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Striped marlin catch and CPUE in the New Zealand sport fishery, 2019-20 to 2021-22

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Fisheries New Zealand
Tini a Tangaroa

Striped marlin catch and CPUE in the New Zealand sport fishery, 2019–20 to 2021–22

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J.C. Holdsworth

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EXECUTIVE SUMMARY

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Striped marlin (*Kajikia audax*) is the dominant 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 East Northland target fishery in 1975.

The New Zealand Billfish Logbook Programme replaced the postal survey in 2006–07 by collecting daily catch and effort data from charter operators and experienced private skippers across New Zealand. It is a voluntary programme aimed at fishers 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 2019–20 to 2021–22, 296 striped marlin were reported in logbooks from 1142 days fished. Fishing clubs affiliated with the New Zealand Sport Fishing Council (NZSFC) reported 3526 striped marlin caught, with 61% tagged and released. Commercial fishers have been required to release all marlin caught for the last 30 years; there is little overlap between the summer sport fishery and the surface longline fishery.

This report also summarises the combined catch from 55 sport fishing clubs affiliated with the NZSFC. 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 processed and smoked). Clubs also record catch details for these fish.

Annual striped marlin catch and effort data are standardised using a negative binomial model that includes zero catches for 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 gradual decreasing trend since then. The 2019–20 season was cut short by government Covid-19 restrictions from 23 March to 12 May 2020. The following two years showed increased CPUE to close to the long-term average.

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. Fishers whose billfish are not included in club records or the New Zealand gamefish tagging programme database are encouraged to enter catch details on the web page at fishcatch.co.nz.

[1] Blue Water Marine Research, New Zealand.

1. INTRODUCTION

Of the five billfish species reported from New Zealand waters, striped marlin (STM, *Kajikia audax*) are the most abundant and main species of the recreational gamefish fishery in northern New Zealand. Recreational fishers increasingly target broadbill swordfish (*Xiphias gladius*) using deep-set baits during the day, and commercial vessels fish with night-set surface longlines. Other billfish occasionally caught by recreational and commercial fishers are blue marlin (*Makaira nigricans*), black marlin (*Istiompax 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 primary 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 when they 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 there are requirements in place for commercial fishers 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 with specialist knowledge and fishing tackle to target marlin. Since 1990 there has been a significant increase in 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 the New Zealand Sport Fishing Council (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.

A 48-year time series of striped marlin catch per unit effort (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 the East Northland area for the 2005–06 season (Holdsworth et al. 2007). Since then, the Billfish Logbook Programme has collected daily information on billfish catch, hours fished, and environmental variables from private and charter skippers in fished areas (Holdsworth & Saul 2017).

Recreational charter boat operators have been required to report their fishing activity since November 2010 under the Ministry for Primary Industries (MPI) Amateur Fishing Charter Vessel (AFCV) requirements. Subsequently, they have also had to report the area of operation and the catch of certain species. There will unavoidably be some duplication of data reporting between the two reporting schemes. However, as billfish are not 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 charter boats targeting billfish over the last nine years due to changes in the tax provisions and maritime safety regulations.

This report summarises the results for Fisheries New Zealand project STM2019-01, which had the following objectives:

1. To update time series of catches, landings, and size composition data collected from recreational sources for the 2019–20, 2020–21, and 2021–22 fishing years.
2. To undertake a logbook programme for striped marlin for the recreational fishery for the 2019–20, 2020–21, and 2021–22 fishing years.

2. METHODS

2.1 Catches, landings, and size composition

The number of billfish, sharks, 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 (see Appendix 1). 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 data from the three Northland clubs with the longest time series. Where a club landed fewer than 10 striped marlin in a season the average weight was not plotted.

Amateur fishing charter vessels (AFCV) have been required to register and record fishing effort and target species since 2010–11. Billfish are not listed as species that skippers are required to report. An extract of the Fisheries New Zealand AFCV database was nevertheless obtained with all fishing events targeting or catching billfish because a number of charter boats had been reporting billfish total catch and retained catch. This is summarised by October fishing year, but billfish catch is rare from July to September.

2.2 Logbook programme

The main objective of the logbook scheme is to collect data on striped marlin CPUE. However, data on other New Zealand gamefish species are also recorded. 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 (see Appendix 4). Distribution of logbooks has focused on charter vessels and private boats that target billfish more than ten days per season. Fishing effort is measured as vessel days or vessel hours targeting billfish, because the number of lines set or the 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 they are 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 16 years (2006–07 to 2021–22) and collects data on catch and effort from charter and private vessels 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 48 years. It excludes catch and effort from the productive fishery in the Three Kings Islands area, 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 from North Cape to the northern point of Great Barrier Island.

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 24 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 four relatively poor years. Government Covid-19 restrictions prevented travel and fishing during part of the 2020 marlin fishing season, but striped marlin catch was above average in 2020–21 and 2021–22 (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. The 2015–16 fishing year was also a productive year in the yellowfin tuna fishery with over 550 landed or tagged. Catches were low in two of the following three years, then recovered in 2019–20 and 2020–21, before decreasing again in 2021–22.

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 no longer accept sharks at their weigh stations.

Blue marlin is, 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 in a fishing year (Figure 2 and Figure 3). Over the last three fishing years an average of 88 blue marlin were landed and 36 were released. Swordfish catch has increased over the last ten years to over 80 fish landed and 40 tagged and released per year, but the numbers have fluctuated over the last three fishing years with an average of 73 landed and 26 tagged and released per year. The number of shortbill spearfish that have been landed and tagged and released has declined since 2019–20. Black marlin are caught in low numbers, generally between 5 and 15 each year (Figure 2, Figure 3).

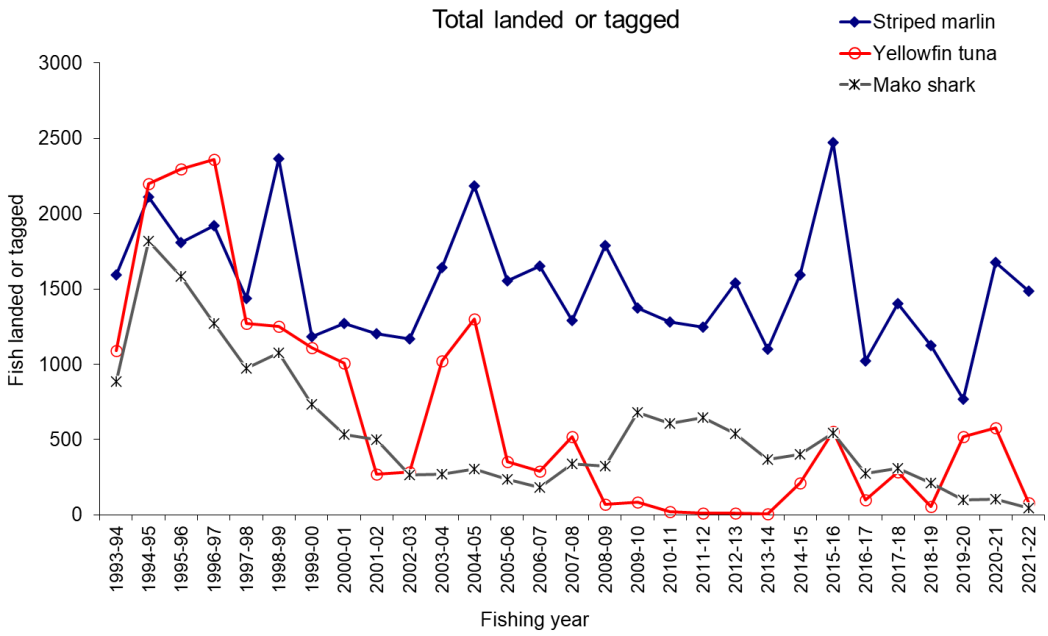

Figure 1: The total of landed or tagged fish by year for the main billfish, tuna, and shark species in the New Zealand gamefish fishery.

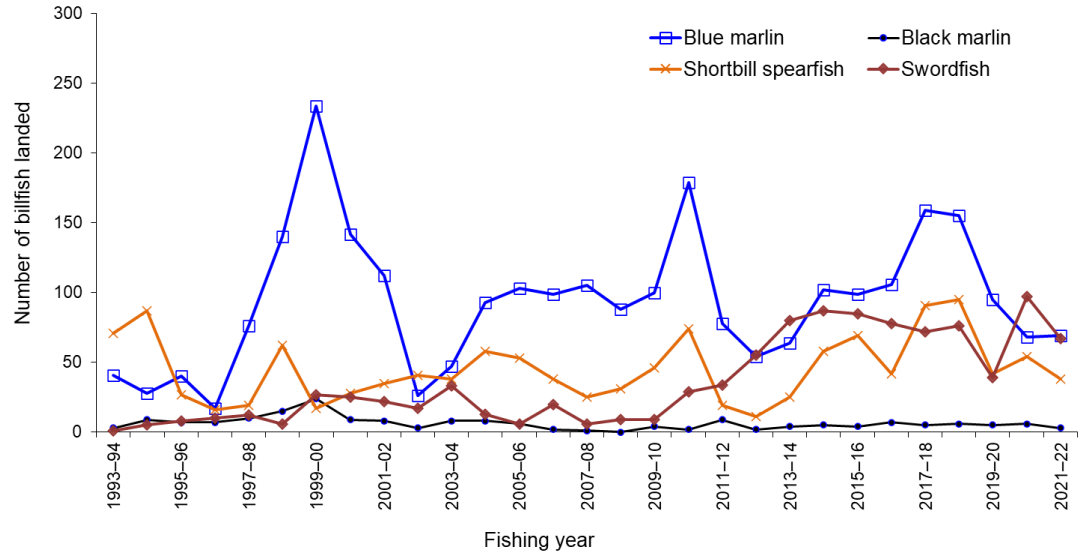

Figure 2: Total number of billfish, other than striped marlin, landed by year in New Zealand from New Zealand Sport Fishing Council records.

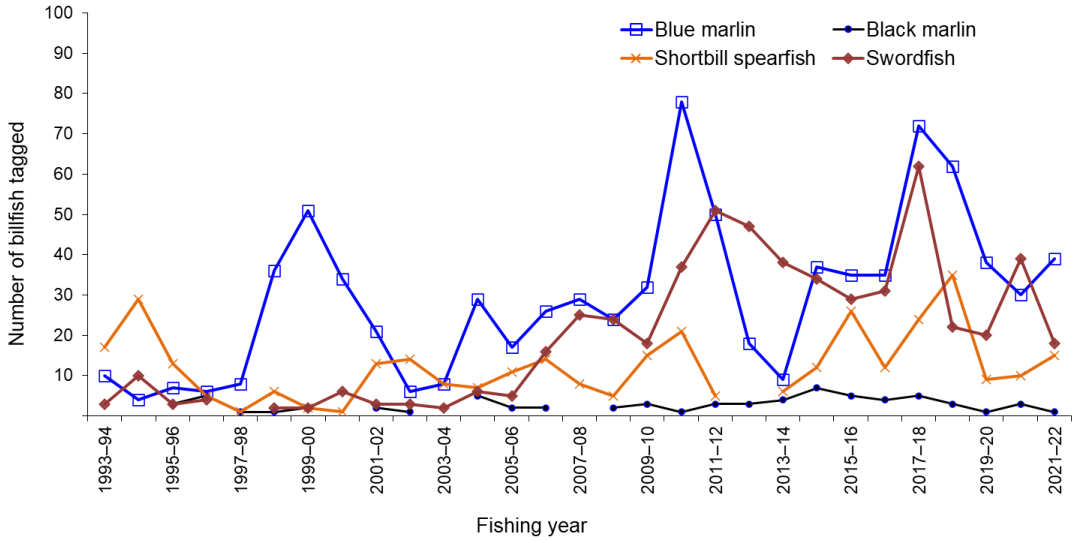

Figure 3: The number of tagged billfish per year, other than striped marlin, in the New Zealand gamefish tagging programme.

The number of striped marlin caught by sport fishers in New Zealand has increased significantly since the early 1970s, with a peak in 2015–16 (Figure 4). The majority of striped marlin caught in the first half of the time series came from the East Northland charter fleet. In 2021–22 the number of striped marlin reported from the recreational fishery dropped to 802 as a result of the fishing season ending in March 2020. The historical club landed weight and catch data were important inputs to the 2019 stock assessment for striped marlin in the southwest Pacific (Ducharme-Barth et al. 2019).

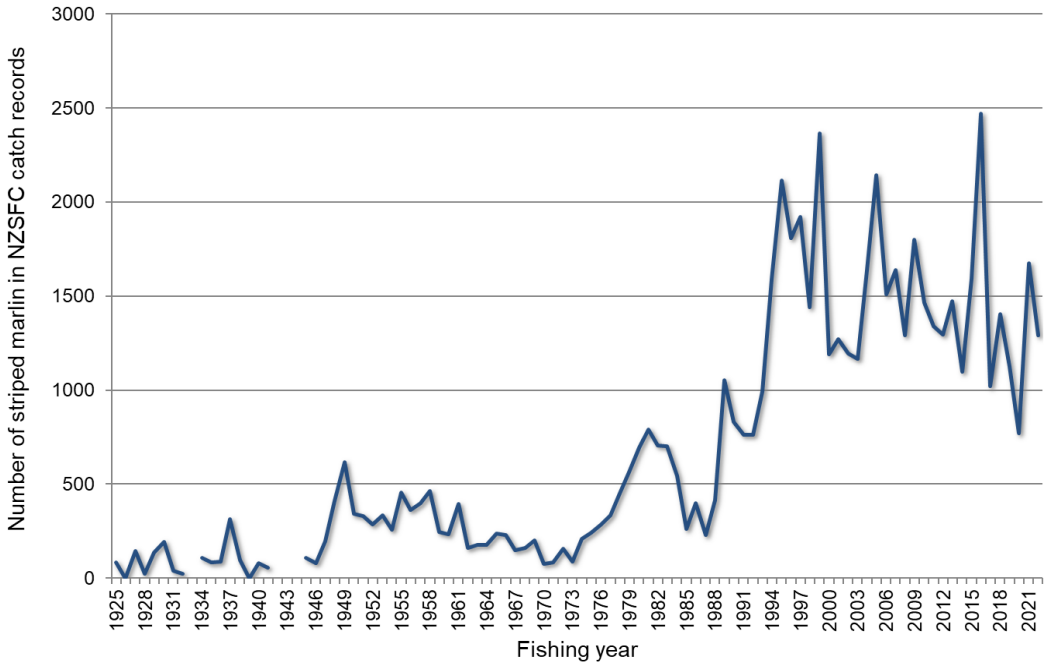

Figure 4: The number of striped marlin landed or tagged in NZSFC club records by fishing year. Fishing years are labelled by the later calendar year, e.g., 2018 is 2017–18.

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 35 years, annual median weight has cycled, and smaller striped marlin were caught in early 2021 and 2022 fishing seasons; this is usually associated with warmer years often associated with La Niña events. The 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 since 1988 (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 Islands toward many new entrants to the fishery in trailer boats that catch one or two fish per year.

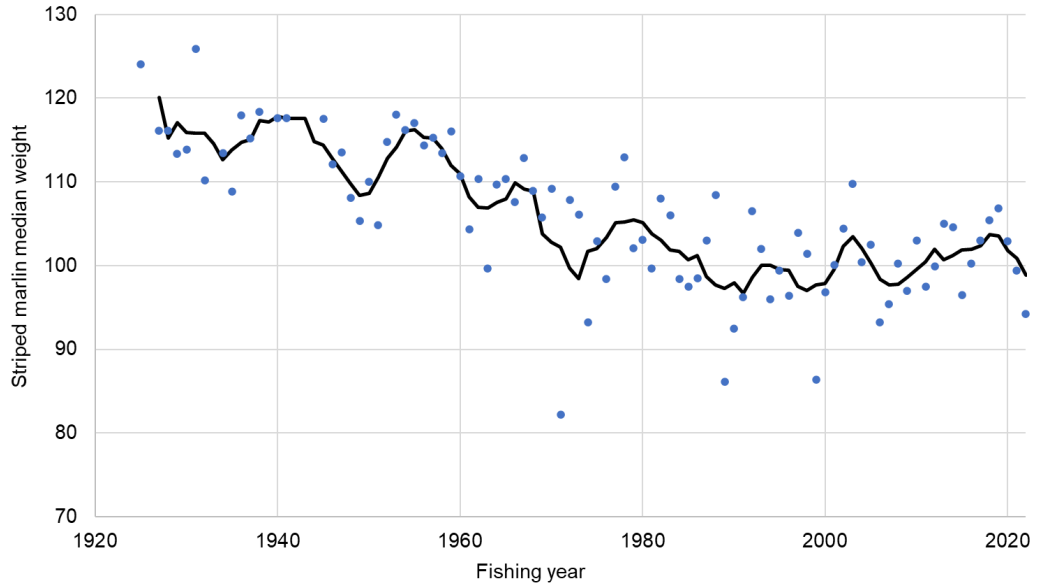

Figure 5: The median weight of landed striped marlin (blue dots) from NZSFC clubs and the five-year rolling average (black line) by fishing year.

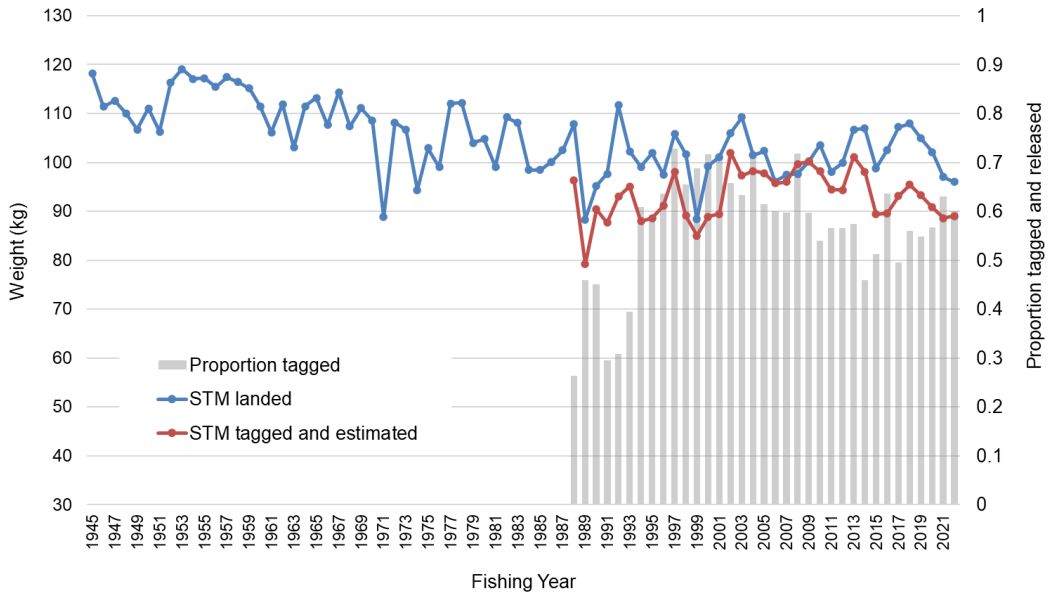

Figure 6: Average weight of landed striped marlin and tagged striped marlin from NZSFC clubs and the proportion tagged and released by fishing year.

3.2 Billfish logbook programme

The Billfish Logbook Programme has collected 16 years of data with an average of 192 (sd = 92.7) striped marlin recorded yearly. The annual catch of striped marlin by sport fishers in New Zealand has been variable in recent years. It ranged from 802 in 2019–20 to 1433 in 2020–21 and was 1268 in 2021–22 (Table 1). The average annual reported total catch is 1404 (sd = 392.9) over the last 16 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 have 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 2019–20 to 2021–22, there were 338 logbook days targeting billfish and 47 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 vessel was used for private fishing.

The main season for striped marlin across all logbook years is from January to May. In most years the highest catches are recorded in February and March (Figure 8). Billfish logbook data for 2019–20 to 2020–21 by month and region show most catch was from the East Northland area. Striped marlin catch in the Far North area is often high, but variable. However, the majority of striped marlin catch for 2021–22 came from the Far North. March 2022 was the month with highest catch recorded in logbooks with 33 striped marlin caught in the Far North area alone (Figure 9).

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 9).

Table 1: Number of New Zealand landed striped marlin (STM) 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 2021–22.

Fishing year	Recreational striped marlin numbers			East Northland charter survey STM	Billfish logbook STM	Proportion of catch surveyed
	Landed	Tagged	Total			
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	1 206	2 116	510		0.24
1995–96	705	1 104	1 809	489		0.27
1996–97	619	1 302	1 921	116		0.06
1997–98	543	898	1 441	116		0.08
1998–99	823	1 541	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	1 058	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	1 140		206	0.18
2014–15	696	1 088	1 784		209	0.12
2015–16	900	1 653	2 553		207	0.09
2016–17	516	517	1 033		66	0.07
2017–18	618	752	1 370		163	0.14
2018–19	507	652	1 159		78	0.08
2019–20	333	469	802		56	0.07
2020–21	627	806	1 433		95	0.07
2021–22	377	891	1 268		145	0.11
Total	26 830	28 414	55 244	6 017	3 075	

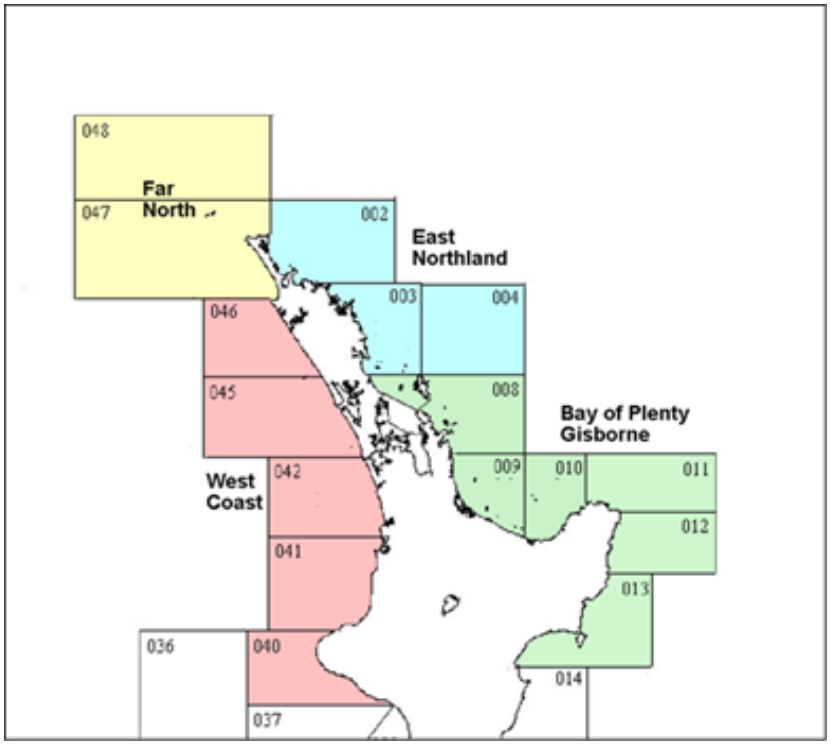

Figure 7: General Statistical Areas and the regional boundaries used in this report.

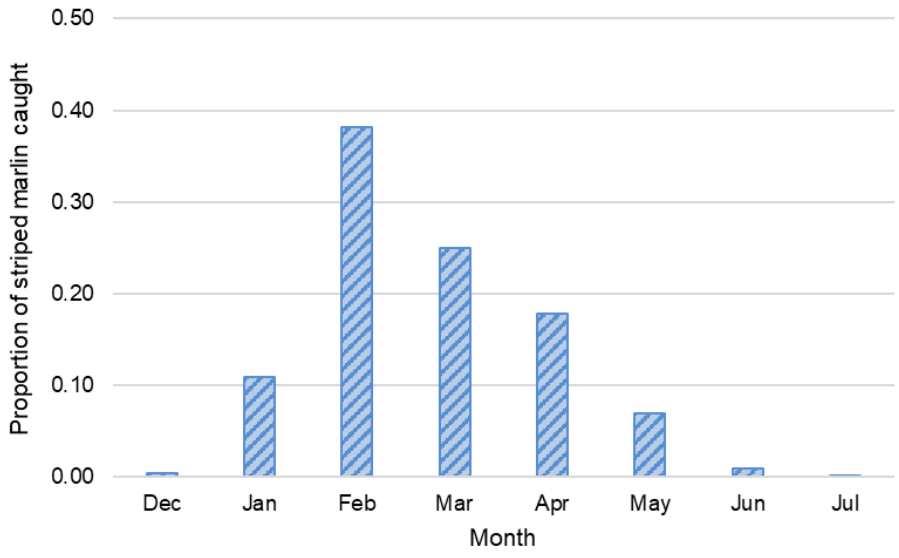

Figure 8: Proportion of striped marlin caught by month from all logbooks, 2005–06 to 2021–22.

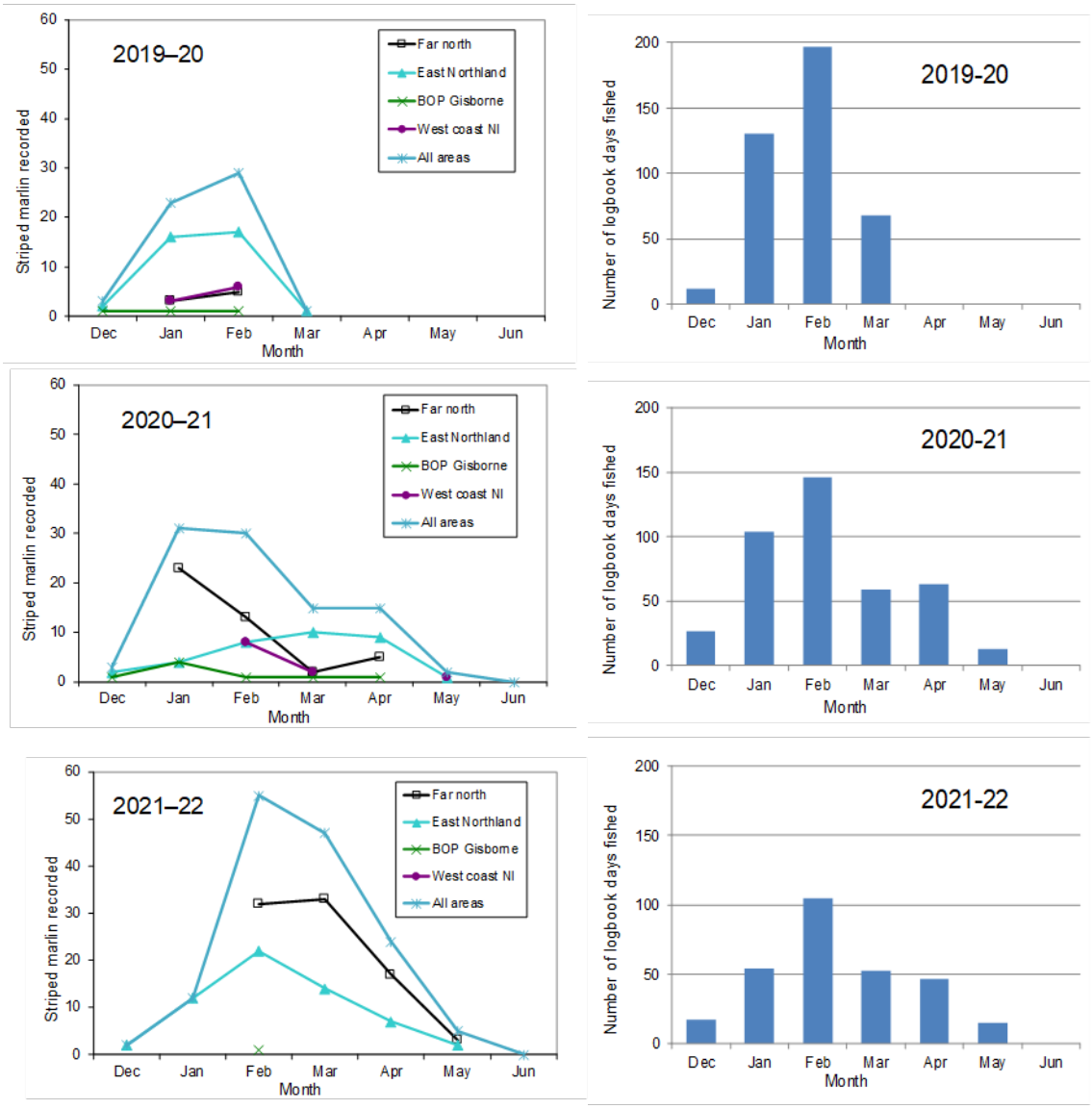

Figure 9: Logbook reported number of striped marlin caught by region and month (left) and total logbook days fished targeting billfish by month (right) for 2019–20 to 2021–22.

Striped marlin and blue marlin catch and billfish strikes by week are shown in Figure 10. 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 striped marlin caught fluctuates across all three fishing seasons for both species (Figure 10). The highest number of blue marlin caught was in 2019–20 prior to the government Covid-19 restrictions; the high blue marlin catch in March 2020 (week 9 and 10) indicates that the water was still warm during this time. 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 fishing effort and catch for many species at this time.

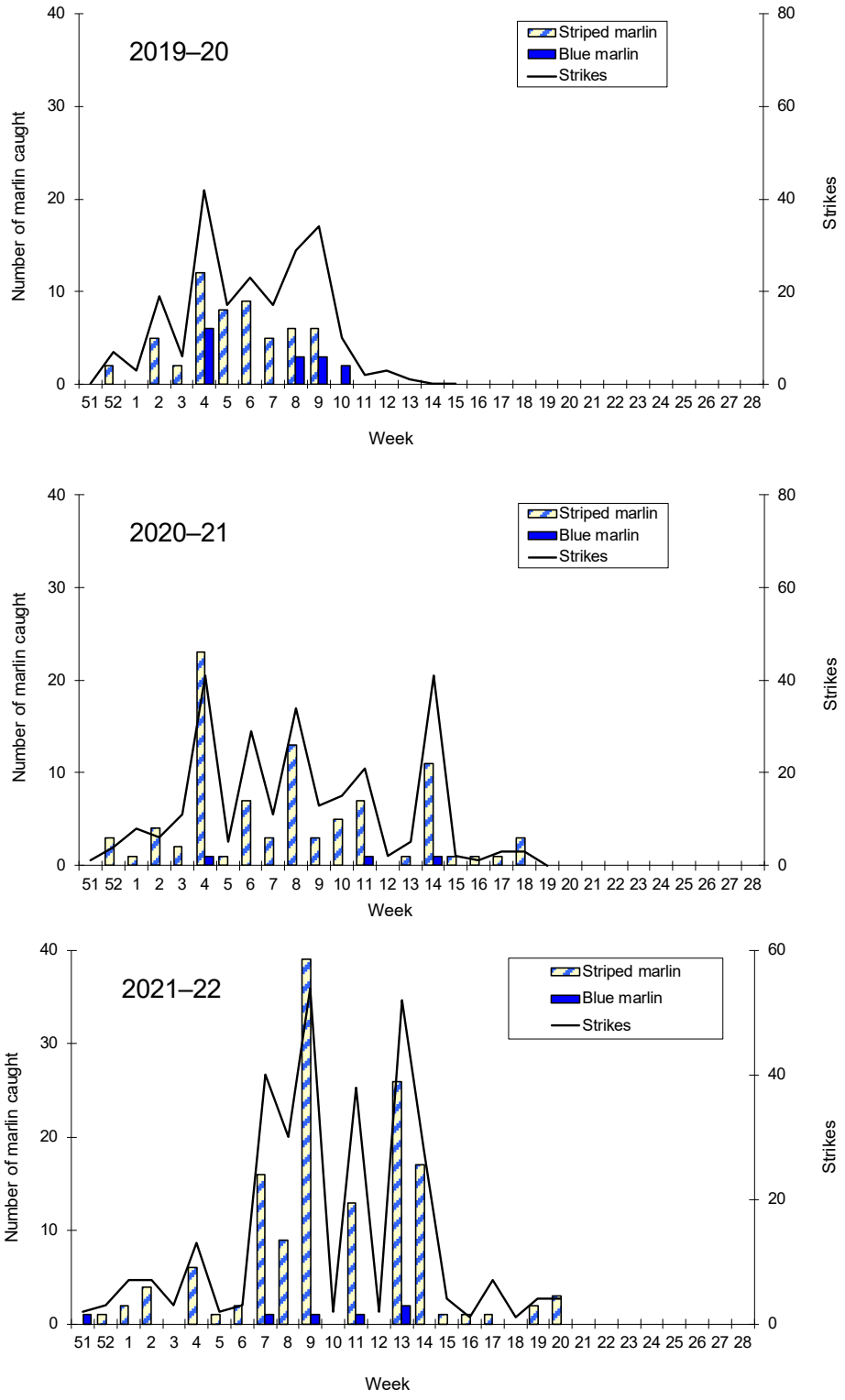

Figure 10: The number of striped or blue marlin caught by week (left axis) and the number of strikes per week (right axis) 2019–20 to 2021–22.

Catch rates of striped marlin per vessel day have been consistently low across the main fishing areas from 2019–20 to 2021–22, below 0.3 fish per day apart from March 2022. The Far North, which includes the Three Kings Islands area, has higher catch rates than other areas (Figure 11), but the number of fishable days and the distance from port limit fishing effort. Late season catch rates can be higher, but this is based on limited data from a few days fishing.

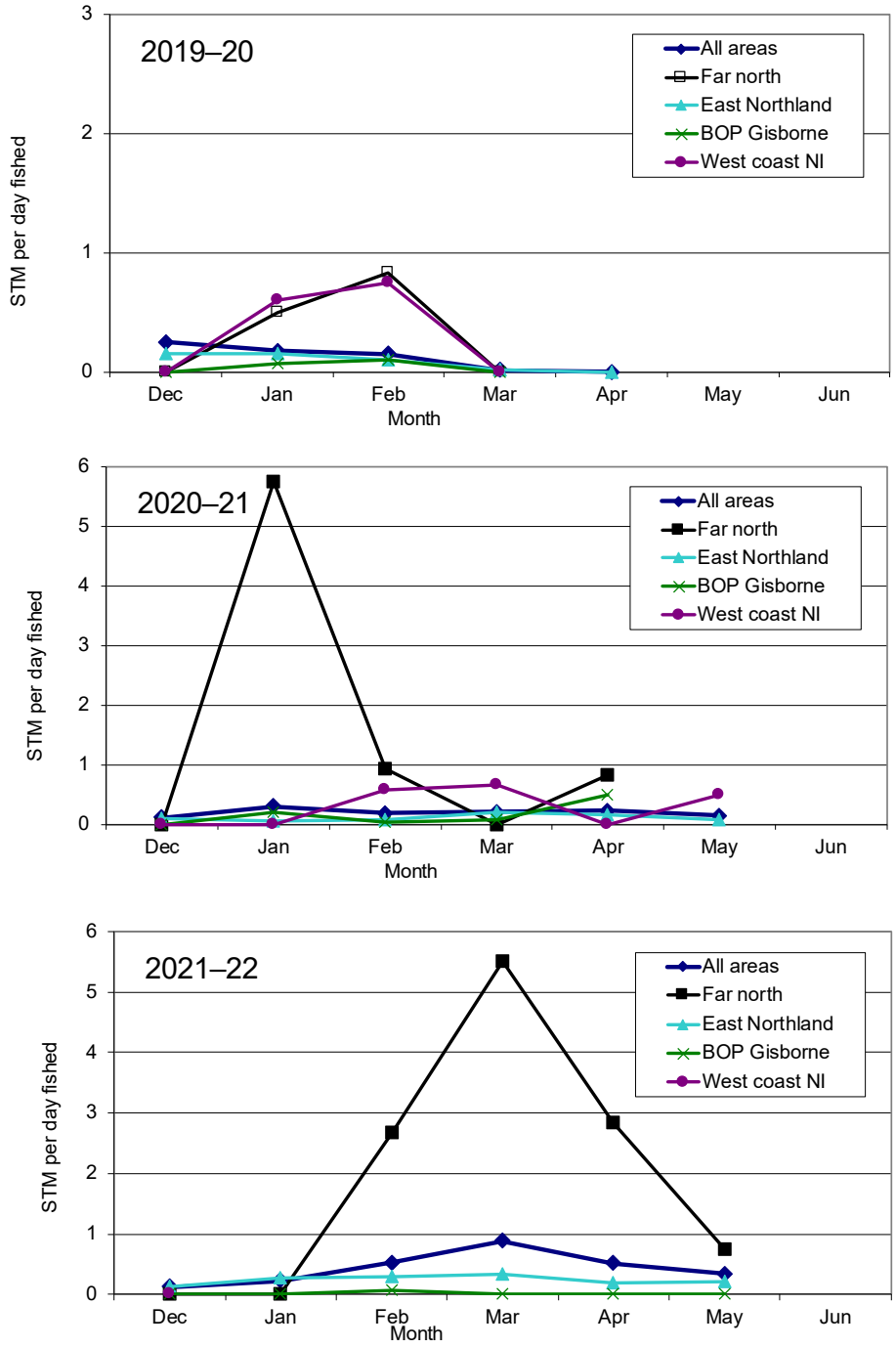

Figure 11: Striped marlin catch per vessel day by area and month from logbook data for 2019–20 to 2021–22.

3.3 Amateur fishing charter vessel records

Registered amateur fishing charter vessel skippers are not required to report billfish, but there has been some voluntary reporting billfish total catch and retained catch by species. An extract of the Fisheries New Zealand AFCV database was obtained with all fishing events targeting or catching billfish. A total of 464 striped marlin have been caught and 137 (30%) retained since 2010–11. The number of striped marlin reported was highest in 2013–14, then declined after 2015–16 before increasing again in 2020–21 and 2021–22 (Figure 12). This is a similar pattern to that seen from club records. The seasonality of catch by month of AFCV striped marlin (Figure 13) is also similar to catch in the logbook programme (Figure 8).

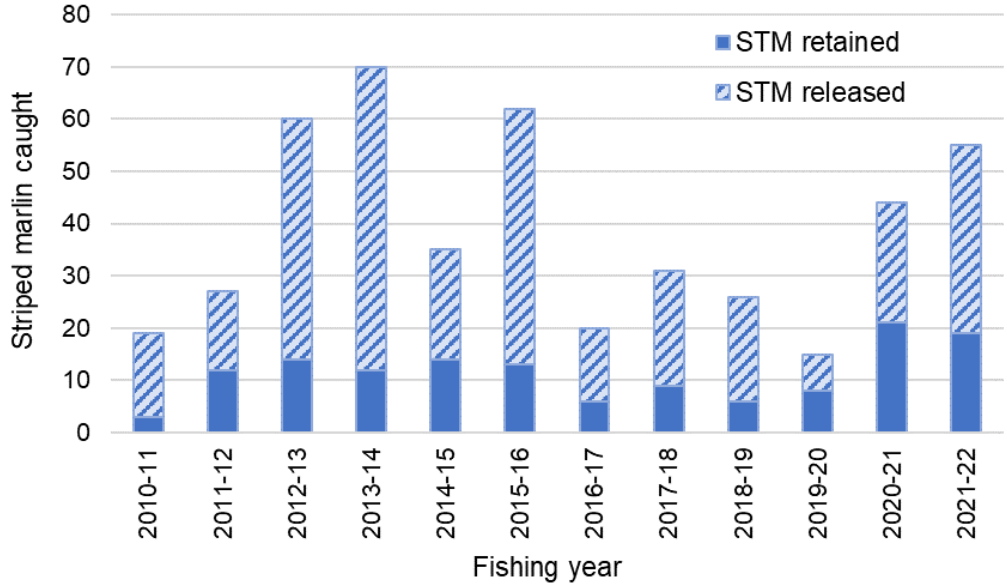

Figure 12: The number of striped marlin reported in AFCV logbooks, by October fishing year.

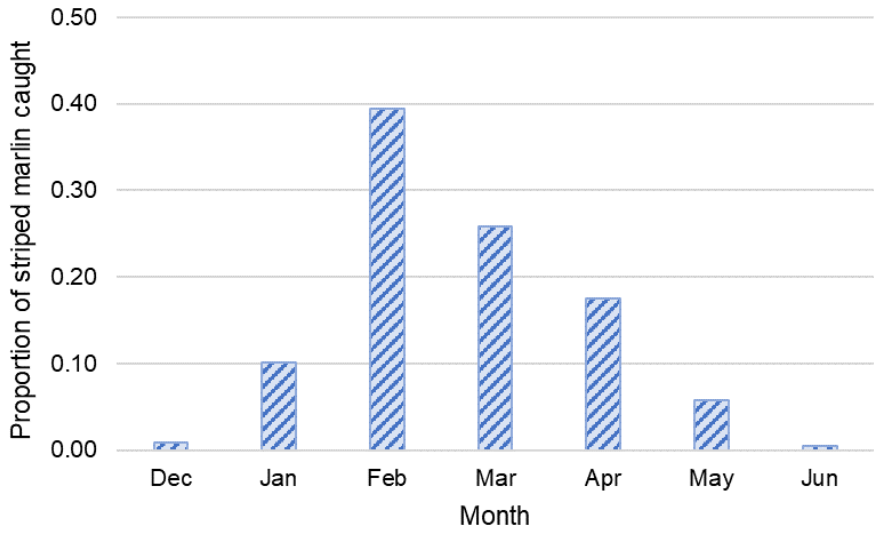

Figure 13: Proportion of striped marlin caught by month from AFCV logbooks, 2010–11 to 2021–22.

3.4 East Northland charter CPUE time series

The 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 2021–22. The data were restricted to recreational charter vessels fishing in East Northland (General Statistical Areas 002, 003, and 004; Figure 7).

The data available are 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 14).

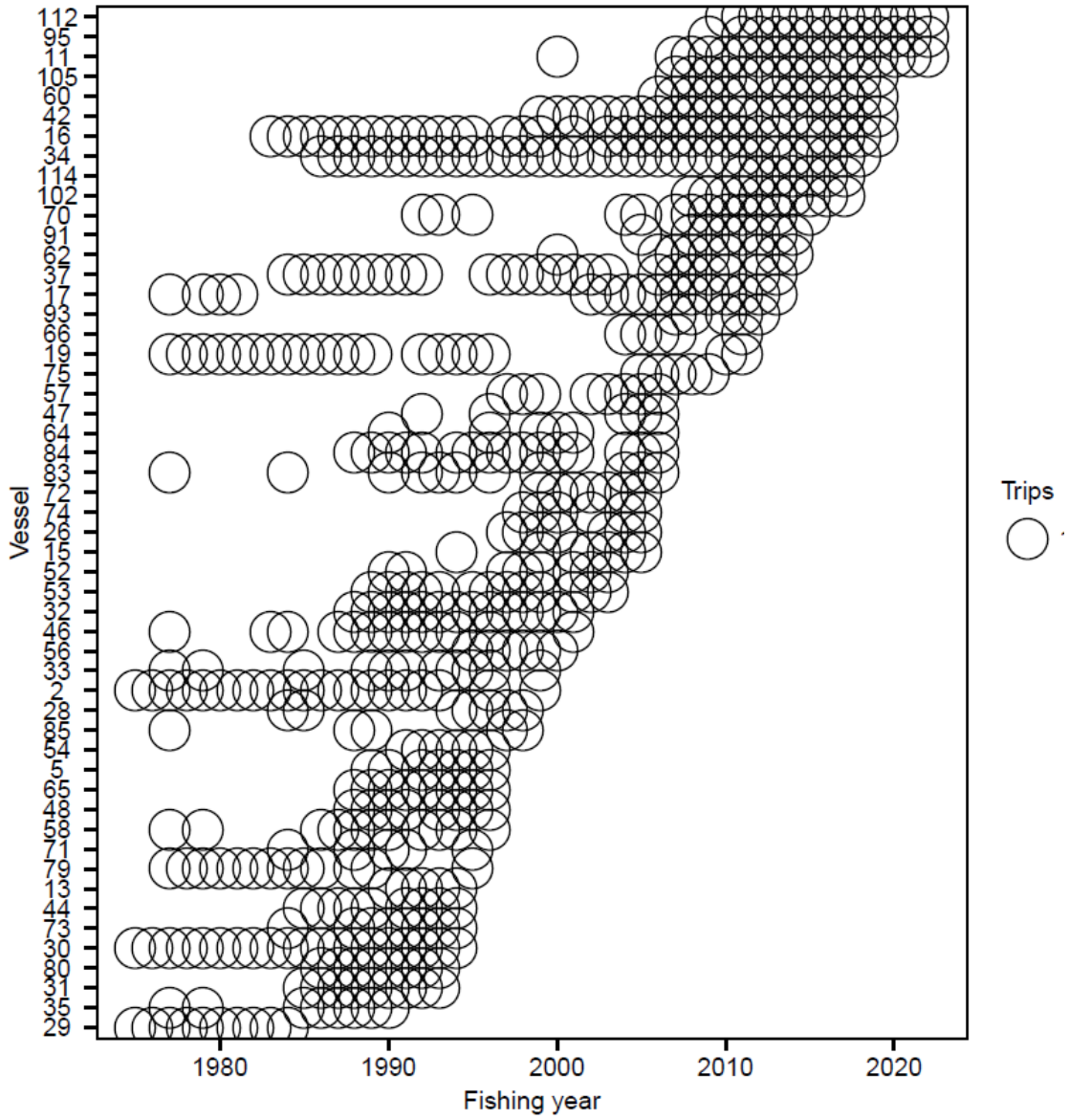

Figure 14: Participation of the core charter vessels used. Each observation summarises one year of fishing, whether or not successful with respect to striped marlin. Fishing years are labelled by the later calendar year, e.g., 1990 = 1989–90.

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* + *poly(log(days), 3)*

with the term *fyear* forced into the model. *Area* denotes the home port of the vessel. Terms were only added to the model if they increased the percent deviance explained by at least 1%. Table 2 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 2: 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	48	-1 699	3 494	37.05	39.61	*
poly(log(days), 3)	51	-1 555	3 212	61.36	63.16	*
vessel	102	-1 429	3 063	74.78	76.12	*

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 15). 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 16). Distribution and influence plots are provided in Appendix 3.

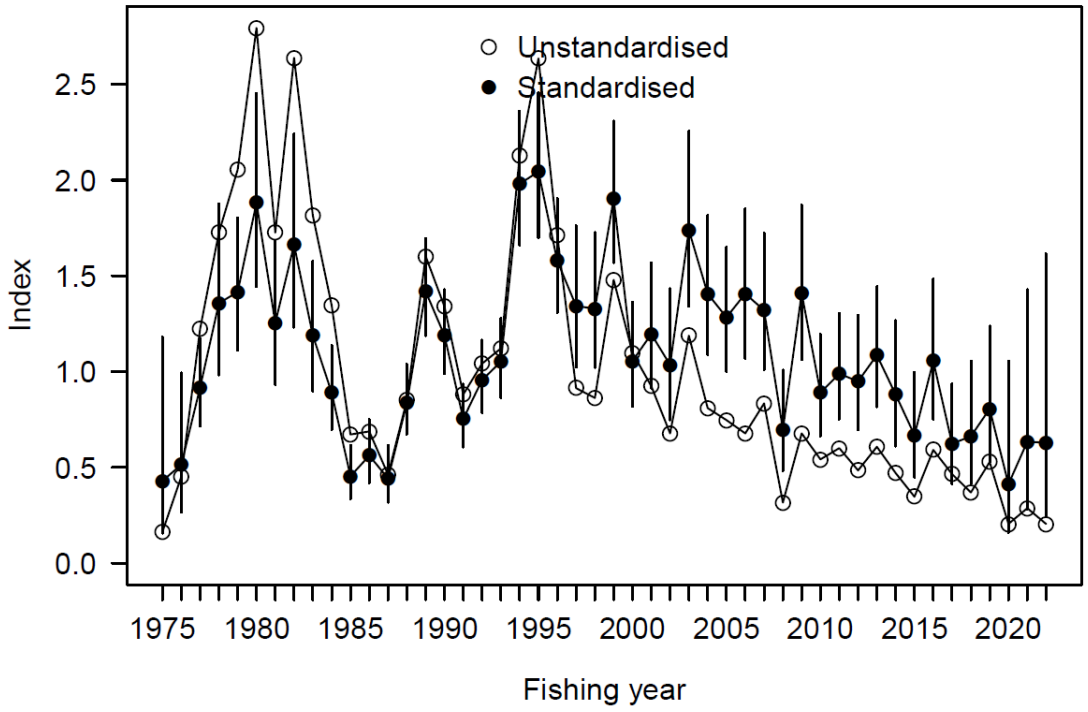

Figure 15: The effect of standardisation on East Northland charter boat striped marlin catch. The unstandardised index is based on the geometric mean of the catch only and is not adjusted for effort. The standardised index is adjusted for fishing effort and vessel.

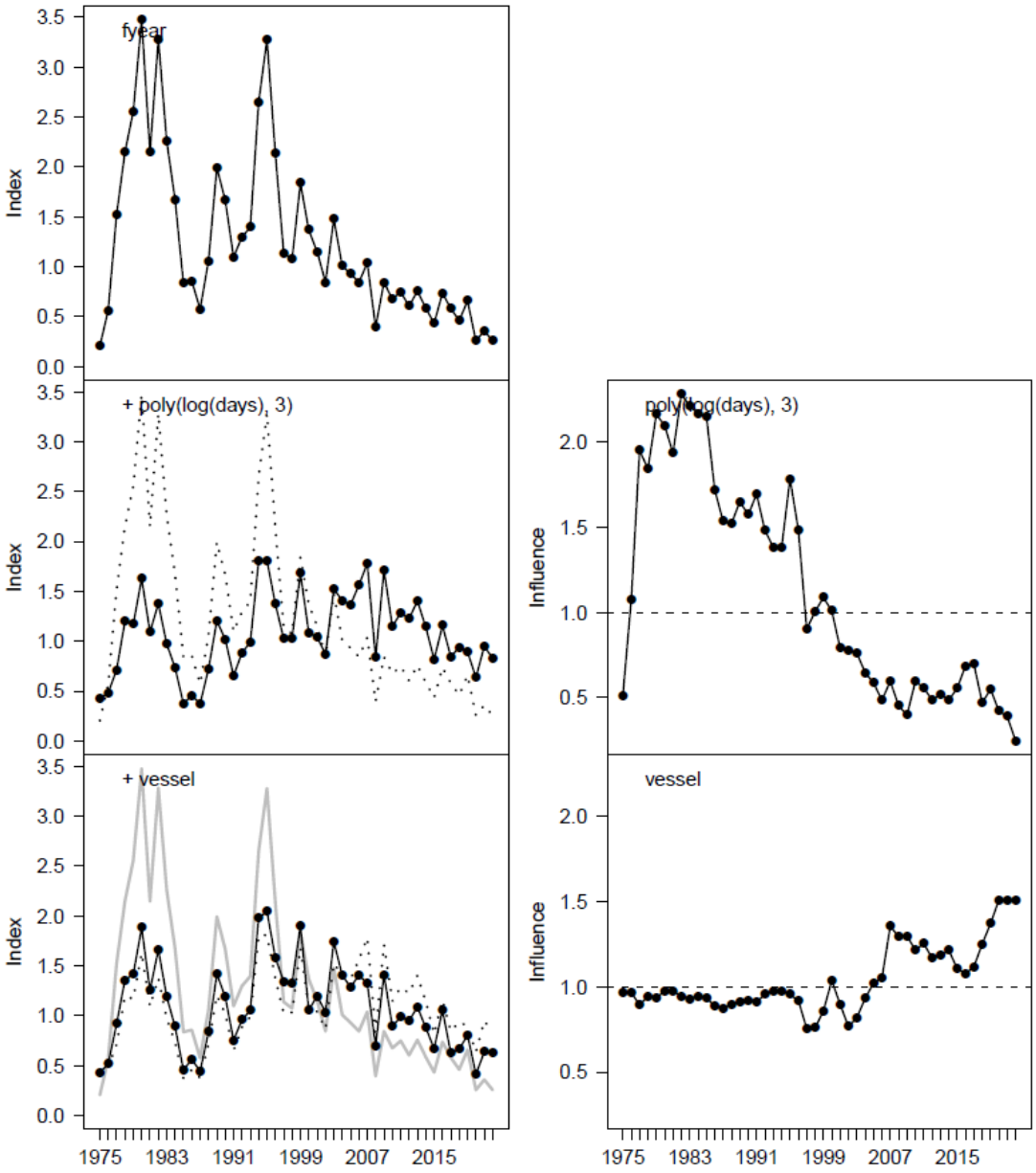

Figure 16: Step plot (left) and influence plots (right) with fishing year at the top, adding polynomial of days fished in the middle, and adding vessel at the bottom.

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 17).

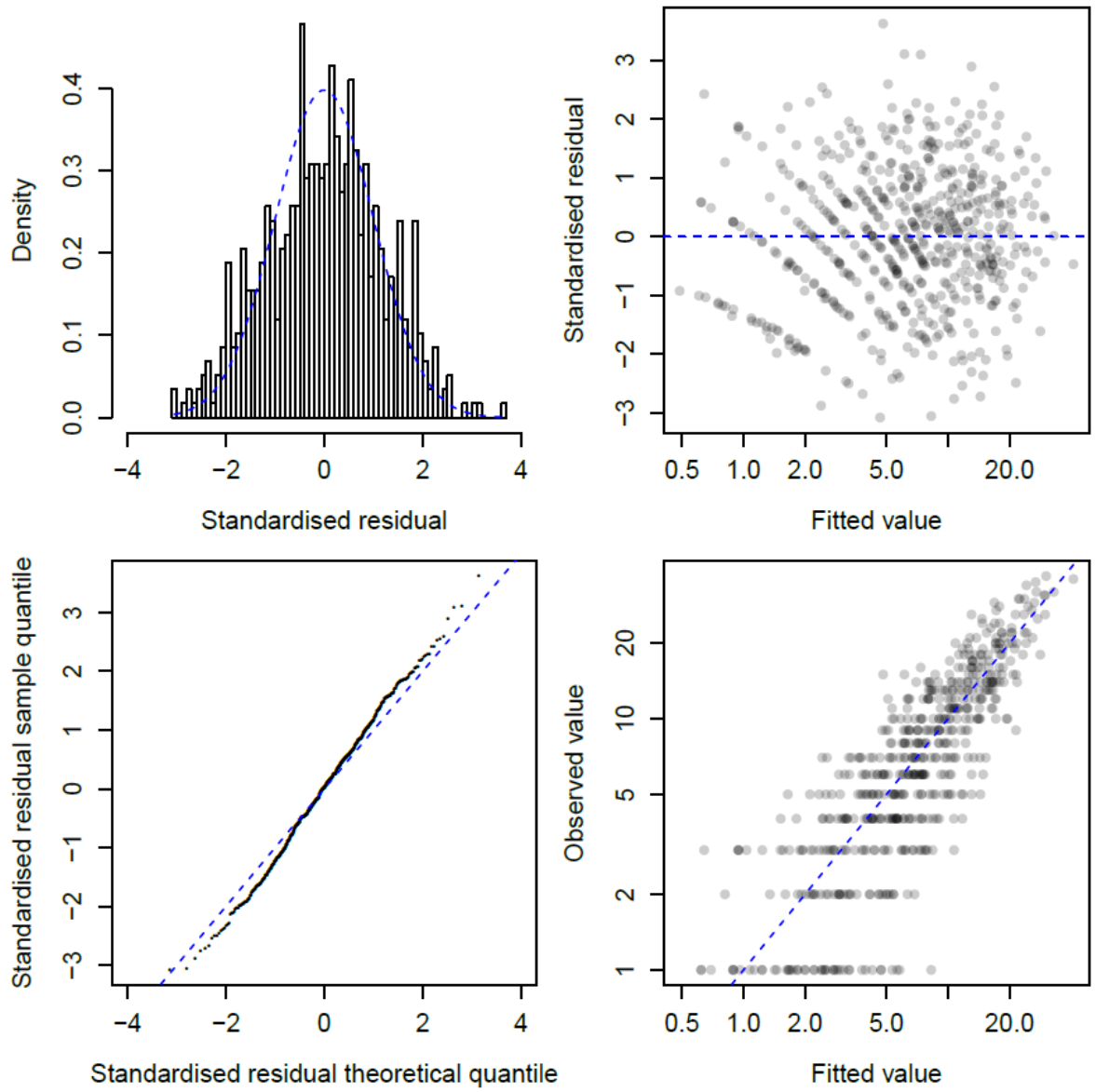

Figure 17: Residual diagnostics for the charter vessel model. Top left: histogram of standardised residuals compared to standard normal distribution. Bottom left: quantile-quantile plot of standardised residuals. Top right: fitted values versus standardised residuals. Bottom right: observed values versus fitted values.

3.5 Billfish logbook CPUE time series

The Billfish Logbook Programme has been collecting daily catch effort and environmental data from participating fishers since 2006–07. Over these 16 years, 96 boats have participated and reported 11 489 days targeting billfish for a catch of 3075 striped marlin and 210 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 35 vessels which took 76% of the catch (Figure 18).

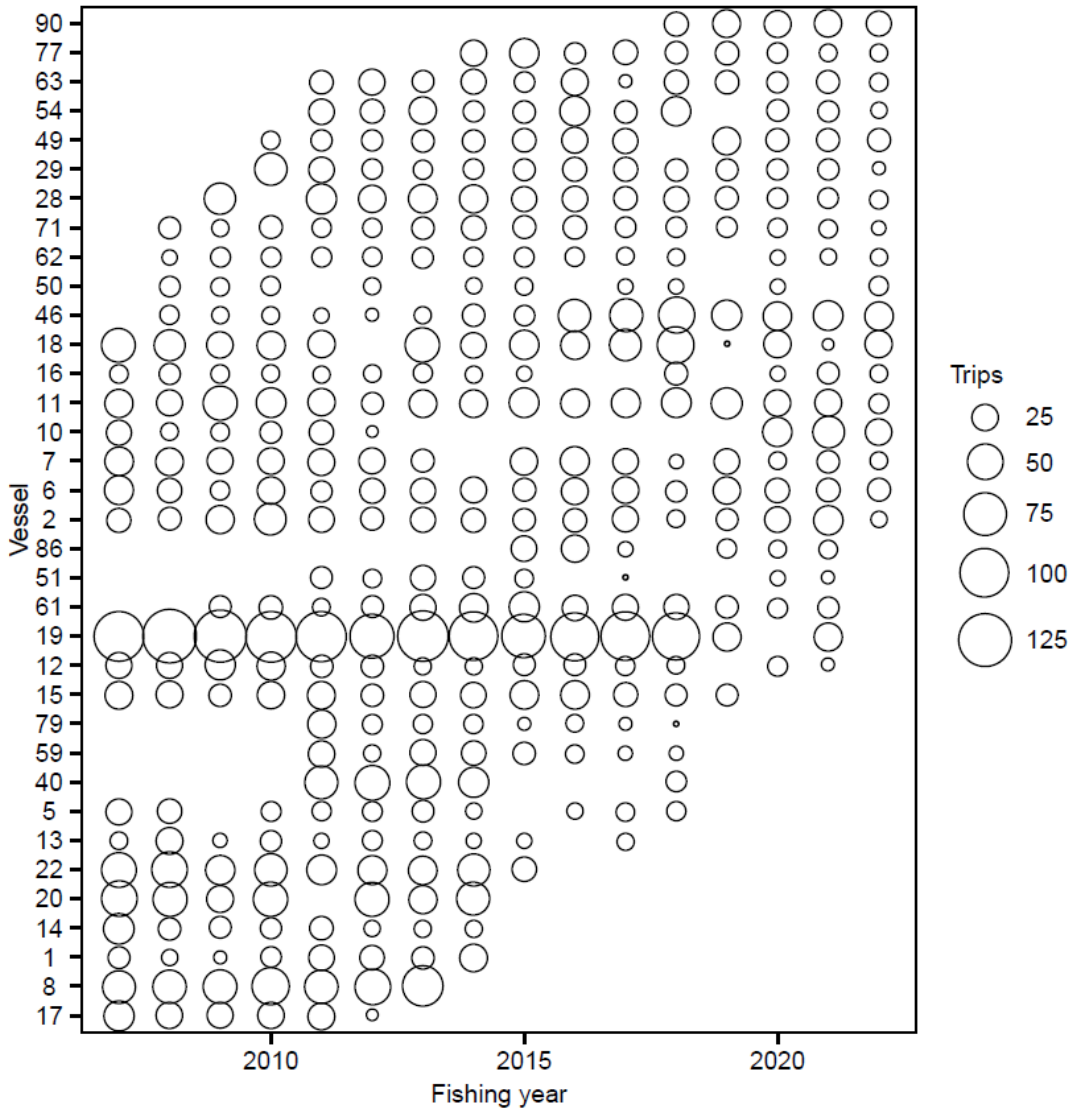

Figure 18: Participation of core vessels providing billfish logbook data by fishing year. The area of circles is proportional to the number of trips for a vessel in a fishing year.

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* splits the North Island into four fishing areas (Figure 7), *fleet* separates charter from private vessels, *target* is the main target species, *duration* is hours fished per day, and *temp* is the sea surface temperature (SST) at noon. Terms were only added to the model if they increased the percent deviance explained by 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* + *vessel* + *zone* + *poly(log(duration), 3)*

Table 3: 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	16	-4 939	9 909	3.26	2.41	*
vessel	50	-4 372	8 844	26.74	21.02	*
zone	53	-4 243	8 592	31.21	24.88	*
poly(log(duration), 3)	56	-4 203	8 518	32.54	26.05	*
target	63	-4 189	8 504	33.00	26.45	
poly(temp, 3)	66	-4 180	8 491	33.31	26.72	
month	74	-4 171	8 490	33.59	26.98	

The CPUE index based on daily billfish logbook data shows a flat or slightly declining trend with a lower CPUE in 2017 and 2020 (Figure 19). Explaining most variance was the vessel effect which pushed the standardised index down in the first two years and in 2022. 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 20). Sea surface temperature and month did not explain more than 1% of the deviance after vessel and zone were included in the 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 21).

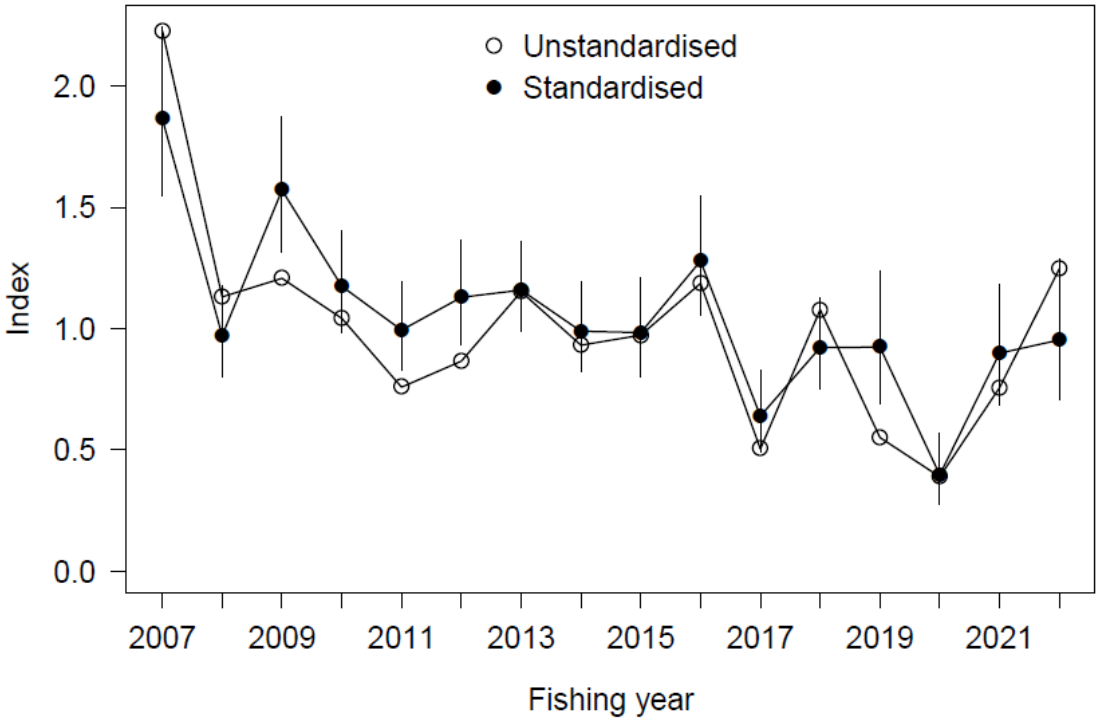

Figure 19: Overall standardisation effect from the billfish logbook model of striped marlin CPUE. The unstandardised index is based on the geometric mean of the catch per year and is not adjusted for effort. Fishing years are labelled by the later calendar year, e.g., 2007 = 2006–07.

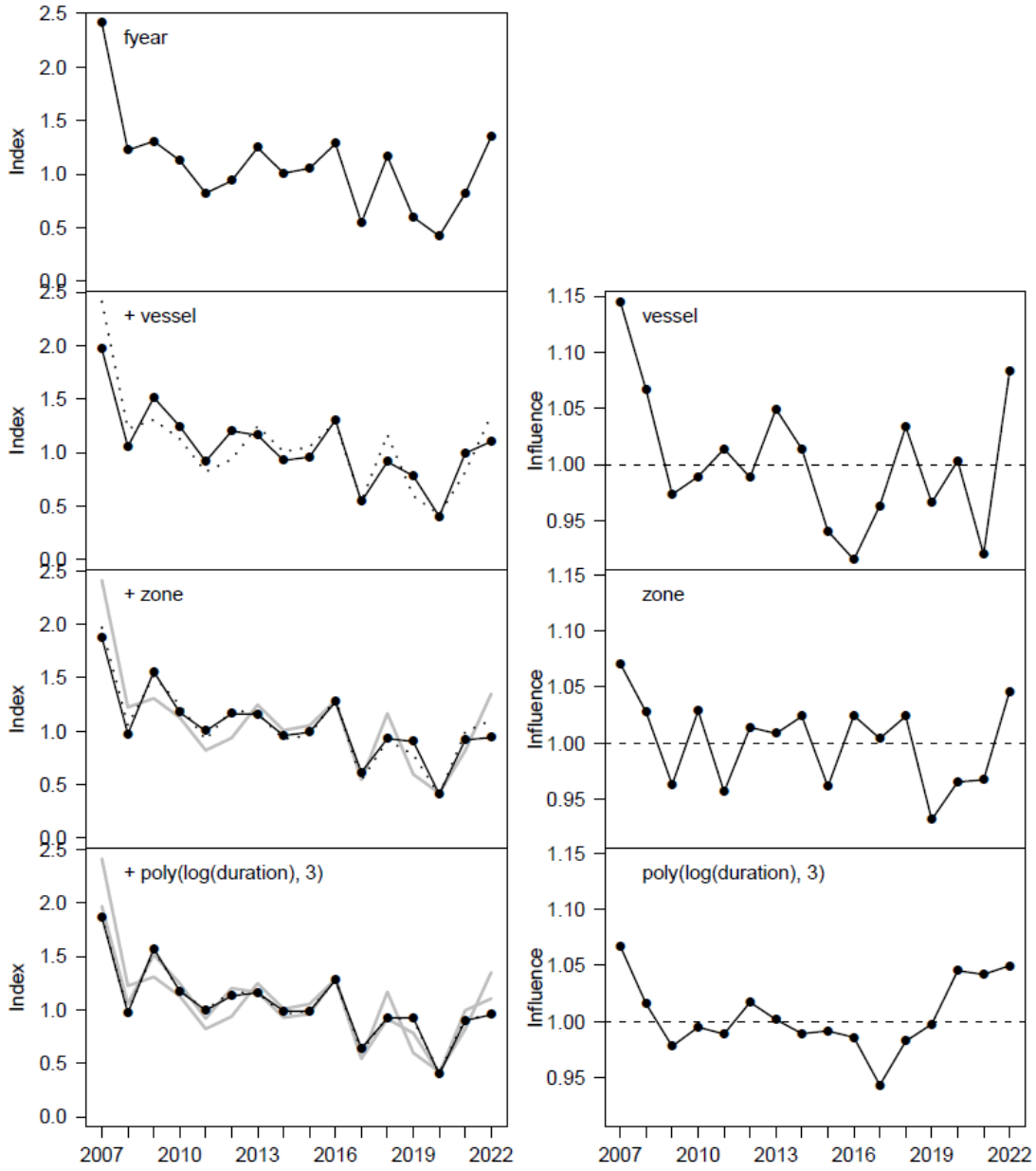

Figure 20: Step and influence plot from the billfish logbook model.

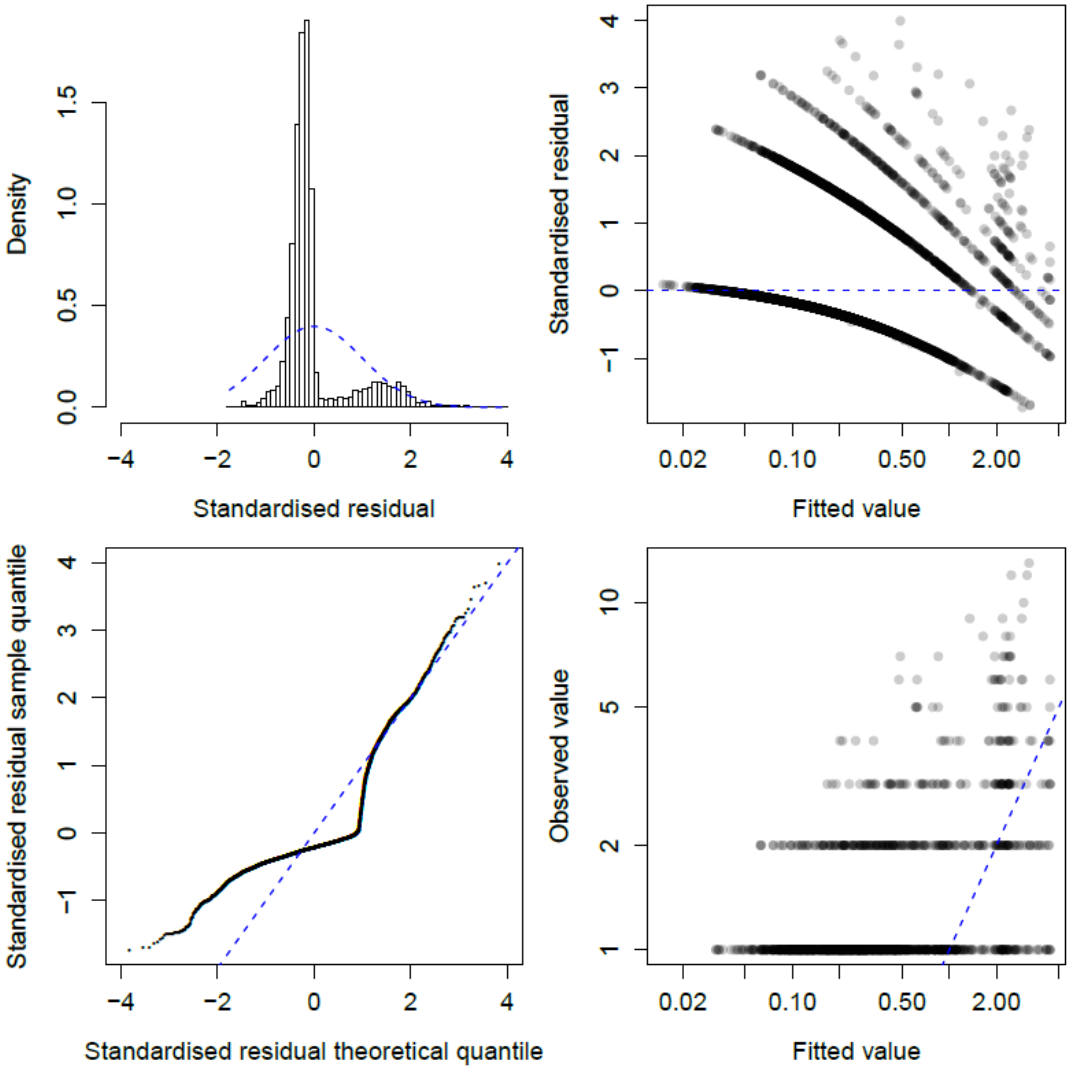

Figure 21: Residual diagnostics for the billfish logbook model. Top left: histogram of standardised residuals compared with the standard normal distribution. Bottom left: quantile-quantile plot of standardised residuals. Top right: fitted values versus standardised residuals. Bottom right: observed values versus fitted values from the billfish logbook model.

The logbook and East Northland charter standardised CPUE indices show a similar pattern in the years where they overlap (Figure 22). This is expected because 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 22). The 2019–20 to 2021–22 seasons were relatively poor years for the recreational striped marlin fishery in comparison to earlier years. There was a reduction in catch in the 2020 fishing year due to Covid-19 lockdown restrictions, followed by an increase in catch similar to that seen in the 2018–19 fishing year.

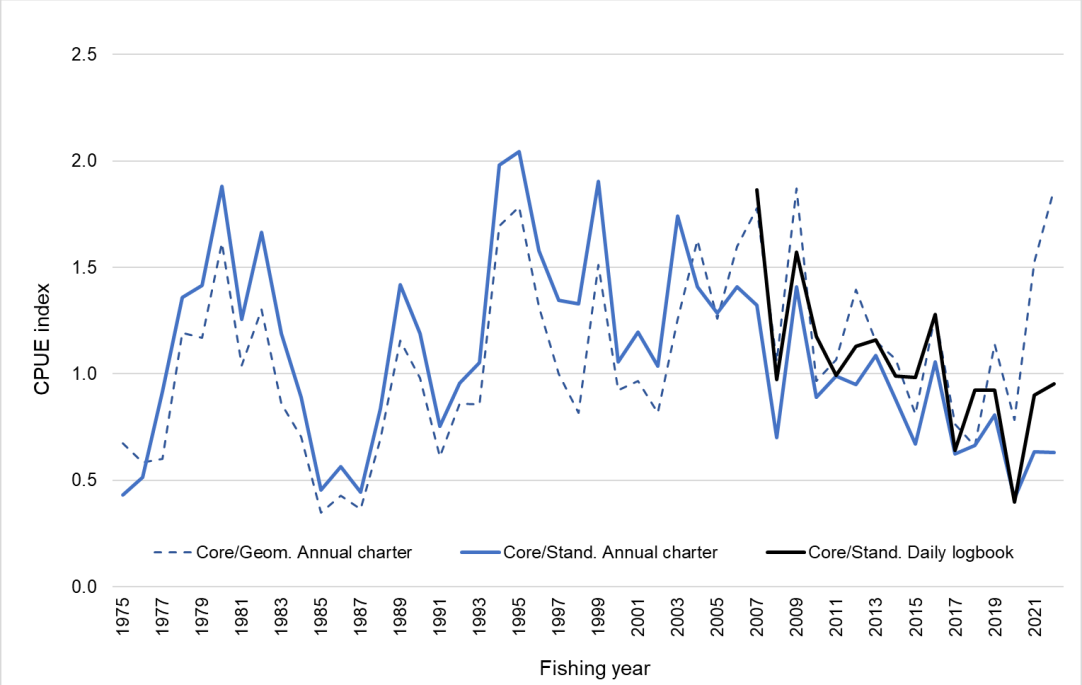

Figure 22: Comparison between the negative binomial model of the East Northland recreational charter boat annual CPUE since 1975 (1974–75 fishing year) and billfish logbook daily CPUE 2007 to 2022.

4. DISCUSSION

The Billfish Logbook Programme collects details of daily fishing efforts 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. However, changes to the maritime safety regulations and rules around running cost claims from owning a charter boat against tax have 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, and the number of days fishing for marlin per vessel has declined significantly—most evident in the plot of days fished by core vessels in Appendix 3 (Figure A3.1). New charter operators recruited to the logbook scheme must remain in the programme for five years before they are included in the core vessel selection.

In future, the logbook data from private and charter vessels for the East Northland region could be used to continue the 48-year-long CPUE time series. Fisheries New Zealand requires charter operators to register and report fishing efforts, target species, and catch of selected species. Of the 67 AFCVs targeting billfish, 64 voluntarily reported catching billfish, mainly striped marlin. Integrating data collected from the AFCV database into the CPUE time series may be beneficial because there is an existing AFCV time series of fishing effort targeting billfish. Charter skippers who are not currently participating in the billfish logbook progamme can be approached and asked whether they have accurately recorded all billfish captures in their AFCV logbooks in the past and whether they will continue reporting these voluntarily. An end-of-year interview can verify who has maintained a complete record of billfish catch for inclusion in the CPUE analysis. Records from the AFCV database for selected vessels could be included in the CPUE standardisation where the criteria for core vessel selection are met (currently 5 years of reporting).

There are 16 years of logbook data sufficient to generate a standardised CPUE index based on the 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. Over the last 16 years, the charter CPUE trend has been similar to the daily logbook data, partly because it is a subset of data rolled up to annual catch and days fished, and the model terms selected are similar.

In some years, there are very high catch rates in the Far North region, including the Three Kings Islands, King Bank, and Middlesex Bank and in other years striped marlin are scarce. The CPUE from this area may influence the billfish logbook index but is excluded from the East Northland charter boat data because this area was not fished, even though the same vessels fish in both areas.

A characterisation of striped marlin bycatch in New Zealand commercial surface longline fisheries found that bycatch levels were stable from 2003–04 to 2018–19. The most catch was recorded in waters 20 °C and warmer from the Bay of Plenty to the Northland region. Increases in sea surface temperatures may have impacted the distribution of striped marlin in New Zealand waters as the boundary of striped marlin bycatch has expanded southward along the South Island's west coast in recent years (Tremblay-Boyer 2021).

Data from New Zealand striped marlin fisheries were documented and summarised for the 2019 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 of the 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° and 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 the last ten years when 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 the NZSFC clubs were collected and added to the existing time series, which for some clubs goes back to 1925. Prior to 1988, most recreational striped marlin catch was weighed on certified scales by club weighmasters. The NZSFC club catch records for landed striped marlin were one of the most influential data components in the stock assessment, because they provide 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.

The stock assessment model shows a persistent decline in spawning biomass and an increase in fishing mortality from the beginning of the model period, which is consistent with what was found in the previous assessment. Fishing mortality continued to increase in the 2000s to a peak in the early 2010s, coinciding with the lowest estimates of spawning biomass. Recent years show a slight improvement in stock status relative to the early 2010s. The 2019 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). The next striped marlin stock assessment is scheduled for 2024.

Over the last 10 to 20 years, there has been an increase in the number of well-appointed trailer boats targeting pelagic gamefish in New Zealand. These can launch from various locations and are less likely to be affiliated with 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 smokehouse. Anecdotally, there is 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. Fishers whose billfish are not included in club records or the New Zealand gamefish tagging programme database are encouraged to enter catch details on the web page at fishcatch.co.nz

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. The next estimate for harvest by amateur fishers by NPS is currently underway for the 2022–23 October fishing year.

5. ACKNOWLEDGEMENTS

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 and Sydney Curtis-Wilson for reviewing this report. This project was reviewed by the Highly Migratory Species Working Group chaired by Dr Leyla Knittweis from Fisheries New Zealand. Fisheries New Zealand provided funding for this project STM2019-01, "Multi-year stock monitoring of striped marlin including logbook programme implementation".

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APPENDIX 1. Catch from New Zealand sport fishing clubs

Table A1.1: 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
2019–20	333	95	5	42	39	598	494	6	0	5	0
2020–21	627	68	6	54	97	600	556	2	0	5	0
2021–22	377	100	5	51	84	461	72	2	5	0	0
Total	17 781	2 764	184	1 327	1 054	21 579	16 926	3 511	1 368	529	137

APPENDIX 2. Tables of CPUE indices

Table A2.1: 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		2020	127	193	102.11	90.81
1973	76		106.65		2021	140	370	97.03	88.58
1974	184		94.38		2022	165	504	96.03	89.00
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					

Table A2.2: 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	0.6077	0.6179	0.6725	0.4301	0.50489
1976	0.3900	0.3965	0.5819	0.5148	0.32902
1977	0.6446	0.6555	0.6007	0.9168	0.12433
1978	1.1604	1.1798	1.1925	1.3574	0.16181
1979	1.1205	1.1393	1.1701	1.4161	0.12071
1980	1.5450	1.5710	1.6138	1.8821	0.13257
1981	1.0533	1.0709	1.0400	1.2545	0.14772
1982	1.3866	1.3102	1.3026	1.6627	0.14975
1983	1.0224	0.9381	0.8591	1.1889	0.14127
1984	0.6914	0.7042	0.7047	0.8902	0.12232
1985	0.3258	0.3527	0.3464	0.4545	0.15249
1986	0.4064	0.4132	0.4282	0.5622	0.14575
1987	0.3964	0.4011	0.3650	0.4426	0.16588
1988	0.7064	0.7209	0.6935	0.8367	0.10860
1989	1.2593	1.1893	1.1566	1.4189	0.08881
1990	0.9952	0.9941	0.9787	1.1890	0.09194
1991	0.7382	0.6637	0.6103	0.7537	0.10824
1992	0.8078	0.8876	0.8605	0.9569	0.09819
1993	0.9368	0.9927	0.8573	1.0522	0.09805
1994	1.5156	1.7254	1.6958	1.9806	0.08791
1995	1.5757	1.7633	1.7836	2.0444	0.09182
1996	1.2983	1.3748	1.3161	1.5787	0.09431
1997	1.0252	0.8976	0.9989	1.3435	0.13605
1998	1.0329	0.9746	0.8177	1.3285	0.13131
1999	1.6953	1.6819	1.5118	1.9030	0.09645
2000	0.9869	0.9343	0.9226	1.0558	0.12752
2001	0.9442	0.8194	0.9657	1.1965	0.13542
2002	0.9360	0.7455	0.8156	1.0358	0.16291
2003	1.3935	1.4168	1.2541	1.7398	0.12992
2004	1.7332	1.5201	1.6265	1.4069	0.12767
2005	1.6595	1.6098	1.2576	1.2841	0.12552
2006	2.0632	1.9232	1.5969	1.4075	0.13673
2007	1.7961	1.9968	1.7769	1.3203	0.13320
2008	1.1310	1.2284	1.0558	0.6984	0.18359
2009	1.8300	1.9006	1.8689	1.4097	0.14140
2010	1.2333	1.2313	0.9656	0.8907	0.14749
2011	1.1991	1.2011	1.0656	0.9899	0.13783
2012	1.1951	1.2496	1.3950	0.9495	0.15499
2013	1.3544	1.3688	1.1512	1.0867	0.14261
2014	1.3107	1.3327	1.0687	0.8804	0.18225
2015	0.8327	0.8467	0.8111	0.6692	0.19985
2016	1.1924	1.2124	1.2776	1.0559	0.17088
2017	0.8307	0.8447	0.7633	0.6247	0.20322
2018	0.9353	0.9509	0.6603	0.6625	0.23346
2019	0.8330	0.8469	1.1397	0.8061	0.21445
2020	0.6985	0.7102	0.7845	0.4132	0.46924
2021	0.9940	1.0107	1.5230	0.6347	0.40583
2022	0.5821	0.5918	1.8682	0.6294	0.47167

Table A2.3: 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	1.2977	1.5799	1.0255	1.8637	0.09258
2008	1.1445	1.1119	1.0070	0.9712	0.09527
2009	1.5367	1.4014	1.0886	1.5708	0.08795
2010	1.1637	1.2037	0.9879	1.1746	0.08980
2011	0.8926	0.8973	0.9311	0.9938	0.09261
2012	1.0558	0.9980	0.8763	1.1291	0.09408
2013	1.2684	1.2965	1.0082	1.1589	0.08068
2014	1.0440	1.0985	1.0697	0.9891	0.09363
2015	1.3260	1.0949	1.0678	0.9836	0.10322
2016	1.2718	1.3346	1.0711	1.2787	0.09481
2017	0.5411	0.5812	0.8810	0.6394	0.13033
2018	1.1078	1.0902	1.0616	0.9218	0.10128
2019	0.7202	0.7461	1.0541	0.9238	0.14584
2020	0.4524	0.3856	0.8563	0.3969	0.18025
2021	0.7924	0.7857	0.9782	0.8986	0.13757
2022	1.1559	1.2645	1.0835	0.9532	0.15001

APPENDIX 3. Coefficient, distribution, and influence plots

East Northland charter vessels

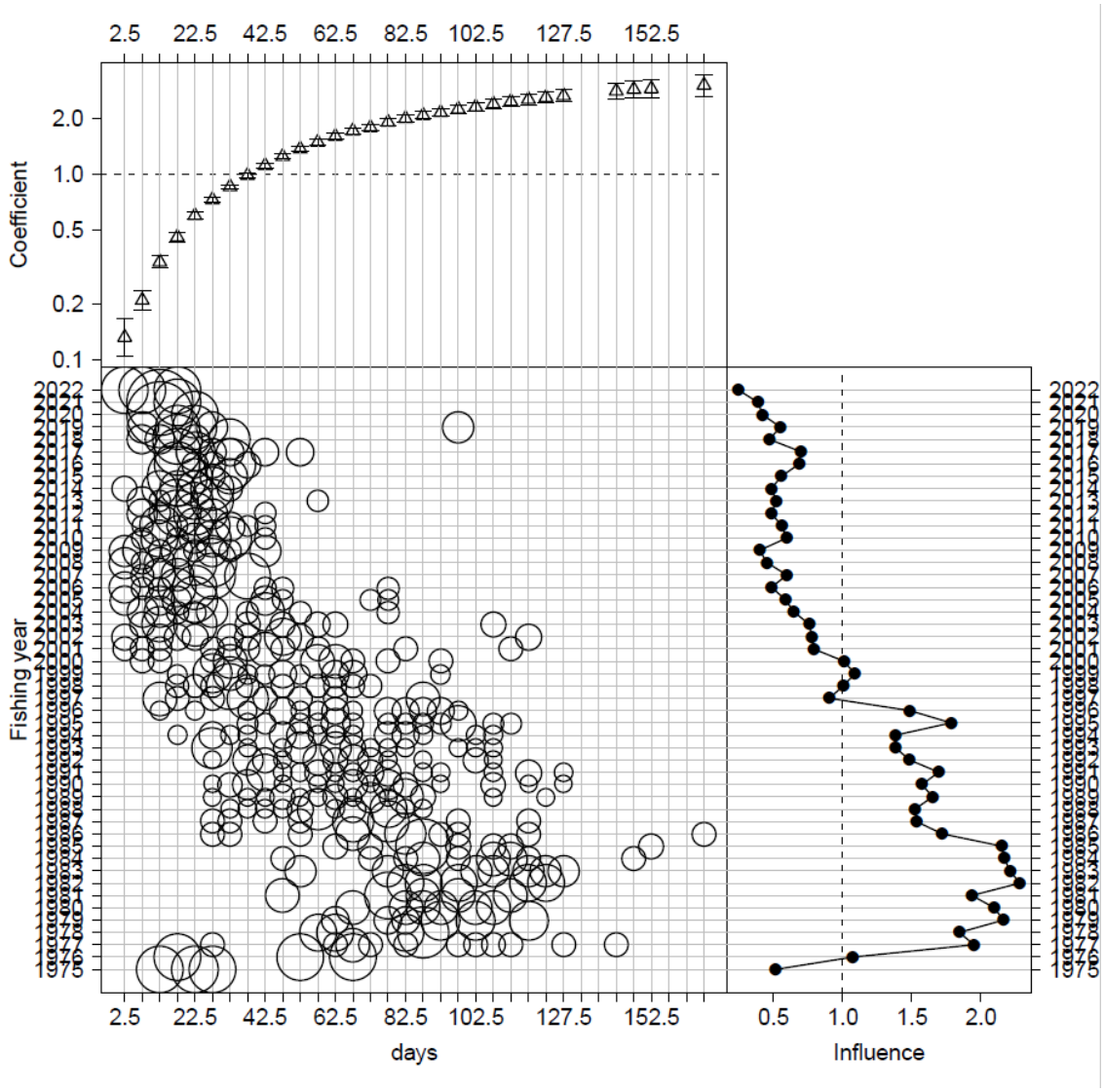


Figure A3.1: Coefficient-distribution-influence plot for *poly(log(days), 3)* for the East Northland charter vessel model.

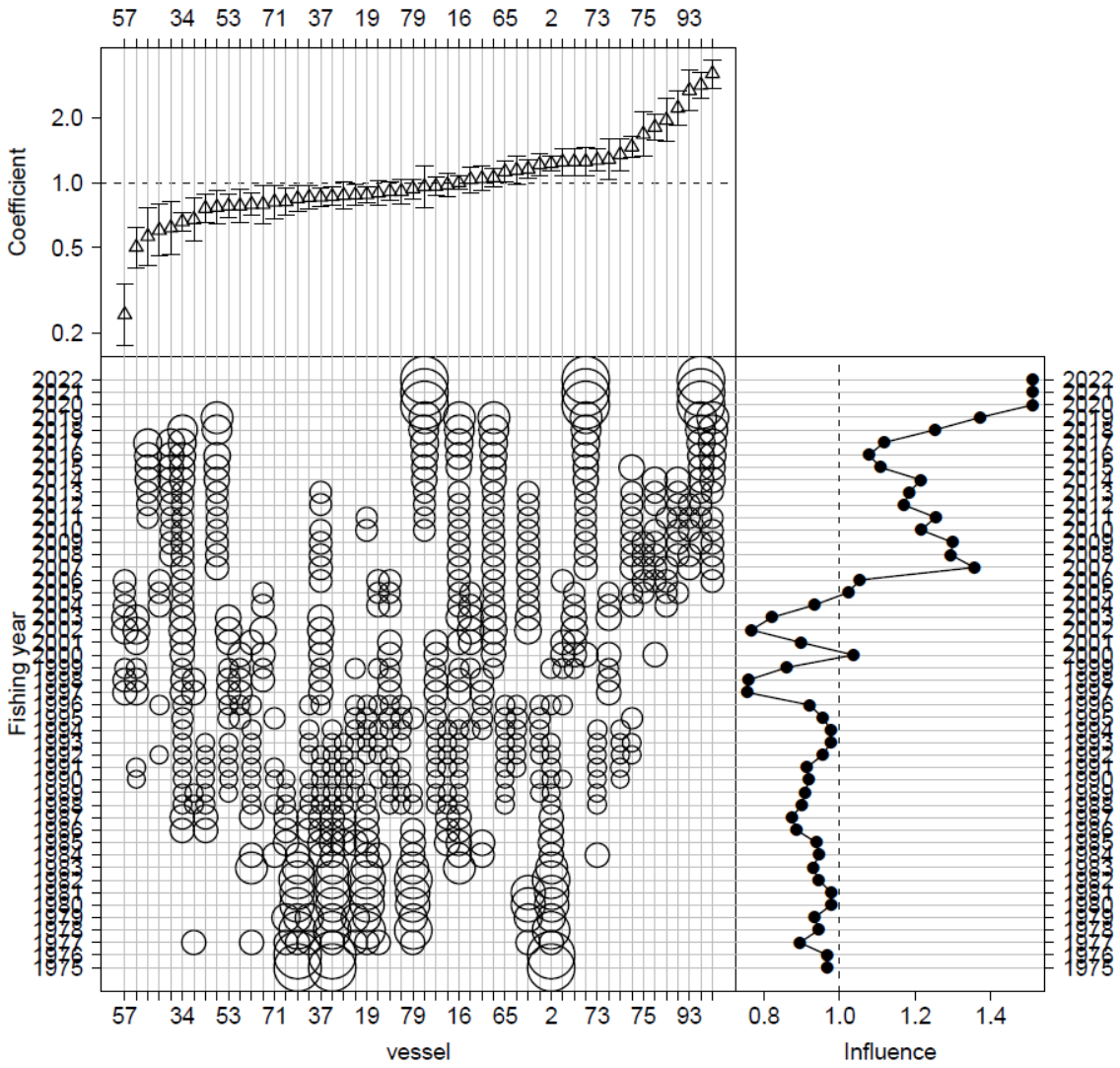


Figure A3.2: Coefficient-distribution-influence plot for *vessel* in the East Northland charter vessel model.

Billfish logbook vessels

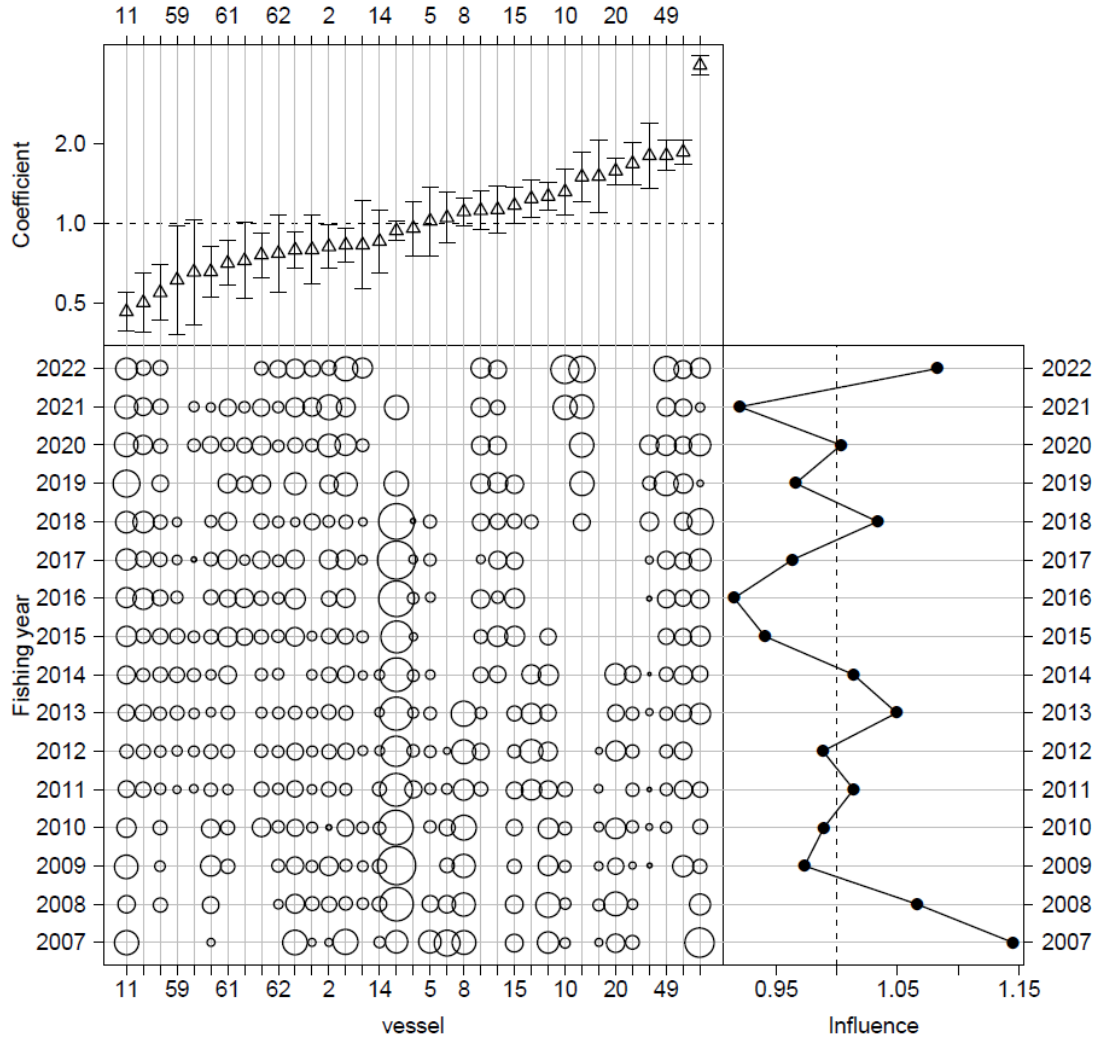


Figure A3.3: Coefficient-distribution-influence plot for *vessel* from the billfish logbook model.

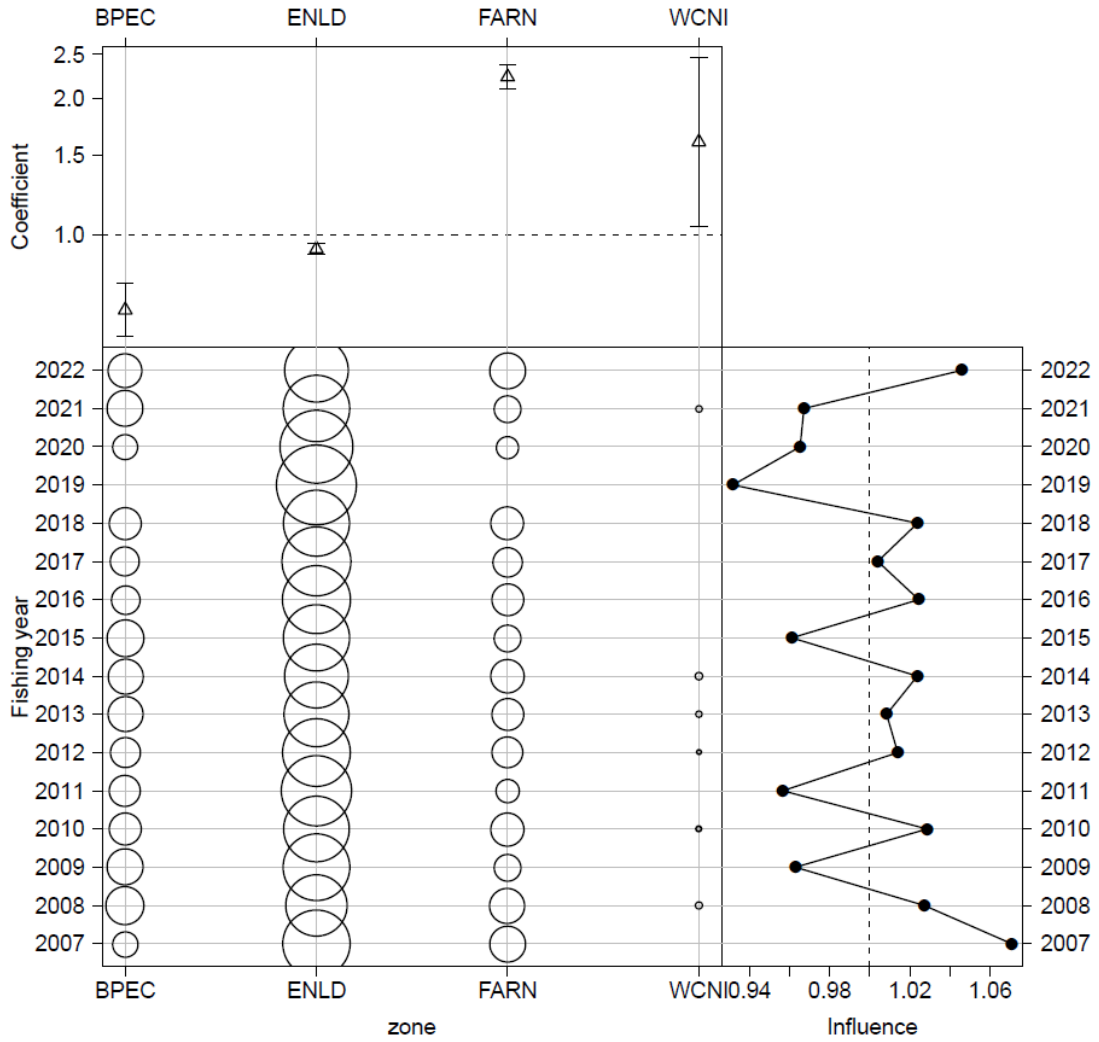


Figure A3.4: Coefficient-distribution-influence plot for *zone* from the billfish logbook model.

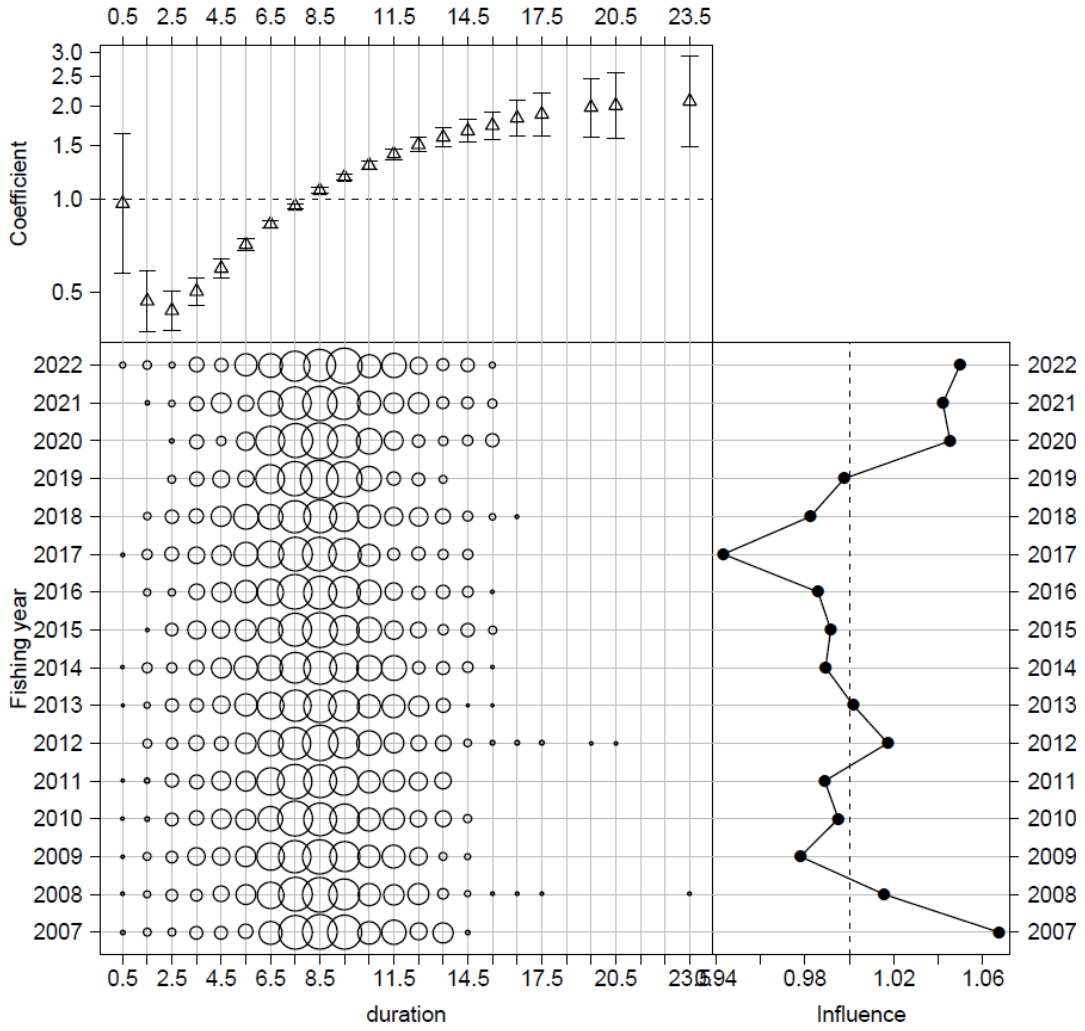
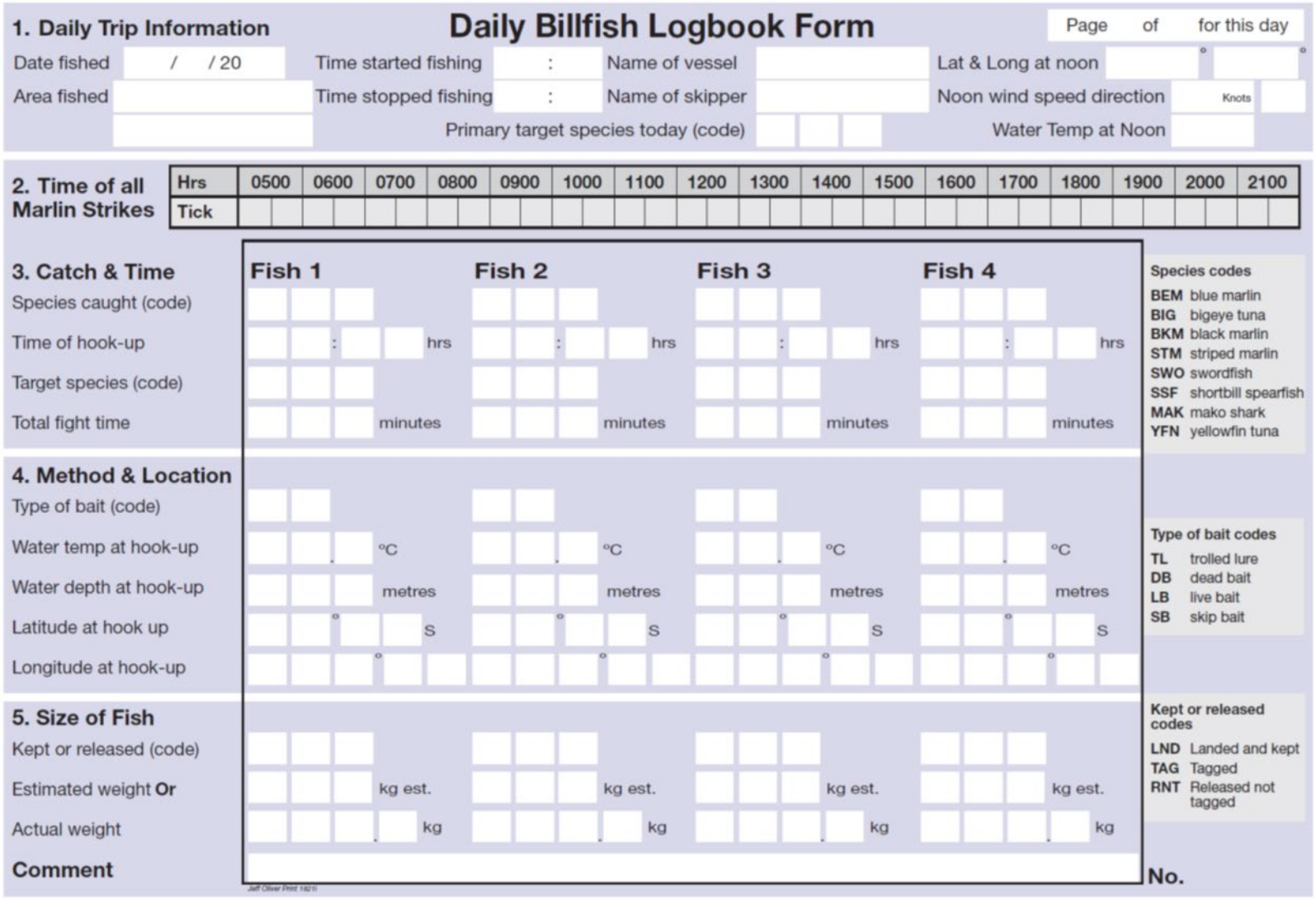


Figure A3.5: Coefficient-distribution-influence plot for *poly(log(duration), 3)* from the billfish logbook model.

APPENDIX 4. Billfish logbook form



1. Daily Trip Information

Daily Billfish Logbook Form

Page of for this day

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

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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

No.