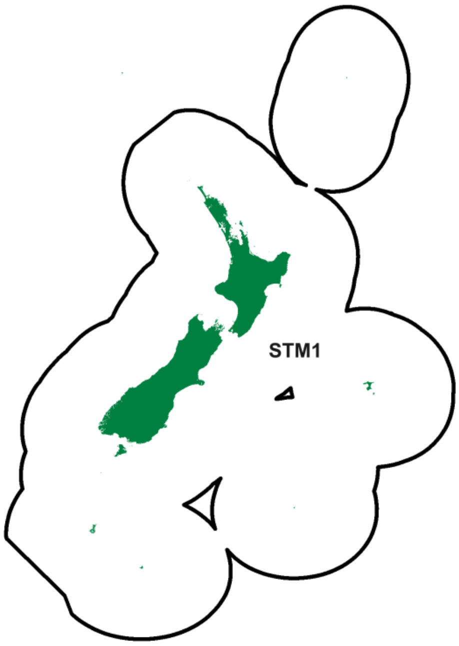
STRIPED MARLIN (STM)

(*Kajikia audax*)



1. FISHERY SUMMARY

All marlin species are currently managed outside the Quota Management System.

Management of the striped marlin and other highly migratory pelagic species throughout the western and central Pacific Ocean (WCPO) is the responsibility of the Western and Central Pacific Fisheries Commission (WCPFC). Under this regional convention, New Zealand is responsible for ensuring that the fisheries management measures applied within New Zealand fisheries waters are compatible with those of the Commission.

At its third annual meeting (2006) the WCPFC passed a Conservation and Management Measure (CMM) (this is a binding measure that all parties must abide by) relating to conservation and management of striped marlin in the southwest Pacific Ocean (www.wcpfc.int). This measure restricts the number of vessels a state can have targeting striped marlin on the high seas. However, this does not apply to those coastal states (including New Zealand) south of 15 degrees south in the Convention Area who have already taken, and continue to take, significant steps to address concerns over the status of striped marlin in the Southwestern Pacific region, through the establishment of a commercial moratorium on the landing of striped marlin caught within waters under their national jurisdiction.

1.1 Commercial fisheries

Most of the commercial striped marlin catch in the southwest Pacific is caught in the tuna surface longline fishery, which started in 1952, and in the New Zealand region in 1956. Since 1980 foreign fishing vessels had to obtain a license to fish in New Zealand's EEZ and were required to provide records of catch and effort. New Zealand domestic vessels commenced fishing with surface longlines in 1989 and the number of vessels and the fishing effort expanded rapidly during the 1990s. Also in 1989, licences were issued to charter up to five Japanese surface longline vessels to fish on behalf of

New Zealand companies. Very few striped marlin are caught by other commercial methods, although there are occasional reports of striped marlin caught in purse seine nets.

A three-year billfish moratorium was introduced in October 1987 in response to concerns over the decline in availability of striped marlin to recreational fishers. The moratorium prohibited access to the Auckland Fisheries Management Area (AFMA - Tirua Point to Cape Runaway) by foreign licensed and chartered tuna longline vessels between 1 October and 31 May each year. Licence restrictions required that all billfish, including broadbill swordfish, caught in the AFMA be released. In 1990 the moratorium was renewed for a further three years with some amended conditions and it was reviewed and extended in 1993 for a further year.

Regulations have prohibited domestic commercial fishing vessels from retaining billfish caught within the AFMA since 1988. In 1991 these regulations were amended to allow the retention of broadbill swordfish and prohibited the retention of marlin species (striped, blue and black marlin) by commercial fishers in New Zealand fishery waters. These regulations, and government policy changes on the access rights of foreign licensed surface longline vessels, have replaced the billfish moratorium. A billfish memorandum of understanding (MOU) between representatives of commercial fishers and recreational interests provided a framework for discussion and agreement on billfish management measures. This MOU was reviewed annually between 1990 and 1997 and was last signed in 1996.

A review of marlin regulations and management was identified as an issue during the development of the National Fisheries Plan for Highly Migratory Species. The main focus was on the relative benefits of alternative management options for striped marlin that might either allow for some limited commercial utilisation on the one hand, or further consolidate the current status of marlin as a non-commercial species, on the other hand.

At the review meetings in 2013 there was no agreement between sector representatives on alternative management measures for marlin. The Minister decided to retain the moratorium on commercial landings of marlin caught in New Zealand waters.

Estimates of total landings (commercial and recreational) for New Zealand are given in Table 1. Commercial catch of striped marlin reported on Catch Effort Landing Returns (CELRs) and Tuna Longline Catch and Effort Returns (TLCERs) and recreational catches from New Zealand Big Game Fishing Council records are given in Table 1. Figure 1 shows historic landings and longline fishing effort for the STM stocks.

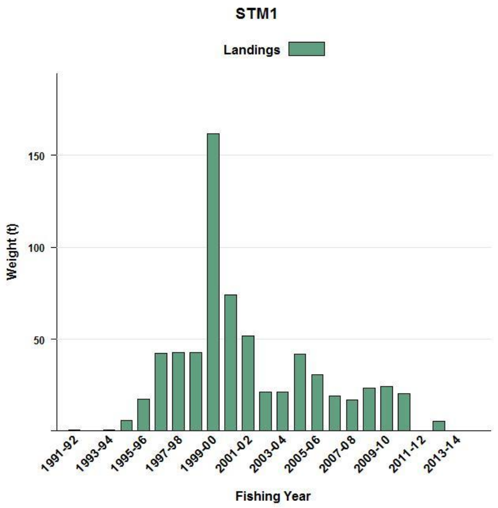


Figure 1: Striped marlin catch (commercial discards) between 1991–92 and 2014–15 within New Zealand waters (STM 1). [Figure continued on next page.]

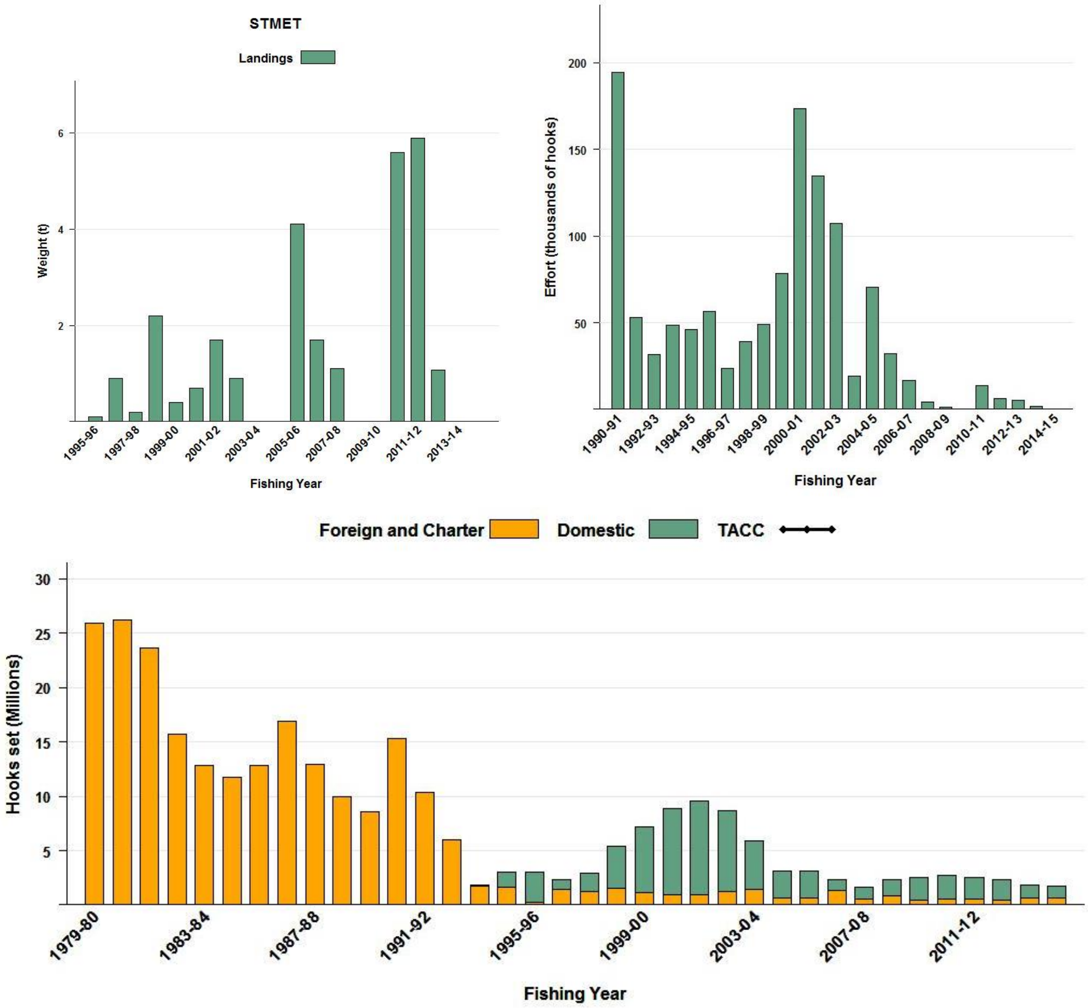


Figure 1 [Continued]: [Top left] Striped marlin catch between 1995–96 and 2014–15 on the high seas (STM ET). [Top right] Fishing effort (number of hooks set) for all high seas New Zealand flagged surface longline vessels, 1990–91 to 2014–15 and [Bottom] domestic vessels (including effort by foreign vessels chartered by New Zealand fishing companies), from 1979–80 to 2014–15.

Table 1: Commercial landings and discards (number of fish) of striped marlin in the New Zealand EEZ reported by fishing nation (CELRs and TLCERs), and recreational landings and number of fish tagged, by fishing year [Continued on next page].

Fishing	Japan		Korea	Philippine	Australia	Domestic	NZ Recreational		Total
Year	Landed	Discarded	Landed	Discarded	Discarded	Discarded	Landed	Tagged	
1979–80	659						692	17	1 368
1980–81	1 663		46				792	2	2 503
1981–82	2 796		44				704	11	3 555
1982–83	973		32				702	6	1 713
1983–84	1 172		199				543	9	1 923
1984–85	548		160				262		970
1985–86	1 503		19				395	2	1 919
1986–87	1 925		26				226	2	2 179
1987–88	197		100				281	136	714
1988–89	23		30			5	647	408	1 113
1989–90	138					1	463	367	969
1990–91		1				6	532	232	771
1991–92		17				1	519	242	779

Table 1 [Continued]: Commercial landings and discards (number of fish) of striped marlin in the New Zealand EEZ reported by fishing nation (CELRs and TLCERs), and recreational landings and number of fish tagged, by fishing year.

Fishing	Japan		Korea	Philippine	Australia	Domestic	NZ Recreational		Total
Year	Landed	Discarded	Landed	Discarded	Discarded	Discarded	Landed	Tagged	
1992–93						7	608	386	1 001
1993–94						59	663	929	1 651
1994–95						182	910	1 206	2 298
1995–96						456	705	1 104	2 265
1996–97						441	619	1 302	2 362
1997–98						445	543	898	1 886
1998–99						1 642	823	1 541	4 006
1999–00		2				798	398	791	1 989
2000–01						527	422	851	1 800
2001–02						225	430	771	1 426
2002–03		3		7		205	495	671	1 371
2003–04		1				423	592	1 051	2 066
2004–05						258	834	1 348	2 440
2005–06						168	630	923	1 721
2006–07					9	154	688	964	1 806
2007–08		1				208	485	806	1 499
2008–09						241	731	1 058	2 030
2009–10						195	607	858	1 660
2010–11						269	607	731	1 601
2011–12						241	635	663	1 531
2012–13		1				216	744	853	1 813
2013–14						202	620	519	1 341
2014–15						371	696	1 086	2 153

Total recorded commercial catch was highest in 1981–82 at 2843 fish and 198 t. Following the introduction of the billfish regulations, striped marlin caught on commercial vessels were required to be returned to the sea and few of these fish were recorded on catch/effort returns. In 1995 the Ministry of Fisheries (now MPI) instructed that commercially caught marlin be recorded on TLCERs. However, compliance with this requirement was inconsistent and estimated catches in the tuna longline fishery (calculated by scaling-up observed catches to the entire fleet) are considerably higher than reported catches in fishing years for which these estimates are available. However, the estimates are probably imprecise as MPI observer coverage of the domestic fleet has been low (just below 10% for the years 2007–2010) and has not adequately covered the spatial and temporal distribution of the fishery over summer.

Few striped marlin in the TLCER database were reported south of 42ºS and most striped marlin reported by commercial fishers were caught north of 38ºS. Historically, Japanese and Korean vessels caught most striped marlin between 31ºS and 35ºS with a peak at 33ºS. The New Zealand domestic fleet caught the majority of their striped marlin in the Bay of Plenty, East Cape area, between 36ºS and 37ºS.

A significant number of catch records from domestic commercial vessels provide the number of fish caught but not the estimated catch weight. The total weight of striped marlin caught per season was therefore calculated using fisher estimates from TLCER and CELR records plus the number of fish with no weights multiplied by the mean recreational striped marlin weight for that season. Reported total landings and discards (commercial and recreational) and commercial landings from outside the EEZ are shown in Table 2.

Combined landings from within New Zealand fisheries waters are relatively small compared to commercial landings from the greater stock in the southwest Pacific Ocean (8% average for 2002–

2006). In New Zealand, striped marlin are landed almost exclusively by the recreational sector, but there are no current estimates of recreational catch from elsewhere in the southwest Pacific.

Table 2: Reported total New Zealand landings and discards (commercial and recreational) (t) and commercial landings from the western and Central Pacific Ocean (WCPO) (t) of striped marlin from 1991 to 2015.

	Commercial		Recreational		EEZ	NZ Commercial	WCPO all
	Landed	Discarded	Landed	Tagged	Total	Outside the EEZ	gears *
1991	0.1	0.5	52	21	73		7 076
1992	0.8	0.1	57.8	21.9	81		6 878
1993	0	0.8	62.8	34.4	99		11 867
1994		5.7	66.3	81.2	153		8 013
1995		17.2	95	100	214	0.1	8 437
1996		42.3	70.6	91.6	204	0.9	6 746
1997		42.9	64.4	127.8	230	0.2	6 027
1998		42.7	56.5	80.9	182	2.2	8 501
1999		161.9	73.2	130.9	345	0.4	7 222
2000		74.1	40.9	72.1	179	0.7	5 644
2001		51.6	45.5	78.7	177	1.7	6 149
2002		21.2	45.8	76.9	144	0.9	5 962
2003		21.1	54.6	65.4	142		6 625
2004		41.7	62.7	105.6	208		6 551
2005		30.7	86.6	131.3	249	3.5	5 611
2006	0.4	19.0	60.8	85.8	166	3.2	5 534
2007	1.2	16.9	67.5	93.4	179	1.9	4 486
2008		22.6	48.6	79.7	152	1.1	5 057
2009		25.3	73.7	104.4	202		3 930
2010		18.6	63.1	79.5	163	5.6	3 530
2011		27.4	51.1	66.6	144	5.9	4 174
2012		24.0	75.9	77.6	153	1.8	4 060
2013		22.8	80.6	86.4	190	1.1	3 684
2014		19.8	66.0	51.0	137	0	2 251
2015		32.6	68.5	97.4	199		2 157

Source: TLCER and CELRs; NZSFC; Holdsworth (2008); Holdsworth & Saul (2014);* Anon (2013).

The majority of striped marlin (65%) caught in the New Zealand commercial fisheries are caught as bycatch in the bigeye tuna target surface longline fishery (Figure 2) however striped marlin are not allowed to be retained by commercial fishers in New Zealand fishery waters and as a result do not show up in the reported catch (Figure 3). Longline fishing effort is distributed along the east coast of the North Island and the south west coast of the South Island. The west coast South Island fishery predominantly targets southern bluefin tuna, whereas the east coast of the North Island targets a range of species including bigeye, swordfish, and southern bluefin tuna.

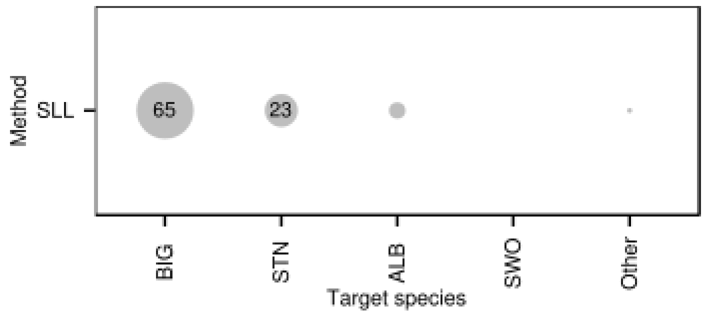


Figure 2: A summary of the proportion of striped marlin taken by each target fishery and fishing method for 2012-13. The area of each circle is proportional to the percentage of landings taken using each combination of fishing method and target species. The number in the circle is the percentage. SLL = surface longline (Bentley et al 2013).

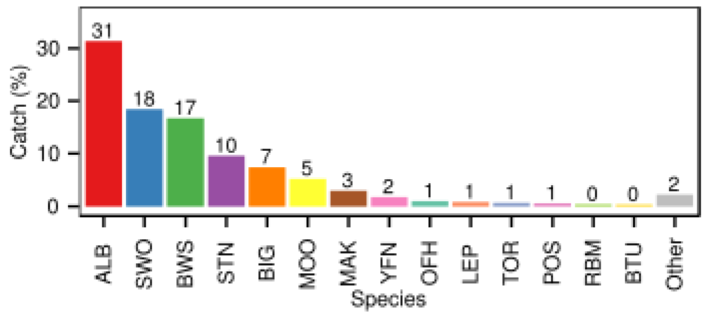


Figure 3: A summary of species composition of the reported surface longline catch for 2012–13. The percentage by weight of each species is calculated for all surface longline trips (Bentley et al 2013).

In the longline fishery 70% of the striped marlin were alive when brought to the side of the vessel for all fleets (Table 3), and almost all were discarded (Table 4) as required by New Zealand legislation.

Table 3: Percentage of striped marlin (including discards) that were alive or dead when arriving at the longline vessel and observed during 2006–07 to 2009–10, by fishing year, fleet and region. Small sample sizes (number observed < 20) were omitted Griggs & Baird (2013).

Year	Fleet	Area	% alive	% dead	Number
2006–07	Total		65.0	35.0	20
2007–08	Total		100.0	0.0	6
2008–09	Total		50.0	50.0	8
2009–10	Domestic	North	72.7	27.3	22
	Total		72.7	27.3	22
Total all strata			69.6	30.4	56

Table 4: Percentage of striped marlin that were retained, or discarded or lost, when observed on a longline vessel during 2006–07 to 2009–10, by fishing year and fleet. Small sample sizes (number observed < 20) omitted Griggs & Baird (2013).

Year	Fleet	% retained	% discarded or lost	Number
2006–07	Total	10.0	90.0	20
2007–08	Total	0.0	100.0	6
2008–09	Total	0.0	100.0	9
2009–10	Domestic	4.3	95.7	23
	Total	4.3	95.7	23

1.2 Recreational fisheries

The striped marlin fishery is an important component of the recreational fishery and tourist industry from late December to May in northern New Zealand. There are approximately 100 recreational charter boats that derive part of their income from marlin fishing and a growing number of private vessels participating in the fishery. Many of the largest fishing clubs in New Zealand target gamefish and are affiliated to the national body, the New Zealand Sport Fishing Council (NZSFC). Clubs provide facilities to weigh fish and keep catch records. The sport fishing season runs from 1 July to 30 June the following year. Almost all striped marlin are caught between January and June in the later half of the season.

In 1988 the NZSFC proposed a voluntary minimum size of 90 kg for striped marlin in order to encourage tag and release. Fish landed under this size do not count for club or national contests or trophies but most are included in the catch records for each fishing season. In 2014–15 the 56 recreational fishing clubs affiliated to NZSFC reported landing 3776 billfish, sharks, kingfish, mahimahi, and tuna, and tagged and released a further 1300 gamefish. In 2014–15, 696 striped marlin were landed and weighed by clubs (18% of landed fish in NZSFC records) and 898 were tagged and released (42% of tagged fish in NZSFC records).

There is an almost complete historical database of recreational catch for individual striped marlin caught by the Bay of Islands Swordfish Club and the Whangaroa Big Game Fishing Club going back to the 1920s, when this fishery started.

1.3 Customary non-commercial fisheries

Maori traditionally ate a wide variety of seafood, however, no record of specific marlin fishing methods has been found to date. An estimate of the current customary catch is not available.

1.4 Illegal catch

There is no known illegal catch of striped marlin.

1.5 Other sources of mortality

Some fish that break free from commercial or recreational fishing gear may die due to hook damage or entanglement in trailing line. A high proportion of fish that are caught are released alive by both commercial and recreational fishers. Data collected by MPI Observer Services from the tuna longline fishery suggest that most striped marlin are alive on retrieval (72% of the observed catch). The proportion of striped marlin brought to the boat alive was similar on domestic longliners and foreign and charter vessels. However, post release survival rates are unknown.

Recreational anglers tag and release 50 to 60% of their striped marlin catch. Most of these fish are caught on lures. Reported results from 66 pop-up satellite archival tags (PSATs) deployed on lure caught striped marlin in New Zealand showed a high survival rate following catch and release. The pop-up archival tags are programmed to release from the fish following death. No fish died and sank to the seafloor. One fish was eaten (tag and all) by a lamnid shark about 15 hours after it was tagged and released. A small proportion of other PSAT tags failed to report so the fate of these fish is unknown.

Striped marlin caught on baits in Mexico showed a 26% mortality rate within 5 days of release. Injury was a clear predictor of mortality; 100% of fish that were bleeding from the gill cavity died, 63% of fish hooked deep died, and 9% of those released in good condition died.

2. BIOLOGY

Striped marlin is one of eight species of billfish in the family Istiophoridae. They are epi-pelagic predators in the tropical, subtropical and temperate pelagic ecosystem of the Pacific and Indian Oceans. Juveniles generally stay in warmer waters, while adults move into higher latitudes and temperate water feeding grounds in summer (i.e. the first quarter of the calendar year in the southern hemisphere; the third quarter in the northern hemisphere). The latitudinal range estimated from longline data extends from 45ºN to 40ºS in the Pacific and from continental Asia to 45ºS in the Indian Ocean. Striped marlin are not uniformly distributed, having a number of areas of high abundance. Fish tagged in New Zealand have undergone extensive seasonal migrations within the southwest Pacific but not beyond.

Samples from recreationally caught striped marlin in New Zealand indicate that the most frequent prey items are saury and arrow squid, followed by jack mackerel. However, 28 fish species and 4 cephalopod species have been identified from stomach contents indicating that they are opportunistic predators.

The highest striped marlin catch for the surface longline method is recorded in January–February but striped marlin have been caught in New Zealand fisheries waters in every month, with lowest catches in November and December.

Striped marlin are oviparous and are known to spawn in the Coral Sea between Australia and New Caledonia. Their ovaries start to mature in this region during late September or early October. Spawning peaks in November and December and 60–70% of fish captured at this time are in spawning condition. The minimum size of mature fish in the Coral Sea is recorded at approximately 170 cm lower jaw-fork length (LJFL) and 36 kg. Striped marlin captured in New Zealand are rarely less than 200 cm (LJFL) suggesting that these fish are all mature. Female striped marlin are larger than males on average but sexual dimorphism is not as marked as that seen in blue and black marlin. The sex ratio of striped marlin sampled from the recreational fishery in Northland (n = 61) was 1:1 prior to the introduction of the voluntary minimum size restriction (90 kg). There is no clear evidence of striped marlin reproductive activity in New Zealand waters. The northern edge of the EEZ around the Kermadec Islands extends into subtropical waters. According to historical longline records, in some years there are moderate numbers of striped marlin in this area from October to December. Therefore, striped marlin spawning could occur in this area.

Estimated growth and validated age estimates of striped marlin were derived from fin spine and otolith age estimates from 425 striped marlin collected between 2006 and 2009. Samples came from the Australian commercial longline and recreational fisheries, longline fisheries in Pacific Island countries and 133 samples from the New Zealand recreational fishery. Ages ranged from 130 days to 8 years, in striped marlin ranging in length from 990 mm (about 4 kg) to 2871 mm (about 168 kg) LJFL (Kopf et al 2010). Estimated ages of striped marlin from New Zealand ranged from 2 to 8 years in fish ranging in length from 2000 mm to 2871 mm LJFL. The median age of striped marlin landed in the New Zealand recreational fishery was 4.4 years for females and 3.8 years for males.

Growth for striped marlin in the southwest Pacific is broadly comparable with overseas studies. Melo-Barrera et al (2003) identified between 2 and 11 growth bands from fish sampled in Mexico, and Skillman & Yong (1976) classified up to 12 age groups from length frequency analysis of striped marlin in Hawaii. Recreational catch records kept by the International Game Fish Association (IGFA) list the heaviest striped marlin as 224.1 kg caught in New Zealand in 1975.

Estimates of biological parameters for striped marlin in New Zealand waters are given in Table 5.

Table 5: Estimates of biological parameters.

Parameter	Estimate				Source
1. Natural mortality (M)					
STM	0.49–1.33				Boggs (1989)
STM	0.389–0.818				Hinton & Bayliff (2002)
2. Weight = a (length)^{b} (Weight in kg, length in mm lower jaw fork length)					
	a	b			
STM	1.012×10^{-10}	3.55		South West Pacific	Kopf et al (2010)
STM males	4.171×10^{-11}	3.67		South West Pacific	
STM females	1.902×10^{-9}	3.16		South West Pacific	
STM males	2.0×10^{-8}	2.88		New Zealand	Kopf et al (2005)
STM females	2.0×10^{-8}	2.90			
3. Von Bertalanffy model parameter estimates					
	k	t_0	L_∞		
STM	0.44	-1.07	2636	South West Pacific	Kopf et al (2010)
STM	0.22	-0.04	3010	New Zealand	Kopf et al (2005)
STM	0.23	-1.6	2210	Mexico	Melo-Barrera et al (2003)
STM male	0.315–0.417	-0.521	2 774–3 144	Hawaii	Skillman & Yong (1976)
STM female	0.686–0.709	0.136	2 887–3 262	Hawaii	Skillman & Yong (1976)

3. STOCKS AND AREAS

Striped marlin are a highly migratory species, and fish caught in the New Zealand fisheries waters are part of a wider stock. The stock structure of striped marlin in the Pacific Ocean is not well understood, but resolving stock structure uncertainties is the focus of current research activities. The two most frequently considered hypotheses are: (1) a single-unit stock in the Pacific, which is supported by the continuous “horseshoe-shaped” distribution of striped marlin; and (2) a two-stock structure, with the stocks separated roughly at the Equator, albeit with some intermixing in the eastern Pacific.

Spawning occurs in water warmer than 24°C, in the southern hemisphere, mainly in November and December. Known spawning areas in the southwest Pacific are in the Coral Sea in the west and in French Polynesia in the east of the region. The southern hemisphere spawning season is out of phase with the north Pacific. Very warm equatorial water in the western Pacific, where striped marlin are seldom caught, may be acting as a natural barrier to stock mixing. However, in the eastern Pacific striped marlin may be found in equatorial waters and three fish tagged in the northern hemisphere were recaptured in the southern hemisphere. The results of mitochondrial DNA analysis are consistent with shallow population structuring within striped marlin in the Pacific.

The New Zealand Gamefish Tagging Programme tagged and released 22 367 striped marlin between 1 July 1975 and 30 June 2014. Of the 90 recaptures reported, 33 have been made outside the EEZ spread across the region from French Polynesia (142°W) to eastern Australia (154°E) and from latitude 2°S to 38°S. There have been no reports of striped marlin tagged in the southwestern Pacific being recaptured elsewhere in the Pacific Ocean.

Projects by New Zealand and US researchers using electronic tags have described the movement and habitat preferences of Pacific striped marlin.

Striped marlin are believed to have a preference for sea surface temperatures of 20 to 25°C. Generally striped marlin arrive in New Zealand fisheries waters in January and February, and tag recaptures indicate that most leave the New Zealand EEZ between March and June; although they have been caught by surface longliners in the EEZ in every month. Within the EEZ most striped marlin are caught in FMA 1 and FMA 9.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This summary is from the perspective of striped marlin but there is no directed fishery for them.

4.1 Role in the ecosystem

Striped marlin (*Kajikia audax*) are large pelagic predators, so they are likely to have a 'top down' effect on the squid, fish and crustaceans they feed on.

4.2 Incidental fish bycatch

Observer records indicate that a wide range of species are landed by the longline fleets in New Zealand fishery waters. Blue sharks are the most commonly landed species (by number), followed by Ray's bream (Table 6).

Table 6: Total estimated catch (numbers of fish) of common bycatch species in the New Zealand longline fishery as estimated from observer data from 2011 to 2015. Also provided is the percentage of these species retained (2015 data only) and the percentage of fish that were alive when discarded, N/A (none discarded).

Species	2012	2013	2014	2015	% retained (2015)	discards % alive (2015)
Blue shark	132 925	158 736	80 118	72 480	0.3	87.0
Ray's bream	19 918	13 568	4 591	17 555	95.3	13.7
Lancetfish	7 866	19 172	21 002	12 962	0.2	44.6
Porbeagle shark	7 019	9 805	5 061	4 058	5.1	64.0
Moonfish	2 363	2 470	1 655	3 060	95.6	45.5
Mako shark	3 902	3 981	4 506	2 667	16.1	72.2
Butterfly tuna	713	1 030	699	1 309	86.9	11.1
Pelagic stingray	712	1 199	684	979	0.0	97.2
Dealfish	372	237	910	842	0.4	22.9
Sunfish	3 265	1 937	1 981	770	0.0	100.0
Escolar	2 181	2 088	656	653	82.5	71.4
Oilfish	509	386	518	584	46.7	83.3
Deepwater dogfish	647	743	600	545	2.3	88.3
Rudderfish	491	362	327	373	26.9	78.9
Thresher shark	246	256	261	177	0.0	53.3
Skipjack tuna	123	240	90	150	10.0	n/a
Striped marlin	124	182	151	120	10.0	55.6
School shark	477	21	119	88	43.5	76.9
Big scale pomfret	108	67	164	59	32.5	96.3

5. STOCK ASSESSMENT

With the establishment of WCPFC in 2004, the Scientific Committee of the Western and Central Pacific Fisheries Commission (WCPFC) will review stock assessments of striped marlin in the western and central Pacific Ocean stock.

In 2012, scientists from Australia and the Secretariat of the Pacific Community (SPC) collaborated on an assessment for striped marlin in the southwest Pacific Ocean (further details can be found in Davies et al (2012). This was the second attempt to carry out an assessment for this stock and contained many improvements from the previous assessment. Excerpts from the stock assessment are provided below, as are several figures and tables regarding stock status that reflect the model runs selected by SC for the determination of current stock status and the provision of management advice. This assessment is supported by several other analyses which are documented separately, but should be considered when reviewing this assessment as they underpin many of the fundamental inputs to the models. These include standardised CPUE analyses of aggregate Japanese and Taiwanese longline catch and effort data; standardised CPUE analyses of operational catch and effort data for the Australian longline fishery; standardized CPUE for the recreational fisheries in Australia and New Zealand (Holdsworth & Kendrick 2012), and new biological estimates for growth, the length-weight relationship, and maturity at age (Kopf 2009, 2011). The assessment includes a series of model runs describing stepwise changes from the 2006 assessment model (bcase06) to develop a new "reference case" model (Ref.case), and then a series of "one-off" sensitivity models that represent a single change from the Ref.case model run. A sub-set of key model runs was taken from the sensitivities that represent a set of plausible model runs, and these were included in a structural uncertainty analysis (grid) for consideration in developing management advice.

Besides updating the input data to December 2011, the main developments to the inputs compared to the 2006 assessment included:

a) Japanese longline catches for 1952–2011 revised downwards by approximately 50%;
b) Nine revised and new standardised CPUE time series (with temporal CVs) derived from:
    - aggregate catch-effort data for Japanese and Taiwanese longline fisheries;
    - operational catch-effort data for the Australian longline fishery;
    - operational catch-effort data for the Australian and New Zealand recreational fisheries, and
c) Size composition data for the Australian recreational fishery.

The main developments to model structural assumptions were to: fix steepness at 0.8; fix growth at the published estimates; estimate spline selectivities for the main longline fisheries; estimate logistic selectivity for the Australian recreational fishery; include time-variant precision in fitting the model to standardized CPUE indices; and remove conflict among the CPUE indices by taking only the Japanese longline index in model area 2 as being representative for the Ref.case.

The primary factors causing the differences between the 2006 and 2012 assessments are:

- The approximately 50% reduction in Japanese longline catches over the entire model time period;
- The faster growth rates;
- Steepness fixed at 0.8 rather than estimated (0.546);
- Selectivities for the major longline fisheries use cubic splines, and are not constrained to be asymptotic;
- Removing conflict among the CPUE indices by separating conflicting indices into different models.

Together these changes produce an estimated absolute biomass that is around 30% lower than the 2006 base case and MSY is estimated to be 20% lower. Current biomass levels are higher relative to the MSY reference point levels.

The main conclusions of the 2012 assessment undertaken by SPC (Davies et al 2012) and reviewed by the WCPFC Scientific Committee in August 2012 are as follows:

a) "The decreasing trend in recruitment estimated in the 2006 assessment remains a feature of the current assessment, particularly during the first 20 years. It is concurrent with large declines in catch and CPUE in the Japanese longline fishery in area 2. Recruitment over the latter 40 years of the model period declines slightly.

b) Estimates of absolute biomass were sensitive to assumptions about selectivity and to conflicts among the standardized CPUE time series. The reference case model (Ref.case) estimated selectivity functions that decrease with age for the main longline fisheries that achieved the best fit to the size data. The CPUE time series for the Japanese longline fishery in area 2 was selected for fitting the Ref.case model because this time series was considered to be the most representative of changes in overall population relative to abundance. Alternative options for selectivity assumptions and the CPUE time series included in the model fit were explored in sensitivity and structural uncertainty analyses, and are presented as the key model runs.

c) Estimates of equilibrium yield and the associated reference points are highly sensitive to the assumed values of natural mortality and, to a lesser extent, steepness in the stock-recruitment relationship. Estimates of stock status are therefore uncertain with respect to these assumptions.

d) If one considers the recruitment estimates since 1970 to be more plausible and representative of the overall productivity of the striped marlin stock than estimates of earlier recruitments, the results of the ‘msy_recent’ analysis could be used for formulating management advice. Under this productivity assumption *MSY* was 16% lower than the grid median value, but the general conclusions regarding stock status were similar.

e) Total and spawning biomass are estimated to have declined to at least 50% of their initial levels by 1970, with more gradual declines since then in both total biomass ($B_{current}/B_0$ = 36%) and spawning biomass ($SB_{current}/SB_0$ = 29%).

f) When the non-equilibrium nature of recent recruitment is taken into account, we can estimate the level of depletion that has occurred. It is estimated that, for the period 2007–2010, spawning potential is at 43% of the level predicted to exist in the absence of fishing, and for 2011 is at 46%.

g) The attribution of depletion to various fisheries or groups of fisheries indicates that the Japanese longline fisheries have impacted the population for the longest period, but this has declined to low levels since 1990. Most of the recent impacts are attributed to the ‘Other’ group of longline fisheries in areas 1 and 4, and to a lesser extent the ‘Other’ and Australian fisheries in areas 2 and 3.

h) Recent catches are 20% below the *MSY* level of 2182 t. In contrast, the ‘msy-recent’ analysis calculates *MSY* to be 1839 t, which places current catches 5% below this alternative *MSY* level. Based on these results, we conclude that current levels of catch are below MSY but are approaching MSY at the recent [low] levels of recruitment estimated for the last four decades.

i) Fishing mortality for adult and juvenile striped marlin is estimated to have increased continuously since the beginning of industrial tuna fishing. Apart from those model runs that assumed lower natural mortality or steepness, $F_{current}/F_{MSY}$ was estimated to be lower than 1. For the grid median, this ratio is estimated at 0.58. Based on these results, we conclude that overfishing is not occurring in the striped marlin stock.

j) The reference points that predict the status of the stock under equilibrium conditions at current F are $B_{Fcurrent}/B_{MSY}$ and $SB_{Fcurrent}/SB_{MSY}$. The model predicts that at equilibrium the biomass and spawning biomass would increase to 129% and 144%, respectively, of the level that supports *MSY*. This is equivalent to 39% of virgin spawning biomass. Current stock status compared to these reference points indicates that the current total and spawning biomass are close to the associated MSY levels ($B_{current}/B_{MSY}$ = 0.96 and $SB_{current}/SB_{MSY}$ = 1.09) based on the medians from the structural uncertainty grid. The structural uncertainty analysis indicates a 50% probability that $SB_{current}<SB_{MSY}$, and 6 of the 10 key model runs indicate the ratio to be < 1. Based on these results above, and the recent trend in spawning biomass, we conclude that striped marlin is approaching an overfished state.”

The Scientific Committee selected the reference case model from the assessment to characterize stock status and selected several key sensitivity runs to characterize uncertainty in trends in abundance and stock status (Figures 4–8 and Tables 7 and 8). It was noted that the use of the reference case and key sensitivities selected by the Scientific Committee in 2012 (Table 7) leads to slightly different conclusions in terms of stock status compared to that based on the uncertainty grid used in the assessment. The reference case and five of the six other key sensitivity runs estimated $F_{current}/F_{MSY}$ to be less than one indicating that overfishing is unlikely to be occurring. However, when considering $SB_{current}/SB_{MSY}$, the reference case and four of the six other key sensitivity runs are estimated to be less than one, indicating evidence that the stock may be overfished.

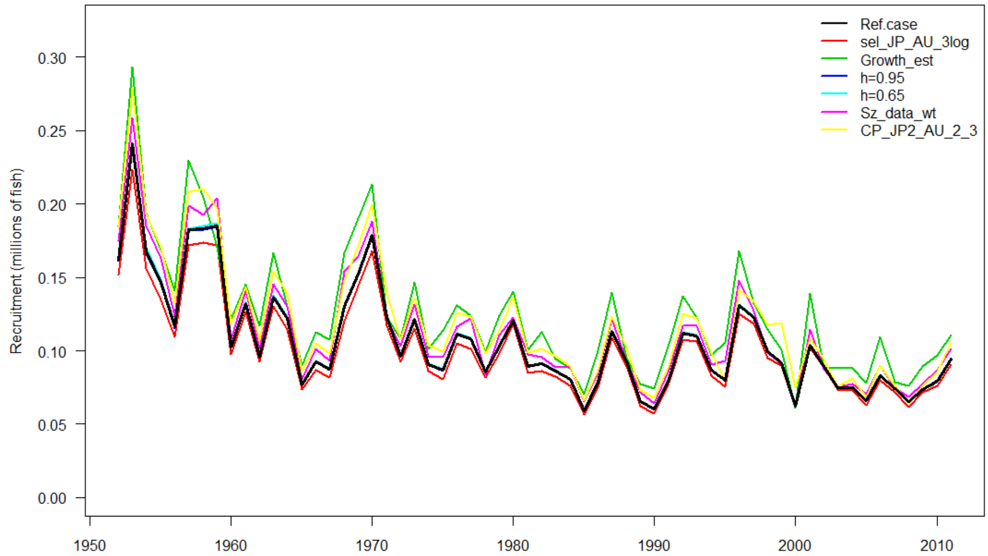


Figure 4: Estimated annual recruitment (millions of fish) for the southwest Pacific Ocean striped marlin obtained from the Ref.case model (black line) and the six plausible key model runs.

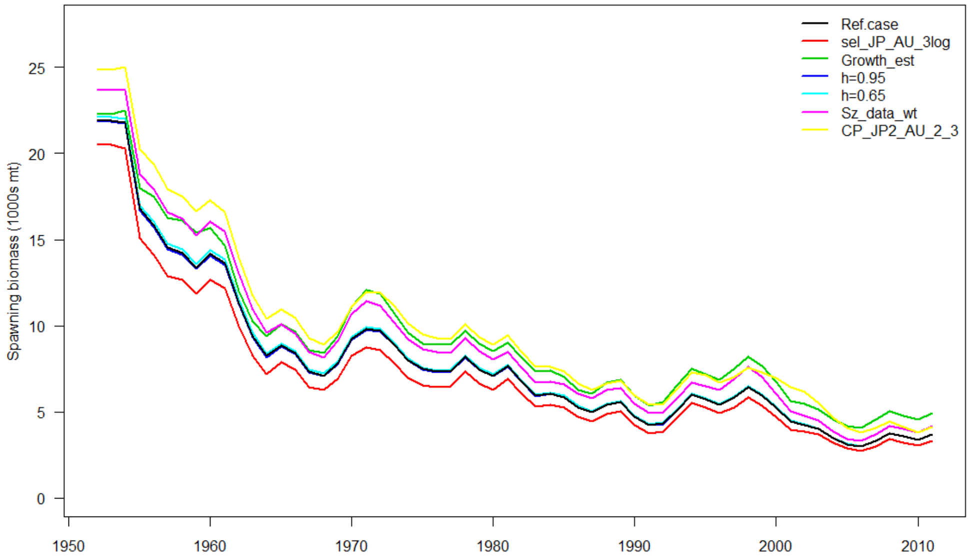


Figure 5: Estimated average annual average spawning potential for the southwest Pacific Ocean striped marlin obtained from the Ref.case model (black line) and the six plausible key model runs.

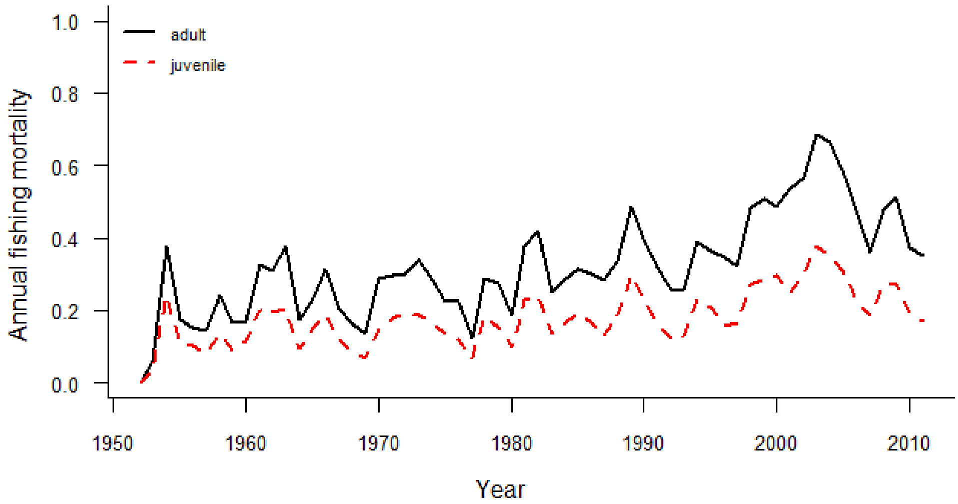


Figure 6: Estimated annual average juvenile and adult fishing mortality for the southwest Pacific Ocean striped marlin obtained from the Ref.case model.

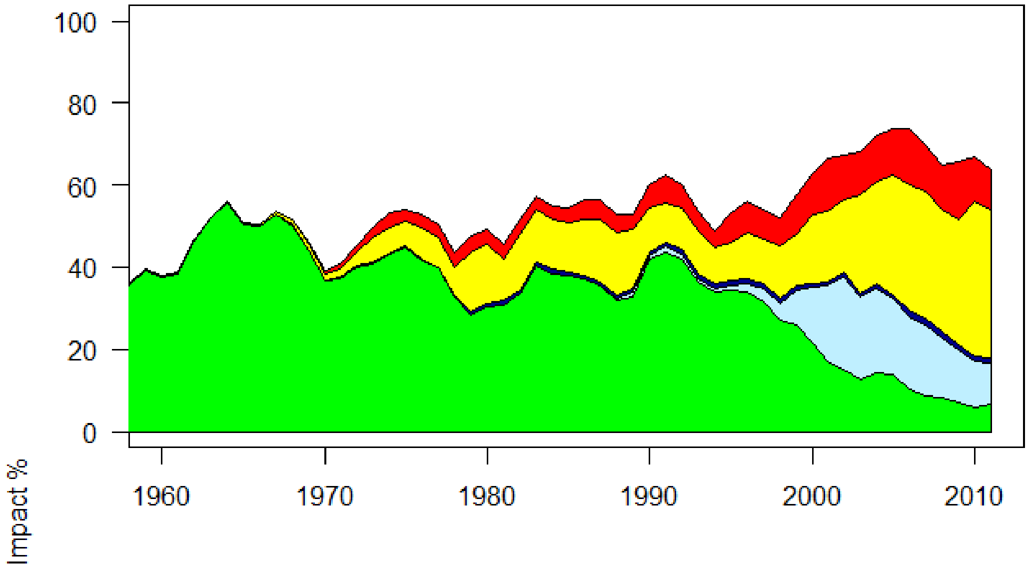
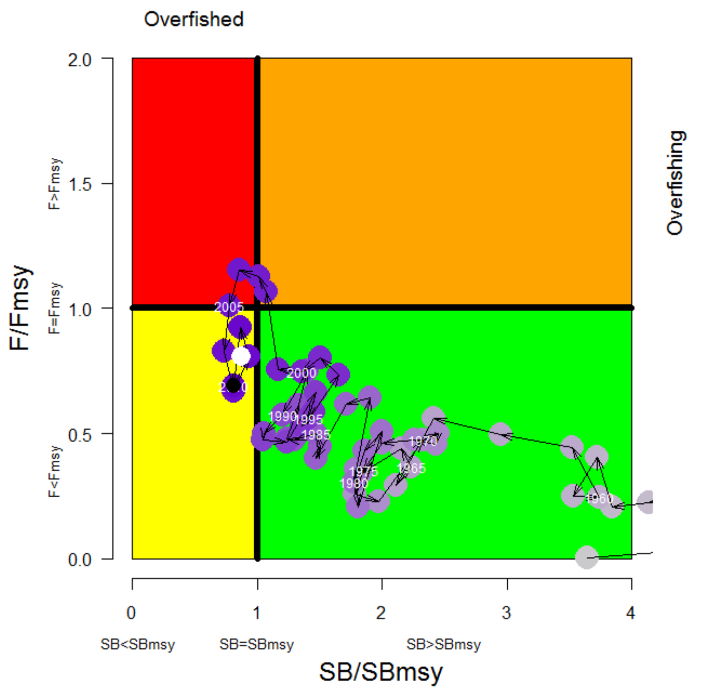


Figure 7: Estimates of reduction in spawning potential due to fishing (fishery impact = 1-SBt/SB$_{tF=0}$) for the southwest Pacific Ocean striped marlin attributed to various fishery groups (Ref.case model). Green = Japanese longline fisheries in sub-areas 1 to 4 and Taiwanese longline fishery in sub-area 4; Light blue = Australian and New Zealand longline fisheries; Dark blue = Australian and New Zealand recreational fisheries; Yellow = all longline fisheries in sub-areas 1 and 4 excluding Taiwanese in sub-area 4 and excluding Japanese; Red = all longline fisheries in sub-areas 2 and 3 excluding Japanese, Australian and New Zealand.



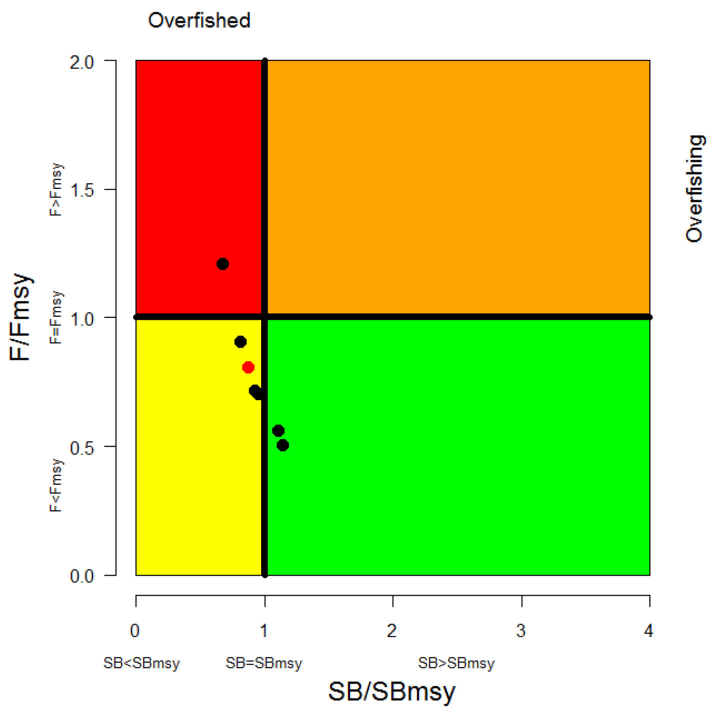


Figure 8: Temporal trend in annual stock status, relative to SB_{MSY} (x-axis) and F_{MSY} (y-axis) reference points for the Ref.case (top) and $F_{current}/F_{MSY}$ and $SB_{current}/SB_{MSY}$ for the Ref.case (red circle) and the six plausible key model runs. See Table 7 to determine the individual model runs.

Table 7. Estimates of management quantities for selected stock assessment models from the 2012 Ref.case model and the six plausible key model runs. For the purpose of this assessment, "current" is the average over the period 2007–2010 and "latest" is 2011.

	Ref.case	sel_JP_AU_3log	CP_JP2_AU_2_3	h=0.65	h=0.95	Growth_est	Sz_data_wt
$C_{current}$	1 758	1 753	1 785	1 759	1 759	1 707	1 764
C_{latest}	1 522	1 523	1 512	1 522	1 522	1 476	1 521
MSY	2 081	2 017	2 256	1 914	2 276	2 182	2 179
$C_{current}/MSY$	0.85	0.87	0.79	0.92	0.77	0.78	0.81
C_{latest}/MSY	0.73	0.76	0.67	0.80	0.67	0.68	0.70
F_{mult}	1.24	1.10	1.39	0.83	1.98	1.79	1.42
$F_{current}/F_{MSY}$	0.81	0.91	0.72	1.21	0.51	0.56	0.71
SB_0	15 130	14 530	16 590	16 790	14 220	15 360	16 000
SB_{MSY}/SB_0	0.27	0.27	0.27	0.32	0.22	0.28	0.26
$SB_{current}/SB_0$	0.24	0.22	0.25	0.21	0.25	0.31	0.25
SB_{latest}/SB_0	0.24	0.23	0.25	0.22	0.26	0.32	0.26
$SB_{current}/SB_{MSY}$	0.87	0.81	0.92	0.67	1.14	1.11	0.95
SB_{latest}/SB_{MSY}	0.90	0.84	0.92	0.70	1.19	1.14	1.00
$SB_{curr}/SB_{curr_{F=0}}$	0.34	0.32	0.37	0.34	0.34	0.44	0.37
$SB_{latest}/SB_{latest_{F=0}}$	0.37	0.34	0.39	0.37	0.37	0.46	0.40
Steepness (h)	0.80	0.80	0.80	0.65	0.95	0.80	0.80

Table 8: Comparison of southwest Pacific Ocean striped marlin reference points from the 2012 reference case model and the range of the seven models in Table 7; the 2006 base case model (steepness estimated as 0.51). *NA* = not available.

Management quantity	2012 assessment Ref.case (uncertainty)	2006 assessment Base case
Most recent catch	1758 t (2011)	1412 t (2004)
MSY	2081 t (1914 – 2276)	2610 t
$F_{current}/F_{MSY}$	0.81 (0.51–1.21)	1.25
$B_{current}/B_{MSY}$	0.83 (0.70–0.99)	0.70
$SB_{current}/SB_{MSY}$	0.87 (0.67–1.14)	0.68
$Y_{Fcurrent}/MSY$	0.99 (0.93–1.00)	0.99
$B_{current}/B_{current, F=0}$	0.46 (0.44–0.53)	0.53
$SB_{current}/SB_{current, F=0}$	0.34 (0.32–0.44)	*NA*

Commercial catch and effort returns in New Zealand

The commercial TLCER data are compromised by the failure of many vessels to report their catch of striped marlin which they are required to release. Since 2000 the standardised series of positive catches shows some promise as an index of relative abundance.

The non-zero model explained almost 25% of the variance in log catch, largely by standardising for changes in the core fleet and in the month fished, both of which are predicted to have improved observed catches over the study period. No measure of effort entered the model.

Log(number STM per set) = fishing year + vessel + month

Positive catches usually comprise a single fish and rarely more than two fish per set. There is thus little contrast in catch rate in positive sets, but the standardised series suggests an overall decline in abundance (Figure 9). The fit of positive catches to the lognormal assumption is poor and is improved slightly by assuming an inverse Gaussian error distribution. The effect of the alternative error distribution on the annual indices is to steepen the decline slightly in recent years. The series is based on recorded catches and has large error bars around each point due to the small number of records.

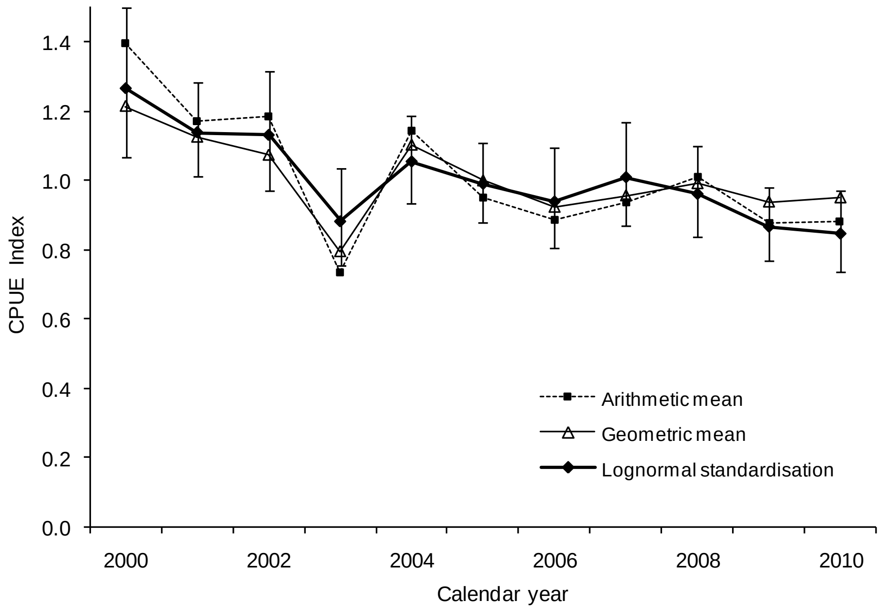


Figure 9: Unstandardised commercial logbook CPUE (annual geometric mean number of STM per set), the year effects from the model of non-zero catches (± 2 s.e.).

These CPUE analyses are done on the data that were groomed and submitted to WCPFC. In respect of some potential explanatory variables these datasets are not complete, and there is some potential to improve the analyses in future with dedicated data extracts. The shortened time series of commercial data used reflects the period for which we have confidence that striped marlin were being reported, however, there is some potential to extend that series back a little further in time for the positive catches only.

Observer logbook data

The observer database is limited in its coverage of the striped marlin which is largely a bycatch of bigeye tuna and swordfish target fisheries from the northern part of the EEZ, because observer effort is focused on the charter fleet that fishes further south for southern bluefin tuna.

The final non-zero model of observer logbook data explained 30% of the variance in catch rate. Fishing year was forced as the first variable and explained most of the variance in catch (16%). Sea surface temperature entered the model as the second most important variable explaining an additional 5% of the variance and it was followed by longitude, buoy-line length and longline length, each adding little additional explanatory power.

The final model form was as follows:

Log(number STM per set) = fishing year + temperature + longitude + buoy-line length + longline length

The effect of standardisation is marked because of the unbalanced nature of the dataset that the model attempts to account for. The standardised series is smoother than the unstandardised with most of the anomalous peaks being removed. The first two years in the series was comprised entirely of sets in cool water which the model accounts for by lifting the standardised CPUE in those years relative to the unstandardised model, but the error around each point is large and the overall trend is essentially flat (Figure 10).

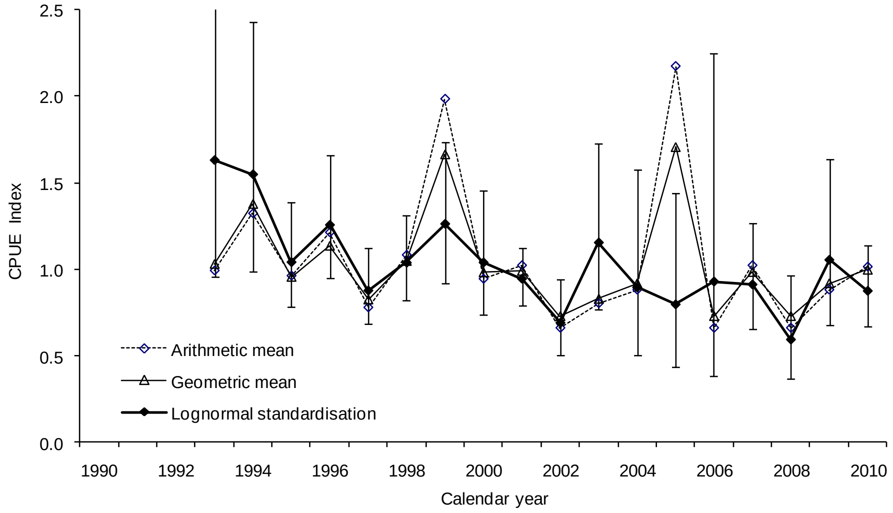


Figure 10: Unstandardised observer logbook CPUE (arithmetic and geometric mean numbers of STM per set) and the year effects from the lognormal model of catch rates in successful sets (± 2 s.e.).

Recreational charter boat data

A time series of data was collected using annual postal surveys of East Northland gamefish charter skippers. They provided striped marlin catch and effort information giving an average catch per vessel day fished over the whole season. Since 2006–07 more detailed daily catch and effort information has been collected from all regions with the billfish logbook programme. A subset of these data from east northland charter vessels extends the existing data series. Survey responses were trimmed to include vessels with six or more years of data and a range of factors were investigated using GLMs. Fine scale spatial and environmental variables are not available for most earlier years and were not offered to the model. A negative binomial model was fitted to all data including zero catches.

The final model form was as follows:

~ fishing year + poly(log(days fished), 3) + vessel + area

The standardization effect of the model was a tendency to reduce the index in the early years and lift the index since the late 1990s (Figure 11). 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.

Recreational charter CPUE increased in the late 1970s followed by three very poor years in the mid-1980s (Figure 11). Charter CPUE was high again in the mid-1990s and above average in the mid-2000s. CPUE over the last four years has been relatively poor. While these data are informative on recreational fishing success in east Northland care should be taken making more general assumptions because of the relatively small area where this fishery operates.

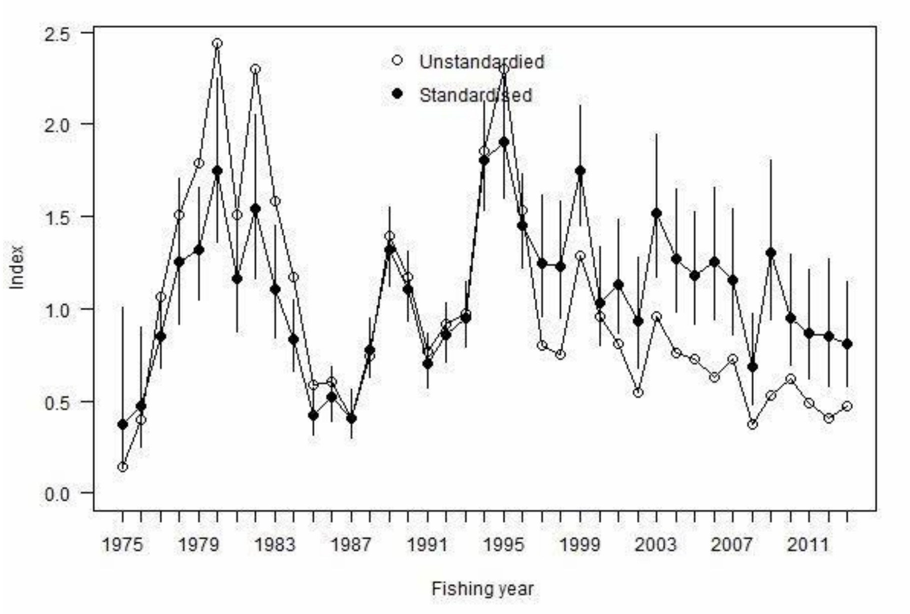


Figure 11: Overall standardization effect of the model of recreational charter boat catch. The unstandardised index is based on the geometric mean of the catch per strata and is not adjusted for effort.

Comparison of models

The standardised series of observed non-zero commercial catches shows considerable interannual variance due to the small number of records, but does not disagree with the better estimated series for the core longline vessels reporting in commercial catch reporting, in describing a flat or maybe slightly declining trajectory over the last decade (Figure 12). There is also considerable interannual variability in the standardised series from the recreational charter fishery but trends are similar to the non-zero commercial and observer time series with high CPUE in the mid-1990s, a peak in 1999 and a declining trend over the last decade (Figure 12).

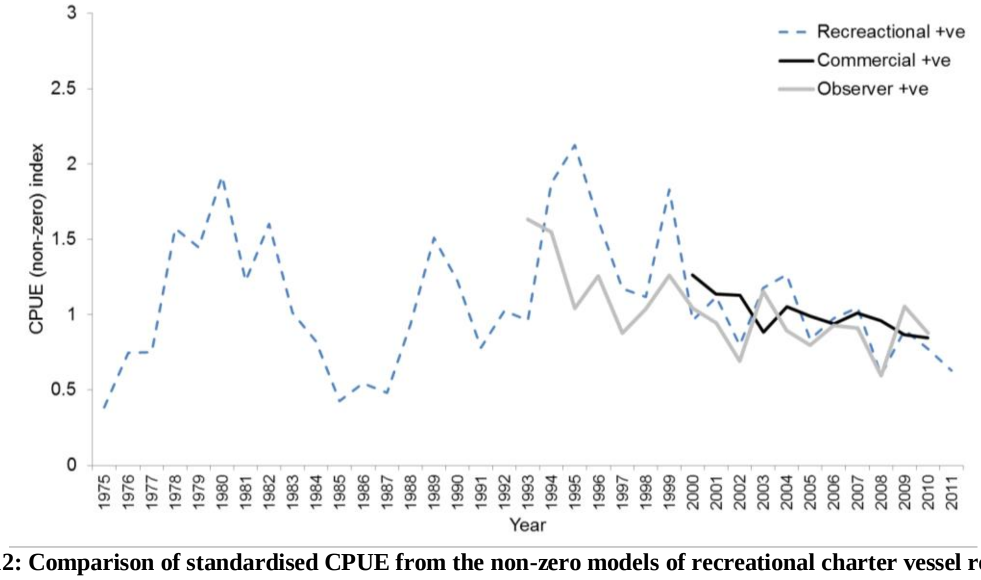


Figure 12: Comparison of standardised CPUE from the non-zero models of recreational charter vessel records with non-zero models of commercial and observer logbook records.

All the New Zealand CPUE data sets suffer from a limited spatial scale and limited numbers of records. There are some quite large changes in availability from year to year which appear in all indices. These may be indicative of changes in abundance or recruitment in some part of the south western Pacific stock but the scale may be amplified by annual variability in oceanographic conditions.

5.1 Biomass and yield estimates
No estimates of biomass or yield are available for New Zealand.

5.2 Other factors
Given that New Zealand fishers encounter some of the largest striped marlin in the Pacific, the abundance of fish found within New Zealand fisheries waters will be very sensitive to the status of the stock. In addition, environmental factors may also influence availability. The average size of striped marlin in the recreational fishery has declined over the last 80 years. Individual weights were averaged from published catch records in sport fishing club year books (Figure 13).

A commercial marlin fishery was started in waters north of New Zealand in 1956 by Japanese surface longline vessels. Mean fish weight has declined since then and there is more inter-annual variability. There have been changes to recreational fishing methods in the area fished over this time. The most significant change was in the late 1980s when there was a switch from trolled baits to artificial lures. Over the last 15 years more than half the weights have been estimated following tag and release.

In 2006–07 the Ministry of Fisheries instigated a billfish logbook programme to capture fine scale temporal and spatial information along with marlin catch and effort. Data collection expanded to include private vessels in all areas, including Bay of Plenty, West Coast North Island and the Three Kings.

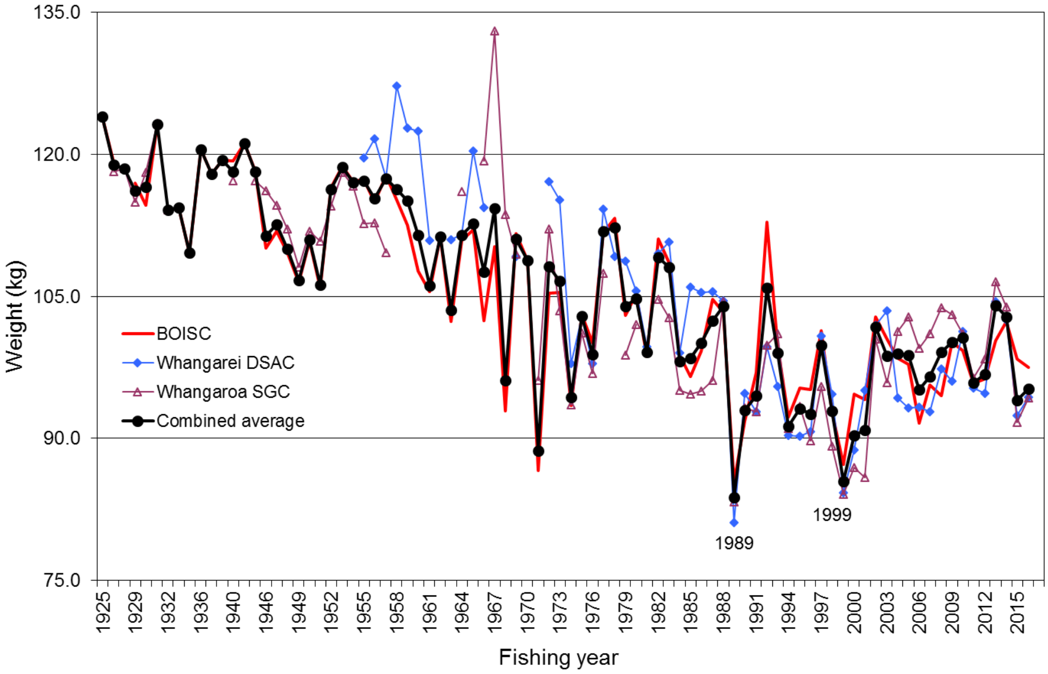


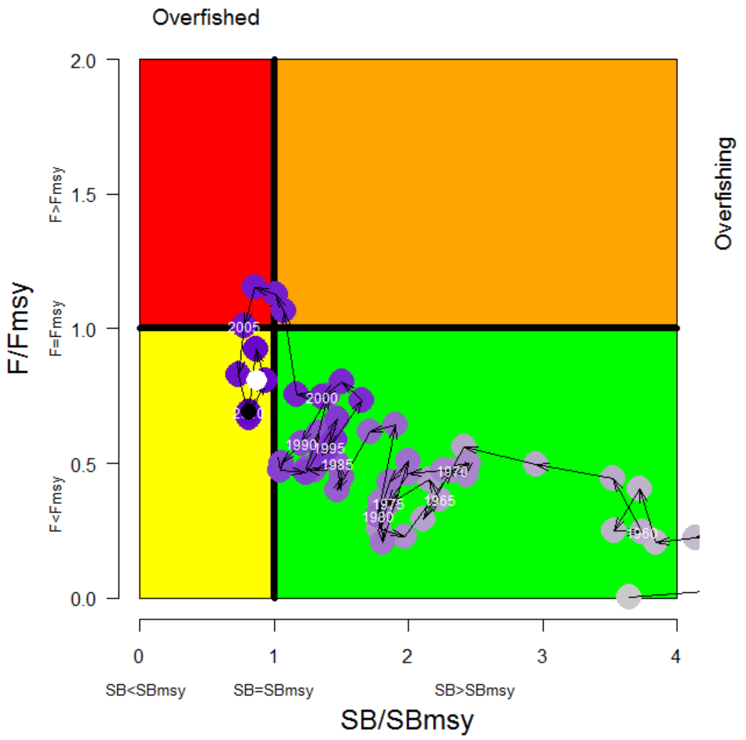
Figure 13: The mean annual weight of striped marlin (landed and tagged) caught in New Zealand fishery waters by recreational fishers by season from club records.

6. STATUS OF THE STOCK

Stock structure assumptions
Western and Central Pacific Ocean.
All biomass in this table refers to spawning biomass (SB)

Stock Status	
Year of Most Recent Assessment	2012
Assessment Runs Presented	Reference case (ref.case) and six sensitivity runs

Reference Points	Target: $SB > SB_{MSY}$ and $F < F_{MSY}$ Soft Limit: Not established by WCPFC but evaluated using HSS default of 20% SB_0 Hard Limit: Not established by WCPFC but evaluated using HSS default of 10% SB_0 Overfishing threshold: F_{MSY}
Status in relation to Target	About as Likely as Not (40–60%) that SB is at or above SB_{MSY} Likely (> 60%) that F is at or below F_{MSY}
Status in relation to Limits	Soft Limit: Unlikely (< 40%) to be below Hard Limit: Unlikely (< 40%) to be below
Status in relation to Overfishing	Overfishing is Unlikely (< 40%) to be occurring
Historical Stock Status Trajectory and Current Status	



Temporal trend in annual stock status, relative to SB_{MSY} (x-axis) and F_{MSY} (y-axis) reference points for the Ref.case

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Stock biomass declined rapidly through the 1960s, but the stock decline has been more gradual from 1970 through to 2011.
Recent Trend in Fishing Intensity or Proxy	Overall fishing mortality has shown a slow but continuous decrease since 2004.
Other Abundance Indices	Recruitment is variable but has declined by 50% since the 1950s.
Trends in Other Relevant Indicator or Variables	-
Projections and Prognosis	
Stock Projections or Prognosis	The stock is likely to decline without management intervention
Probability of Current Catch or TACC causing Biomass to	Soft Limit: Unknown

remain below or to decline below Limits	Hard Limit: Unknown		
Probability of Current Catch or TACC causing Overfishing to continue or commence	Unlikely (< 40%)		
Assessment Methodology and Evaluation			
Assessment Type	Level 1: Quantitative Stock assessment		
Assessment Method	MULTIFAN-CL		
Assessment Dates	Latest assessment: 2012	Next assessment: 2017	
Overall assessment quality rank	1 - High Quality		
Main data inputs (rank)	a) Japanese longline catches for 1952–2011 revised downwards by approximately 50%; b) Nine revised and new standardised CPUE time series (with temporal CVs) derived from: • aggregate catch-effort data for Japanese and Taiwanese longline fisheries; • operational catch-effort data for the Australian longline fishery; • operational catch-effort data for the Australian and New Zealand recreational fisheries, and c) Size composition data for the Australian recreational fishery.	1 – High Quality 1 - High Quality1 - High Quality	
Data not used (rank)	N/A		
Changes to Model Structure and Assumptions	-		
Major Sources of Uncertainty	Catch estimated from the most recent years is uncertain as some catch has still not been reported. There are high levels of uncertainty regarding recruitment estimates and the resulting estimates of steepness.		

Qualifying Comments
At a 2012 ISC Billfish Working Group a meta-analysis was presented that included a) a review of all known estimates of striped marlin steepness including the 2006 WCPFC assessment of southwest Pacific striped marlin; b) a description of the analytical methods used; and c) a description of the data. The point estimate of steepness from the meta-analysis was M = 0.38 with a credible range of 0.3 to 0.5. Based on the results of this meta-analysis, SPC considered that the southwest Pacific striped marlin model runs where M was set to be 0.2 and 0.6 should have a low weight as they are probably outside the plausible range of natural mortality rates.
Fishery Interactions

7. FOR FURTHER INFORMATION

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