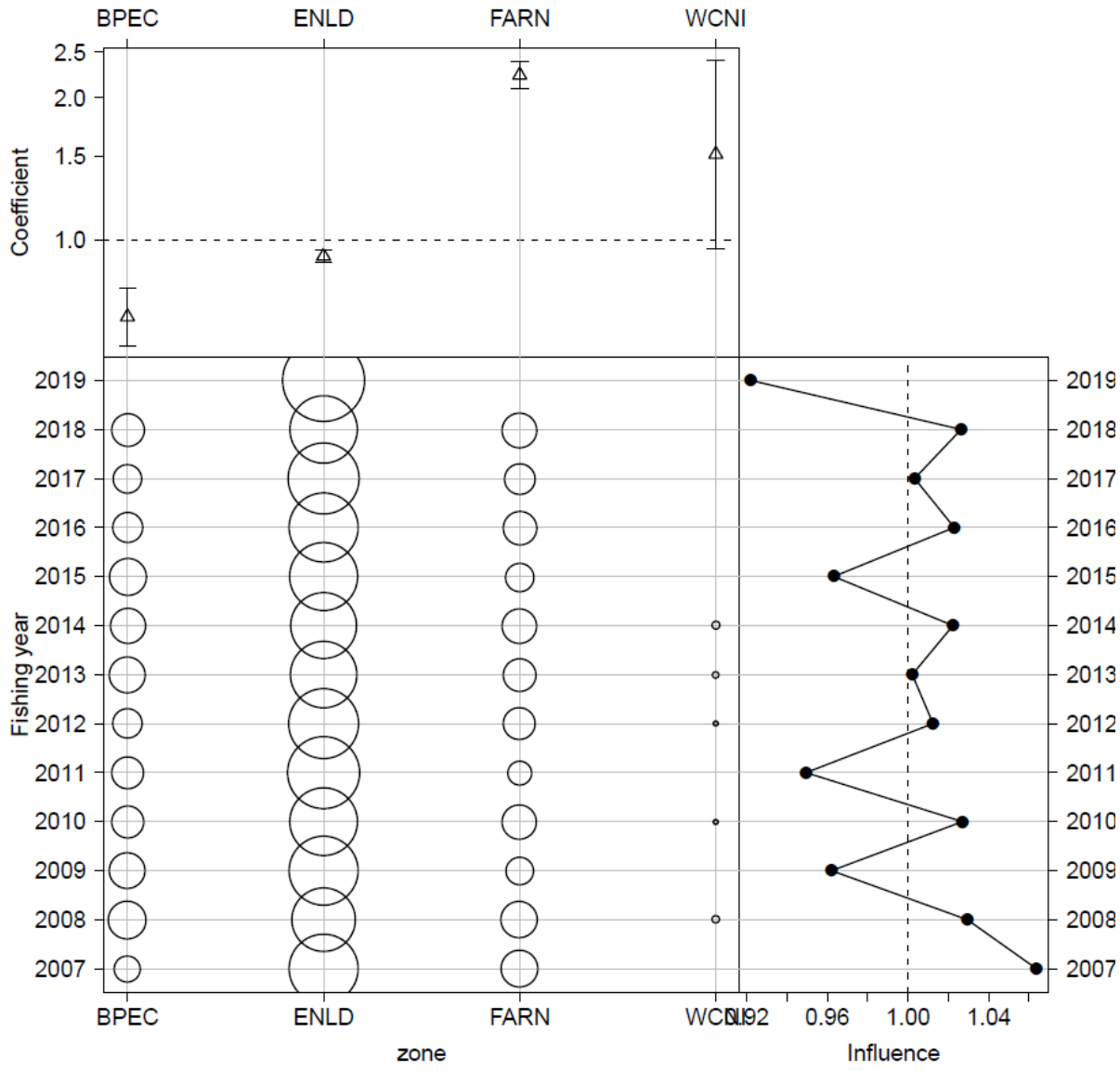

Figure A4: Coefficient-distribution-influence plot for *zone* from the billfish logbook model.

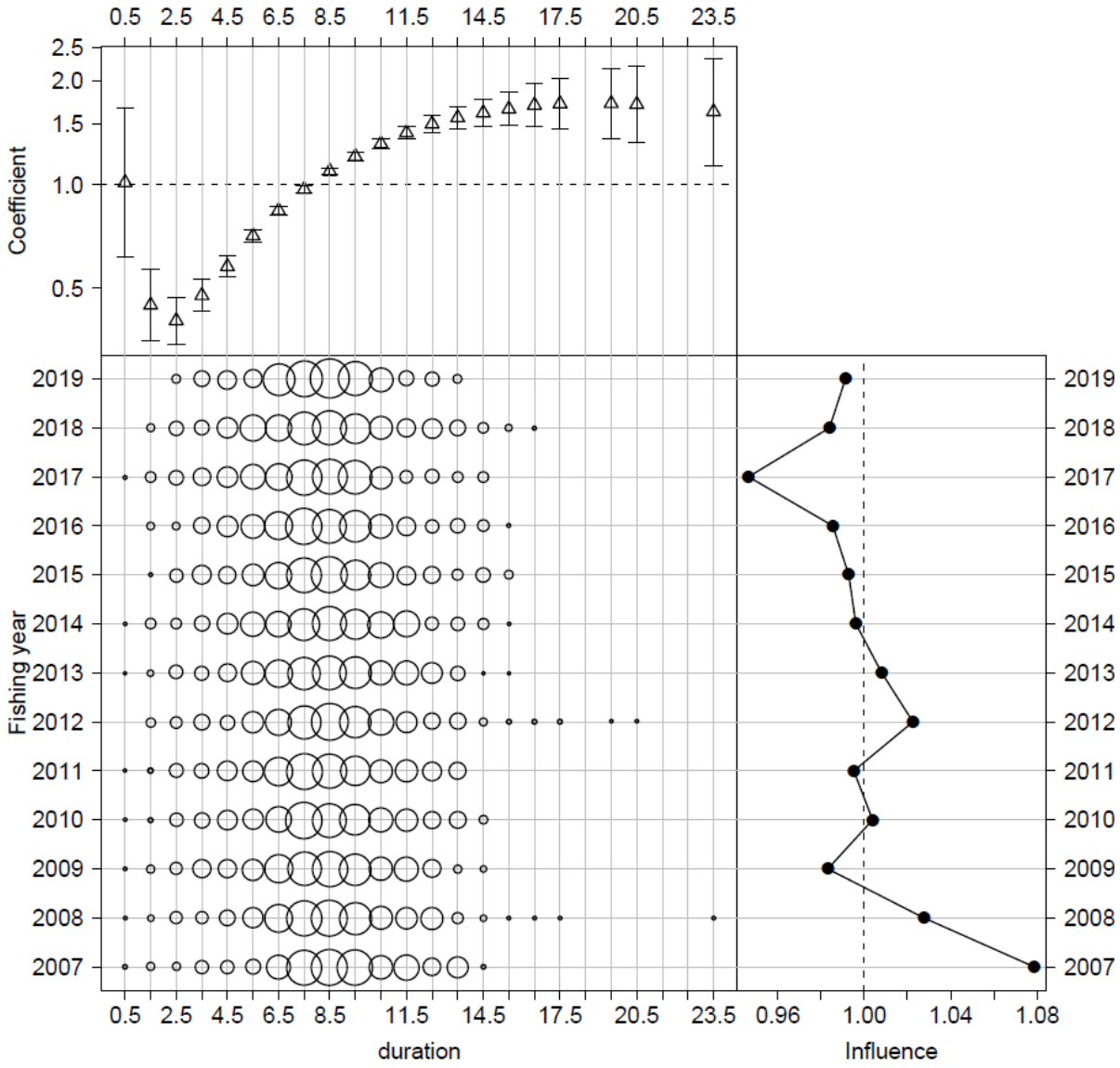

Figure A5: Coefficient-distribution-influence plot for *poly(log(duration), 3)* from the billfish logbook model.

APPENDIX 4. BILLFISH LOGBOOK FORM

Daily Billfish Logbook Form

Page of for this day

1. Daily Trip Information

Date fished / / 20 | Time started fishing : | Name of vessel | Lat & Long at noon ° °

Area fished | Time stopped fishing : | Name of skipper | Noon wind speed direction Knots

Primary target species today (code) | Water Temp at Noon

2. Time of all Marlin Strikes

Hrs	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100
Tick																	

3. Catch & Time

	Fish 1	Fish 2	Fish 3	Fish 4
Species caught (code)				
Time of hook-up	: hrs	: hrs	: hrs	: hrs
Target species (code)				
Total fight time	minutes	minutes	minutes	minutes

4. Method & Location

	Fish 1	Fish 2	Fish 3	Fish 4
Type of bait (code)				
Water temp at hook-up	°C	°C	°C	°C
Water depth at hook-up	metres	metres	metres	metres
Latitude at hook up	° S	° S	° S	° S
Longitude at hook-up	°	°	°	°

5. Size of Fish

	Fish 1	Fish 2	Fish 3	Fish 4
Kept or released (code)				
Estimated weight **Or**	kg est.	kg est.	kg est.	kg est.
Actual weight	kg	kg	kg	kg

Comment

No.

Species codes

BEM	blue marlin
BIG	bigeye tuna
BKM	black marlin
STM	striped marlin
SWO	swordfish
SSF	shortbill spearfish
MAK	mako shark
YFN	yellowfin tuna

Type of bait codes

TL	trolled lure
DB	dead bait
LB	live bait
SB	skip bait

Kept or released codes

LND	Landed and kept
TAG	Tagged
RNT	Released not tagged

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