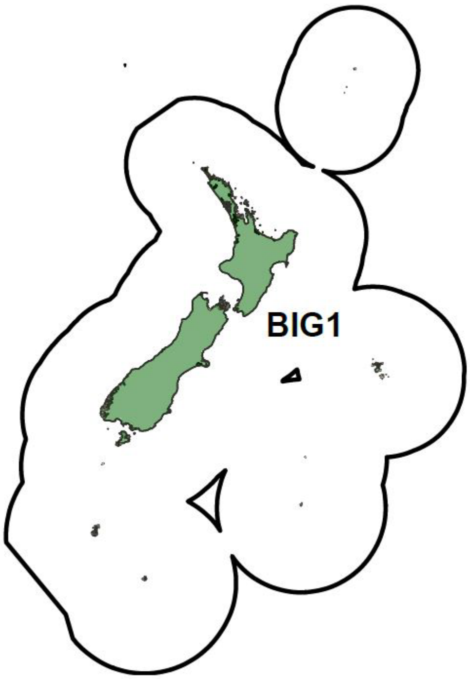
BIGEYE TUNA (BIG)

(Thunnus obesus)



1. FISHERY SUMMARY

Bigeye tuna were introduced into the Quota Management System on 1 October 2004 under a single Quota Management Area, BIG 1, with allowances, Total Allowable Commercial Catch (TACC), and Total Allowable Catch (TAC) given in Table 1.

Table 1: Recreational and customary non-commercial allowances, TACC, and TAC (all in t) for BIG 1.

Fishstock	Recreational allowance	Customary non-commercial allowance	Other mortality	TACC	TAC
BIG 1	8	4	14	714	740

Bigeye were added to the Third Schedule of the 1996 Fisheries Act with a TAC set under s14 because bigeye 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.

Management of the bigeye stock 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 management measures applied within New Zealand fisheries waters are compatible with those of the Commission.

At its second annual meeting (2005) 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 tunas. Key aspects of this resolution were presented in the 2006 Plenary document. A number of subsequent CMMs that impact on the catches of bigeye have since been approved by the WCPFC.

At its annual meeting in 2014 the WCPFC approved CMM 2014-01. The aim of this CMM for bigeye is to reduce the fishing mortality rate for bigeye to a level no greater than F_{MSY}. This objective was achieved through a step-by-step approach to 2017 in accordance with the CMM. This measure is large and detailed with numerous exemptions and provisions. Reductions in fishing mortality are being attempted through seasonal Fish Aggregating Device (FAD) closures, high seas area closures (in high seas pockets) for the purse seine fleets, purse seine effort limits, longline effort reductions, bigeye longline catch limits by flag, as well as other methods. This measure was amended and updated in 2015 through CMM2015-01 and in 2017 through CMM2017-01.

In 2018 CMM 2018-01 (commonly referred to the "The tropical tuna bridging measure") was approved stating that, pending agreement on a target reference point for bigeye, the spawning biomass depletion ratio ($SB/SB_{F=0}$) is to be maintained at or above the average $SB/SB_{F=0}$ for 2012–2015.These measures were subsequently amended and further strengthened in CMM 2020-01 and CMM 2021-01.

1.1 Commercial fisheries

Commercial catches of bigeye tuna by distant water Asian longliners in New Zealand fisheries waters began in 1962 and continued under foreign licence agreements until 1993. Bigeye were not a primary target species for these fleets and catches remained modest with the maximum catch in the 1980s reaching 680 t. Domestic tuna longline vessels began targeting bigeye tuna in 1990. There was an exponential increase in the number of hooks targeting bigeye, which reached a high of approximately 6.6 million hooks in 2000–01 and then declined thereafter.

Catches from New Zealand fisheries are very small (0.07% average for 2015–24) compared with those from the greater stock in the WCPO (Table 2 and 3). Figure 1 shows historical landings and TACC values for BIG 1 and BIG ET. In contrast to New Zealand, where bigeye are taken almost exclusively by longline, about 30% of the WCPO catches of bigeye were taken by purse seine and 30 % by troll in 2024.

Table 2: Reported total New Zealand (within EEZ) landings (t) and landings from the western and central Pacific Ocean (t) of bigeye tuna by calendar year from 1991 to present.

Year	NZ landings (t)	Total WCPO landings (t)	Year	NZ landings (t)	Total WCPO landings (t)
1991	44	107 725	2008	133	171 317
1992	39	131 195	2009	254	169 294
1993	74	113 419	2010	132	139 796
1994	71	124 624	2011	174	168 119
1995	60	110 385	2012	154	167 245
1996	89	107 168	2013	110	154 783
1997	142	133 495	2014	122	169 046
1998	388	152 415	2015	81	145 709
1999	421	162 524	2016	177	156 656
2000	422	148 094	2017	97	130 595
2001	480	134 459	2018	136	154 404
2002	200	157 958	2019	50	131 808
2003	205	143 471	2020	67	142 638
2004	185	182 599	2021	86	127 738
2005	176	154 748	2022	51	136 914
2006	178	165 386	2023	153	126 924
2007	213	165 365	2024	61	109 937

From 2020–21 to 2022–23 100% of bigeye tuna caught within the EEZ were caught by domestic surface longliners (Kendrick 2025). While bigeye was the target species of the surface longline fishery, swordfish (24%) and yellowfin tuna (18%) made up a significant proportion of the catch in 2024–25 (Figure 2). Longline fishing effort is distributed off the east coast of the North Island and the south-west coast of the South Island. The south-west coast South Island fishery predominantly targets southern bluefin tuna (*Thunnus maccoyii*), whereas the east coast North Island longline effort targets a range of species including bigeye, swordfish, and southern bluefin tuna.

Table 3: Reported catches and landings (t) of bigeye tuna by fleet and fishing year. JPNFL: Japanese foreign licensed vessels; KORFL: foreign licensed vessels from the Republic of Korea; NZ/MHR: New Zealand domestic and charter fleet Monthly Harvest Returns; and LFRR: estimated landings from Licensed Fish Receiver Returns.

	BIG 1 (all FMAs)				
Fishing year	**JPNFL**	**KORFL**	**NZ/MHR**	**Total**	**LFRR**
1979–80	205.8			205.8	
1980–81	395.9	65.3		461.2	
1981–82	655.3	16.8		672.1	
1982–83	437.1	11.1		448.2	
1983–84	567.0	21.8		588.8	
1984–85	506.3	51.6		557.9	
1985–86	621.6	10.2		631.8	
1986–87	536.1	17.6		553.7	
1987–88	226.9	22.2		249.1	
1988–89	165.6	5.5		171.1	4.0
1989–90	302.7		12.7	315.4	30.7
1990–91	145.6		12.6	158.2	36.0
1991–92	78.0		40.9	118.9	50.0
1992–93	3.4		43.8	47.2	48.8
1993–94			67.9	67.9	89.3
1994–95			47.2	47.2	49.8
1995–96			66.9	66.9	79.3
1996–97			89.8	89.8	104.9
1997–98			271.9	271.9	339.7
1998–99			306.5	306.5	391.2
1999–00			411.7	411.7	466.0
2000–01			425.4	425.4	578.1
2001–02			248.9	248.9	276.3
2002–03			196.1	196.1	195.1
2003–04			216.3	216.3	217.5
2004–05*			162.9	162.9	163.6
2005–06*			177.5	177.5	177.1
2006–07*			196.7	196.7	201.4
2007–08*			140.5	140.5	143.8
2008–09*			237.2	237.2	240.2
2009–10*			161.2	161.2	169.7
2010–11*			181.1	181.1	201.0
2011–12*			174.0	174.0	276.5
2012–13*			154.0	154.0	148.0
2013–14*			116.0	116.0	116.0
2014–15*			83.2	83.2	83.2
2015–16*			172.8	172.8	172.8
2016–17			104.9	104.9	104.9
2017–18			136.7	136.7	136.7
2018–19			54.6	54.6	54.47
2019–20			59.4	59.4	77.35
2020–21			93.99	93.99	93.7
2021–22			32.9	32.9	33.25
2022–23			164.4	164.4	164.3
2023–24			60.8	60.8	
2024–25			90.0	90.0	

* MHR rather than LFRR data.

1.2 Recreational fisheries

Recreational fishers make occasional catches of bigeye tuna while trolling for other tunas and billfish, but the recreational fishery does not regularly target this species. There is no information on the size of the catch.

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 Unreported catch

There is no known unreported catch of bigeye tuna in the EEZ.

1.5 Other sources of mortality

The estimated overall incidental mortality rate from observed longline effort is 0.23% of the catch. Discard rates are 0.34% on average (from observer data), of which approximately 70% are discarded dead (usually because of shark damage). Fish are also lost at the surface in the longline fishery, 0.09% on average (from observer data), of which 100% are thought to escape alive.

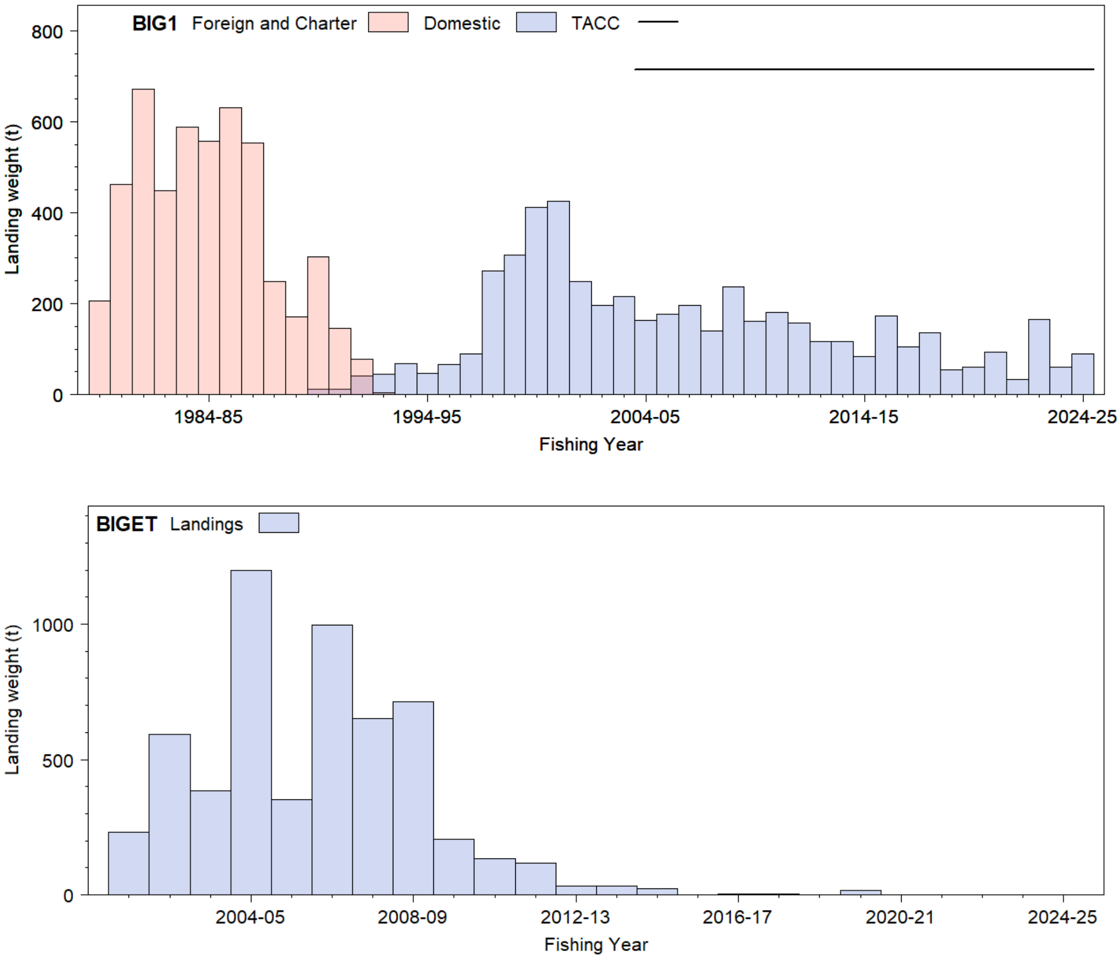


Figure 1: [Top] Bigeye catch by foreign licensed, foreign charter, and New Zealand vessels from 1979–80 to present within New Zealand waters (BIG 1) and [Bottom] bigeye catch by foreign licensed and New Zealand vessels on the high seas from 2001–02 to present for New Zealand vessels fishing on the high seas (BIG ET).

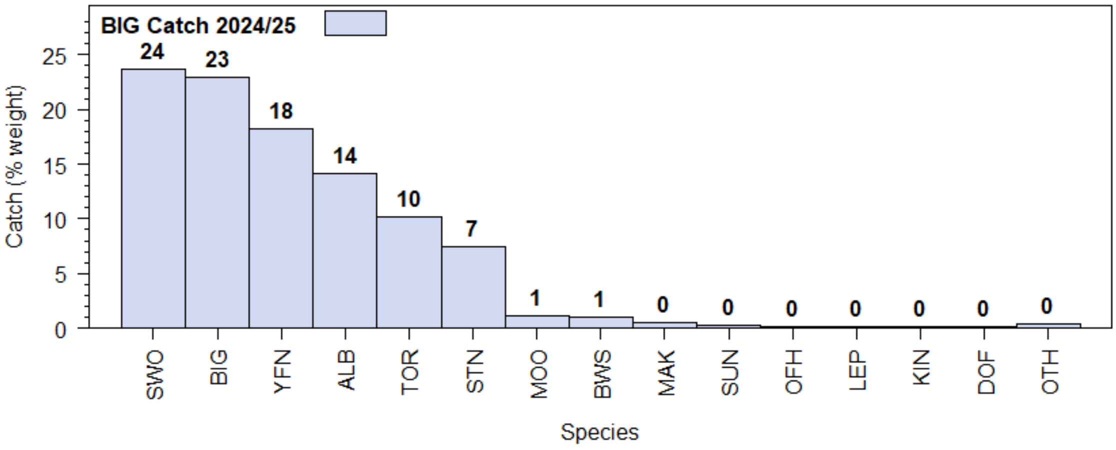


Figure 2: A summary of species composition of the bigeye target surface longline estimated catch for the most recent fishing year. The percentage by weight of each species is calculated for all surface longline trips targeting bigeye tuna.

2. BIOLOGY

Bigeye tuna are epipelagic opportunistic predators of fish, crustaceans, and cephalopods generally found within the upper few hundred metres of the ocean. Tagged bigeye tuna have been shown to be capable of movements of over 4000 nautical miles over periods of one to several years. Juveniles and small adults school near the surface in tropical waters whereas adults tend to live in deeper water. Individuals found in New Zealand waters are mostly adults. Adult bigeye tuna are distributed broadly across the Pacific Ocean, in both the Northern Hemisphere and Southern Hemisphere and reach a maximum size of 210 kg and maximum length of 250 cm. The maximum reported age is 14 years old and tag recapture data indicate that significant numbers of bigeye reach at least 8 years old. Spawning takes place in the equatorial waters of the Western Pacific Ocean (WPO) in spring and early summer.

Natural mortality and growth rates are both estimated within the stock assessment. Natural mortality is assumed to vary with age with values about 0.5 for bigeye longer than 40 cm. A range of von Bertalanffy growth parameters has been estimated for bigeye in the Pacific Ocean depending on area (Table 4).

Table 4: Biological growth parameters for bigeye tuna, by country.

Country	L_∞ (cm)	K	t_0
Mexico	169.0	0.608	
French Polynesia	187.0	0.380	
Japan	195.0	0.106	-1.13
Hawaii	196.0	0.167	
Hawaii	222.0	0.114	
Hawaii	220.0	0.183	

SC14-SA-WP-03 provides an update on a regional study of bigeye tuna age and growth in the WCPO presented at the WCPFC Scientific Committee meeting in 2017. The objectives of this extension project are to (i) prepare and read an additional 125 otoliths from fish >130 cm fork length (FL) using the annual increment method identified by Farley et al. (2017), and (ii) revise and update the age and growth estimates provided by Farley et al. (2017) based on the additional new data.

Annual age estimates were obtained for an additional 237 bigeye tuna in the WCPO to strengthen the growth analysis reported by Farley et al. (2017). Of these, 188 were from fish >130 cm FL and 49 from fish 90–129 cm FL. Daily age was also estimated for an additional 11 very small bigeye (31–39 cm FL). The new annual and daily age estimates were combined with those of Project 35 and historical SPC daily age estimates to obtain new von Bertalanffy growth parameters for bigeye tuna. Fish caught east of the assessment area and daily age estimates >1 year were excluded from the analysis. The resulting L_∞ estimate was 156.9 cm FL, which is similar to that reported from Project 35 at SC13. The results of exploratory spatial analysis continue to indicate that there are differences in the growth rates of bigeye tuna across the Pacific.

The SPC Pre-assessment workshop in April 2018 recommended inter-laboratory comparison work be undertaken to standardise daily ageing methods between the WCPO and the EPO (Eastern Pacific Ocean). The results of this comparison work were reported by SC15-SA-WP-02 *Workshop on yellowfin and bigeye age and growth,* with reference to SC15-SA-IP-19 *Report of the Workshop on Age and Growth of Bigeye and Yellowfin Tunas in the Pacific Ocean.* The paper described work undertaken by CSIRO, Fish Ageing Services (FAS), and the Inter-American Tropical Tuna Commission (IATTC) to assess and improve consistency in ageing methods using otoliths for bigeye and yellowfin (*Thunnus albacares*). The objectives were to analyse otoliths from mark-recapture individuals for age validation purposes; compare daily and annual age estimates from paired otoliths from the same fish; analyse otoliths from 50 very small bigeye from assessment area 7 using daily ageing methods; and participate in an inter-lab workshop to jointly read and examine otoliths and share ageing methods to improve skill and resolve differences in the approaches used. However, differences in age estimates from counting daily (IATTC) and annual (FAS) increments in sister otoliths from the same individuals were not resolved in the workshop. They may only be resolved through large-scale direct age validation studies, such as mark-recapture experiments and/or the application of bomb radiocarbon validation methods.

In 2020, daily age counts were obtained for an additional 34 small fish ranging from 14 to 40 cm FL and reported in SC16-SA-WP-02. These samples were included to strengthen the growth analysis previously reported by Farley et al. (2018) and to aid the estimation of the L1 parameter within the assessment model. The new age algorithm developed for yellowfin tuna was also applied to the bigeye tuna annual count data used by Farley et al. (2018). Parameter estimates for standard von Bertalanffy and Richards growth models were obtained from the updated combined daily and annual age estimates, with the Richards model preferred based on statistical tests and residuals analysis. The resulting Richards model parameter estimates, using only high readability age determinations, were L_∞= 161.1 cm FL, $K = 0.24$ y^{-1}, $b = 0.58$, and t_0= -2.26 y.

3. STOCKS AND AREAS

Bigeye tuna are distributed throughout the tropical and sub-tropical waters of the Pacific Ocean. Analysis of mtDNA and DNA microsatellites in nearly 800 bigeye tuna failed to reveal significant evidence of widespread population subdivision in the Pacific Ocean (Grewe & Hampton 1998). Although these results are not conclusive regarding the rate of mixing of bigeye tuna throughout the Pacific, they are broadly consistent with the results of the SPC and IATTC tagging experiments on bigeye tuna. Before 2008, most bigeye tuna tagging in the Pacific occurred in the far eastern Pacific (east of about 120° W) and in the western Pacific (west of about 180°). Although some of these tagged bigeye were recaptured at distances from release of up to 4000 nautical miles over periods of one to several years, the large majority of tag returns were recaptured closer to their release points (Schaefer & Fuller 2002, Hampton & Williams 2005).

Since 2008, bigeye tuna tagging by the Pacific Tuna Tagging Programme has been focused in the equatorial central Pacific, between 180° and 140° W. Returns of both conventional and electronic tags from this programme have been suggestive of more extensive longitudinal, particularly west to east, displacements. It is hypothesised that although bigeye tuna in the far eastern and western Pacific may have relatively little exchange, those in the central part of the Pacific between about 180° and 120° W may mix more rapidly over distances of 1000–3000 nautical miles. In any event, it is clear that there is extensive movement of bigeye across the nominal WCPO/EPO boundary of 150° W. Although stock assessments of bigeye tuna are routinely undertaken for the WCPO and EPO separately, these new data suggest that examination of bigeye tuna exploitation and stock status on a Pacific-wide scale, using an appropriately spatially structured model, should be a high priority.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

The figures and tables in this section were updated and additional text included for the November 2024 Fishery Assessment Plenary. This summary is from the perspective of the bigeye tuna longline fishery; a more detailed summary from an issue-by-issue perspective is available in the Aquatic Environment and Biodiversity Annual Review where the consequences are also discussed (Aquatic environment and biodiversity annual review (AEBAR) | NZ Government (mpi.govt.nz)).

4.1 Role in the ecosystem

Bigeye tuna are large pelagic predators, so they are likely to have a ‘top down’ effect on the fish, crustaceans, and squid they feed on.

4.2 Incidental catch of seabirds, sea turtles, and mammals

The capture estimates for protected species 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 Incidental catch of seabirds

Between 2002–03 and 2022–23, there were 156 observed captures of seabirds in bigeye target longline fisheries (Table 5); capture rates and estimated captures are presented in Table 6. Lower levels of observer coverage and higher commercial effort from 2002–03 to 2007–08 (Figure 3) contributed to a highly variable observed capture rate during these years of the fishery (Table 6). A subsequent decline in effort, where in 2022–23 effort was 15% of that recorded in 2002–03, has reduced estimated captures but a recent decrease in observer coverage due to Health and Safety concerns has also increased uncertainty. Seabird captures were most frequent off the east coast North Island and Kermadec Island regions coinciding with the fishing effort (see Table 5 and Figure 4). Observed and estimated seabird captures in bigeye longline fisheries are provided in Table 6.

Table 5: Number of observed seabird captures in bigeye tuna longline fisheries, 2002–03 to 2022–23, by taxon and area. The risk category is an estimate of aggregate potential fatalities for trawl and longline fisheries relative to the Population Sustainability Threshold, PST (an analogue of the PBR approach) (Edwards et al. 2023). The current version of the risk assessment does not include recovery factor.

Taxon	Risk ratio	Northland and Hauraki	East coast North Island	West coast North Island	Bay of Plenty	Kermadec Islands	Total
Antipodean albatross	Medium	12	4	1	1		**18**
Southern Buller's albatross	Very high	3	4	1			**8**
Northern Buller's albatross	Medium	1					**1**
Buller's albatross	NA	3	2				**5**
Gibson's albatross	Medium	10		1			**11**
Campbell black-browed albatross	Low	3					**3**
Salvin's albatross	High	1	2		1		**4**
Southern royal albatross	Low	2	1				**3**
Antipodean and Gibson's albatrosses	NA	2					**2**
New Zealand white-capped albatross	High	2			2		**4**
Wandering albatross	NA	2					**2**
Wandering albatrosses	NA				1		**1**
Northern royal albatross	Low	1			1		**2**
Albatrosses	NA		1	1			**2**
Black-browed albatrosses	NA		1	1			**2**
All albatrosses		**42**	**15**	**5**	**6**		**68**
Black petrel	High	27	4		19	1	**51**
Flesh-footed shearwater	Medium	1	10	2	11		**24**
Buller's shearwater	Negligible				1		**1**
White-chinned petrel	Low	2		3	1		**6**
Grey-faced petrel	Negligible	1			3		**4**
Gadfly petrels		1					**1**
Australasian gannet	Negligible		1				**1**
Total other seabirds		**32**	**15**	**5**	**35**	**1**	**88**

Throughout 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 s11 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 re-promulgated 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. Trials have been undertaken to assess the operational functionality of an underwater bait setter during production fishing and the work is ongoing. The aim of this work was to assess the device without the use of other existing mitigation measures in the New Zealand surface longline fleet.

Current results for the risk posed by commercial fishing to seabirds have been assessed via a spatially explicit fisheries risk assessment (SEFRA), supported under the NPOA-Seabirds 2020 risk assessment framework (Fisheries New Zealand & Department of Conservation 2020). The method used in the risk assessment arose initially from an expert workshop hosted by the Ministry of Fisheries in 2008. The overall framework is described in Chapter 3 of the AEBAR and has been variously applied and improved in multiple iterations (most recently Edwards et al. 2023). The method applies an 'exposureeffects' approach where exposure refers to the number of fatalities and 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 with the population's productivity, based on population estimates and biological characteristics, to yield estimates of population-level risk.

Table 6: Effort, observed, and estimated seabird captures by fishing year for the bigeye tuna 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 by Abraham & Berkenbusch (2019).

Fishing	Fishing effort			Observed captures		Estimated captures	
year	All hooks	Observed hooks	% observed	Number	Rate	Mean	95% c.i.
2002–03	5 188 207	80 640	1.6	0	0.00	1 015	773–1 326
2003–04	3 507 507	120 740	3.4	1	0.01	685	510–916
2004–05	1 649 081	33 116	2.0	2	0.06	325	231–444
2005–06	1 869 436	45 100	2.4	6	0.13	389	277–527
2006–07	1 532 071	84 150	5.5	5	0.06	303	214–415
2007–08	967 829	24 295	2.5	6	0.25	211	146–293
2008–09	1 565 517	91 295	5.8	9	0.10	317	228–422
2009–10	1 247 437	76 859	6.2	20	0.26	305	223–418
2010–11	1 646 956	87 730	5.3	15	0.17	374	280–493
2011–12	1 291 923	39 210	3.0	7	0.18	268	196–358
2012–13	994 535	60 280	6.1	3	0.05	216	152–294
2013–14	743 981	29 651	4.0	2	0.07	192	133–266
2014–15	387 005	24 470	6.3	0	0.00	90	57–134
2015–16	623 659	40 510	6.5	13	0.32	153	105–214
2016–17	497 967	55 041	11.1	9	0.16	122	82–171
2017–18	569 203	51 020	9.0	16	0.31	152	106–211
2018–19	435 998	52 615	12.1	13	0.25	106	70–154
2019–20	397 825	54 239	13.6	13	0.24	100	66–147
2020–21	351 693	62 888	17.9	12	0.19	81	50–121
2021–22	186 781	14 750	7.9	4	0.27	57	31–92
2022–23	386 781	0	0.0	0		119	67–196

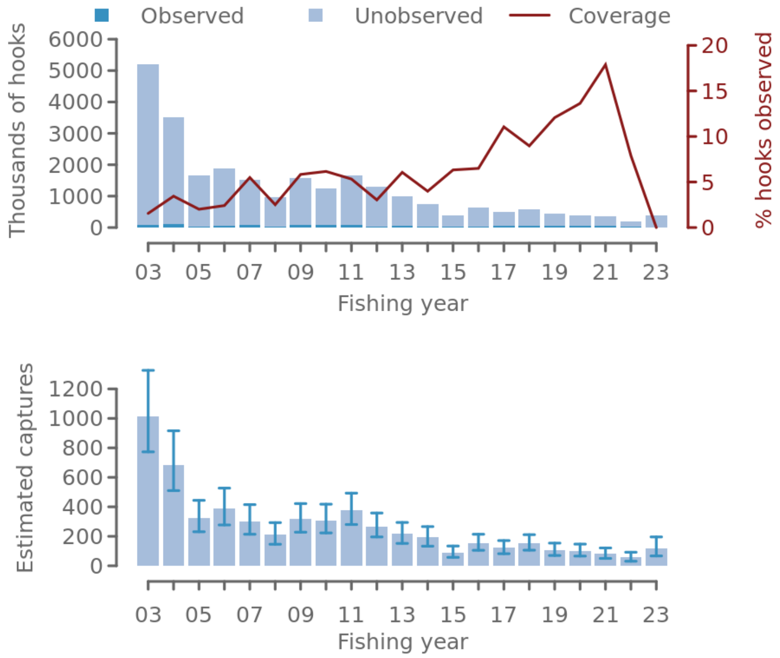


Figure 3: Fishing effort and observations (top) and estimated seabird captures (bottom) in the bigeye tuna longline fisheries from 2002–03 to 2022–23.

The risk ratio is an estimate of potential deaths from interactions with trawl and bottom-longline and surface longline fisheries relative to the Population Sustainability Threshold (PST) for each species assessed. PST provides a reference point of anthropogonic deaths that can be sustained by the population relative to its size and reproductive rate and still meet long term recovery goals. A risk ratio above 1 indicates that domestic fishing related deaths alone exceed PST and the population is at risk of not obtaining long term recovery goals.

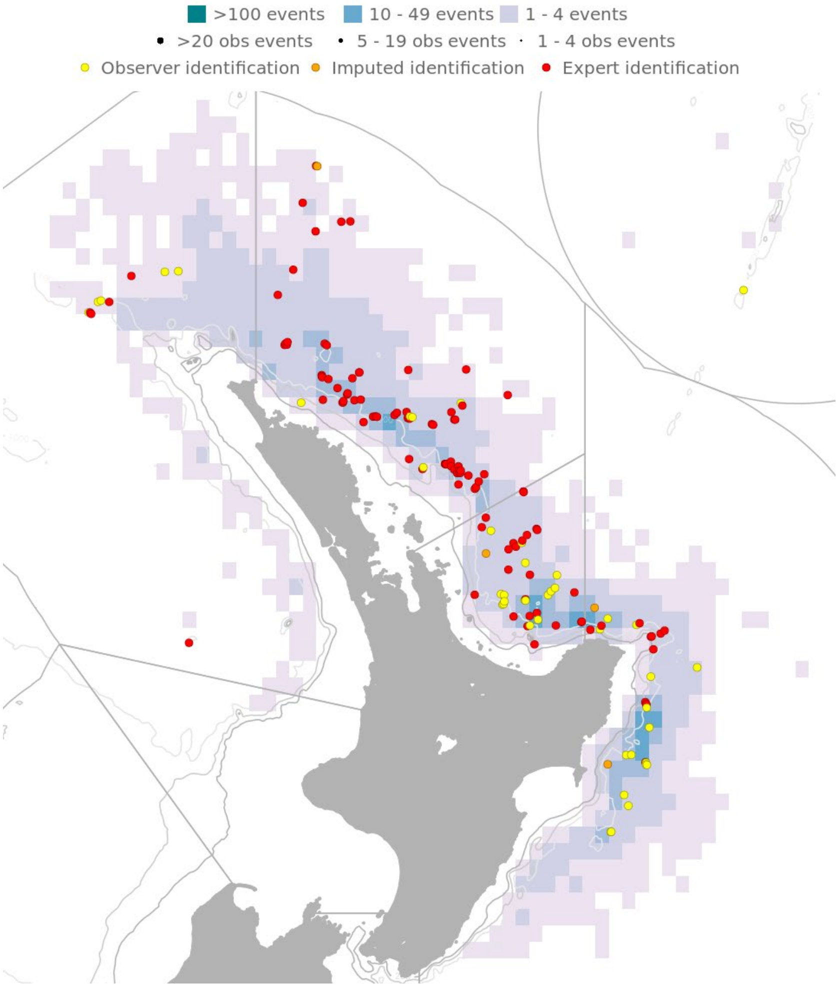


Figure 4: Distribution of fishing effort targeting bigeye tuna and observed seabird captures, 2002–03 to 2022–23. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by orange, red, and yellow 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 by Abraham & Berkenbusch (2019).

Edwards et al. (2023) assessed the domestic tuna and swordfish surface longline fishery contribution to the total risk posed by New Zealand commercial fishing to seabirds (Table 7). This fishery (which includes Bigeye tuna targeting) contributes 0.313 of risk to Southern Buller's albatross (26.8% of the total risk posed by New Zealand commercial fishing included in the risk assessment), the only species categorised as Very high risk (Edwards et al. 2023), and 0.115, 0.089 and 0.042 of risk to Black petrel, Westland petrel and New Zealand white-capped albatross, respectively; these were assessed to be at high risk from New Zealand commercial fishing. The wider surface longline fishery contributes most of risk to species in the wandering albatross family: Gibson's albatross and Antipodean albatross, contributing 87% and 94% of their total risk respectively.

Table 7: Risk ratio of seabirds predicted by the SEFRA for the domestic tuna and swordfish surface longline fishery and all fisheries included in the SEFRA, 2006–07 to 2019–20, with a risk posed by the domestic tuna and swordfish SLL fishery. 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 the PBR approach) (Edwards et al. 2023). The current version of the risk assessment does not include a recovery factor. The New Zealand threat classifications are shown (Robertson et al. 2021).

	Risk ratio				
Species name	**Domestic SLL**	**Total risk from NZ commercial fishing**	**% of total risk from NZ commercial fishing**	**Risk category**	**NZ Threat Classification**
Southern Buller's albatross	0.313	1.19	26.8	Very high	At Risk: Declining
Antipodean albatross	0.141	0.16	94.4	Medium	Threatened: Nationally Critical
Gibson's albatross	0.137	0.16	89.7	Medium	Threatened: Nationally Critical
Black petrel	0.115	0.49	24.5	High	Threatened: Nationally Vulnerable
Westland petrel	0.089	0.38	25.9	High	At Risk: Naturally Uncommon
New Zealand white-capped albatross	0.042	0.5	8.7	High	At Risk: Declining
Northern Buller's albatross	0.038	0.19	20.6	Medium	At Risk: Naturally Uncommon
Southern royal albatross	0.018	0.08	24.4	Low	Threatened: Nationally Vulnerable
Campbell black-browed albatross	0.016	0.05	30.2	Low	At Risk: Naturally Uncommon
Flesh-footed shearwater	0.015	0.22	7.3	Medium	At Risk: Relict

4.2.2 Incidental catch of sea turtles

Between 2002–03 and 2022–23, there were 32 observed captures of turtles in bigeye tuna longline fisheries (Figure 5, Table 8, and Table 9). Observer recordings documented all but two sea turtles as captured and released alive. Sea turtle capture distributions are more common off the east coast North Island (Figure 6).

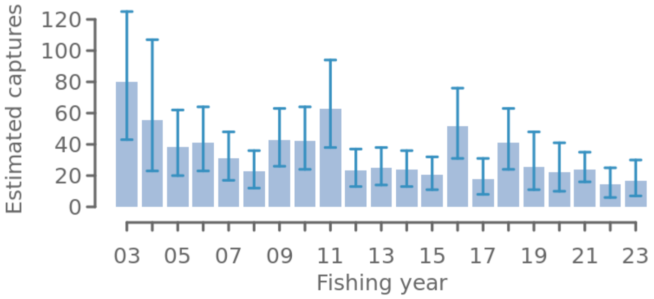


Figure 5: Estimated captures of sea turtles in bigeye tuna longline fisheries from 2002–03 to 2022–23.

Table 8: Total observed captures of sea turtles in bigeye tuna longline fisheries between 2002–03 and 2022–23. Data grooming methods are described by Abraham & Berkenbusch (2019).

Species	**East Coast North Island**	**Bay of Plenty**	**Kermadec Islands**	**West Coast North Island**	**Northland and Hauraki**	**Total**
Green turtle	1					1
Leatherback turtle	10	8	1	3	3	25
Loggerhead turtle	1					1
Unidentified turtle	3		0	2		5
Total	15	8	1	5	3	32

Table 9: Fishing effort and estimated sea turtle captures by fishing year for bigeye tuna longline fisheries 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); and the capture rate (captures per thousand hooks); and the mean number of estimated total captures (with 95% confidence interval). Data grooming methods are described by Abraham & Berkenbusch (2019).

Fishing	Fishing effort			Observed captures		Estimated captures	
year	All hooks	Observed hooks	% observed	Number	Rate	Mean	95% c.i.
2002–03	5 188 207	80 640	1.6	0	0.00	80	43–125
2003–04	3 507 507	120 740	3.4	1	0.01	56	23–107
2004–05	1 649 081	33 116	2.0	2	0.06	38	20–62
2005–06	1 869 436	45 100	2.4	1	0.02	41	23–64
2006–07	1 532 071	84 150	5.5	1	0.01	31	17–48
2007–08	967 829	24 295	2.5	0	0.00	23	12–36
2008–09	1 565 517	91 295	5.8	2	0.02	43	26–63
2009–10	1 247 437	76 859	6.2	0	0.00	42	24–64
2010–11	1 646 956	87 730	5.3	1	0.01	63	38–94
2011–12	1 291 923	39 210	3.0	0	0.00	23	13–37
2012–13	994 535	60 280	6.1	2	0.03	25	14–38
2013–14	743 981	29 651	4.0	0	0.00	24	13–36
2014–15	387 005	24 470	6.3	1	0.04	21	11–32
2015–16	623 659	40 510	6.5	3	0.07	51	31–76
2016–17	497 967	55 041	11.1	0	0.00	18	8–31
2017–18	569 203	51 020	9.0	3	0.06	41	24–63
2018–19	435 998	52 615	12.1	0	0.00	25	11–48
2019–20	397 825	54 239	13.6	1	0.02	22	10–41
2020–21	351 693	62 888	17.9	13	0.21	24	16–35
2021–22	186 781	14 750	7.9	1	0.07	14	6–25
2022–23	386 781	0	0.0	0		17	7–30

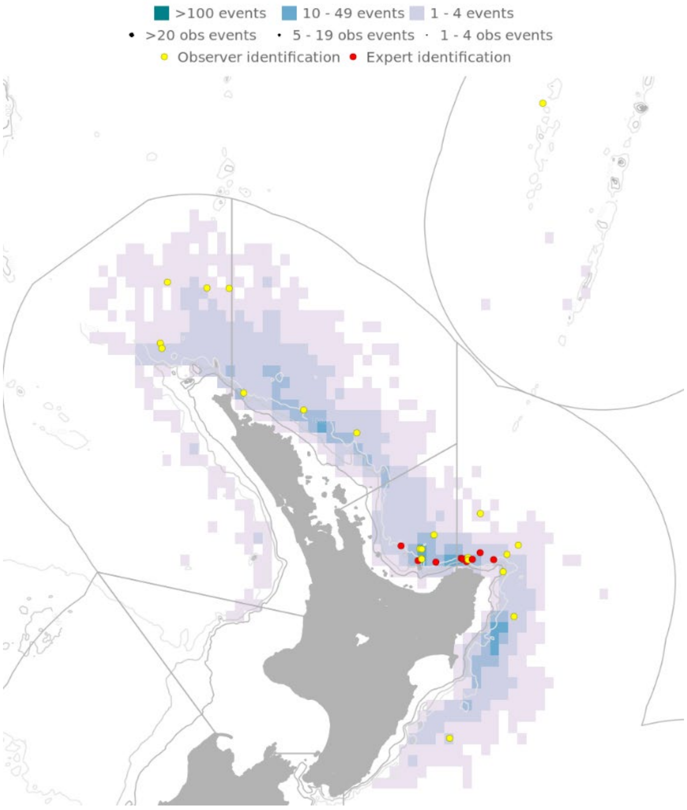


Figure 6: Distribution of fishing effort targeting bigeye tuna and observed sea turtle captures, 2002–03 to 2022–23. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by red and yellow 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 by Abraham & Berkenbusch (2019).

4.2.3 Incidental catch of marine mammals

4.2.3.1 Cetaceans

Cetaceans are dispersed throughout New Zealand waters (Perrin et al. 2008). The spatial and temporal overlap of commercial fishing grounds and cetacean foraging areas has resulted in cetacean captures in fishing gear (Abraham & Thompson 2009, 2011). The analytical methods used to estimate capture numbers across the commercial fisheries have depended on the quantity and quality of the data, in terms of the numbers observed captured and the representativeness of the observer coverage. Previously, ratio estimation was used to calculate total captures in longline fisheries by target fishery fleet and area (Baird 2008) and by all fishing methods (Abraham et al. 2010), but this is only reliable is observer coverage is random and representative of all fishing effort.

Between 2002–03 and 2022–23, there was one observed unidentified cetacean capture, two common dolphin, one orca, and one long-finned pilot whale in bigeye longline fisheries (Table 10 and 11, Figure 7). The capture of the unidentified cetacean took place off the west coast North Island and the common dolphins were caught in the Bay of Plenty and off Northland and Hauraki Gulf (Figure 8). The long-finned pilot whale recorded in 2018 was the first capture recorded off the east coast North Island. All captures were recorded as being caught and released alive.

Table 10: Number of observed cetacean captures in bigeye tuna longline fisheries, 2002–03 to 2022–23, by species and area. Data preparation methods are described by Abraham & Berkenbusch (2019).

Species	East Coast North Island	West Coast North Island	Bay of Plenty	Northland and Hauraki	Total
Unidentified cetacean		1			1
Common dolphin			1	1	2
Pilot whale long-finned	1				1
Orca	1				1
Total	2	1	1	1	5

Table 11: Effort and cetacean captures by fishing year in bigeye tuna fisheries. 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). Data preparation methods are described by Abraham & Berkenbusch (2019).

	Fishing effort			Observed captures	
Fishing year	All hooks	Observed hooks	% observed	Number	Rate
2002–03	5 188 207	80 640	1.6	0	0.000
2003–04	3 507 507	120 740	3.4	1	0.008
2004–05	1 649 081	33 116	2.0	0	0.000
2005–06	1 869 436	45 100	2.4	0	0.000
2006–07	1 532 071	84 150	5.5	0	0.000
2007–08	967 829	24 295	2.5	0	0.000
2008–09	1 565 517	91 295	5.8	0	0.000
2009–10	1 247 437	76 859	6.2	0	0.000
2010–11	1 646 956	87 730	5.3	0	0.000
2011–12	1 291 923	39 210	3.0	0	0.000
2012–13	994 535	60 280	6.1	0	0.000
2013–14	743 981	29 651	4.0	0	0.000
2014–15	387 005	24 470	6.3	1	0.041
2015–16	623 659	40 510	6.5	0	0.000
2016–17	497 967	55 041	11.1	1	0.018
2017–18	569 203	51 020	9.0	1	0.020
2018–19	435 998	52 615	12.1	0	0.000
2019–20	397 825	54 239	13.6	0	0.000
2020–21	351 693	62 888	17.9	1	0.016
2021–22	186 781	14 750	7.9	0	0.000
2022–23	386 781	0	0.0	0	0.000

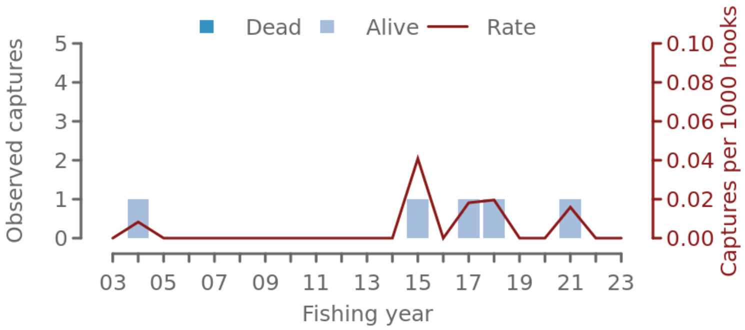


Figure 7: Observed captures of cetaceans in bigeye longline fisheries from 2002–03 to 2022–23. Data grooming methods are described by Abraham & Berkenbusch (2019).

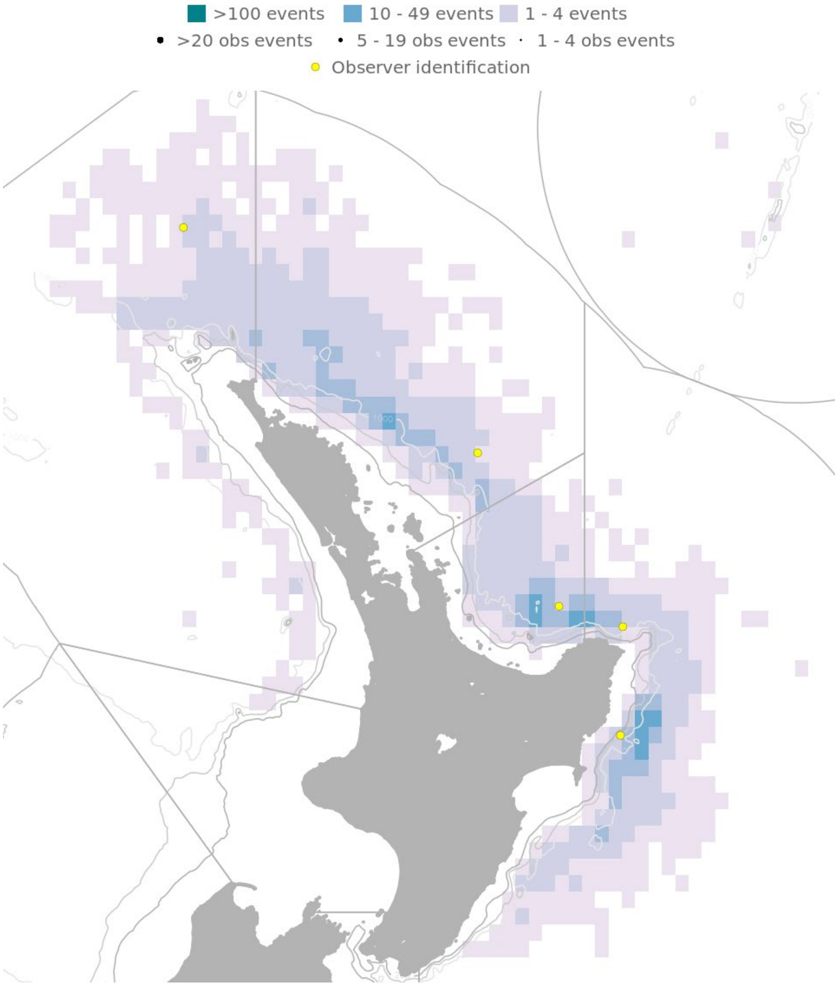


Figure 8: Distribution of fishing effort targeting bigeye tuna and observed cetacean captures, 2002–03 to 2022–23. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by yellow 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 by Abraham & Berkenbusch (2019).

4.2.3.2 New Zealand fur seals

Currently, New Zealand fur seals are dispersed throughout New Zealand waters, especially 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.

The analytical methods used to estimate capture numbers across the commercial fisheries have depended on the quantity and quality of the data, in terms of the numbers observed captured and the representativeness of the observer coverage. New Zealand fur seal captures in surface longline fisheries have been generally observed in waters south and west of Fiordland, but also in the Bay of Plenty/East Cape area. The capture rates include animals that are released alive (100% of observed surface longline capture in 2008–09, Thompson & Abraham 2010). Between 2002–03 and 2022–23, there were seven observed captures of New Zealand fur seals in bigeye longline fisheries (Table 12 and 13, Figure 9 and 10).

Table 12: Number of observed New Zealand fur seal captures in bigeye tuna longline fisheries, 2002–03 to 2022–23 by species and area. Data grooming methods are described by Abraham & Berkenbusch (2019).

	East Coast North Island	Bay of Plenty	West coast North Island	Total
New Zealand fur seal	4	1	2	7

Table 13: Effort and captures of New Zealand fur seals by fishing year in bigeye tuna longline fisheries. 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 by Abraham & Berkenbusch (2019).

	Fishing effort			Observed captures		Estimated captures	
Fishing year	All hooks	Observed hooks	% observed	Number	Rate	Mean	95% c.i.
2002–03	5 188 207	80 640	1.6	0	0.00	18	4-42
2003–04	3 507 507	120 740	3.4	0	0.00	14	2-33
2004–05	1 649 081	33 116	2.0	0	0.00	6	1-17
2005–06	1 869 436	45 100	2.4	0	0.00	10	2-24
2006–07	1 532 071	84 150	5.5	0	0.00	7	1-17
2007–08	967 829	24 295	2.5	2	0.08	7	2-15
2008–09	1 565 517	91 295	5.8	0	0.00	7	1-18
2009–10	1 247 437	76 859	6.2	0	0.00	6	0-16
2010–11	1 646 956	87 730	5.3	0	0.00	6	1-16
2011–12	1 291 923	39 210	3.0	0	0.00	5	0-14
2012–13	994 535	60 280	6.1	0	0.00	4	0-11
2013–14	743 981	29 651	4.0	0	0.00	3	0-8
2014–15	387 005	24 470	6.3	0	0.00	2	0-6
2015–16	623 659	40 510	6.5	0	0.00	4	0-11
2016–17	497 967	55 041	11.1	0	0.00	2	0-7
2017–18	569 203	51 020	9.0	0	0.00	3	0-9
2018–19	435 998	52 615	12.1	0	0.00	3	0-8
2019–20	397 825	54 239	13.6	1	0.02	5	1-13
2020–21	351 693	62 888	17.9	4	0.06	7	4-14
2021–22	186 781	14 750	7.9	0	0.00	2	0-7
2022–23	386 781	0	0.0	0		5	0-16

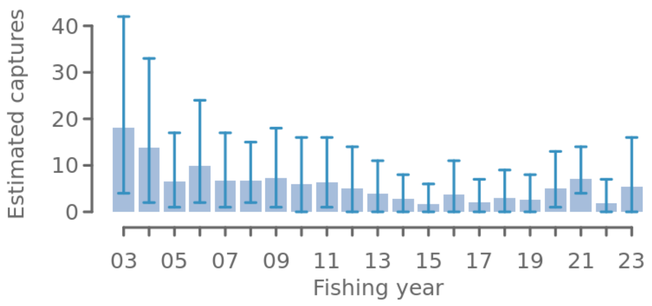


Figure 9: Estimated captures of New Zealand fur seals in bigeye tuna longline fisheries from 2002–03 to 2022–23. Data grooming methods are described by Abraham & Berkenbusch (2019).

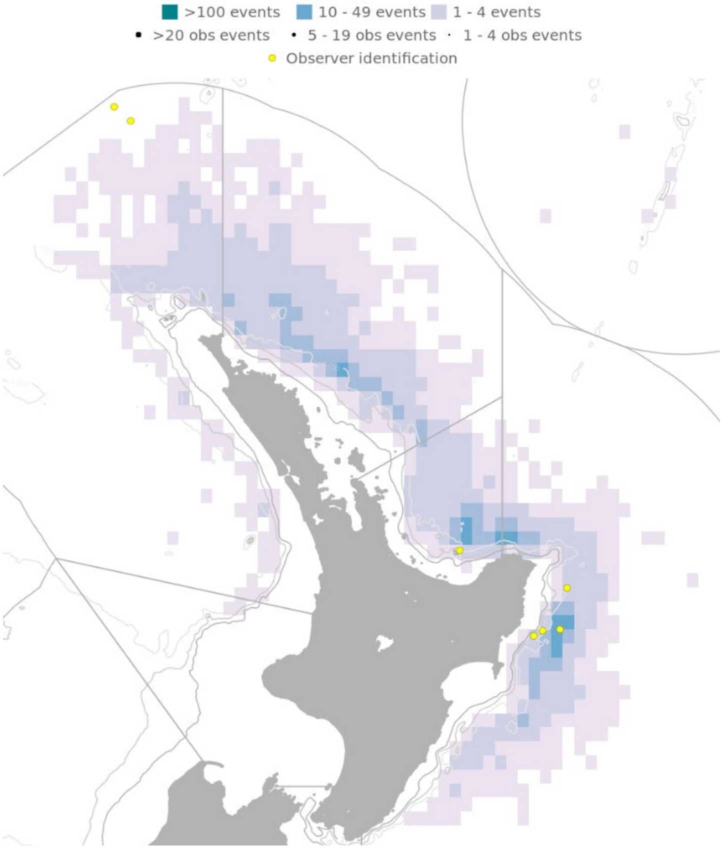


Figure 10: Distribution of fishing effort targeting bigeye tuna and observed New Zealand fur seal captures, 2002–03 to 2022–23. Fishing effort is mapped into 0.2-degree cells, with the colour of each cell being related to the amount of effort. Observed fishing events are indicated by black dots, and observed captures are indicated by yellow 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 by Abraham & Berkenbusch (2019).

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 caught species (by number), followed by lancetfish and porbeagle shark (Table 14).

Table 14: Total estimated catch (numbers of fish) of common bycatch species in the New Zealand surface longline fishery as estimated from observer data from 2017 to 2022. Observer data too limited to raise to the fleet for 2023. Also provided is the percentage of these species retained (2022 data only) and the percentage of fish that were alive when discarded, N/A (none discarded).

Species	2017	2018	2019	2020	2021	2022	% retained (2022)	discards % alive (2022)
Blue shark	49 924	63 618	89 377	37 093	39 524	65 277	0	91.9
Porbeagle shark	3 101	2 594	2 883	1 320	2 248	2 810	0	29.2
Lancetfish	13 274	13 163	18 747	11 457	4 211	2 212	0	2.1
Butterfly tuna	406	419	348	120	388	663	96.0	0
Moonfish	2 022	2 698	1 975	1 834	1 033	526	100.0	N/A
Oilfish	227	602	417	1 149	504	510	0	74.3
Pelagic stingray	1 798	2 949	526	1721	3 182	508	0	97.1
Ray's bream	2 421	1 579	1 949	3 211	2 514	494	90.0	10.0
Mako shark	1 391	2 721	1 138	859	933	310	0	72.2
Striped marlin	290	247	157	279	426	175	0	66.7
Escolar	300	594	488	808	388	146	0	30.0
Skipjack tuna	57	184	8	134	110	117	100.0	N/A
Rudderfish	680	253	186	164	221	80	66.7	33.3
Dealfish	72	25	23	69	18	80	0	33.3
Sunfish	1 648	3 648	1 982	1 618	1 537	56	0	100.0
Big scale pomfret	17	34	0	52	17	53	0	50.0
School shark	59	187	116	29	64	27	100.0	N/A
Deepwater dogfish	32	6	90	29	42	27	0	100.0
Thresher shark	260	253	193	269	161	15	0	0

4.4 Benthic interactions

There are no known interactions with benthic habitats.

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 surface longline fleet is not spatially and temporally representative of the fishing effort.

5. STOCK ASSESSMENT

With the establishment of the WCPFC in 2004, stock assessments of the WCPO stock of bigeye tuna are undertaken by the Oceanic Fisheries Programme (OFP) of Secretariat of the Pacific Community under contract to WCPFC. As noted above, there is continuing work on a Pacific-wide bigeye assessment.

No assessment is possible for bigeye within the New Zealand EEZ because the proportion of the total stock found within New Zealand fisheries waters is unknown and is likely to vary from year to year.

The bigeye stock assessment in the western and central Pacific Ocean was fully assessed in 2023 in paper SC-19-SA-WP-05. An additional three years of data were available since the previous assessment in 2020, and the model includes data to the end of 2021. New developments to the stock assessment include:

- Conversion from a catch-errors to a catch-conditioned modelling framework, and the inclusion of a likelihood component for the CPUE from the index fisheries.
- Change from using VAST to sdmTMB to standardise the input CPUE series and the inclusion of additional covariates in the CPUE model.
- Different CPUE variances used for the CPUE associated with each index fishery, applying a new approach to estimate these variances.
- Internal estimation of natural mortality using the Lorenzen functional form for natural mortality at age.
- Additional procedures adopted to achieve more reliable model convergence, including extensive jittering and checking the Hessian status for all grid models.
- Integration of parameter estimation uncertainty with model-based uncertainty across the model grid for the key management reference points.
- Additional size composition filtering.
- Modifications to selectivity estimation settings, changes to fisheries with non-decreasing selectivity.
- Adoption of revised tagger effect modelling framework, reverting to assumptions similar to those used in 2017.
- Changes to size data weighting used in the structural uncertainty grid.
- Use of conditional age-at-length data, and internal estimation of growth, with alternative weighting of these data included in the structural uncertainty grid.

The general conclusions of this assessment are as follows:

- The spawning potential of the stock has become more depleted across all model regions until around 2010, after which it has become more stable.
- Average fishing mortality rates for juvenile and adult age-classes have increased throughout the period of the assessment until around 2000, after which they have stabilised,

but with high inter-annual variability for juveniles. Juveniles have experienced considerably higher fishing mortality than adults.
- Overall, the median depletion from the uncertainty grid for the recent period (2018–2021; $SB_{recent}/SB_{F=0}$) is estimated at 0.35 (80 percentile range including estimation and structural uncertainty 0.30–0.40, full range 0.25–0.46).
- No models from the uncertainty grid, including estimation uncertainty, estimate the stock to be below the limit reference point (LRP) of 20% $SB_{F=0}$.
- CMM 2021-01 contains an objective to maintain the spawning biomass depletion ratio above the average for 2012–2015, $SB_{2012-2015}/SB_{F=0}$, which is a value of 0.34 calculated across the unweighted grid. Based upon the estimates of $SB_{recent}/SB_{F=0}$ of 0.35 this objective has currently been met.
- Recent (2017–2020) median fishing mortality (F_{recent}/F_{MSY}) was 0.59 (80 percentile range, including estimation and structural uncertainty 0.46–0.74, full range 0.37–0.99).
- Assessment results suggest that the bigeye stock in the WCPO is not overfished, nor undergoing overfishing.

Across the 54 models in the structural uncertainty grid, the most important factors when evaluating stock status were: the assumed tag mixing period and the steepness of the stock recruitment relationship, followed by weighting of the size composition data. The move away from using the complex fixed functional form for natural mortality at age function, as used in the previous assessment, to estimating natural mortality internally with a Lorenzen functional form followed recommendations from various reviews on stock assessment methods and was supported by a recent tuna stock assessment good practices workshop. The internal estimation of natural mortality allowed natural mortality to be dropped from the structural uncertainty grid. SC19 recommended that the proposed axes of uncertainty be accepted and that all models should be weighted equally (Table 15). SC19 noted that an important improvement in the structural uncertainty grid was the inclusion of estimation uncertainty for each of the models in the grid.

SC19 adopted several research recommendations for the further development and improvement of the WCPO bigeye tuna stock assessment:

- Continued collection of more representative biological data (e.g., age composition) and tagging data.
- Develop additional CPUE index series testing key uncertainties about the analysis (e.g., regional vs. global model, classification of catchability vs. abundance covariates, etc.) and explore those as one-off sensitivities to the stock assessment.
- Consideration of options to account for effort creep in CPUE standardisation and/or the assessment model.
- Simulation study to explore appropriate spatial structure of the stock assessment with a focus on simplifying the spatial structure (e.g., areas-as-fleets and/or 6 region structure) given the estimates of limited movement rates among regions.
- Investigation of the 2023 model specifications with respect to the increase in unfished *SSB* overtime for the tropical regions (3, 4, 7, and 8).
- Yield per recruit analyses comparing fishery sectors with different selectivity patterns.
- Evaluation of the variability and plausibility of estimated growth and mortality-at-age relationship across the structural uncertainty grid.
- Additional one-off sensitivities exploring key uncertainties in biological assumptions, model specification, and data inputs (e.g., tag mixing, data weighting, and growth).
- Identification of key parameters that are either highly correlated or highly sensitive to the jittering procedure to inform possible changes in model specification with the aim to decrease model complexity and/or sensitivity to starting conditions.
- Exploration of seasonal and regional growth traits for the stock assessment.
- Comprehensive review of the representativeness of the size composition data given conflicts identified in the likelihood profiles.
- Investigation of the 2023 model specifications that led to the inversion of the effect of

the weight vs. tagging data signal on the total biomass, as shown in the likelihood profile.
- Further exploration of the advantages and disadvantages of strategies to decrease model sensitivity to starting conditions, including but not limited to multi-start approaches.
- Pursue development of tag mixing diagnostics and approaches and investigate the impacts of tag mixing assumptions.

Tag mixing in particular is a key issue for a tag-based model that deserves more time. Preliminary analysis of individual tagging events was undertaken in 2023 but more could potentially be achieved by extending this approach. Tags from region 9 were clearly influential and appear to behave differently. While the tagging data are very valuable for this assessment, the current tagging programmes could be better balanced spatially and temporally to inform the assessment.

Data weighting is an area that is difficult given the complexity and running time for these models. Iterative schemes have been used elsewhere to weight compositional data and conditional age-at length data. While running these iterative approaches to convergence is clearly not practical, this is an area that could be explored.

Additional biological sampling, including age samples, and potentially the use of epigenetic ageing is very important for these models. The sample size of only 1004 otoliths is a major weakness in the data input to this assessment. A well balanced statistically designed sampling programme to achieve representative temporal and spatial samples over the full range of the assessment area would be beneficial to this assessment and an increase in investment will improve the reliability of the model outputs.

Simpler regional structures are an area that deserves more attention. This assessment is large and complex, so there is potentially much to gain though judicious simplification. While a simpler structure could have modelling benefits, there are also potential issues with the eastern boundary. Recaptures of tagged fish demonstrate that fish cross this boundary and the large catches of bigeye near this boundary warrant consideration of alternatives assessment structures.

The spatial structure used in the 2023 stock assessment is shown in Figure 11. Time series of total annual catch by fishing gear over the full assessment period is shown in Figure 12. The time series of total annual catch by fishing gear and assessment region is shown in Figure 13. Estimated annual spawning potential, average recruitment, and total biomass by model region are shown in Figure 14. Estimated trend in spawning potential depletion ($SB/SB_{F=0}$) for the 54 models in the structural uncertainty grid is shown in Figure 15, and juvenile and adult fishing mortality rates from the diagnostic model is shown in Figure 16. Estimates of the reduction in spawning potential due to fishing by region are shown in Figure 17. A comparison of the dynamic *MSY* for the diagnostic model compared with annual catch by the main gear types is shown in Figure 18, and estimated age specific fishing mortality for the diagnostic model, by region and overall are in Figure 19.

SC19 noted that the preliminary estimate of total catch of WCPO bigeye tuna for 2022 was 140 664 mt which was similar to the 2021 level. Longline catch in 2022 (54 800 mt) was similar to the 2021 catch and lower than the recent ten-year average and understood to be partly due to the impacts of the COVID-19 pandemic. Purse-seine catch in 2022 (62 811 mt) was also similar to the 2021 catch, and lower than the recent ten-year average (Figure 12).

The 2023 WCPO bigeye tuna stock assessment median depletion from the model grid for the recent period (2018–2021; $SB_{recent}/SB_{F=0}$) was 0.35 (10th to 90th percentile interval of 0.30 to 0.40, including estimation and structural uncertainty, Table 16). For all models in the grid $SB_{recent}/SB_{F=0}$ was above the biomass limit reference point. The recent median fishing mortality (2017–2020; F_{recent}/F_{MSY}) was 0.59 (10th to 90th percentile interval of 0.46 to 0.74, including estimation and structural uncertainty, Table 16). For all models in the grid, F_{recent}/F_{MSY} was less than one.

SC19 noted that the results show that both total and spawning potential has been continuously declining since the late 1950s until the mid-1970s, followed by a more gradual decline to the present (Figure 14).

SC19 noted that the catch in the last year of the assessment (2021) was less than the median *MSY* (164 640 mt), which is a 17% increase in the estimated *MSY* for bigeye tuna from the 2020 stock assessment (140 720 mt).

Majuro (Figure 20) and Kobe (Figure 21) plots show that the stock status estimates across the 54 models are all within plot zones that indicate that the stock is not overfished nor undergoing overfishing.

Table 15: Description of the updated structural sensitivity grid used to characterise uncertainty in the assessment with bolded values indicating the diagnostic case.

Axis	**Value 1**	**Value 2**	**Value 3**
Steepness	0.65	**0.8**	0.95
Tag mixing (# quarters)	1	**2**	
Size data weighting divisor	10	**20**	40
Age data weighting	0.5	**0.75**	1

Table 16: Summary of reference points over the 54 models in the structural uncertainty grid. Note that "recent" is the average over the period 2018–2021 for *SB* and fishing mortality, while "latest" is 2021. The values of the upper 90th and lower 10th percentiles of the empirical distributions are also shown. F_{mult} is the multiplier of recent (2018–2021) fishing mortality required to produce *MSY*.

	Mean	**Median**	**Minimum**	**10th percentile**	**90th percentile**	**Maximum**
C_{latest}	139 314	139 199	138 527	138 947	139 939	140 347
$Y_{Frecent}$	37 982	37 805	33 400	34 365	42 369	42 980
F_{MSY}	0.06	0.06	0.04	0.04	0.07	0.08
F_{mult}	1.69	1.67	2.27	2.17	1.35	1.22
MSY	162 248	164 640	137 920	143 112	180 820	184 440
F_{recent}/F_{MSY}	0.59	0.59	0.37	0.46	0.74	0.99
$SB_{F=0}$	1 952 050	1 921 715	1 460 378	1 612 630	2 356 598	2 561 690
SB_{MSY}	393 037	376 300	225 100	277 230	534 330	595 900
$SB_{MSY}/SB_{F=0}$	0.20	0.20	0.15	0.17	0.23	0.24
$SB_{latest}/SB_{F=0}$	0.34	0.34	0.27	0.30	0.38	0.40
SB_{latest}/SB_{MSY}	1.76	1.77	1.16	1.28	2.31	2.46
$SB_{recent}/SB_{F=0}$	0.35	0.35	0.28	0.31	0.40	0.41
SB_{recent}/SB_{MSY}	1.82	1.83	1.20	1.32	2.38	2.54
Including estimation uncertainty						
	Mean	**Median**	**Minimum**	**10th percentile**	**90th percentile**	**Maximum**
$SB_{recent}/SB_{F=0}$	0.35	0.35	0.25	0.30	0.40	0.46
F_{recent}/F_{MSY}	0.59	0.59	0.37	0.46	0.74	0.99
SB_{recent}/SB_{MSY}	1.82	1.79	0.94	1.32	2.41	2.96

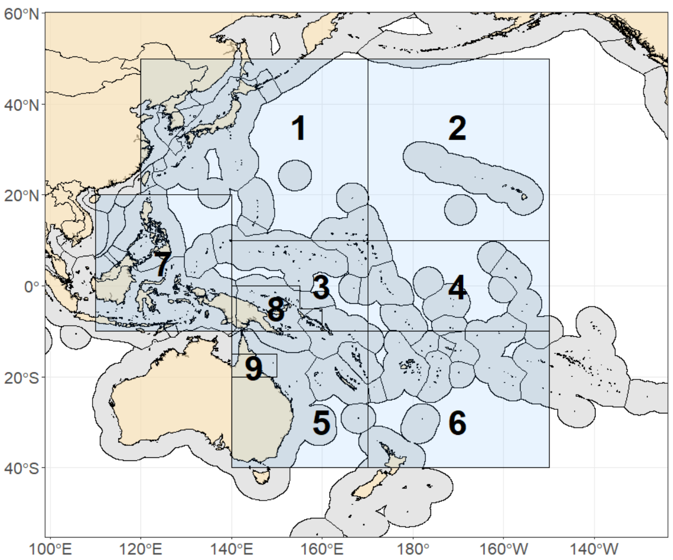


Figure 11: Spatial structure for the 2023 bigeye tuna stock assessment.

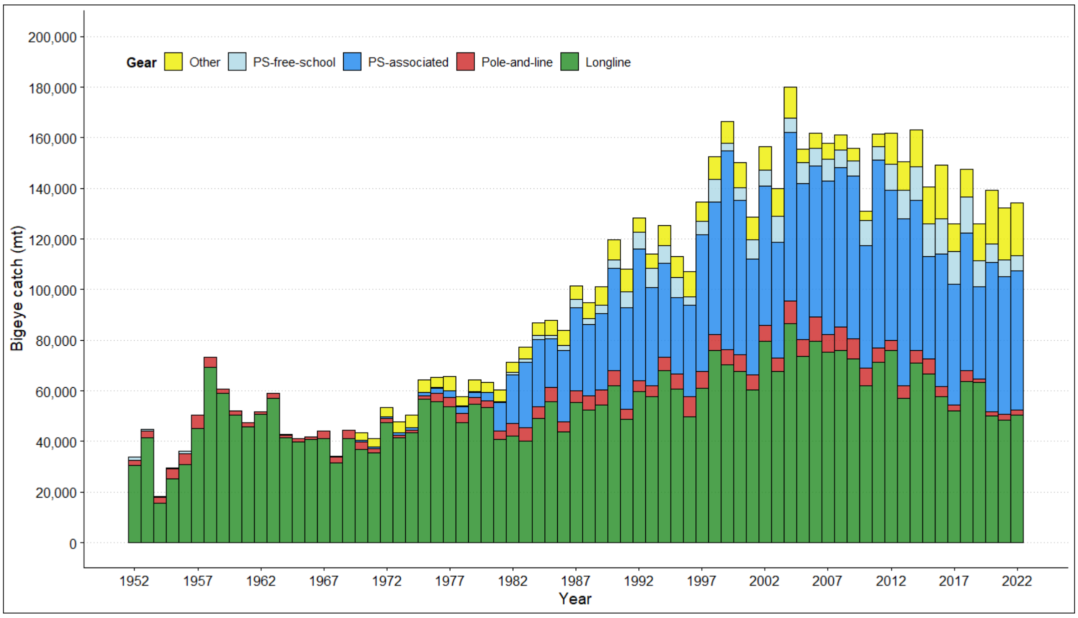


Figure 12: Time series of total annual catch (1000s mt) by fishing gear for the diagnostic model over the full assessment period. The different colours refer to longline (green), pole-and-line (red), purse seine associated (mid blue), purse seine unassociated (light blue), and miscellaneous (yellow). Note that the catch by longline gear has been converted into catch-in-weight from catch-in-numbers and so may differ from the annual catch estimates presented by Williams & Ruaia. (2023), however these catches enter the model as catch-in-numbers.

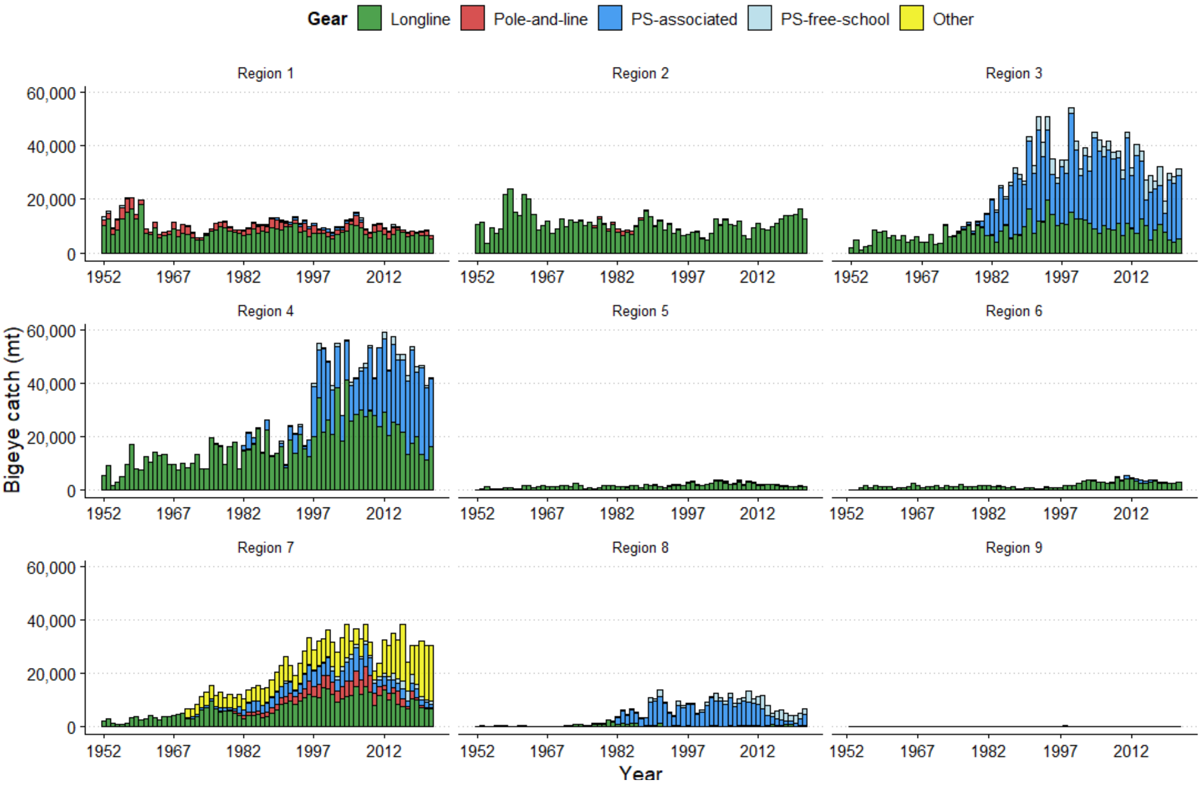


Figure 13: Annual catches of bigeye by gear type for each of the nine model regions.

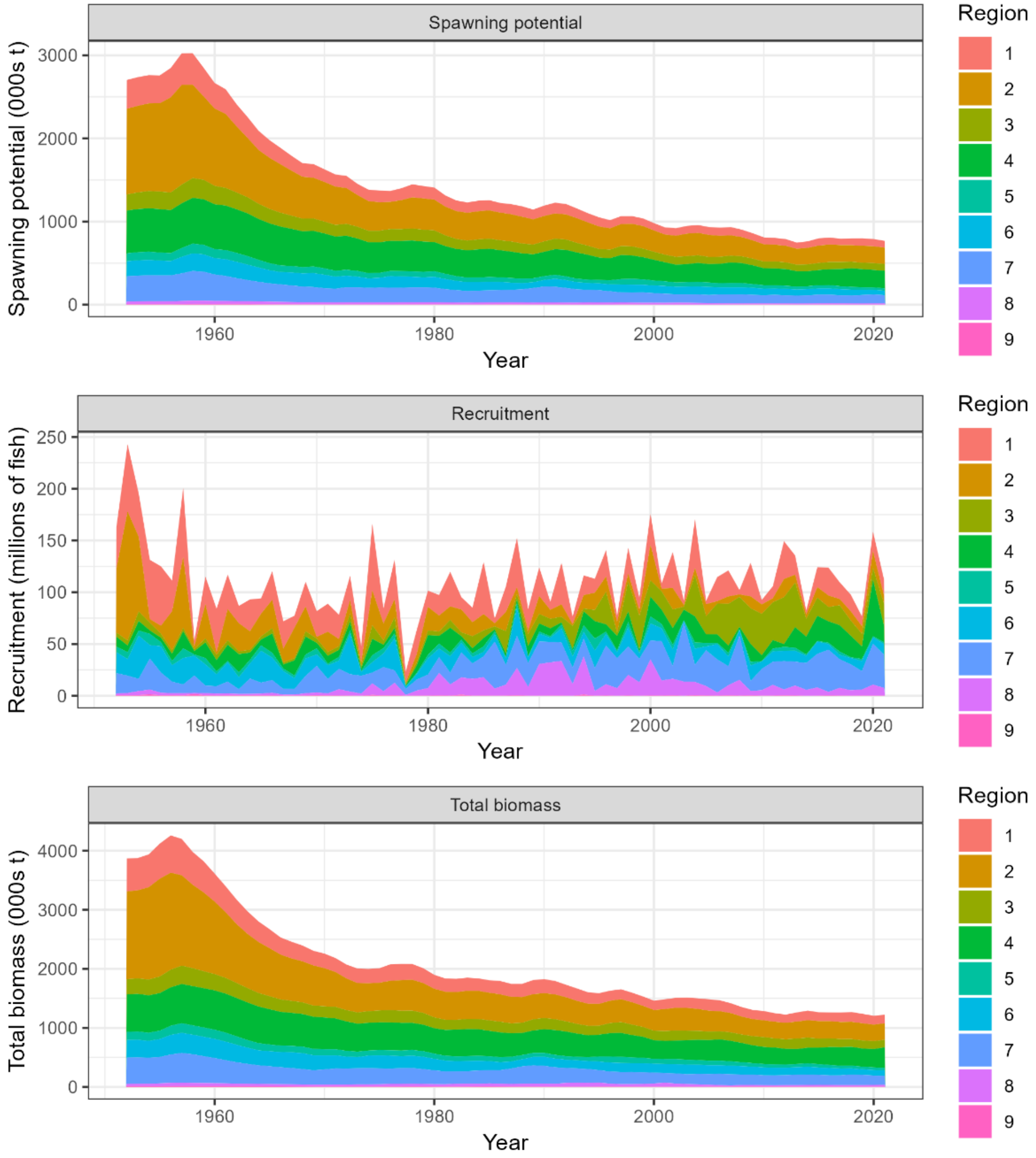


Figure 14: Time series of estimated annual spawning potential, recruitment, and total biomass by model region for the diagnostic model, showing the relative proportions among regions. Note the data represent the averages of the quarterly model time steps for each year for spawning potential and total biomass and the sum of the quarterly recruitment estimates for annual recruitment.

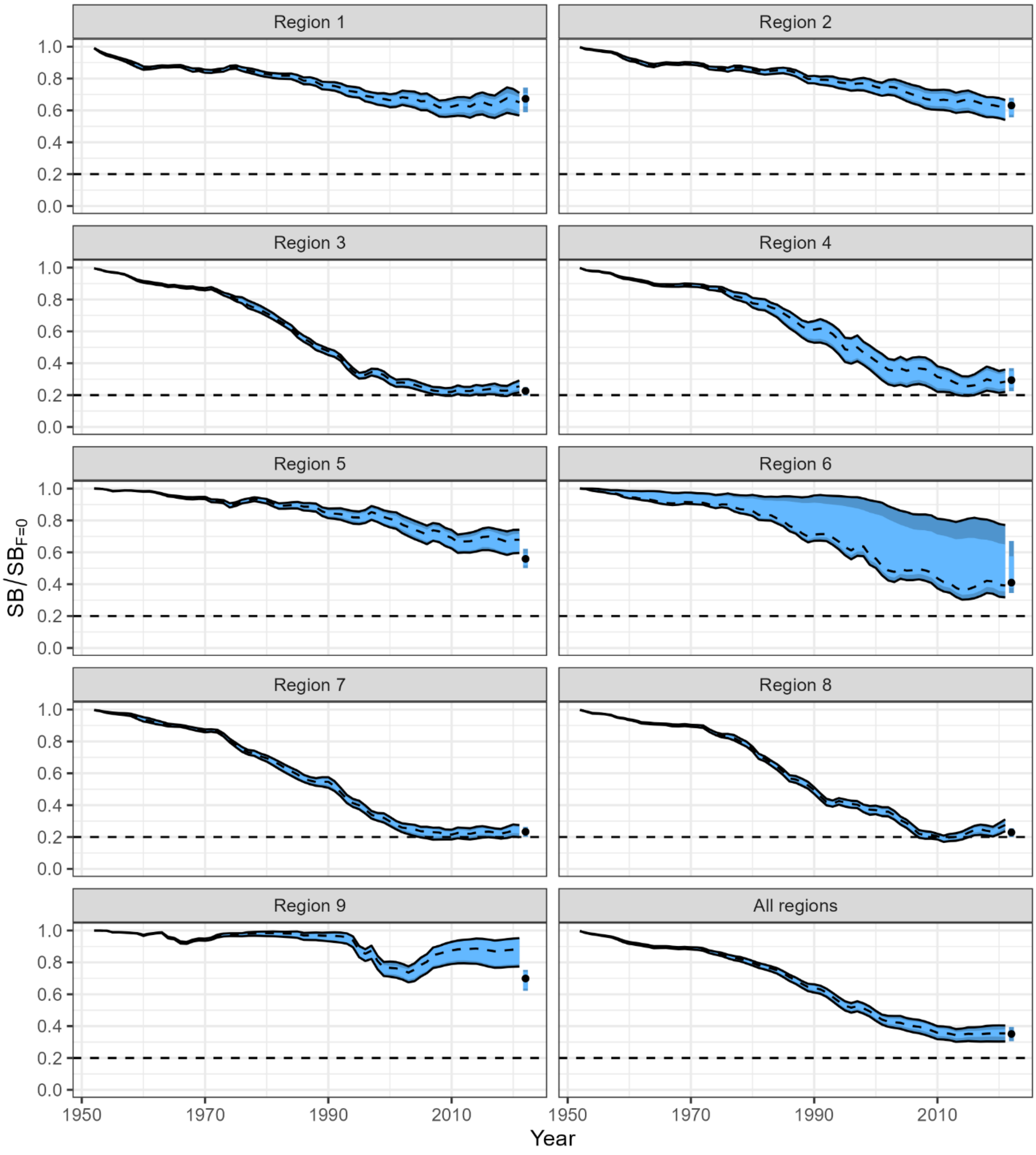


Figure 15: Estimated spawning depletion across all models in the structural uncertainty grid over the period 1952–2021. The lighter band shows the 25th and 75th percentiles, and the dark band shows the 10th and 90th percentiles of the model estimates. The bar at the right of each ribbon indicates the median (black dot) with the 10th and 90th percentiles for $SB_{recent}/SB_{F=0}$.

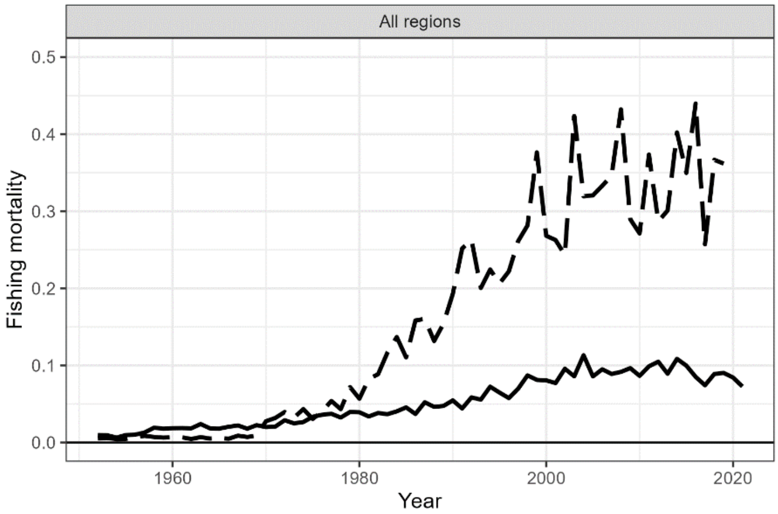


Figure 16: Estimated annual average adult (solid line) and juvenile (dashed line) fishing mortality for the 2023 diagnostic model.

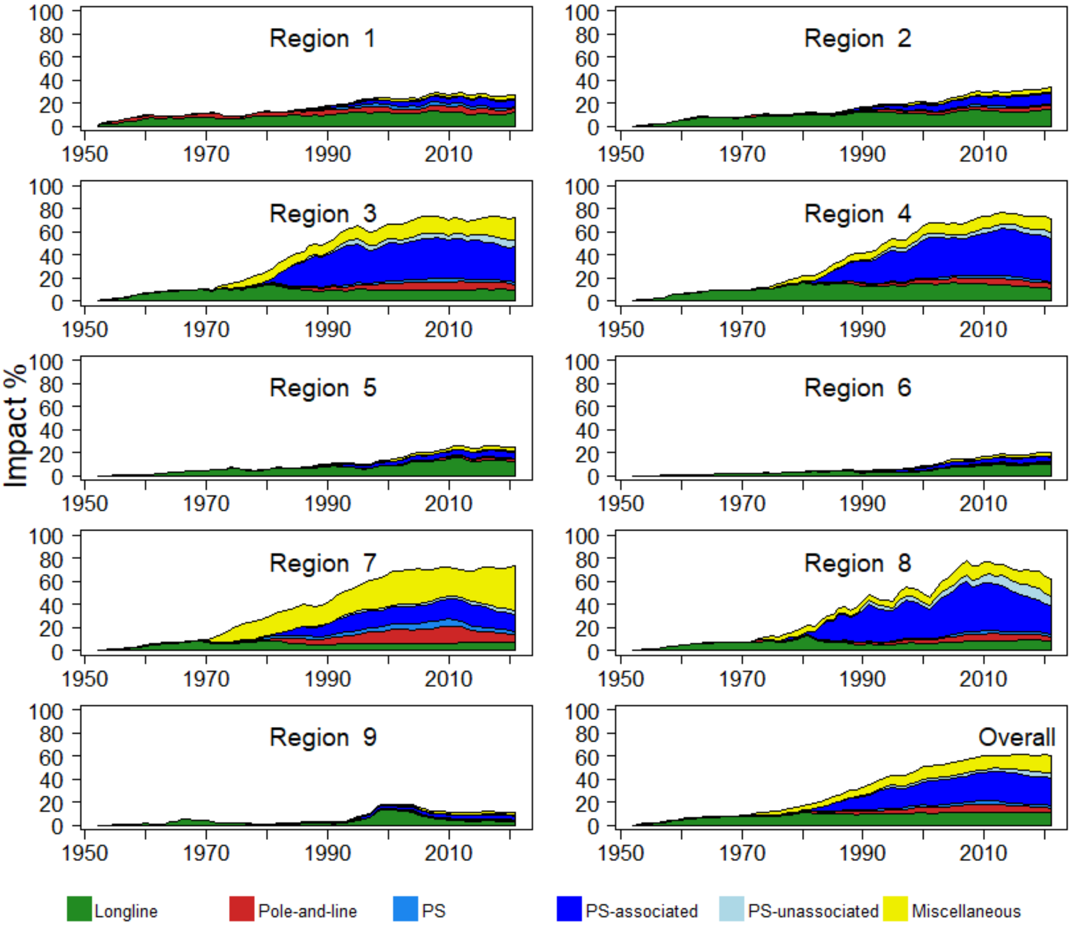


Figure 17: Estimates of reduction in spawning potential due to fishing (fishery impact = (1-$SB_t/SB_{t,F=0}$) * 100%) by region, and over all regions (lower right panel), attributed to various fishery groups for the 2023 diagnostic model.

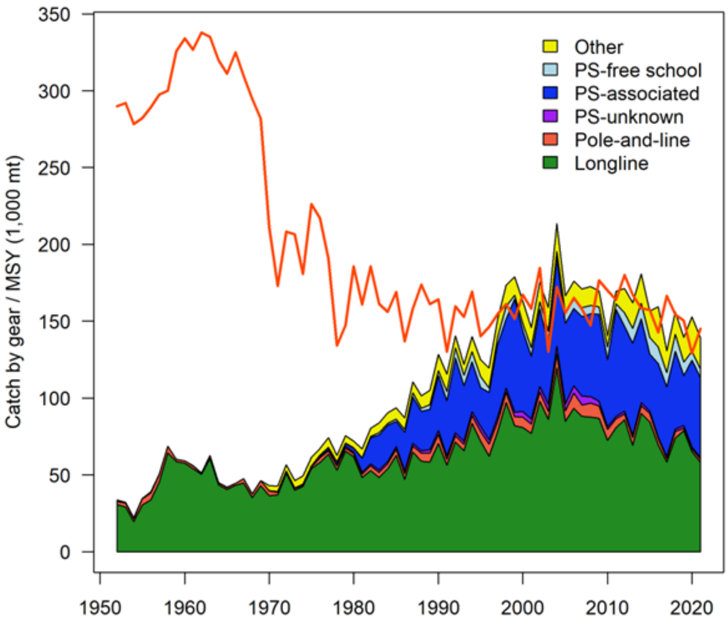


Figure 18: History of the annual estimates of *MSY* (red line) for the diagnostic model compared with annual catch by the main gear types. Note that this is a 'dynamic' *MSY*.

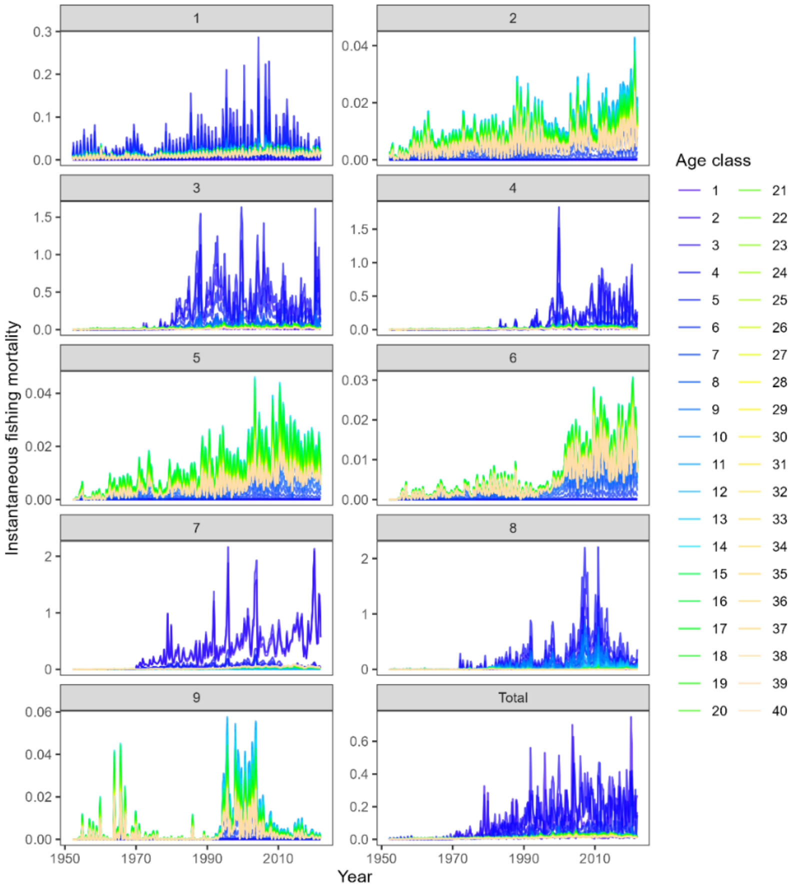


Figure 19: Estimated age specific fishing mortality for the diagnostic model, by region and overall.

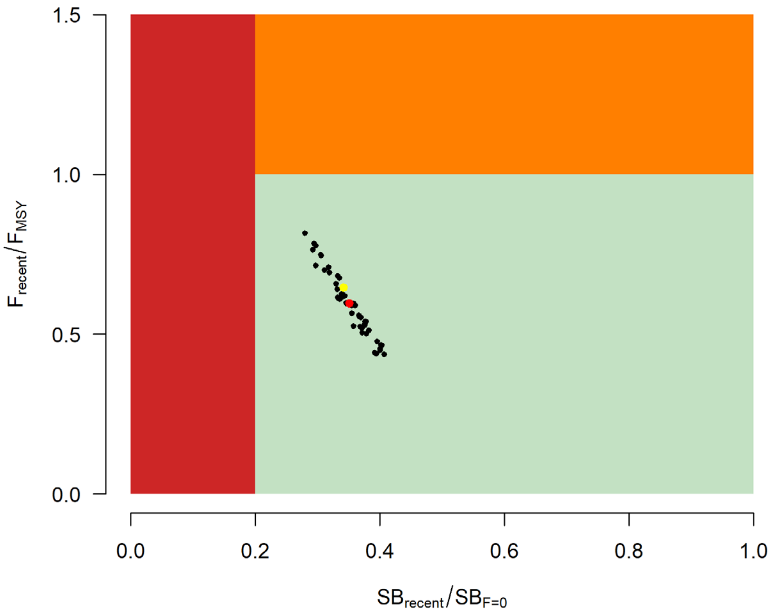


Figure 20: Majuro plot for the recent spawning potential (2018–2021) summarising the results for each of the models in the structural uncertainty grid. The plots represent estimates of stock status in terms of spawning biomass depletion and fishing mortality. The yellow point is the 2023 diagnostic model and red point is the median.

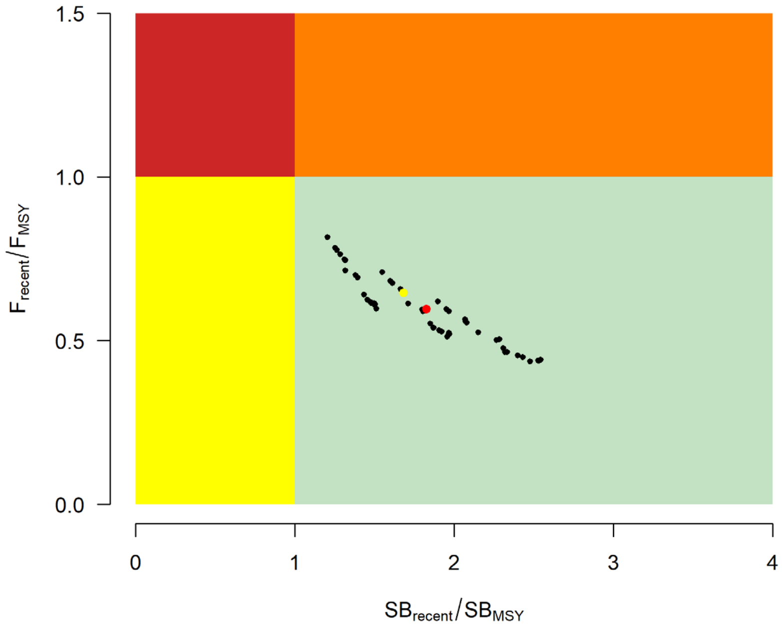


Figure 21: Kobe plot for the recent spawning potential (2018–2021) summarising the results for each of the models in the structural uncertainty grid. The plots represent estimates of stock status in terms of spawning biomass depletion and fishing mortality. The yellow point is the 2023 diagnostic model and red point is the median.

SC19 noted that the objective for bigeye tuna in CMM 2021-01 (the Tropical Tuna Measure)—to maintain the spawning biomass depletion ratio at or above the average $SB/SB_{F=0}$ for 2012–2015—is being achieved. $SB_{recent}/SB_{F=0}$ (35%) is very close to the average $SB/SB_{F=0}$ for 2012–2015 (34%) calculated across the unweighted grid.

The WCPO bigeye tuna spawning biomass is above the biomass LRP, and F_{recent} is below F_{MSY} for all models in the uncertainty grid. The stock is very likely not experiencing overfishing (100% probability $F_{recent}<F_{MSY}$) and is not in an overfished condition (0% probability $SB_{recent}/SB_{F=0}<$LRP).

SC19 also noted that average fishing mortality rates for juvenile and adult age classes have increased throughout the period of the assessment (Figure 19), although more so for juveniles which have experienced considerably higher annual fishing mortality than adults (Figure 16). The purse seine associated fishery has the most impact, with that of the miscellaneous and longline fisheries also being notable (Figure 17). Higher fishing mortality rates on juvenile bigeye tuna reduce the realised yield per recruit for the bigeye fishery.

SC19 noted that levels of fishing mortality and depletion differ among regions, and that fishery impact was higher in the tropical regions (regions 3, 4, 7, and 8 in the stock assessment model), with particularly high fishing mortality on juvenile bigeye tuna in these regions.

There is also evidence that the overall stock status is buffered with biomass and low exploitation in the temperate region (1, 2, 6, and 9) and most of the predicted movement is within the equatorial region. Exchange rates between temperate and tropical regions are estimated to be low.

SC19 noted that the reduction of fishing mortality on fisheries that take juveniles could increase bigeye fishery yields and reduce any further impacts on spawning biomass of this stock. SC19 also noted that this could require considering the impact on other fisheries and stocks.

The interim objective of bigeye tuna stock under CMM 2021-01 is to maintain the depletion level of the stock at or above the average $SB/SB_{F=0}$ for 2012–2015. The recent depletion level of bigeye tuna is close to this interim objective.

Projection results based on the 2023 bigeye tuna assessment were not available for SC19 to review.

5.1 Estimates of fishery parameters and abundance

There are no fishery-independent indices of abundance for the bigeye stock. Relative abundance information is available from longline catch per unit effort data; details on the analysis of catch and effort data for longline fisheries to provide regional abundance indices are given by Teears et al. (2023). Returns from a large-scale tagging programme undertaken in the early 1990s, and an updated programme from 2007–09 undertaken by the SPC, provided information on rates of fishing mortality, which in turn has improved estimates of abundance.

5.2 Biomass estimates

The 2023 diagnostic model estimates an initial decline in both the total biomass and spawning potential, from the late 1950s until the mid-1970s, followed by a more gradual decline to the present. The pattern in the decline in spawning potential over time, which is consistent with the CPUE indices, is generally similar in all regions, with the early decline to the mid-1970s being more noticeable in regions 1 and 2 than in the other regions.

5.3 Yield estimates and projections

The yield analysis conducted in the 2023 bigeye tuna stock assessment incorporates the spawner recruitment relationship into the equilibrium biomass and yield computations. In the diagnostic model, the steepness of the SRR was fixed at 0.8 so only the scaling parameter was estimated. Other models in the one-off sensitivity analyses and structural uncertainty analyses assume steepness values of 0.65 and 0.95.

The yield distributions under different values of fishing effort relative to the current effort are shown in Figure 22 for select models representing different axes of the structural uncertainty grid (specifically, the two levels of tag mixing). For the diagnostic model, it is estimated that *MSY* would be achieved by increasing fishing mortality by a factor of 1.3, although the resulting increase in yield would be relatively small (3%). The different example yield curves under the alternative mixing assumption display a similar pattern over the scale of fishing mortality although the absolute value of the yield curve and behaviour of the descending limb differs.

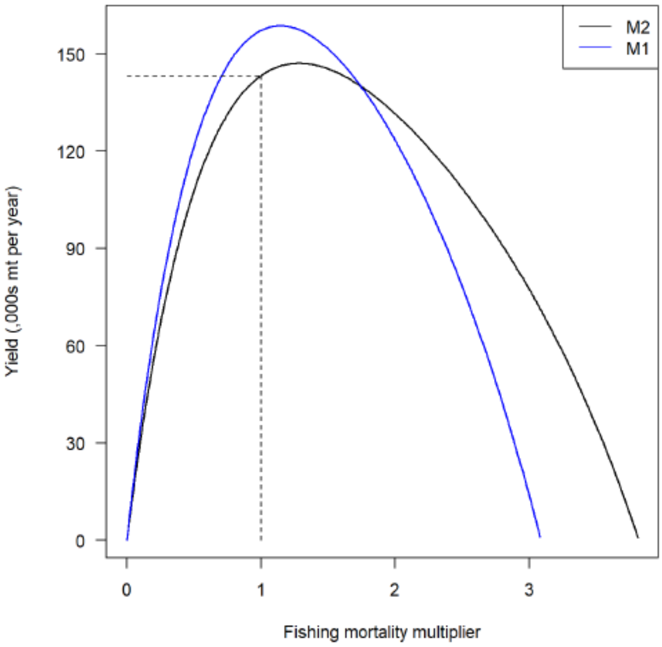


Figure 22: Estimated yield as a function of fishing mortality multiplier for the diagnostic model and the alternative mixing scenario model. The black dashed line indicates the equilibrium yield at current fishing mortality.

The yield analysis also enables an assessment of the *MSY* level that would be theoretically achievable under the different patterns of age-specific fishing mortality observed through the history of the fishery (Figure 18). Prior to 1970, the WCPO bigeye fishery was almost exclusively conducted using longline gear, with a low exploitation of small bigeye. The associated age-specific selectivity pattern resulted in a much higher *MSY* in the early period compared with the recent estimates. This pronounced decline occurred after the expansion of the small-fish fisheries in region 7 and, soon after, the rapid expansion of the purse seine fishery which shifted the age composition of the catch towards much younger fish. This lower *MSY* is due to a combination of fish being removed from the system at smaller sizes and before they have the chance to reproduce.

No estimates of *MCY* and *CAY* are available.

5.4 Reference points

The unfished spawning potential ($SB_{F=0}$) in each time period was calculated given the estimated recruitments and the Beverton-Holt SRR. This offers a basis for comparing the exploited population relative to the population subject to natural mortality only. The WCPFC adopted 20% $SB_{F=0}$ as a limit reference point (LRP) for the bigeye stock where $SB_{F=0}$ for this assessment is calculated as the average over the period 2012–2021.

There is no agreed WCPFC target reference point for the bigeye tuna stock however CMM 2021-01 states in para 11 "*Pending agreement of a target reference point the spawning biomass depletion ratio* ($SB/S_{BF=0}$) *is to be maintained at or above the average* $SB/SB_{F=0}$ *for 2012–2015*". Stock status was referenced against these points by calculating the reference points; $SB_{recent}/SB_{F=0}$ and $SB_{latest}/SB_{F=0}$ where $SB_{F=0}$ is calculated over 2012–2021 and SB_{recent} and SB_{latest} are the mean of the estimated spawning potential over 2018–2021 and 2021, respectively.

The other key reference point, F_{recent}/F_{MSY}, is the estimated average fishing mortality at the full assessment area scale over a recent period of time (F_{recent}; 2017–2020 for this stock assessment) divided by the fishing mortality producing *MSY* which is a product of the yield analysis.

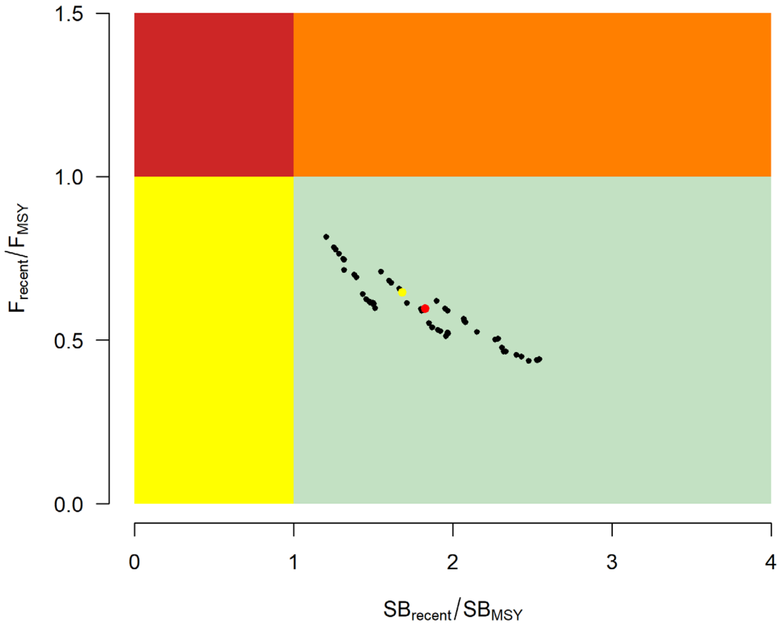
6. STATUS OF THE STOCKS

Stock structure assumptions

The stock is considered to cover the western and central Pacific Ocean. All estimates of biomass in this table refer to spawning biomass (*SB*).

Stock Status		
Most Recent Assessment Plenary Publication Year	2023	
Intrinsic productivity level		
Catch in most recent year of assessment	Year: 2021	Catch: 139 705 t
Assessment Runs Presented	Median of the structural uncertainty grid incorporating estimation uncertainty and 80% Probability Intervals (PI)	
Reference Points	There is no agreed WCPFC target reference point for the bigeye tuna stock however CMM 2021-01 states "*Pending agreement of a target reference point the spawning biomass depletion ratio ($SB/SB_{F=0}$) is to be maintained at or above the average $SB/SB_{F=0}$ for 2012–2015*", which is 34% SB_0 Limit reference point of 20% SB_0 established by WCPFC equivalent to the 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	Recent levels of spawning biomass (2018–2021) are 35% SB_0; About as Likely as Not (40–60%) to be at or above the target	
Status in relation to Limits	Soft Limit: Very Unlikely (< 10%) to be below Hard Limit: Very Unlikely (< 10%) to be below	
Status in relation to Overfishing	Overfishing is Very Unlikely (< 10%) to be occurring	

Historical Stock Status Trajectory and Current Status



Kobe plot for the recent spawning potential (2018–2021) summarising the results for each of the models in the structural uncertainty grid. The plots represent estimates of stock status in terms of spawning biomass depletion and fishing mortality. The yellow point is the 2023 diagnostic model and red point is the median.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The 2023 diagnostic model shows an initial gradual decline in spawning potential depletion, $SB/SB_{F=0}$ to the mid-1970s, followed by a faster decline to about 2010, at a level of around 0.34, followed by a 10-year period of stability to 2021. This pattern varies regionally, with the lowest values for $SB/SB_{F=0}$ in the equatorial regions (3, 4, 7, and 8), with $SB/SB_{F=0}$ approaching values close to 0.2 for all four of these equatorial regions from around 2010 onwards. In contrast, in the temperate regions (1, 2, 5, 6, and 9) $SB/SB_{F=0}$ is higher than 0.6 for the entire time series.
Recent Trend in Fishing Intensity or Proxy	Average fishing mortality rates increased throughout the period of the assessment, in particular for juveniles and in tropical regions. The recent median fishing mortality (2017-2020; F_{recent}/F_{MSY}) was 0.59, which is still far below F_{MSY}.
Other Abundance Indices	-
Trends in Other Relevant Indicator or Variables	While the estimated total annual recruitment across all regions showed considerable interannual variation, the trend in recruitment was estimated to be stable since 1960. At the regional scale, the patterns in recruitment in the 2023 diagnostic model were largely similar to those seen in the 2020 diagnostic model, albeit at a reduced scale,

Projections and Prognosis	
Stock Projections or Prognosis	“Status quo” stochastic stock projections for WCPO bigeye tuna were not presented at SC19.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Not estimated
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Not estimated

Assessment Methodology and Evaluation		
Assessment Type	Level 1 – Full Quantitative Stock Assessment	
Assessment Method	MULTIFAN-CL	
Assessment Dates	Latest assessment Plenary publication year: 2023	Next assessment: 2026
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data - Size data - Growth data; and - Tagging data	1 – All High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	- Changes to the data from the 2020 assessment included: - Conversion to a catch-conditioned modelling framework; inclusion of likelihood component for CPUE from index fisheries - Change from using VAST to sdmTMB - Different CPUE variances used for the CPUE associated with each index fishery	

	- Internal estimation of natural mortality - Additional procedures adopted to achieve more reliable model convergence - Integration of parameter estimation uncertainty - Additional size composition filtering - Modifications to selectivity estimation settings - Adoption of revised tagger effect modelling framework - Changes to size data weighting in the structural uncertainty grid - Use of conditional age-at-length data, and internal estimation of growth
Major Sources of Uncertainty	- Assumed tag mixing period - Steepness of the stock recruitment relationship - Weighting of the size composition data - Data conflicts between weight and tag data - Influence of effort creep

Qualifying Comments
-

7. FOR FURTHER INFORMATION

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