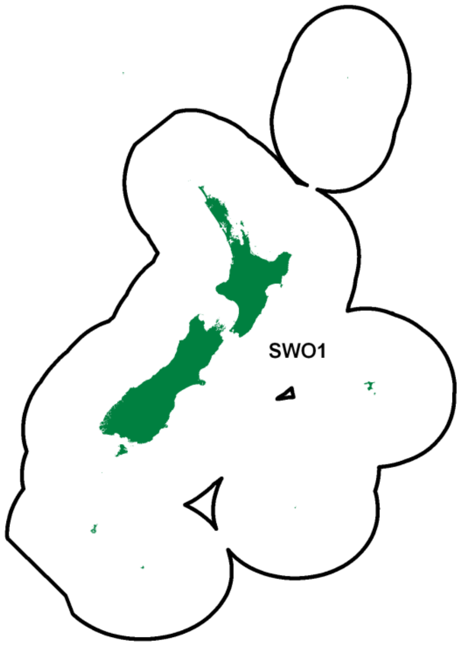
SWORDFISH (SWO)

(*Xiphias gladius*)



1. FISHERY SUMMARY

Swordfish were introduced into the QMS on 1 October 2004 under a single QMA, SWO 1, with allowances, TACC, and TAC in Table 1.

Table 1: Recreational and Customary non-commercial allowances, TACC and TAC (all in tonnes) for swordfish.

Fishstock	Recreational Allowance	Customary non-commercial Allowance	Other mortality	TACC	TAC
SWO 1	20	10	4	885	919

Swordfish were added to the Third Schedule of the 1996 Fisheries Act with a TAC set under s14 because swordfish is a highly migratory species and it is not possible to estimate MSY for the part of the stock that is found within New Zealand fisheries waters.

Swordfish were also added to the Sixth Schedule of the 1996 Fisheries Act with the provision that:

> "A commercial fisher may return any swordfish to the waters from which it was taken from if –
> (a) that swordfish is likely to survive on return; and
> (b) the return takes place as soon as practicable after the swordfish is taken; and
> (c) that swordfish has a lower jaw to fork length of less than 1.25m."

Management of swordfish throughout the western and central Pacific Ocean (WCPO) is the responsibility of the Western and Central Pacific Fisheries Commission (WCPFC). At its sixth annual meeting (2009) 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 swordfish in the southwest Pacific Ocean (www.wcpfc.int/). This measure restricts the number of vessels fishing for swordfish and sets catch limits in the convention area south of 20 degrees south.

1.1 Commercial fisheries

Annual swordfish catches throughout the Pacific have been increasing, with catches in the Western and Central Pacific increasing to 20 000 t in 2012 (Williams & Terawasi 2013). The swordfish catch from the southwest Pacific has averaged about 12% of the Pacific Ocean total in recent years. In New Zealand, swordfish are caught throughout the year in oceanic waters, primarily by pelagic longlines in areas where the bottom depth exceeds 1000 m.

Swordfish are either targeted or caught in the tuna longline fishery as a bycatch when targeting bigeye and to a lesser extent when targeting southern bluefin tuna. Swordfish can be caught in most FMAs and adjacent high seas areas although most catches are from waters north of 40ºS. Swordfish catch by domestic vessels increased rapidly from 1994–95 to peak at 1100 t in 2000–01. Since 2000–01 swordfish catches declined in each year coinciding with the decline in effort in the surface longline fishery, until 2005–06 when they increased again (Table 2). This increase is attributed to the development of a target fishery, which was, in part, initiated by the arrival of several surface longline vessels from Australia. Most of the catch is from FMA 1, FMA 2 and FMA 9. Figure 1 shows historical landings and TACCs and longline effort for SWO stocks.

Swordfish are processed at sea and the processed weight of the catch is converted to a greenweight using approved conversion factors. TLCER, CELR and LFRR data are provided for comparative purposes in Table 2 for the domestic fleet (New Zealand owned and operated vessels and chartered longline vessels).

Before the start of the domestic longline fishery in 1990–91, distant water longline fleets were granted foreign license access to fish for southern bluefin and bigeye tuna (Japan) and albacore (Korea). Swordfish catches for the Japanese fleet are given in Table 2 (Japan). The swordfish bycatch by the Japanese foreign licensed fishery averaged 388 t per year between 1979–80 and 1992–93 with a maximum catch of 761 t in 1980–81. Most of the Japanese swordfish catch (85%) was from FMA 2 and FMA 9. Korean catches were only small (0 to 7 t per year) and were mostly (79%) from FMA 9 and FMA 10.

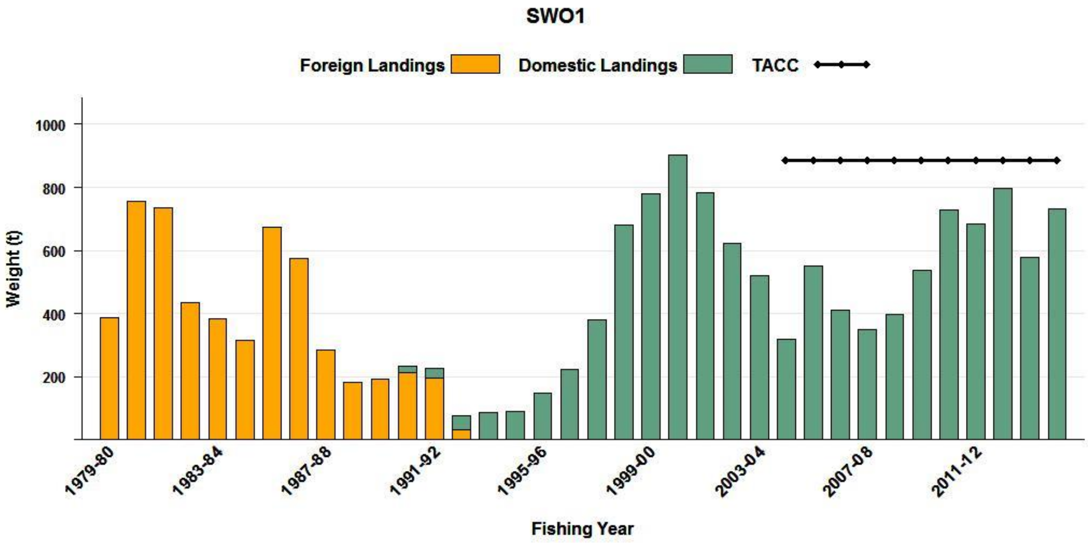


Figure 1: Swordfish catch by foreign licensed and New Zealand vessels from 1979–80 to 2014–15 in New Zealand fishery waters (SWO 1). [Figure continued on next page].

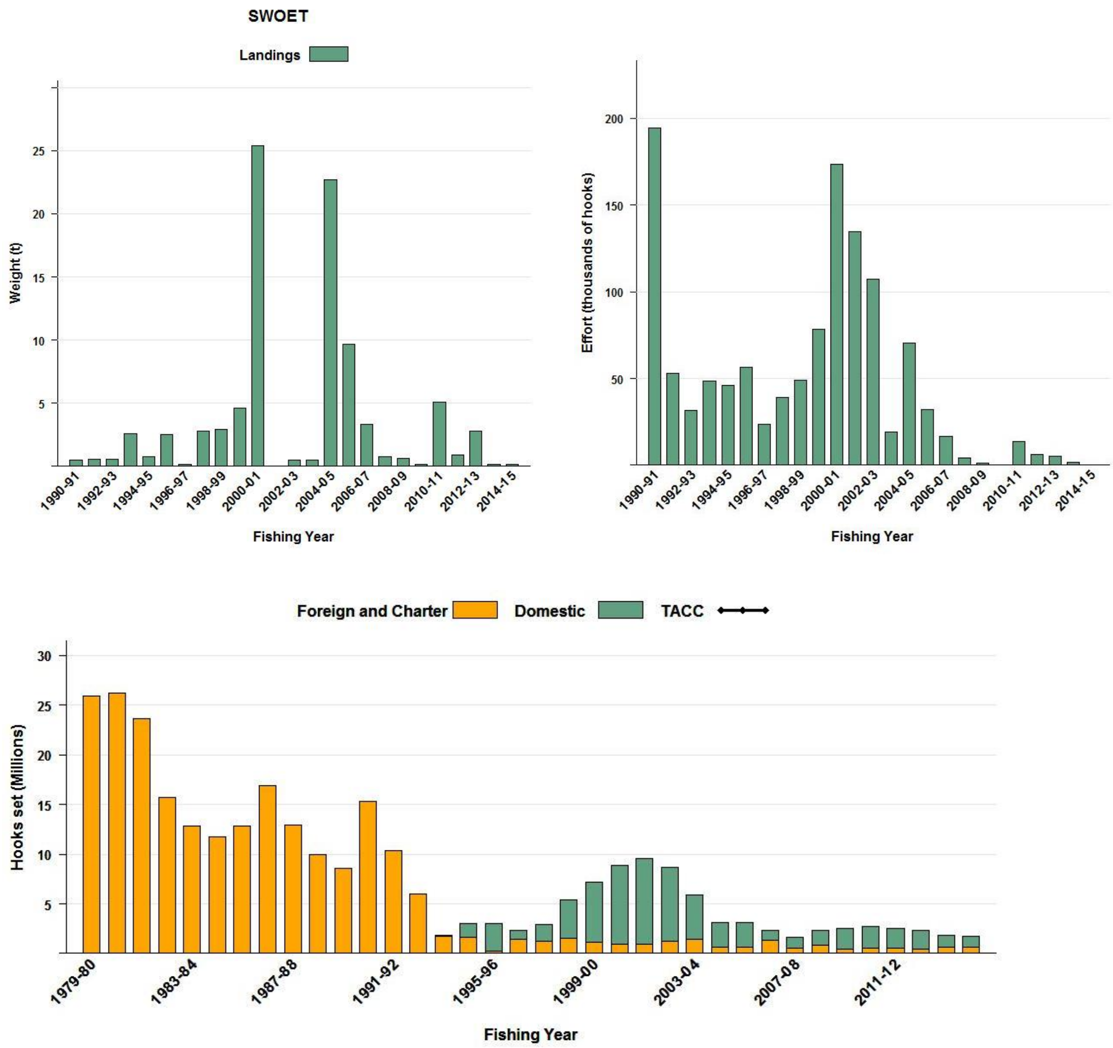


Figure 1 [Continued]: [Top Left]: Swordfish catch from 1990–91 to 2014–15 on the high seas (ALB ET). [Top Right]: Fishing effort (number of hooks set) for all New Zealand vessels fishing on the high seas; and [Bottom] fishing effort (number of hooks set) within New Zealand fishery waters for domestic and foreign vessels (including foreign charter vessels) from 1979–80 to 2014–15.

Table 2: Reported catches (t) of *X. gladius* by fishing year (from TLCER and CELR data) for the New Zealand domestic and chartered vessel fleet 1990–91 to 2014–15 and Japanese foreign licensed fleet 1979–80 to 2014–15; with annual totals from LFRR and MHR data from 2001–02 to present [Continued on next page].

	SWO 1 (all FMAs)				
Year	Japan	NZ/MHR	Total	LFRR	NZ ET
1979–80	386		386		
1980–81	756.1		756.1		
1981–82	734.6		734.6		
1982–83	436.1		436.1		
1983–84	384.8		384.8		
1984–85	316.1		316.1		
1985–86	673.6		673.6		
1986–87	575.5		575.5		
1987–88	286.2		286.2		
1988–89	181.1		181.1		
1989–90	194.3		194.3		
1990–91	211.9	21.9	233.8	41	0.5
1991–92	194.5	33.5	228	32	0.6
1992–93	31.1	46.8	77.9	79	0.6
1993–94		88.2	88.2	102	2.6
1994–95		91.4	91.4	102	0.8

Table 2 [Continued]: Reported catches (t) of *X. gladius* by fishing year (from TLCER and CELR data) for the New Zealand domestic and chartered vessel fleet 1990–91 to 2014–15 and Japanese foreign licensed fleet 1979–80 to 2014–15; with annual totals from LFRR and MHR data from 2001–02 to present.

	SWO 1 (all FMAs)				
Year	Japan	NZ/MHR	Total	LFRR	NZ ET
1995–96		148.6	148.6	187	2.5
1996–97		223.3	223.3	283	0.2
1997–98		379.7	379.7	534	2.8
1998–99		679.1	679.1	965	2.9
1999–00		778	778	976	4.6
2000–01		901.4	901.4	1 022	25.4
2001–02		945	783.9	958.8	
2002–03		673	622.0	670.1	0.5
2003–04		545	519.4	555.2	0.5
2004–05		344	320.7	344.7	22.7
2005–06		560.9	548.3	558.9	9.7
2006–07		412.7	412.7	425.8	3.3
2007–08		350.1	350.1	351.4	0.7
2008–09		398.7	398.7	393.9	0.6
2009–10		536.5	536.5	533.4	0.1
2010–11		729.6	729.6	739	5.1
2011–12		688.1	688.1	686.4	0.9
2012–13		796.8	796.8	788.4	2.8
2013–14		577.0	577.0	562.7	0.2
2014–15		730.3	730.3	716.1	0.2

The majority of swordfish are caught in the bigeye target surface longline fishery (62%) (Figure 2), however, across all longline fisheries swordfish make up 17% of the catch by weight (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.

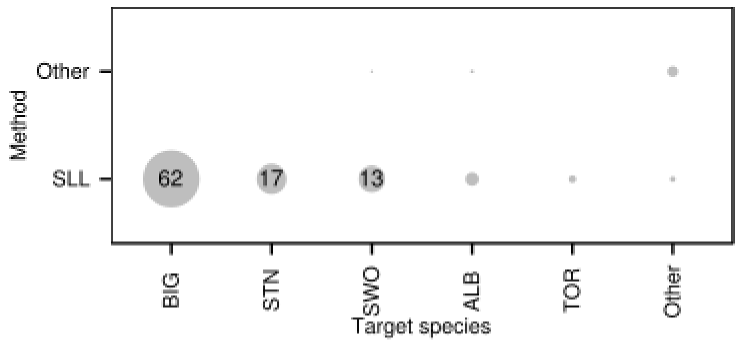


Figure 2: A summary of the proportion of landings of swordfish taken by each target fishery and fishing method for 2012–13. The area of each circle is proportional to the percentage of landings taken using each combination of fishing method and target species. The number in the circle is the percentage.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

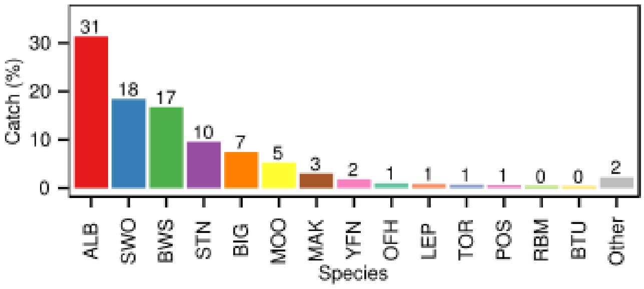


Figure 3: A summary of species composition of the reported surface longline catch for 2012–13. The percentage by weight of each species is calculated for all surface longline trips (Bentley et al 2013).

Across all fleets in the longline fishery, 30.9% of the swordfish were alive when brought to the side of the vessel (Table 3). The domestic fleets retain around 90–99% of their swordfish catch, while the foreign charter fleet retain 99–100% of the swordfish catch, the Australian fleet that fished in New Zealand waters in 2006–07 retained most (94.8%) of their swordfish (Table 4).

Table 3: Percentage of swordfish (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	Australia	North	42.8	57.2	325
	Charter	North	58.9	41.1	90
		South	61.9	38.1	21
	Domestic	North	27.3	72.7	355
	Total		**38.2**	**61.8**	**791**
2007–08	Domestic	North	25.1	74.9	495
	Total		**25.3**	**74.7**	**498**
2008–09	Charter	North	97.0	3.0	33
	Domestic	North	26.0	74.0	416
	Total		**31.6**	**68.4**	**455**
2009–10	Domestic	North	23.2	76.8	448
	Total		**23.7**	**76.3**	**452**
Total all strata			**30.9**	**69.1**	**2 196**

Table 4: Percentage of swordfish 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	Australia	94.8	5.2	326
	Charter	99.1	0.9	115
	Domestic	93.2	6.8	355
	Total	**94.7**	**5.3**	**796**
2007–08	Charter	100.0	0.0	3
	Domestic	91.5	8.5	496
	Total	**91.6**	**8.4**	**499**

Table 4 [Continued]

Year	Fleet	% retained	% discarded or lost	Number
2008–09	Charter	100.0	0.0	43
	Domestic	97.1	2.9	418
	Total	**97.4**	**2.6**	**461**
2009–10	Charter	100.0	0.0	3
	Domestic	94.3	5.7	454
	Total	**94.3**	**5.7**	**457**
Total all strata		**94.5**	**5.5**	**2 213**

1.2 Recreational fisheries

Swordfish are targeted by some recreational sport fishers with the annual recreational landed catch increasing over the last four years to 87 fish in 2014–15. There is renewed recreational interest in swordfish using deep drifted baits during the day rather than drifting or slow trolling at night. There were 29 swordfish tagged and released by recreational fishers and 5 by commercial fishers in 2014–15.

1.3 Customary non-commercial fisheries

An estimate of the current customary catch is not available, but it is considered to be low.

1.4 Illegal catch

Prior to QMS introduction in 2004 it was illegal to target swordfish but analyses of CPUE data suggest targeting did occur. These catches were generally still reported (although as bycatch), so estimates of total annual catch were not affected.

1.5 Other sources of mortality

Swordfish have occasionally been observed as a bycatch in the skipjack tuna purse seine fishery and in trawl fisheries for jack mackerel and hoki.

2. BIOLOGY

Swordfish (*Xiphias gladius* Linnaeus, 1758) are an epi- and mesopelagic highly migratory species found in all tropical and temperate oceans and large seas. Based on longline catches, swordfish range from 50ºN to 45ºS in the western Pacific Ocean and from 45ºN to 35ºS in the eastern Pacific Ocean.

Growth rates have been estimated for Pacific Ocean swordfish caught off Taiwan. Estimates of growth rate indicate rapid growth with fish reaching about 1 m in lower jaw to fork length during the first year. Growth rate slows progressively with age. Females grow significantly faster than males. Asymptotic length for males is 213 cm while asymptotic length for females is about 300 cm. The maximum age observed in Taiwanese samples was 10 years for males and 12 years for females. The maximum size reported for a swordfish is 445 cm total length (includes the bill and furthest extension of the tail) and about 540 kg.

A number of studies of swordfish growth have been undertaken in Australia and New Zealand (Young & Drake 2004; Young et al 2003; Young et al 2008). The results are generally consistent within the two areas, with maximum ages of 18 and 15 years, respectively. It is likely that swordfish attain a maximum age of 20 years. Given the lack of observations of swordfish in New Zealand with ripe or running ripe gonad condition, age-at-maturity was defined on the basis of the Australian estimates of length-at-50% maturity for males and females of 101 and 221 cm, respectively. Using the growth curves estimated for New Zealand swordfish, this corresponds to ages at 50% maturity for males and females of 1 and 10 years, respectively.

In the New Zealand EEZ swordfish size varies markedly with latitude, with larger swordfish (and hence fewer males) caught south of 40ºS. Average size of both males and females is larger in the southern region compared to the north: 228 and 158.4 cm for males, and 231.9 and 175 cm for females, respectively. Average length (lower jaw to fork length) of swordfish caught in the EEZ has been relatively stable since 1991, averaging 196.6 cm for the Japanese charter fleet and 163.9 cm for the domestic owned and operated fleet based on limited observer data. Overall the average size over all fleets since 1991 is 178.3 cm, however, this will be largely representative of the charter fleet. Males are substantially smaller than females with most males smaller than 189 cm (77%) and most females (51%) larger than 189 cm for all fleets. From 1987 to 2005 the average sex ratio of longline-caught swordfish in the EEZ was 1:3.15 (male:female).

A relationship between lower jaw-fork length and weight has been estimated for swordfish from observer records (n = 2 835): weight (kg) = (3.8787×10^{-6}) length$^{3.24}$.

Spawning takes place in the tropical waters of the western Pacific Ocean and to a lesser extent the equatorial waters of the central Pacific Ocean.

Swordfish are serial batch spawners, perhaps spawning as frequently as every few days over several months. Eggs are spawned in the upper layers of the tropical ocean and, like the protracted larval phase, are pelagic. Depending on fish size, swordfish egg production is estimated to range from 1 to 29 million eggs per year (for 68 – 272 kg females respectively).

Little information on mortality rate is available, but M has been estimated elsewhere in the Pacific to be 0.22 yr^{-1}. This value is consistent with the maximum estimated ages for swordfish in Australia and New Zealand.

3. STOCKS AND AREAS

Swordfish found in the New Zealand EEZ are part of a much larger stock that spawns in the tropical central to western Pacific Ocean. They are highly migratory and their residence time in the EEZ and adjacent waters is unknown. In the Pacific Ocean swordfish occur from 50ºN to 45ºS in the western Pacific Ocean and from 45ºN to 35ºS in the eastern Pacific Ocean. Swordfish are visual predators with a wide temperature tolerance. Extensive diel vertical migrations have been observed for swordfish in the Atlantic and Pacific Oceans from waters deeper than 600 m to the surface and across large temperature gradients (e.g., from 8º to 27ºC) in a few hours. Swordfish are found at or near the surface, at night. Within the EEZ most swordfish are caught in FMA 1, FMA 2, and FMA 9 when sea surface temperatures are 17º to 19ºC.

Stock structure is uncertain and recent genetic studies have indicated that there may be multiple Pacific Ocean stocks. There is limited information on swordfish movement from conventional tagging studies. From a release sample of 414 swordfish tagged in the New Zealand EEZ as part of the New Zealand gamefish tagging programme, four have been recaptured. Two small fish were tagged by commercial fishers one 120 nautical miles north of New Zealand and the other 80 nautical miles north east of East Cape. Both were recaptured after extended periods at liberty, 8 and 10 years respectively, and had grown to sizes consistent with being sexually mature. Despite the long liberty period the recapture positions were not far (less than 130 nautical miles) from the release locations. In February 2012 a recreational angler recaptured a 130 kg swordfish he personally had tagged from the same boat and same location 8 months previously. Although the apparent net movement is limited, little can be inferred from this information in relation to swordfish stock structure or migration in, and around, New Zealand waters. In September 2013 a 170 cm tagged swordfish was recaptured by a tuna longline vessel in Tuvalu waters (Latitude

10ºS). This fish was tagged 17 month earlier from a recreational vessel in an area north of the Three Kings Islands.

From a release sample of 672 fish tagged in the Australian EEZ, eight recaptures have been reported. Although some fish tagged in east Australian waters have moved large distances (e.g., 893 nautical miles), none were recaptured outside of the Australian EEZ, or have crossed the Tasman Sea into the New Zealand EEZ. Nineteen pop-off satellite archival tags have been deployed on swordfish in New Zealand with the aim of tracking fish over the spring spawning period. The eight longer term tracks (4 to 8 months) show fish moving into sub-tropical waters in spring and returning to the New Zealand EEZ or adjacent waters in summer. Data from satellite tagged swordfish in New Zealand, Australia and the Cook Islands was used to describe the stock structure in the south-west Pacific region in the 2013 stock assessment model.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

The figures and tables in this section were updated and additional text included for the November 2016 Fishery Assessment Plenary following review of the text by the Aquatic Environment Working Group in 2015. This summary is from the perspective of the swordfish longline fishery; a more detailed summary from an issue-by-issue perspective is available in the Aquatic Environment & Biodiversity Annual Review where the consequences are also discussed (www.mpi.govt.nz/document-vault/11521) (Ministry for Primary Industries 2016).

4.1 Role in the ecosystem

Swordfish (*Xiphias gladius*) 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 catch of seabirds, sea turtles and mammals

These capture estimates relate to the swordfish target longline fishery only, from the New Zealand EEZ. The capture estimates presented here include all animals recovered onto the deck (alive, injured or dead) of fishing vessels but do not include any cryptic mortality (e.g., seabirds caught on a hook but not brought onboard the vessel).

4.2.1 Seabird bycatch

Between 2002–03 and 2014–15, there were 93 observed captures of seabirds in swordfish longline fisheries. Seabird capture rates since 2003 are presented in Figure 4. Peaks in observed capture rate were seen in 2006–07 and 2009–10. The seabird capture locations are predominantly within the northern area of New Zealand’s EEZ (see Table 5 and Figure 5). The high number of captures in 2007 (Figure 4) are anomalous and are the result of an Australian vessel fishing in the EEZ with inappropriate mitigation gear, and this issue has since been resolved Previously bayesian models of varying complexity dependent on data quality were used (Richard & Abraham 2014); more recently a single model structure has been developed to provide a standard basis for estimating seabird captures across a range of fisheries (Richard & Abraham in prep.). Observed and estimated seabird captures in swordfish longline fisheries are provided in Table 6.

Through the 1990s the minimum seabird mitigation requirement for surface longline vessels was the use of a bird scaring device (tori line) but common practice was that vessels set surface longlines primarily at night. In 2007 a notice was implemented under s 11 of the Fisheries Act 1996 to formalise the requirement that surface longline vessels only set during the hours of darkness and use a tori line when setting. This notice was amended in 2008 to add the option of line weighting and tori line use if setting during the day. In 2011 the notices were combined and repromulgated under a new regulation (Regulation 58A of the Fisheries (Commercial Fishing) Regulations 2001) which provides a more flexible regulatory environment under which to set seabird mitigation requirements.

Risk posed by commercial fishing to seabirds has been assessed via a level 2 method which supports much of the NPOA-Seabirds 2013 risk assessment framework (MPI 2013). The method used in the level 2 risk assessment arose initially from an expert workshop hosted by the Ministry of Fisheries in 2008. The overall framework is described in Sharp et al (2011) and has been variously applied and improved in multiple iterations (Waugh et al 2009, Richard et al 2011, Richard & Abraham 2013, Richard et al 2013 and Richard & Abraham 2015). The method applies an “exposure-effects” approach where exposure refers to the number of fatalities is calculated from the overlap of seabirds with fishing effort compared with observed captures to estimate the species vulnerability (capture rates per encounter) to each fishery group. This is then compared to the population’s productivity, based on population estimates and biological characteristics to yield estimates of population-level risk.

The 2016 iteration of the level 2 risk assessment has included significant modifications to the methodology; in order to include the full uncertainty around population size the total population size was included instead of N_{min} in the PST calculation; using the allometric survival rate and age at first reproduction for the calculation of R_{max}, applying a revised correction factor as the previous was found to be biologically implausible; applying a constraint on the fatalities calculated based on observed survival rates; including live release survival; allowing change in vulnerability over time where there is enough data; switch to assuming number of incidents is related to vulnerability. There were also changes made to the fisheries groups, seabird demographic data were updated and the Stewart Island shag was split into the Otago and Foveaux shags. The 2016 iteration derives a risk ratio, which is an estimate of aggregate potential fatalities across trawl and longline fisheries relative to the Population Sustainability Threshold, PST (an analogue of the Potential Biological Removals, PBR, approach) (Richard & Abraham in prep).

The 2016 iteration of the seabird risk assessment (Richard & Abraham in prep) assessed the swordfish target fishery contribution to the total risk posed by New Zealand commercial fishing to seabirds (see Table 7). This target fishery contributed 0.193 of PST to the risk to Gibson’s albatross which was assessed to be at high risk from New Zealand commercial fishing (nearly 58% of the total risk from commercial fishing included in the risk assessment). This fishery also contributed 0.098 of PST to Antipodean albatross, which was assessed to be at medium risk from New Zealand commercial fishing included in the risk assessment (Richard & Abraham in prep).

Table 5: Number of observed seabird captures in swordfish longline fisheries, 2002–03 to 2014–15, by taxon and area. The risk category is an estimate of aggregate potential fatalities across trawl and longline fisheries relative to the Population Sustainability Threshold, PST (an analogue of PBR approach) (Richard & Abraham in prep). The current version of the risk assessment does not include recovery factor. The New Zealand threat classifications are shown (Robertson et al 2013 at http://www.doc.govt.nz/documents/science-and-technical/nztcs4entire.pdf). Other data, version 2016001.

Taxon	Risk category	East Coast North Island	Kermadec Islands	Northland and Hauraki	West Coast North Island	West Coast South Island	Total
Albatrosses	NA		33				33
Antipodean albatross	Medium		12	3			15
Gibson's albatross	High		4	5		3	12
Antipodean and Gibson's albatrosses	NA		5				5
Campbell black-browed albatross	Low			2		2	4
New Zealand white-capped albatross	High				1	2	3
Black-browed albatrosses	NA		2				2
Southern Buller's albatross	High	1					1
Total albatrosses		**1**	**56**	**10**	**1**	**7**	**75**
White-chinned petrel	Negligible		2			6	8
Black petrel	Very high			2	1		3
Grey petrel	Negligible		3				3
Grey-faced petrel	Negligible		1	1	1		3
Flesh-footed shearwater	High	1		1			2
Sooty shearwater	Negligible		1				1
Total other seabirds		**1**	**7**	**4**	**2**	**6**	**20**

Table 6: Effort, observed and estimated seabird captures by fishing year for the swordfish fishery within the EEZ. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); the capture rate (captures per thousand hooks); and the mean number of estimated total captures (with 95% confidence interval). Estimates are based on methods described in Richard and Abraham (in prep) and are available via https://data.dragonfly.co.nz/psc/. Estimates from 2002–03 to 2014–15 are based on data version 2016001.

Fishing year	Fishing effort			Observed captures		Estimated captures	
	All hooks	Observed hooks	% observed	Number	Rate	Mean	95% c.i.
2002–2003	2400	0	0	0		2	0–14
2003–2004	0	0		0			NA
2004–2005	132 503	11 553	8.7	2	0.17	47	15–123
2005–2006	228 305	4 800	2.1	2	0.42	92	34–214
2006–2007	210 175	40 138	19.1	71	1.77	152	99–266
2007–2008	125 330	21 630	17.3	1	0.05	35	9–90
2008–2009	41 700	3 990	9.6	0	0	11	1–39
2009–2010	137 840	500	0.4	3	6	52	18–126
2010–2011	177 248	18 638	10.5	0	0	53	16–133
2011–2012	195 400	43 450	22.2	7	0.16	49	19–115
2012–2013	316 390	8 250	2.6	1	0.12	92	36–209
2013–2014	192 963	4 850	2.5	0	0	68	24–157
2014–2015	447 362	17 650	3.9	6	0.34	144	63–302

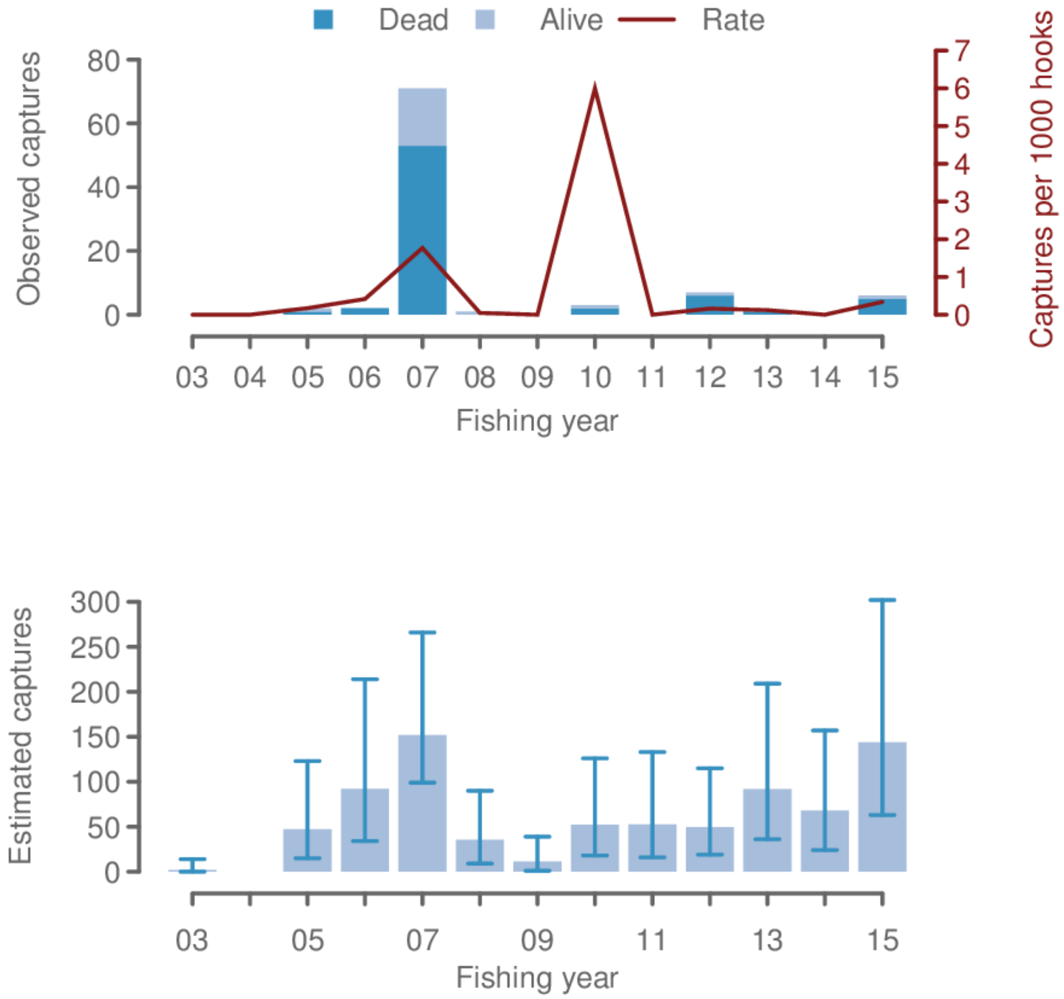


Figure 4: Observed captures and estimated captures of seabirds in swordfish longline fisheries from 2002–03 to 2014–15. Data grooming and estimates are based on methods described in Richard and Abraham (in prep) and are available via https://data.dragonfly.co.nz/psc/. Estimates from 2002–03 to 2014–15 are based on data version 2016001.

Figure 5: Distribution of fishing effort targeting swordfish and observed seabird captures, 2002–03 to 2014–15. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. Data grooming methods are described in Richard and Abraham (in prep) and are available via https://data.dragonfly.co.nz/psc/. Estimates from 2002–03 to 2014–15 are based on data version 2016001.

Table 7: Risk ratio of seabirds predicted by the level two risk assessment for the swordfish target surface longline fisheries and all fisheries included in the level two risk assessment, 2006–07 to 2013–14, showing seabird species with risk category of very high or high, or a medium risk category and risk ratio of at least 1% of the total risk. The risk ratio is an estimate of aggregate potential fatalities across trawl and longline fisheries relative to the Population Sustainability Threshold, PST (an analogue of PBR approach) (from Richard & Abraham, in prep) where full details of the risk assessment approach can be found). Other data, version 2016001. The current version of the risk assessment does not include a recovery factor. The New Zealand threat classifications are shown (Robertson et al 2013 at http://www.doc.govt.nz/documents/science-and-technical/nztcs4entire.pdf)

	Risk ratio				
Species name	SWO target SLL	Total risk from NZ commercial fishing	% of total risk from NZ commercial fishing	Risk category	NZ Threat Classification
Black petrel	0.026	1.153	2.85	Very high	Threatened: Nationally Vulnerable
Salvin's albatross	0.000	0.78	0.1	High	Threatened: Nationally Critical
Flesh-footed shearwater	0.005	0.669	1.13	High	Threatened: Nationally Vulnerable
Westland petrel	0.003	0.476	1.33	High	At Risk: Naturally Uncommon
Southern Buller's albatross	0.000	0.392	0.14	High	At Risk: Naturally Uncommon
Chatham Island albatross	0.000	0.362	0.33	High	At Risk: Naturally Uncommon
New Zealand white-capped albatross	0.001	0.353	0.29	High	At Risk: Declining
Gibson's albatross	0.193	0.337	57.69	High	Threatened: Nationally Critical
Northern Buller's albatross	0.001	0.253	0.48	Medium	At Risk: Naturally Uncommon
Antipodean albatross	0.098	0.203	49.26	Medium	Threatened: Nationally Critical
Northern giant petrel	0.000	0.138	1.06	Medium	Naturally uncommon

4.2.2 Sea turtle bycatch

Between 2002–03 and 2014–15, there were two observed captures of sea turtles in swordfish longline fisheries (Table 8 and Figure 6). Observer recordings documented all sea turtles as captured and released alive. Sea turtle captures for this fishery have only been observed in the Kermadec Islands fishing area (Table 8 and Figure 7).

Table 8: Number of observed sea turtle captures in swordfish longline fisheries, 2002–03 to 2014–15, by species and area. Data grooming methods are described in Thompson et al (2013) and are available via https://data.dragonfly.co.nz/psc/ data version 2016001.

Species	Kermadec Islands	Total
Leatherback turtle	2	2

Table 9: Fishing effort and sea turtle captures in swordfish longline fisheries by fishing year. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). Estimates are based on methods described in Thompson et al (2013) and are available via https://data.dragonfly.co.nz/psc/. Estimates from 2002–03 to 2014–15 are based on data version 2016001.

Fishing year		Fishing effort		Observed captures	
	All hooks	Observed hooks	% observed	Number	Rate
2002–2003	2400	0	0.0	0	N/A
2003–2004	0	0		0	N/A
2004–2005	132 503	11 553	8.7	0	0
2005–2006	228 305	4 800	2.1	0	0
2006–2007	210 175	40 138	19.1	1	0.025
2007–2008	125 330	21 630	17.3	1	0.046
2008–2009	41 700	3 990	9.6	0	0
2009–2010	137 840	500	0.4	0	0
2010–2011	177 248	18 638	10.5	0	0
2011–2012	195 400	43 450	22.2	0	0
2012–2013	316 390	8 250	2.6	0	0
2013–2014	192 963	4 850	2.5	0	0
2014–2015	447 362	17 650	3.9	0	0

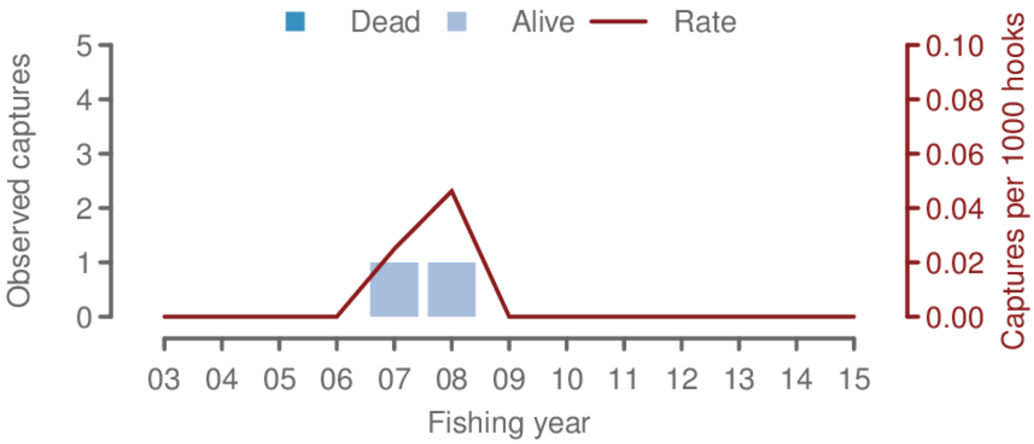


Figure 6: Observed captures of sea turtles in swordfish longline fisheries from 2002–03 to 2014–15. Data preparation methods are described in Thompson et al (2013) and are available via https://data.dragonfly.co.nz/psc/. Data version 2016001.

Figure 7: Distribution of fishing effort targeting swordfish and observed sea turtle captures, 2002–03 to 2014–15. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. Estimates are based on methods described in Thompson et al (2013) are available via https://data.dragonfly.co.nz/psc/Estimates from 2002–03 to 2014 –15 are based on data version 2016001.

4.2.3 Marine Mammals

4.2.3.1 Cetaceans

Between 2002–03 and 2014–15, there were no observed captures of whales or dolphins in swordfish longline fisheries.

4.2.3.2 New Zealand fur seal bycatch

Currently, New Zealand fur seals are dispersed throughout New Zealand waters, but are more common in waters south of about 40º S to Macquarie Island. The spatial and temporal overlap of commercial fishing grounds and New Zealand fur seal foraging areas has resulted in New Zealand fur seal captures in fishing gear (Mattlin 1987, Rowe 2009). Most fisheries with observed captures occur in waters over or close to the continental shelf, which slopes steeply to deeper waters relatively close to shore, and thus rookeries and haulouts, around much of the South Island and offshore islands. Captures on longlines occur when the fur seals attempt to feed on the bait and fish catch during hauling. Most New Zealand fur seals are released alive, typically with a hook and short snood or trace still attached.

Between 2002–03 and 2014–15, there were two observed captures of New Zealand fur seals in swordfish longline fisheries (Table 10 and 11, Figures 8, 9 and 10). These captures include animals that are released alive (Thompson et al 2013).

Table 10: Number of observed New Zealand fur seal captures in swordfish longline fisheries, 2002–03 to 2014–15, by species and area. Data from Thompson et al (2013), retrieved from http://data.dragonfly.co.nz/psc/. See glossary above for a description of the areas used for summarising the fishing effort and protected species captures.

	Bay of Plenty	East Coast North Island	Total
New Zealand fur seal	1	1	2

Table 11: Effort and captures of New Zealand fur seal in swordfish longline fisheries by fishing year. For each fishing year, the table gives the total number of hooks; the number of observed hooks; observer coverage (the percentage of hooks that were observed); the number of observed captures (both dead and alive); and the capture rate (captures per thousand hooks). Estimates are based on methods described in Thompson et al (2013) are available via https://data.dragonfly.co.nz/psc/. Estimates from 2002–03 to 2014 –15 are based on data version 2016001.

Fishing year	Fishing effort			Observed captures		Estimated	
	All hooks	Observed hooks	% observed	Number	Rate	Mean	95%
2002–2003	2400	0	0.0	0	NA	0	0–0
2003–2004	0	0		0	NA		
2004–2005	132 503	11 553	8.7	2	0.173	3	2–5
2005–2006	228 305	4 800	2.1	0	0	1	0–3
2006–2007	210 175	40 138	19.1	0	0	0	0–2
2007–2008	125 330	21 630	17.3	0	0	0	0–2
2008–2009	41 700	3 990	9.6	0	0	0	0–1
2009–2010	137 840	500	0.4	0	0	1	0–3
2010–2011	177 248	18 638	10.5	0	0	1	0–3
2011–2012	195 400	43 450	22.2	0	0	1	0–5
2012–2013	316 390	8 250	2.6	0	0	2	0–7
2013–2014	192 963	4 850	2.5	0	0	2	0–7
2014–2015	447 362	17 650	3.9	0	0	4	0–13

Figure 8: Observed captures of New Zealand fur seal in swordfish longline fisheries from 2002–03 to 2014–15. Estimates are based on methods described in Thompson et al (2013) are available via https://data.dragonfly.co.nz/psc/. Estimates from 2002–03 to 2014 –15 are based on data version 2016001.

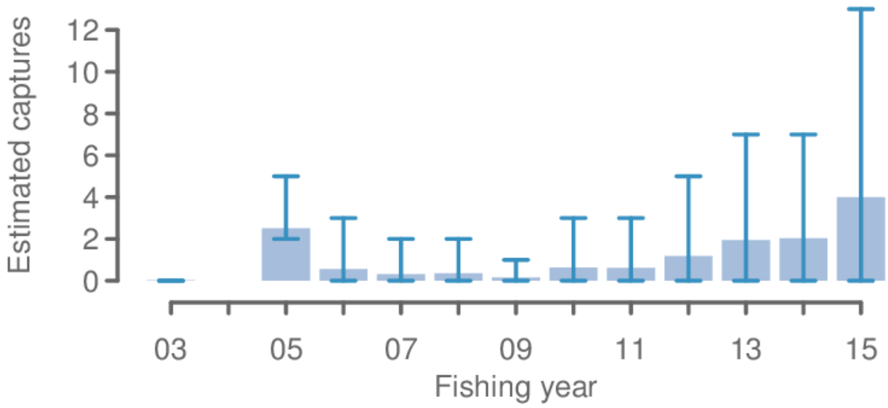


Figure 9: Estimated captures of New Zealand fur seal in swordfish longline fisheries from 2002–03 to 2014–15. Estimates are based on methods described in Thompson et al (2013) are available via https://data.dragonfly.co.nz/psc/. Estimates from 2002–03 to 2014 –15 are based on data version 2016001.

Figure 10: Distribution of fishing effort targeting swordfish and observed New Zealand fur seal captures, 2002–03 to 2014–15. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red dots. Fishing is only shown if the effort could be assigned a latitude and longitude, and if there were three or more vessels fishing within a cell. Estimates are based on methods described in Thompson et al (2013) are available via [hhttps://data.dragonfly.co.nz/psc/](https://data.dragonfly.co.nz/psc/). Estimates from 2002–03 to 2014–15 are based on data version 2016001.

4.3 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 12).

Table 12: 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
Rays 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

4.4 Benthic interactions

N/A

4.5 Key environmental and ecosystem information gaps

Cryptic mortality is unknown at present but developing a better understanding of this in future may be useful for reducing uncertainty of the seabird risk assessment and could be a useful input into risk assessments for other species groups.

The survival rates of released target and bycatch species is currently unknown.

Observer coverage in the New Zealand fleet is not spatially and temporally representative of the fishing effort.

5. STOCK ASSESSMENT

With the establishment of WCPFC in 2004, stock assessments of the western and central Pacific Ocean stock of swordfish are reviewed by the WCPFC. Unlike the major tuna stocks, in the short-term, development of a regional assessment for swordfish is to be undertaken by collaboration among interested members.

Davies et al (2013) undertook a stock assessment for swordfish (*Xiphias gladius*) in the Southwest Pacific. This was presented to the Western and Central Pacific Fisheries Commission Scientific Committee in 2013 and is summarised as follows:

The main developments from previous assessments were to model structural assumptions as follows: assume two model regions, that are biologically connected, this was based on the results of recent electronic tagging programmes; relaxing assumptions such as the relative recruitment to each region; fixing steepness at 0.8; and estimating spline and non-decreasing selectivities for the main longline fisheries. A new statistical assumption was to include time-variant precision in fitting the model to standardized CPUE indices. The model was highly sensitive to the assumption about growth. The full uncertainty grid was presented (Figure 11). Two equally plausible growth schedules were modelled.

The main conclusions of the assessment are:

a) The relatively steep decline in biomass over the period 1997 to 2011 over all key model runs, despite the no concurrent temporal change in recruitment, is a notable feature of the current assessment. It is concurrent with large increases in catch particularly in region 2, and declines in CPUE and median fish sizes in the main fisheries. The recent increase in the AU_1 CPUE index is best described by the Ref.case model for which the faster Hawaiian schedule is made; whereas no increase is predicted when the slower Australian schedule is assumed.
b) Estimates of absolute biomass and equilibrium yield were sensitive to including the NZ_2 standardized CPUE time series in the model fit (key model run cpopt_TW_NZ). The recent declines in the Ref.case model indices for region 2 appear to be consistent with declines in median size over the same period, whereas the NZ_2 index is in conflict with this trend, and is derived from a limited spatial distribution. On this basis, the cpopt_TW_NZ model is considered unreliable, or at least highly uncertain, and this model estimate is excluded from the ranges of the key model runs provided in this section below.
c) The key source of uncertainty in this assessment is the assumed growth/maturity/mortality at age schedule. Estimates of stock status are highly uncertain with respect to this assumption. Across the full uncertainty grid, where the Hawaiian schedule was assumed, the probability of $F_{current}/F_{MSY}$ being greater than 1 was less than 2%, while where the slower Australian schedule was assumed, this increased to 51%.
d) Total and spawning biomass are estimated to have declined most notably since the late 1990s, with more gradual declines before that time. Current levels of total biomass $B_{current}/B_0$ = 44 – 68 % and spawning biomass $SB_{current}/SB_0$ = 27 – 55% (range of key model runs).
e) 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 current period, spawning potential is at 26 – 60% (range of key model runs) of the level predicted to exist in the absence of fishing while assuming the historical estimated annual recruitments.
f) Recent catches are between 82% of the MSY level and 102% above the MSY level of between 5299 and 12 730 t (range of key model runs).
g) Based on these results, it was concluded that under the Hawaiian growth schedule current catches are around the MSY level, while under the Australian growth schedule current levels of catch are above the MSY level.

h) Fishing mortality for adult and juvenile swordfish is estimated to have increased sharply in the mid-1990s following the significant increases in catches at that time. $F_{current}/F_{MSY}$ was estimated to be between 0.33 and 1.77 (range of key model runs). Within this range:

   i. assuming the Hawaiian schedule produces estimates between 0.40 to 0.70, while,

   ii. assuming the Australian schedule produces estimates that are between 1.06 to 1.77.

i) Based on these results, it was concluded that under the Hawaiian schedule overfishing is not occurring, while under the Australian schedule overfishing is occurring.

The Scientific Committee of the Western and Central Pacific Fisheries Commission made the following conclusion regarding the stock status:

- "*The South Pacific swordfish assessment was highly sensitive to growth assumptions. Two different growth models, one from Australia (GA) and the other from Hawaii (GH), were included in alternative model runs. The Scientific Committee could not decide which of these two assumptions was more reliable. Assessment runs using the GA growth data indicated that overfishing was occurring but that the stock was not in an overfished state. Assessment runs using the GH growth data indicate that no overfishing is occurring and that the stock is not in an overfished state.*
- *Although the median of the uncertainty grid indicates that overfishing (Fcurrent/FMSY = 0.74) was not occurring those sensitivity runs that used the GA growth and maturity schedule indicate that overfishing may be occurring (grid range 5th–95th percentiles: 0.51-2.02). Recent preliminary findings from tagging data indicate that this alternative growth schedule (GA) warrants further consideration. Estimates of stock status are highly uncertain with respect to this assumption. The equivalent grid range of Fcurrent/FMSY for the Hawaiian schedule (GH) is 0.25 – 0.97. Across the uncertainty grid of 378 runs, where the Hawaii schedule was assumed, the probability of Fcurrent/FMSY being greater than 1.0 was less than 3%, while when the slower Australian schedule was assumed, 54% of runs estimated the stock to be experiencing overfishing.*"

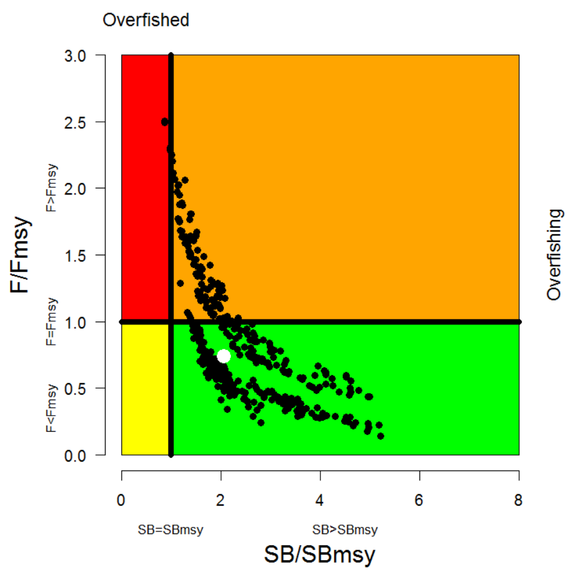


Figure 11: $F_{current}/F_{MSY}$ and $SB_{current}/SB_{MSY}$ for the median of the selected uncertainty grid (white circle) and the individual uncertainty grid runs.

5.1 Catch per unit effort indices (CPUE)

Catch per unit effort (CPUE) indices for swordfish (*Xiphias gladius*) in the New Zealand surface longline fishery were updated to include fishery data from the five years since the previous analysis, for use as relative abundance indices in a revised south Pacific-wide swordfish stock assessment model being assembled by the Western and Central Pacific Fisheries Commission (WCPFC) (Anderson et al 2013).

Examination of changes in the fishery data (including the use of light sticks, depth of the longline, and timing of fishing around hours of darkness and with respect to the fullness of the moon) showed that targeting of swordfish has effectively been increasing over time, particularly since 2004 when targeting became legal after the introduction of swordfish into the Quota Management System (QMS).

Generalised Additive Models (GAMs) assuming a quasi-poisson error distribution were applied to commercial catch-effort data and remote-sensed environmental variables to produce three alternative CPUE series: **all-data**, based on data from 1993 to 2012 and all vessels in the fishery; **core-vessel**, based on a core set of vessels and the more recent fishery, 1998 to 2012; and **late-series**, based on the core set of vessels and the period subsequent to the introduction of swordfish into the QMS, i.e., 2005 to 2012.

Each model showed an increase in CPUE as the fraction of the longline soak-time occurring in darkness increased. Recorded target species in the all-data model, and rate of light stick usage in the late-series model were also significant.

The indices of the updated models followed a similar temporal pattern to each other and to those of the earlier analyses for the overlapping years, indicating a decline in CPUE between 1993 and 2004, followed by a small increase to 2007. For the subsequent period, 2004 to 2012, the revised models all showed a continuation of this increasing CPUE, reaching a level higher than that of any previous year in the series.

Although it was suspected that changes in operational procedures affecting swordfish catch rates were at least partly responsible for the recent increase in CPUE, it was not possible to determine whether these changes were sufficiently accounted for by the model variables and therefore to have confidence in the use of the year-effects as relative abundance indices.

5.2 Other factors

Other fleets also fish the stock fished in the New Zealand EEZ and the impact of current regional catches on the stock are unknown. It is often assumed that swordfish, particularly large swordfish, may have long residence times which may make them vulnerable to over fishing. Recent Australian research suggests that swordfish CPUE has declined in areas that have been fished the longest and that vessels have maintained high catch rates by travelling further each season, suggesting that serial depletion may be occurring.

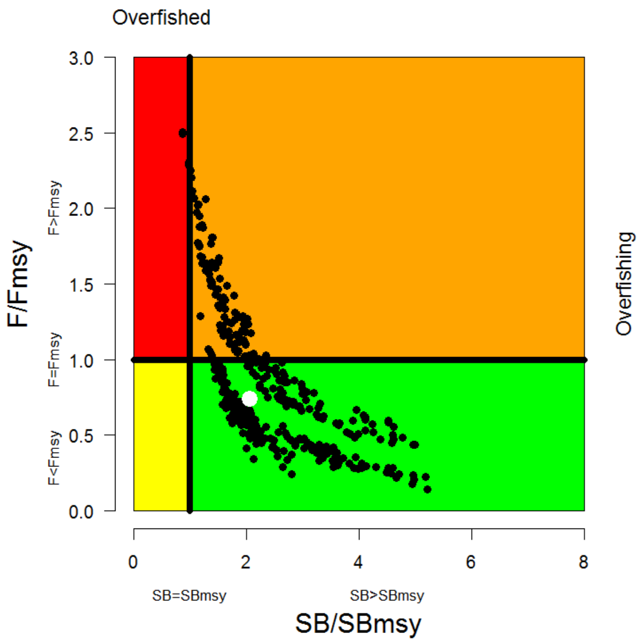
6. STATUS OF THE STOCKS

Stock structure assumptions

Swordfish taken in New Zealand are part of larger southwest and south-central Pacific stocks; the evaluation below refers to the assessment of the southwest portion of that stock.

Stock Status	
Year of Most Recent Assessment	A full stock assessment was conducted in 2013.
Assessment Runs Presented	Full uncertainty grid
Reference Points	Target: $B > B_{MSY}$ 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	Likely (> 60%) that B is at or above B_{MSY} and Likely (> 60%) that $F < F_{MSY}$
Status in relation to Limits	Soft Limit: Unlikely (< 40%) to be below Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	Overfishing is About as Likely as Not (40–60%) to be occurring

Historical Stock Status Trajectory and Current Status



$F_{current}/F_{MSY}$ and $SB_{current}/SB_{MSY}$ for the median of the selected uncertainty grid (white circle) and the individual uncertainty grid runs.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Following a period of continuous decline, the southwest Pacific swordfish biomass has recently increased.
Recent Trend in Fishing Intensity or Proxy	Fishing mortality increased substantially from 1995 to present.
Other Abundance Indices	-
Trends in Other Relevant Indicator or Variables	Recruitment trends have fluctuated without trend from 1950 to present.
Projections and Prognosis	
Stock Projections or Prognosis	Projections based on the model that used Hawaii growth predict further increases in stock size at current fishing mortality levels. However, using the Australian growth the stock is About as Likely as Not to decline.
Probability of Current Catch or TACC causing Biomass to	Soft Limit: Unlikely (< 40%)

remain below or to decline below Limits	Hard Limit: Unlikely (< 40%)	
Probability of Current Catch or TACC causing Overfishing to continue or commence	About as Likely as Not (40–60%)	
Assessment Methodology and Evaluation		
Assessment Type	Level 1: Full Quantitative Stock Assessment	
Assessment Method	The assessment uses the stock assessment model and computer software known as MULTIFAN-CL.	
Assessment Dates	Latest assessment: 2013	Next assessment: 2016
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	Commercial catch and effort data, CPUE, catch-at-age	1 – High Quality
Data not used (rank)		
Changes to Model Structure and Assumptions	Major changes from the 2006 assessment include: • assumes two model regions • relaxing assumptions such as the relative recruitment to each region • fixing steepness at 0.8 • estimating spline and non-decreasing selectivities for the main longline fisheries • A new statistical assumption to include time-variant precision in fitting the model to standardized CPUE indices	
Major Sources of Uncertainty	• Targeting and learned behaviour in the last decade make the CPUE data from many fleets (including New Zealand) unreliable as indices of abundance • Assumed growth schedule	

Qualifying Comments
-

Fishery Interactions
Interactions with protected species are known to occur in the longline fisheries of the South Pacific, particularly south of 25°S. Seabird bycatch mitigation measures are required in the New Zealand and Australian EEZs and through the WCPFC Conservation and Management Measure (CMM2012-07). Sea turtles also get incidentally captured in longline gear; the WCPFC is attempting to reduce sea turtle interactions through Conservation and Management Measure (CMM2008-03). Shark bycatch is common in longline fisheries and largely unavoidable; this is being managed through New Zealand domestic legislation and to a limited extent through Conservation and Management Measure (CMM2010-07).

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