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Summary of bycatch in WCPFC longline fisheries at a regional scale, 2003–2021

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Executive Summary

The Western and Central Pacific Fisheries Commission (WCPFC) has a responsibility to assess the impact of fishing on non-target species. In this report, we estimate the bycatch of the longline fishery operating in the WCPFC Convention Area for the period 2003 to 2021 . The estimates cover the full range of finfish, billfish, shark and ray, marine mammal and sea turtle species that have been recorded in longline observer data. The estimates do not cover domestic longline fisheries in the west-tropical sector of the WCPFC Convention Area, or former shark-targeted fisheries in the EEZs of Papua New Guinea and Solomon Islands.

It is difficult to obtain reliable estimates of WCPO longline catches from observer data, given the low levels and imbalanced nature of observer coverage, and additionally the low coverage of available aggregate effort data disaggregated by hooks between floats in the mid-2000s. Observer coverage has been particularly low in the north west Pacific. As such, the catch estimates for the region north of 10°N, and consequently the catch estimates for the WCPFC Convention Area as a whole, are unlikely to be reliable and should be viewed in that context.

The catch rate models do not appear to adequately capture targeting behaviour, or spatial variation in catch rates more generally. There may be sufficient observer data to consider explicitly capturing spatial variation in catch rate models in the next iteration of this work, given the recent increases in spatial coverage of available observer data.

The Scientific Committee is invited to:

- Note that hooks between floats (HBF) is now estimated for reported effort with no HBF information. This allows uncertainty in estimated HBF to propagate through to uncertainty in estimated catches;
- Note the difficulties in robust estimation of longline catches from observer data, particularly for rarely caught species, given the low levels and imbalanced nature of observer coverage, and for some years the low coverage of available *L BEST HBF* data;
- Note that earlier work suggests that the trends in estimated catch rates are more reliable than the magnitudes of the estimated catches;
- Note that there should be sufficient available observer data to enable a substantive revision of the catch rate models for the next iteration of this work, assuming a timely return of observer coverage to pre-COVID levels;
- Note that enhancement of the level and spatial coverage of observers through human and electronic monitoring approaches would improve the estimation of the catch rate models and catches.

1 Introduction

WCPFC has responsibilities to assess the impact of fishing and environmental factors on non-target species and species belonging to the same ecosystem or dependent upon or associated with the target stocks (Article 5d), to minimize catch of non-target species (Article 5e), to protect biodiversity (Article 5f), and to adopt, when necessary, Conservation and Management Measures (CMMs) for non-target species to ensure the conservation of such species (Article 6c).

Stock assessments have been undertaken for a range of species that are incidentally caught in WCPO longline fisheries, including silky (Clarke et al., 2018) and oceanic whitetip sharks (Tremblay-Boyer et al., 2019). The WCPFC is also contributing to an open resource that focuses on bycatch mitigation and management in oceanic tuna and billfish fisheries: the Bycatch Management Information System (BMIS – https://www.bmis-bycatch.org/; Fitzsimmons et al., 2015).

A number of Conservation and Management Measures (CMMs) have been implemented for non-target species, including:

- A resolution has been taken to encourage avoiding the capture of all non-target fish species and encourage prompt release to the water, unharmed (Resolution 2005-03); and
- CMMs have been implemented for billfishes (CMM 2010-01 for north Pacific striped marlin), and on species of special interest: sea turtles (CMM 2008-03, 2018-04), sharks (CMM 2010-07, CMM 2014-05, CMM 2019-04, CMM 2022-04), oceanic whitetip shark (CMM 2011-04), whale sharks (CMM 2012-04), silky sharks (CMM 2013-08), cetaceans (CMM 2011-03), seabirds (CMM 2018-03) and mobulid rays (CMM 2019-05).

Most of these CMMs encourage better reporting rates for non-target species. CMM 2007-01 requires 5% observer coverage of effort in longline fisheries under the jurisdiction of the Commission. Peatman and Nicol (2020) estimated comprehensive longline catch compositions for longline fisheries in the WCPFC Convention Area, with seabird bycatch estimates generated through WCPFC Project 68 (Peatman et al., 2019). The regional estimates of longline bycatch complement equivalent estimates for the large-scale tropical purse seine fishery (Peatman and Nicol, 2021). This report provides updated catch estimates covering the period 2003 to 2021 for WCPO longline fisheries.

2 Data and methods

The data and methods used in this study were based on those of Peatman et al. (2023). A summary of the methodology is provided here, with an emphasis on aspects that have been revised and improved relative to the previous iteration (Peatman and Nicol, 2020). The overall approach was to fit catch rate models to available observer data, use these models to estimate catch rates for aggregate longline effort data, and then to apply the catch rates to effort to obtain catch estimates.

Following Peatman and Nicol (2020), estimated catches were generated for 45 species, or groups of species, (referred to as “estimation groups’) covering the full range of finfish, shark, marine mammal and sea turtle species observed in longline catches (Table 1). However, reported catches were used where available, i.e. for albacore, bigeye, skipjack and yellowfin tuna, and for all billfish species. Seabird catches are not included here, as they have been estimated and reported separately through WCPFC Project 68 (Peatman et al., 2019). Estimation groups were not mutually exclusive, with observed catches mapped to estimation groups using the most detailed available taxonomic classification.

The catch estimates cover longline fishing from 2003 to 2021 in the WCPFC Convention Area (WCPFC-CA), including the region overlapping the IATTC Convention Area. Catch estimates do not include catches from the domestic longline fisheries of the Philippines, Vietnam and Indonesia, referred to in this report as “west-tropical domestic fisheries”, as SPC holds little representative observer data for these fisheries. Catch estimates also do not include former shark-targeted longline fisheries in the Papua New Guinea (PNG) and Solomon Islands (SB) EEZs as these fisheries are not included in aggregate longline catch and effort data held by SPC.

2.1 Coverage of available data

From 2003 to 2006, coverage of HBF-specific longline aggregate catch and effort (*L BEST HBF*) data varied between 25 and 35% of total longline aggregate (*L BEST*) effort (Figure 1). From 2006 onwards the coverage of *L BEST HBF* data increased, and since 2014 has remained above 75%.

CCMs were required by 30$^{\text{th}}$ June 2012 to achieve 5% coverage in each longline fishery under the jurisdiction of the Commission as stipulated in WCPFC CMM 2007-01. In this study observer coverage is defined as the proportion of total reported hooks accounted for by trips with an observer onboard, and for which observer data are available in SPC observer data holdings. Observer coverage over the whole Convention Area was relatively consistent at approximately 1% from 2003 to 2010 (Figure 2). Observer coverage increased from 2011 onwards, reaching 6% in 2018. Longline fishing effort was deployed widely throughout the WCPFC-CA from 2003 to 2021 (Figure 3). However, observer coverage has not been distributed evenly across the WCPFC-CA. From 2003 to 2021, observer coverage was generally highest in the region around Hawaii, and generally lowest in the north-west Pacific (Figure 4). Observer coverage was more widespread from 2015 onwards (Figure 4).

2.2 Estimation of HBF for *L BEST* data

We used random forest classification models to predict HBF for *L BEST* effort data with no HBF information, trained on *L BEST HBF* (HBF-specific) catch and effort data (following Tremblay-Boyer and Neubauer, 2019; Ducharme-Barth and Vincent, 2020). The models were fitted using the R package ‘randomForest’ (Liaw and Wiener, 2002), using 500 decision trees with 4 covariates selected at random at each node. HBF classes were defined as bins of 5: 1 to 5, 6 to 10 etc. The covariates used to predict HBF class were flag, year, month, 5° latitude band, 5° longitude band, effort (thousand hooks), total reported catch (numbers) of tuna, billfish and shark species, and catch proportions (by number) of albacore, bigeye, yellowfin, swordfish, marlins, and sharks. The reported HBF-specific dataset was randomly split into a training dataset used to train the model, with 90% of the total records, and a testing dataset used to assess predictive performance, with the remaining 10% of the records. Uncertainty in predicted HBF for each record was incorporated by taking random draws from the multinomial distribution defined by the predicted class probabilities from the classification algorithm. The effort-weighted mean of reported HBF for each HBF class was used when estimating catch rates and catches. Set depth was inferred from HBF, with a HBF $\leq$ 10 defined as shallow set and a HBF $>$ 10 defined as deep set, to allow for separation of estimated longline catch estimates by set depth.

2.3 Catch rate models

Generalised Estimating Equations (GEEs) were used to model catch rates, in order to account for correlation between observations within observer trips. Catch rate models were fitted to observer data for each of the 45 species / species groups, except for whale shark for which there were insufficient recorded catch events in the dataset. Models were fitted using the R package *geepack* (Højsgaard et al., 2006) in R v4.3.0 (R Core Team, 2023). An "exchangeable" working correlation structure was used where possible, where residuals from observations from the same observer trip are correlated, with a shared correlation parameter for all observer trips. It was not possible to fit models with exchangeable correlation structures for some models. In these instances independence between residuals within trips was assumed. Poisson-like error structures were used where possible, with a two-stage delta-lognormal modelling approach implemented if necessary to account for zero-inflation. Explanatory variables included in the models were: year, sea-surface temperature (SST) and HBF, included as cubic splines; and categorical variables for flag, and the species composition cluster for the *L BEST* strata. The year effect was modelled as a spline rather than a categorical variable to prevent over-fitting to temporal variation in catch rates, i.e. smoothing of year effects. SST and HBF were included as splines to account for potential non-linearity in effects on catch rates. Species composition cluster was included to account for the effects of fishing strategy and targeting on catch composition.

The specification of the Poisson-like models was:

$$E[Y_{ij}] = \mu_{ij} \qquad\qquad Var[Y_{ij}] = \phi\mu_{ij}$$

$$\ln(\mu_{ij}) = \ln(thooks_{ij}) + \beta_0 + \beta_1 cluster_{ij} + \beta_2 flag_{ij} + f_1(year_{ij}) + f_2(HBF_{ij}) + f_3(SST_{ij})$$

where Y_{ij} denotes observed catch rate (individuals per thousand hooks), subscripts i and j refer to observer trip and set number respectively, f_n represent natural cubic splines and ϕ is a variance inflation parameter.

The specification of the presence-absence component of delta-lognormal models was:

$$E[P_{ij}] = \gamma_{ij} \qquad\qquad Var[P_{ij}] = \phi\gamma_{ij}(1-\gamma_{ij})$$

$$\ln\left(\frac{\gamma_{ij}}{1-\gamma_{ij}}\right) = \beta_0 + \beta_1 cluster_{ij} + \beta_2 flag_{ij} + f_1(year_{ij}) + f_2(HBF_{ij}) + f_3(SST_{ij})$$

and the specification of the positives-component (i.e. catch rate when present) was:

$$E[N_{ij}] = \eta_{ij} \qquad\qquad Var[Y_{ij}] = \sigma^2$$

$$\ln(\eta_{ij}) = \beta_0 + \beta_1 cluster_{ij} + \beta_2 flag_{ij} + f_1(year_{ij}) + f_2(HBF_{ij}) + f_3(SST_{ij})$$

where P_{ij} denotes whether individuals (of the species concerned) were caught and N_{ij} denotes the observed catch rate (numbers per '000 hooks). The overall estimated mean catch rate ζ_{ij} is then $\zeta_{ij} = \gamma_{ij}\eta_{ij}$.

All explanatory variables were retained in catch rate models regardless of statistical significance, though noting that all terms were significant for most models. We did not include, or test for, interactions between explanatory variables. Other variables have been demonstrated to have a strong effect on catch rates of species caught in longline fisheries, including inter alia the diurnal phase when gear is set or soaking, and the shape and size of hooks (e.g. Bigelow et al., 2006; Gilman et al., 2006, 2008). However, explanatory variables could only be included if they were available in aggregate catch and effort datasets held by SPC, or available in external datasets that could be linked back to aggregate data (e.g. oceanographic variables).

2.4 Catch estimation

A simulation modelling framework was used to estimate catches. The WCPFC Convention Area was split into three regions to allow spatially disaggregated summaries of estimated catches: north, $\geq 10°$N; tropical $\geq 10°$S and $< 10°$N; and, south, $< 10°$S. First, the effort dataset for catch estimation was generated by aggregating HBF–specific effort surfaces to a resolution of year, SST, HBF, catch composition cluster, flag and region. SSTs were mean monthly values per 5° grid, rounded to the nearest third of a °C. For each catch rate model, 1,000 random draws of parameters were taken from the multivariate normal distribution defined by the vector of mean parameter values $\boldsymbol{\beta}$ and their covariance matrix $\boldsymbol{\Sigma}$, $N_k(\boldsymbol{\beta}, \boldsymbol{\Sigma})$ where k is the number of estimated parameters. The random draws of parameter values were then used to generate 1,000 estimated catch rates for each record in the effort dataset. Estimated catches were then obtained by taking the product of the catch rates and the effort. The estimated catches were then aggregated to a variety of resolutions, for example species types (Table 1), and summary statistics computed, e.g. medians and 95% confidence intervals. Reported catches were assumed to be known without error.

The natural catch unit for the estimation of longline catches is numbers of individuals. Estimated catch numbers were also converted to weight using estimates of average weight (Peatman et al., 2018). The estimates of average weight were based on either direct measurements of whole weight (where available), or using length measurements and length weight parameters to estimate weight. It is not clear to what extent available length measurements are representative of catches. For example, downwards bias in length measurements might be expected if larger individuals are cut off the line. As such, the estimates of catch numbers are likely to be more reliable than catch weight estimates.

3 Results

The accuracy of the predictive model of HBF was considered adequate. HBF was estimated with a classification accuracy of 66% for the testing dataset and predictions accurate to ± one HBF class for 91% of records in the testing dataset (Table 2). Uncertainty in the overall proportions of inferred shallow-set and deep-set effort was lower for 2007 onwards, when HBF information was more widely available in aggregate longline effort data (Figures 6 and 7).

Annual catch estimates (individuals) for teleosts (excluding billfish), billfish, sharks and rays, marine mammals and turtles are provided in Figure 8 and Table A.1. It is important to note that the catch estimates do not include catches of the west-tropical domestic fisheries, or shark fisheries that are not covered in aggregate longline effort data (see Section 2). The (inferred) depth of setting had a strong effect on the compositions of catches (Figure 9). Catch rates of tropical tuna and albacore were higher for deep sets compared with shallow sets, and the opposite true for the remaining species types (i.e. billfish, other teleosts, elasmobranchs, sea turtles and marine mammals). Estimation-group specific catch estimates are provided in Figures 10 to 13 and Tables A.3 to A.9. This includes tables of estimates of catches in metric tonnes for teleosts (Table A.4), billfish (Table A.6) and elasmobranchs (Table A.8).

Here we briefly summarise the trends in estimated catches, focussing on estimation groups with estimated catches.

Estimated catches of teleosts (excluding tropical tuna, albacore and billfish) increased from 2004 through to 2010, before declining though to 2021 (Figure 8). This trend was largely driven by mahi mahi (Figure 10). Catches of longsnouted lancetfish demonstrated an increasing trend, whereas catches of opah have declined.

Catches of elasmobranchs remained relatively stable from 2003 to 2011, before decreasing sharply. Elasmobranch catches then stabilised from 2013 through to 2019, before declining again (Figure 8). The trend in overall elasmobranch catch was largely driven by catches of blue shark, with silky shark catches also exhibiting a similar trend (Figure 10). Catches of oceanic whitetip and 'thresher sharks' demonstrated a declining trend, and pelagic stingray an increasing trend though with some variability. Shortfin mako and bigeye thresher demonstrated increasing trends in the 2000s, followed by declining trends in the 2010s.

Catches of sea turtles had wide 95% confidence intervals, with evidence of declines in catches from 2009 onwards (Figure 8). This trend in overall sea turtle catch was largely driven by olive ridley turtle, though green and leatherback turtles exhibited similar trends (Figure 13).

Catches of marine mammals demonstrated an increasing trend until 2014, before declining through to 2016 (Figure 8). Catches then increased through to 2019, before declining again.

4 Discussion

This report presents updated estimates of longline catches across the full range of finfish, sharks and rays, sea turtles and marine mammals caught in WCPFC-CA longline fisheries. The analysis was complicated by the coverage of available observer data, and for some years the coverage of HBF-specific aggregate data. The catch estimates presented here must be viewed in the context of the limitations of the dataset, and the methodology used to obtain the estimates.

Observer coverage for some key longline fleets has been limited for the time period considered, with particularly low available observer coverage in the north west Pacific. As such, the catch estimates for the region north of 10°N, and consequently the catch estimates for the WCPFC Convention Area as a whole, are unlikely to be reliable.

Reported catches from aggregate longline catch data were used in this study where available, i.e. for albacore, bigeye, yellowfin, skipjack and billfish species. The reported catches are included in tables of catch estimates to give context to estimated catches of other species. Peatman and Nicol (2020) compared reported catches to estimates generated using the modelling approach outlined in Section 2. These comparisons suggested that the trends in predicted catches through time may be more accurate than the magnitude of those predicted catches.

COVID-19 has impacted the ability of observer programmes to place observers on longliners operating in the WCPO, resulting in a reduction in observer coverage rates in 2020 and 2021 (Figure 2). Additionally, available observer coverage in 2020 and 2021 was more patchy than for the period 2015 onwards. However, observer coverage rates were higher, with more comprehensive spatial coverage, in 2020 and 2021 than for the early part of the analysed time period (Figure 2 and 5).

In this iteration, we have moved to predicting hooks-between-float (HBF) where this information is missing, using random forests, rather than aggregating *L BEST HBF* data to progressively coarser resolutions to assign HBF based on reported information. This approach allows spatial-temporal information, compositions of catches, and other covariates, to directly estimate HBF. Additionally, this approach allowed uncertainty in estimated HBF to propagate through to uncertainty in estimated catches.

Olive ridley turtle catch estimates had a peak of c. 22,000 individuals in 2009, and represented c. 60% of total estimated catches of olive ridley, green, loggerhead and leatherback turtles. This is almost double the estimate of 35%, obtained from the Common Oceans initiative focussing on sea turtle mitigation effectiveness (Common Oceans, 2017). This suggests that the proportional contribution of olive ridley to overall sea turtle catch presented here is overestimated.

Residual diagnostics indicated a lack of fit for a range of log-normal components of catch rate models, and relatively strong spatial patterns in residuals for a range of both delta-lognormal and Poisson models. This appears to reflect the inability of the catch rate models to adequately capture both targeting behaviour and spatial variation in catch rates more generally. Observer coverage in the longline fishery had increased in the period prior to COVID-19, coupled with an increase in spatial coverage both in general and for some of the key longline fleets operating in the region. There may be sufficient observer data to consider explicitly capturing spatial variation in catch rate models in the next iteration of this work. Further refinements to the modelling approach should also be considered in future work, including estimation of marine mammal catch rates and catches at more refined taxonomic groupings. This will likely require consideration of the proportions of observed captures identified to species and family level, as well as the likely accuracy of the identifications.

Catch indices do not necessarily provide an accurate proxy for trends and/or absolute levels of mortalities resulting from the catch and release of individuals. Time series of catches may be particularly misleading for species with no-retention policies either through domestic or regional measures, for example shark species. Catch indices could be converted to time series of mortalities using available observer data and assumptions regarding discard mortality (e.g. Harley et al., 2015; Tremblay-Boyer et al., 2019).

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Tables

Table 1: Estimation groups and their species type.

Estimation group	Scientific name	Species type
Albacore	*Thunnus alalunga*	Tropical tunas & albacore
Lancetfishes	*Alepisauridae*	Teleosts
Longsnouted lancetfish	*Alepisaurus ferox*	Teleosts
Barracudas	*Sphyraenidae*	Teleosts
Bigeye	*Thunnus obesus*	Tropical tunas & albacore
Black marlin	*Makaira indica*	Billfish
Pomfrets	*Bramidae*	Teleosts
Blue shark	*Prionace glauca*	Elasmobranchs
Bigeye thresher	*Alopias superciliosus*	Elasmobranchs
Blue marlin	*Makaira nigricans*	Billfish
Leatherback turtle	*Dermochelys coriacea*	Sea turtles
Mahi mahi	*Coryphaena hippurus*	Teleosts
Silky shark	*Carcharhinus falciformis*	Elasmobranchs
Great barracuda	*Sphyraena barracuda*	Teleosts
Escolars	*Gempylidae*	Teleosts
Opah	*Lampris guttatus*	Teleosts
Olive ridley turtle	*Lepidochelys olivacea*	Sea turtles
Longfin mako	*Isurus paucus*	Elasmobranchs
Lampriformes	Lampriformes	Teleosts
Mako sharks	*Isurus* spp	Elasmobranchs
Marine mammals	Cetacea & pinnipeds	Marine mammals
Mobulid rays	*Mobulidae*	Elasmobranchs
Striped marlin	*Tetrapturus audax*	Billfish
Sunfish	*Molidae*	Teleosts
Oceanic whitetip shark	*Carcharhinus longimanus*	Elasmobranchs
Pelagic stingray	*Pteroplatytrygon violacea*	Elasmobranchs
Porbeagle shark	*Lamna nasus*	Elasmobranchs
Whale shark	*Rhincodon typus*	Elasmobranchs
Slender sunfish	*Ranzania laevis*	Teleosts
Indo-Pacific sailfish	*Istiophorus platypterus*	Billfish
Elasmobranchs	Elasmobranchii	Elasmobranchs
Skipjack	*Katsuwonus pelamis*	Tropical tunas & albacore
Shortfin mako	*Isurus oxyrhinchus*	Elasmobranchs
Hammerhead sharks	*Sphyrnidae*	Elasmobranchs
Shortbill spearfish	*Tetrapturus angustirostris*	Billfish
Swordfish	*Xiphias gladius*	Billfish
Marine fishes	Teleosts	Teleosts
Thresher sharks	*Alopiidae*	Elasmobranchs
Hawksbill turtle	*Eretmochelys imbricata*	Sea turtles
Loggerhead turtle	*Caretta caretta*	Sea turtles
Sea turtles	*Chelonioidea*	Sea turtles
Green turtle	*Chelonia mydas*	Sea turtles
Scombrids	*Scombridae*	Teleosts
Wahoo	*Acanthocybium solandri*	Teleosts
Yellowfin	*Thunnus albacares*	Tropical tunas & albacore

Table 2: Comparison of observed (rows) and predicted (columns) hooks-between-float class for the testing (*L BEST HBF*) dataset. Cells are highlighted grey, with bold type, where predicted HBF equals observed HBF.

Observed HBF	1	6	11	16	21	26	31	36	41	46	51	56	61
1	**2017**	269	35	49	43	3	5	0	0	2	0	0	0
6	353	**1540**	317	163	71	16	1	0	0	1	0	1	0
11	88	369	**1509**	863	137	22	9	4	0	2	0	0	1
16	56	153	411	**5845**	552	134	37	12	0	3	0	0	0
21	30	71	94	637	**2217**	416	69	23	0	2	1	0	0
26	18	37	45	164	456	**2259**	365	92	10	0	0	0	0
31	0	1	11	44	49	453	**819**	153	32	2	0	0	0
36	2	2	6	13	11	130	226	**472**	65	2	1	0	1
41	1	2	5	1	2	14	65	106	**62**	10	0	0	1
46	0	1	2	2	5	7	25	32	29	**24**	0	2	0
51	1	0	0	3	8	2	4	6	10	0	**2**	0	0
56	3	0	1	1	2	5	2	5	2	1	0	**13**	0
61	0	0	0	0	1	2	1	2	1	0	0	2	**0**

Figures

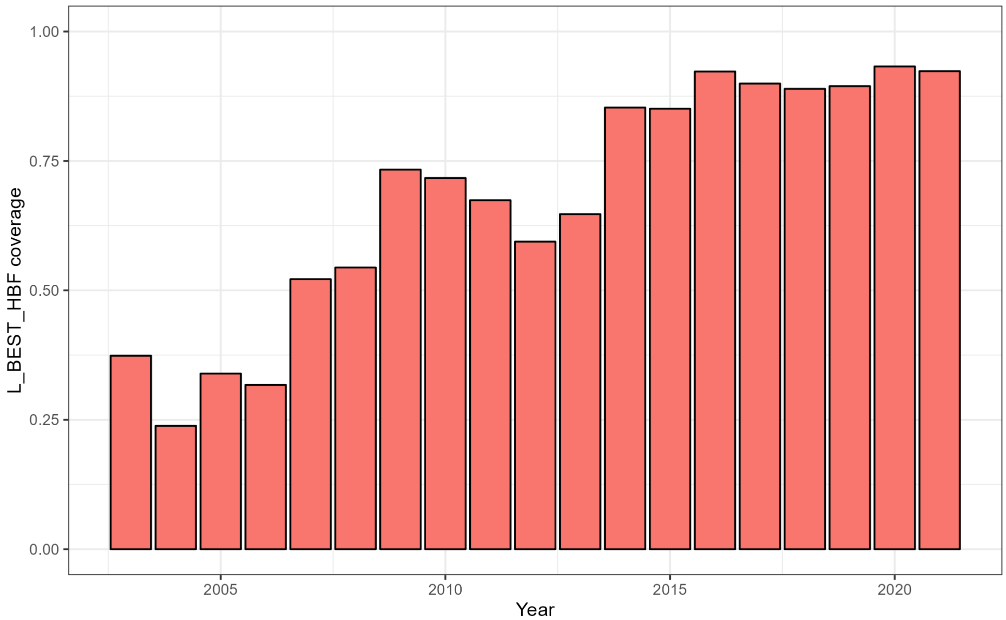


Figure 1: Overall annual coverage of *L BEST HBF* aggregate data (proportion of number of hooks) across the WCPFC-CA. Effort from west-tropical domestic fisheries was excluded.

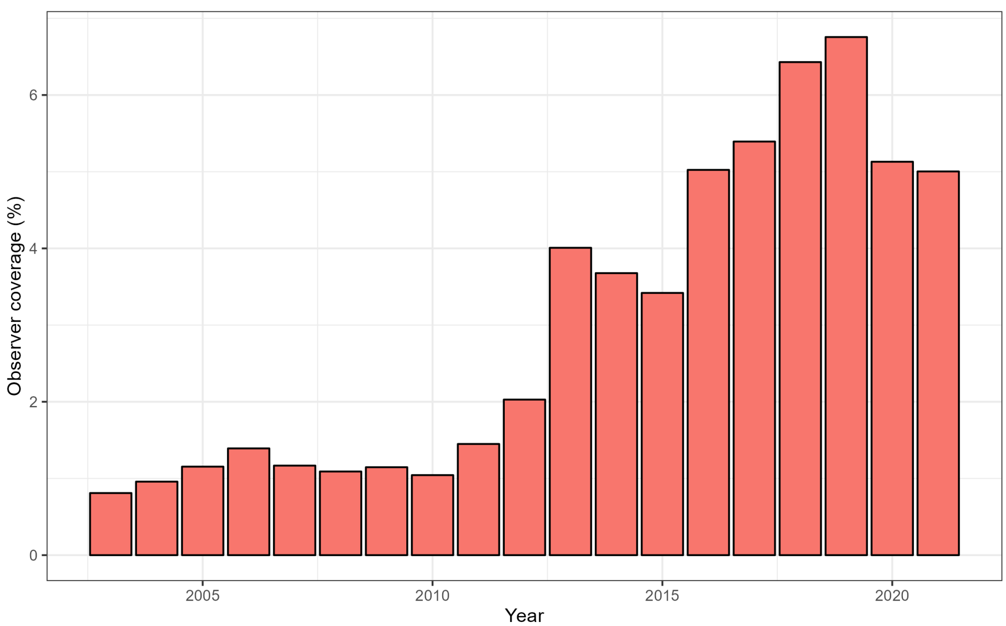
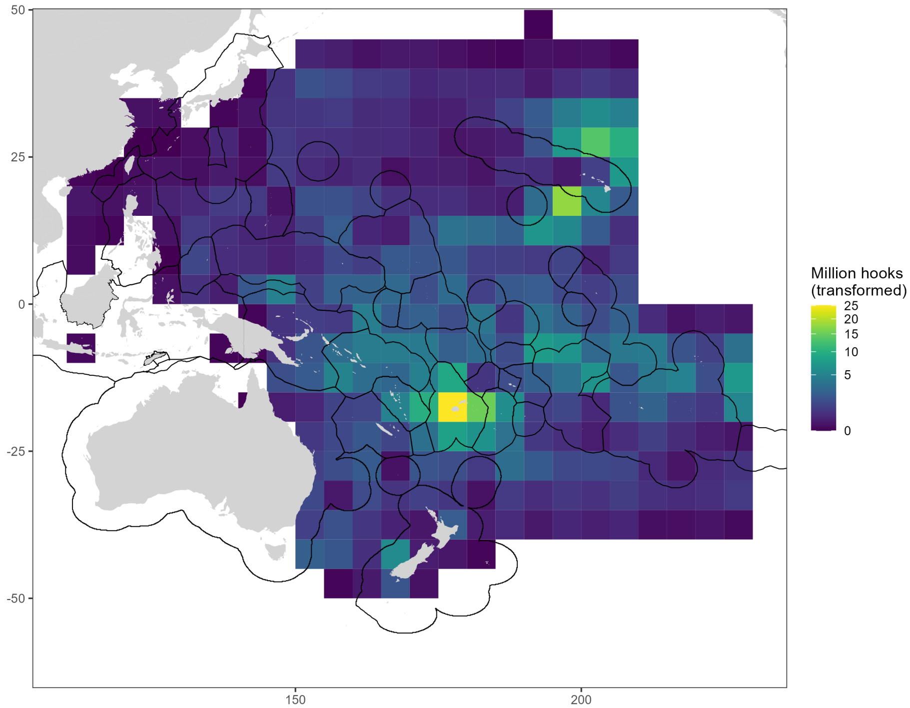
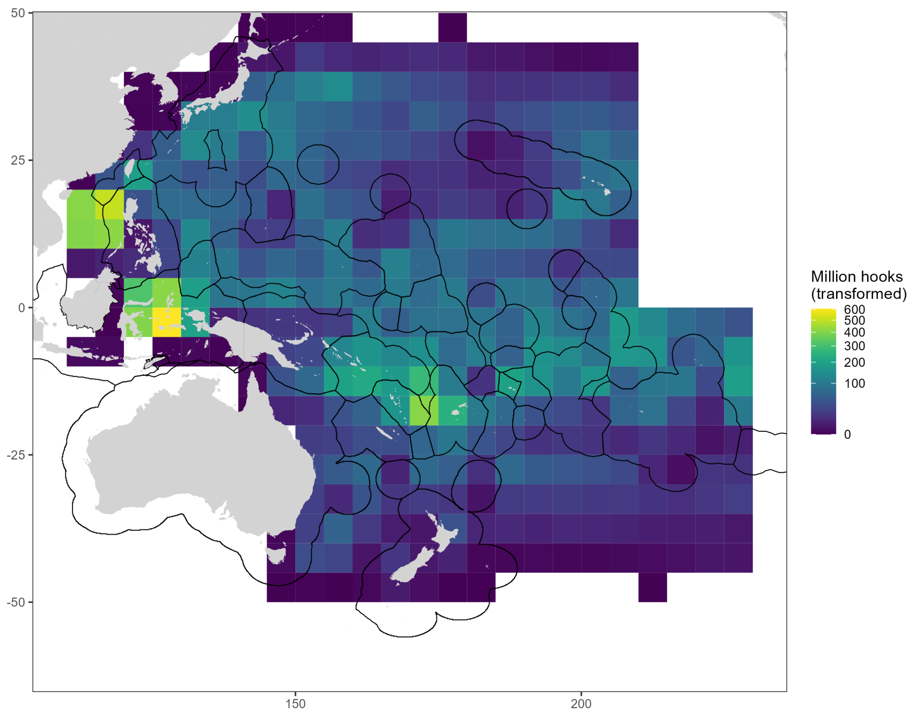


Figure 2: Overall annual observer coverage (proportion of number of hooks) of longline fleets in the WCPFC-CA. Effort from west-tropical domestic fisheries was excluded.

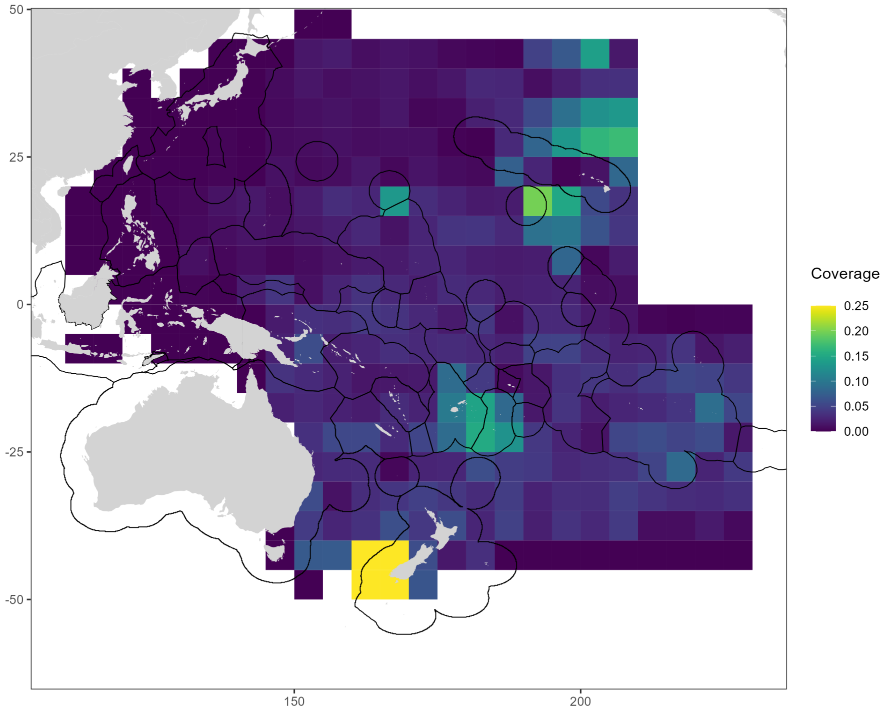


(a) Observed effort

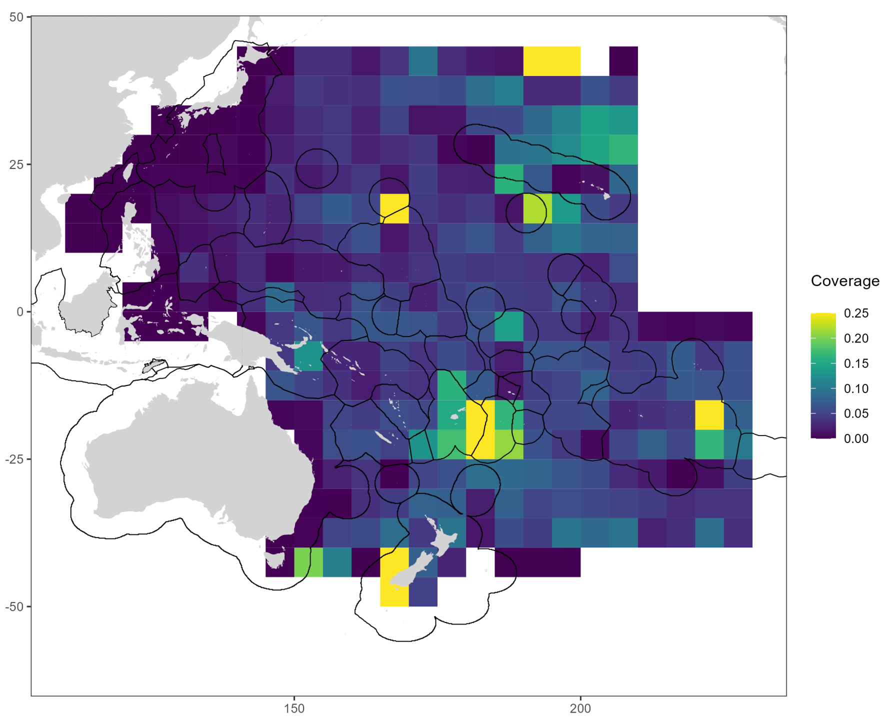


(b) Reported effort

Figure 3: (a) Observed and (b) total reported longline fishing effort (bottom) in '000 hooks from 2003 to 2021 in the WCPFC-CA. Note that colour scales are different for the two panels, and a square root transformation was applied.

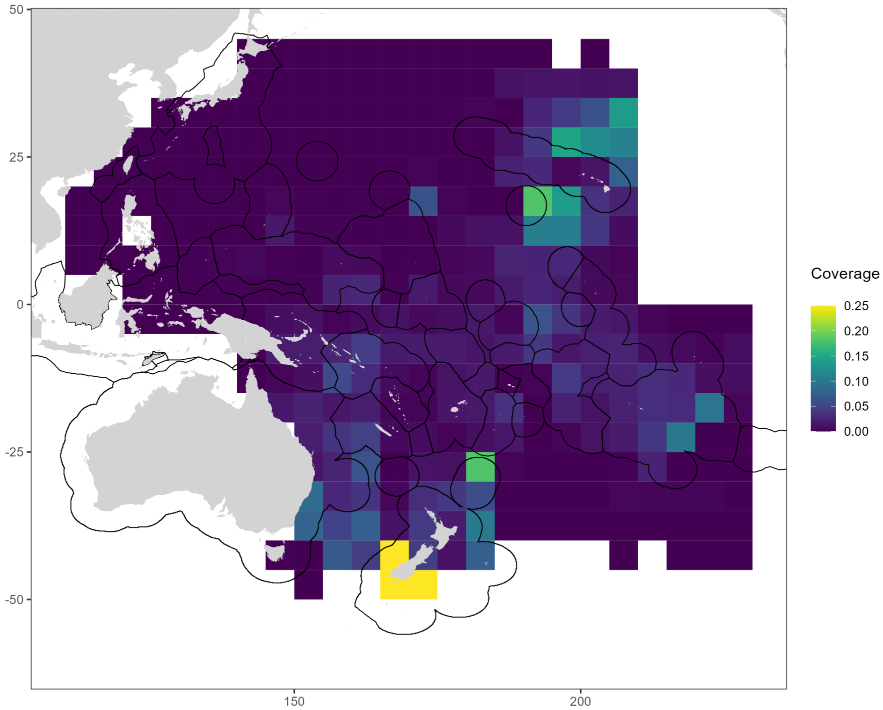


(a) 2003 - 2021

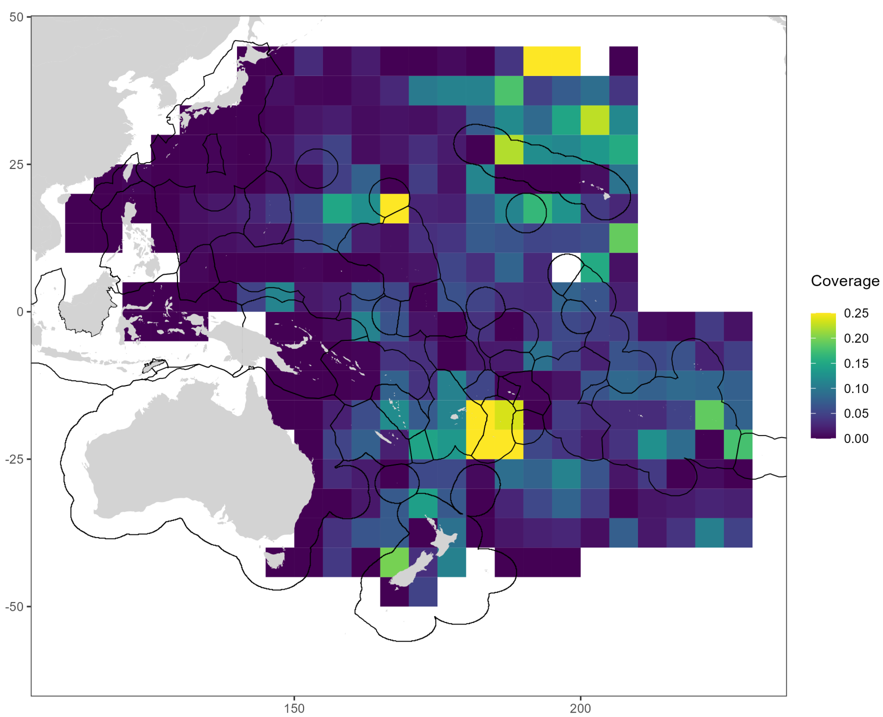


(b) 2015 - 2021

Figure 4: Observer coverage (proportion of hooks) of longline fleets in the WCPFC-CA from a) 2003 to 2021 and b) 2015 to 2021. Coverage was capped at 25% to facilitate interpretation.



(a) 2003 - 2012



(b) 2020 - 2021

Figure 5: Observer coverage (proportion of hooks) of longline fleets in the WCPFC-CA from a) 2003 to 2012 and b) 2020 to 2021. Coverage was capped at 25% to facilitate interpretation.

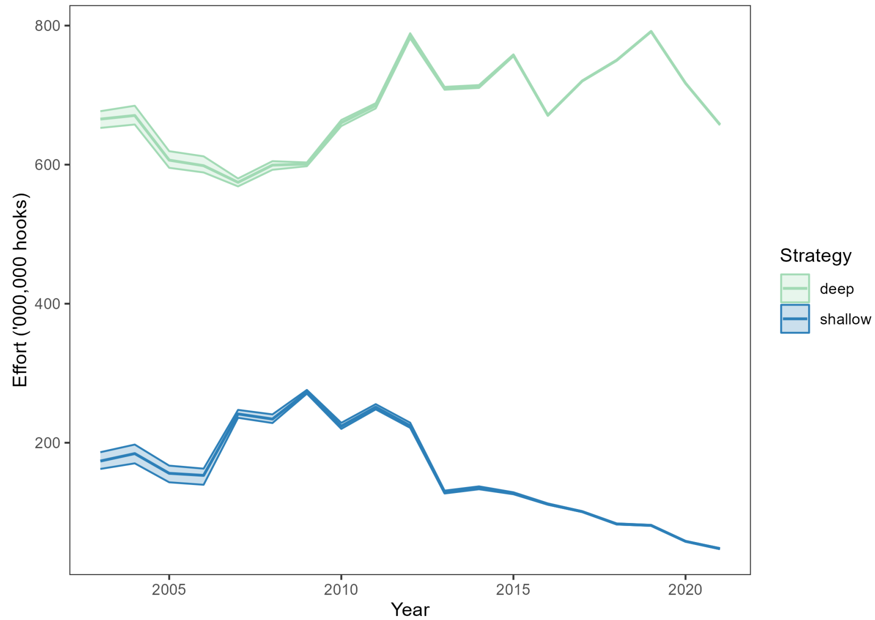


Figure 6: Estimated total annual effort of longline fleets in the WCPFC-CA by 'fishing strategy' (shallow – ≤ 10 HBF; deep – > 10 HBF). Effort from west-tropical domestic fisheries was excluded.

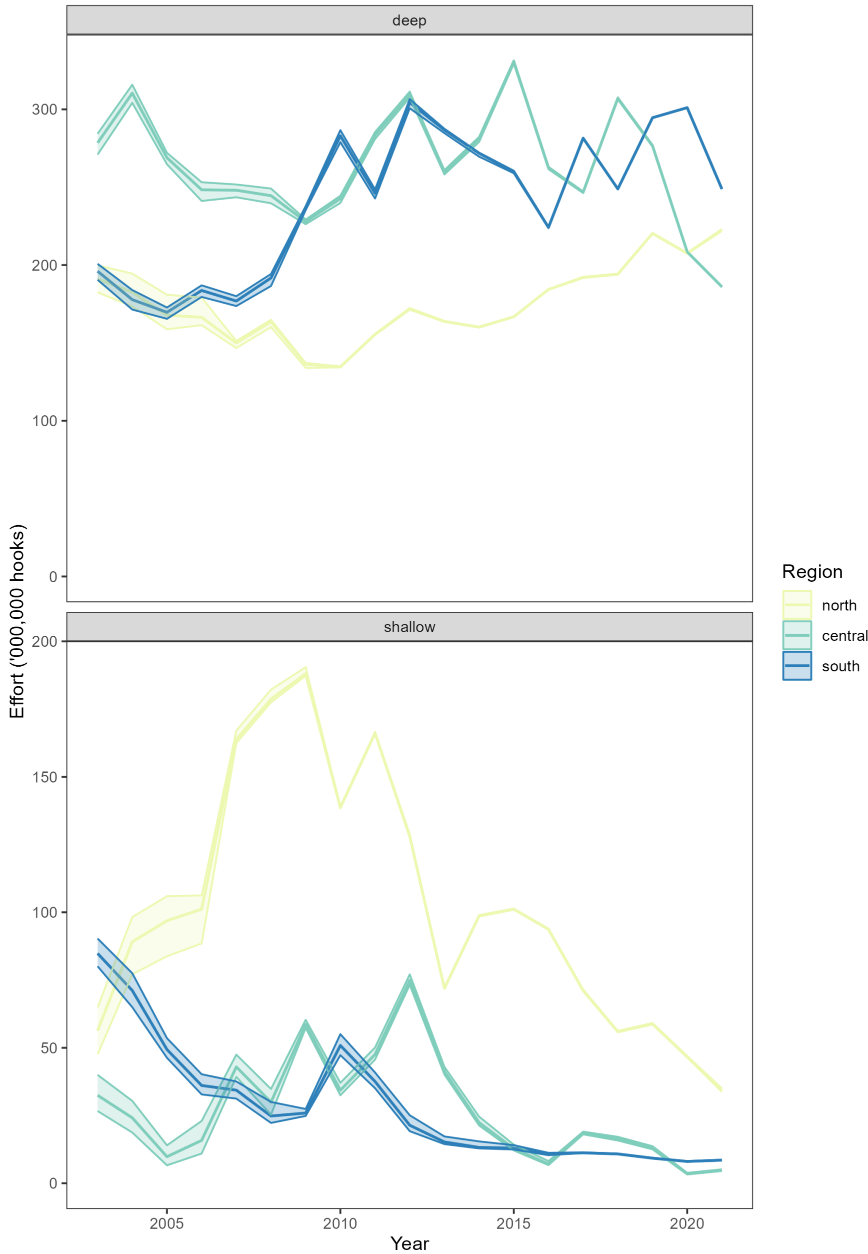


Figure 7: Estimated total annual effort of longline fleets in the WCPFC-CA by region and 'fishing strategy' (shallow – ≤ 10 HBF; deep – > 10 HBF). Effort from west-tropical domestic fisheries was excluded.

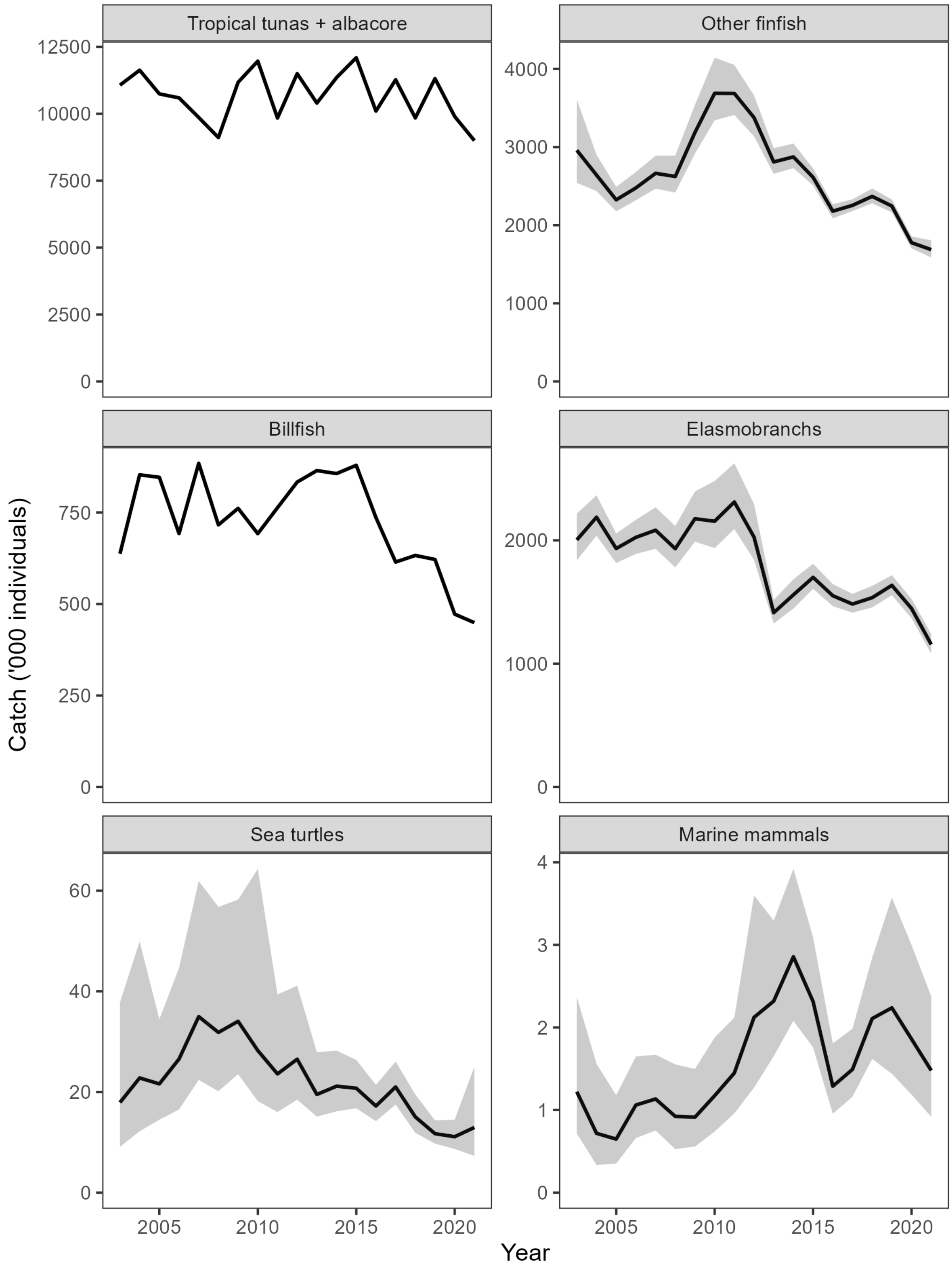


Figure 8: Total estimated annual catch ('000 individuals; grey region provides 95% CIs) for the WCPO longline fishery by species type. Estimated catches do not cover west-tropical domestic fisheries and former shark-targeted fisheries in the EEZs of Papua New Guinea and Solomon Islands. Reported catches were used where available, covering tropical tuna, albacore and billfish and were assumed to be known without error.

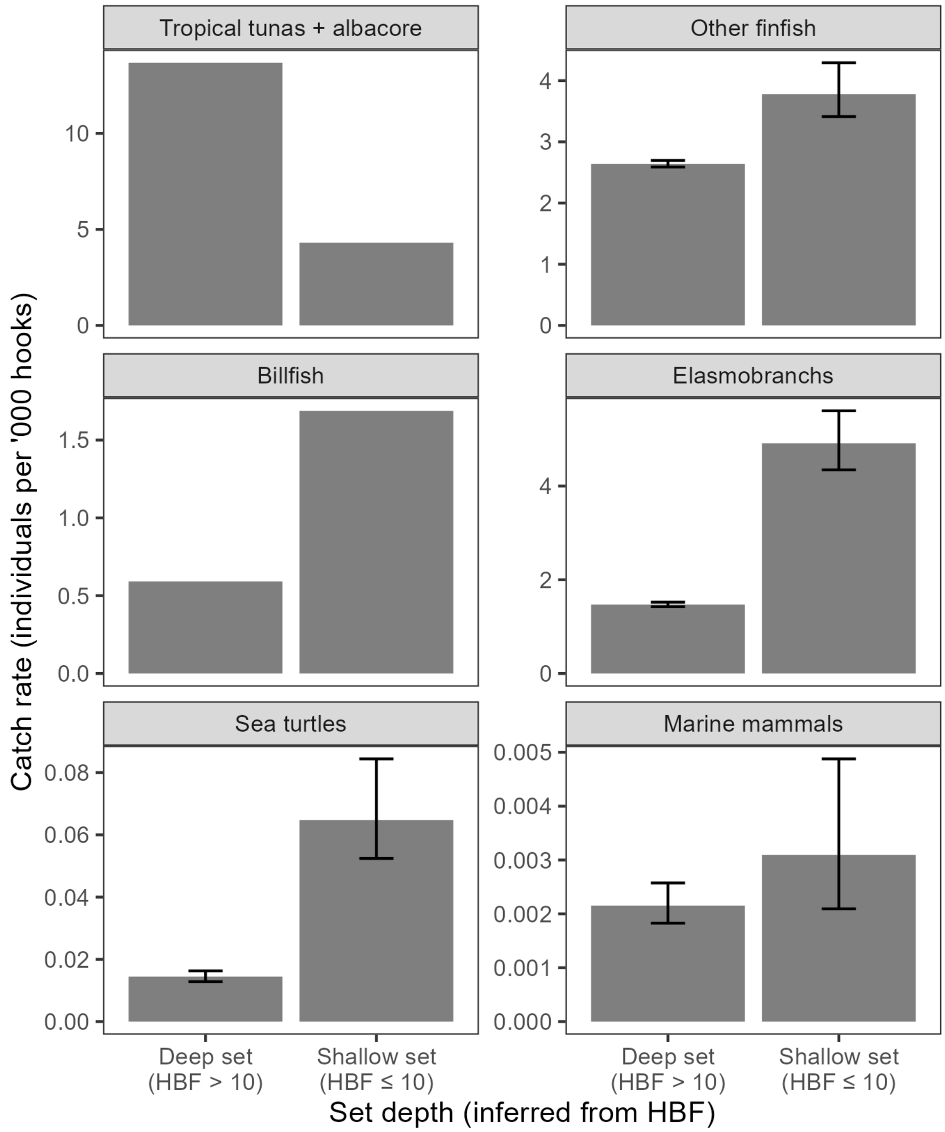


Figure 9: Estimated average catch rates (individuals per '000 hooks, 95% confidence intervals in parentheses) for the WCPO longline fishery from 2017 to 2021, by species type and set depth inferred from hooks between floats. Teleosts excludes tropical tuna, albacore and billfish species. Reported catch and effort from hook-between-floats specific aggregate data were used to calculate catch rates for tropical tuna, albacore and billfish.

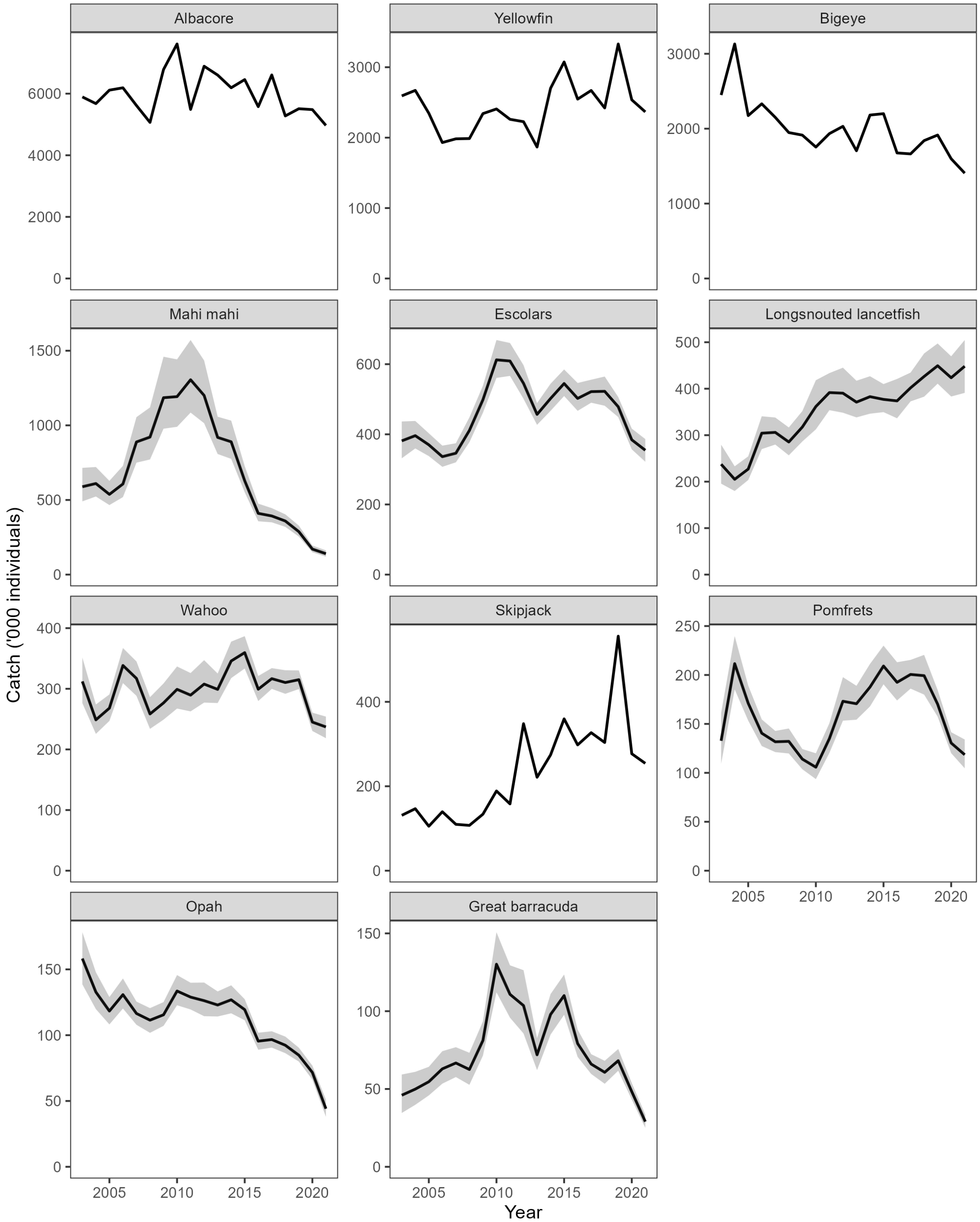


Figure 10: Total estimated annual catch for selected teleost estimation groups ('000 individuals; grey region provides 95% CIs) for the WCPO longline fishery. Billfish catches are reported separately. Estimated catches do not cover west-tropical domestic fisheries and former shark-targeted fisheries in the EEZs of Papua New Guinea and Solomon Islands. Reported catches were used where available, covering tropical tuna and albacore.

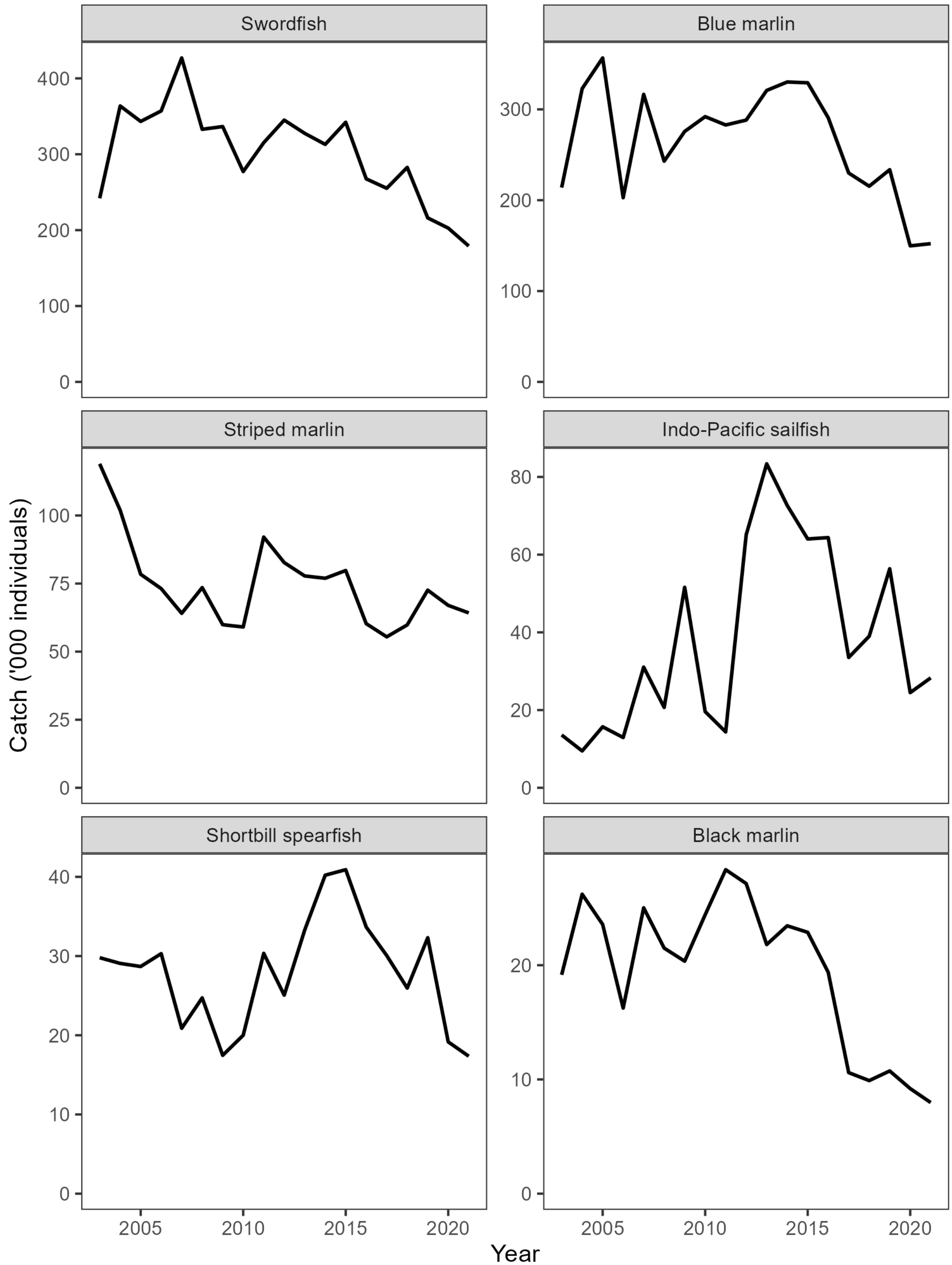


Figure 11: Total annual catch for billfish estimation groups ('000 individuals) for the WCPO longline fishery. Catches do not cover west-tropical domestic fisheries and former shark-targeted fisheries in the EEZs of Papua New Guinea and Solomon Islands. Reported catches were used for all billfish estimation groups.

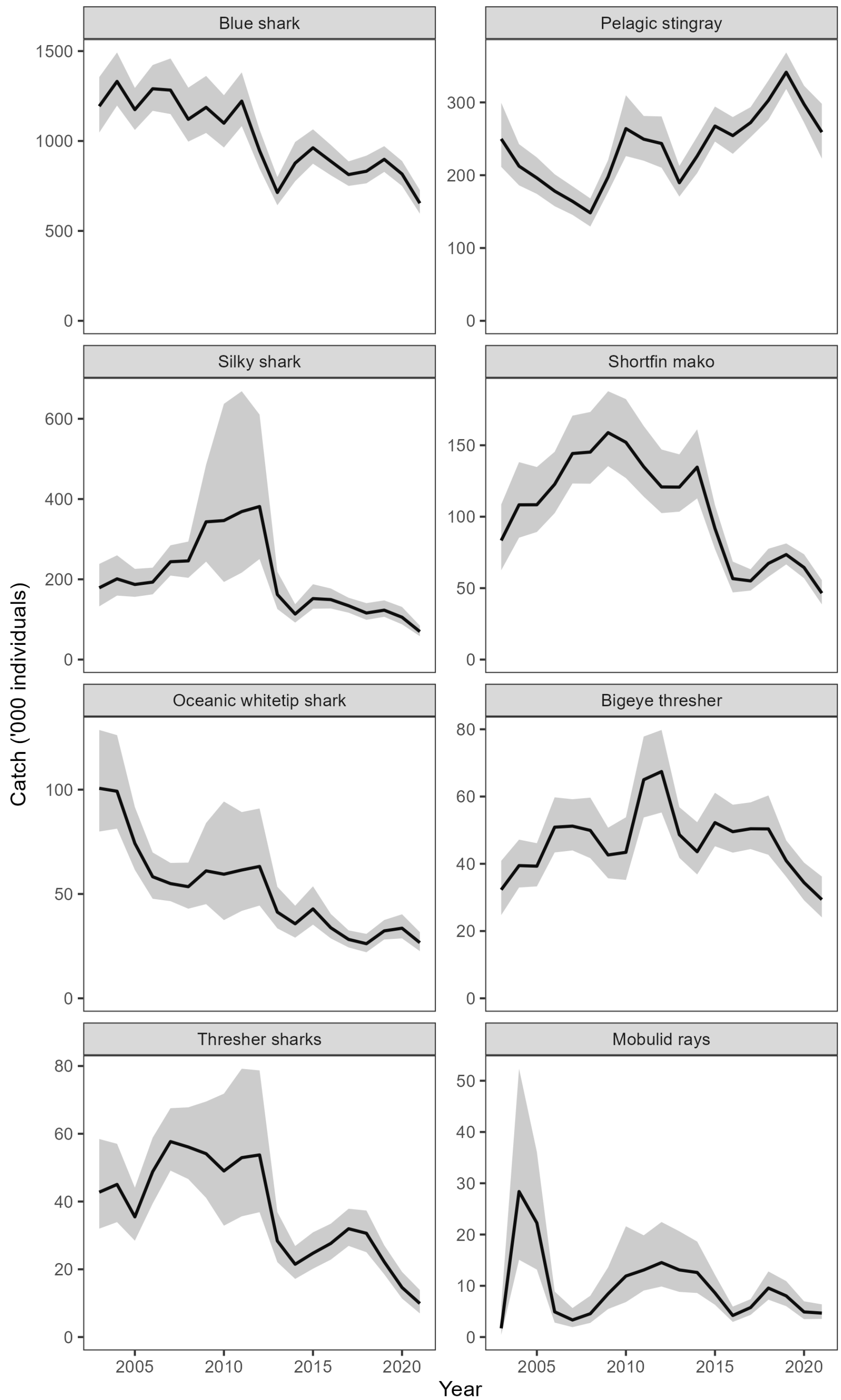


Figure 12: Total estimated annual catch for selected elasmobranch estimation groups ('000 individuals; grey region provides 95% CIs) for the WCPO longline fishery. Estimated catches do not cover west-tropical domestic fisheries and former shark-targeted fisheries in the EEZs of Papua New Guinea and Solomon Islands.

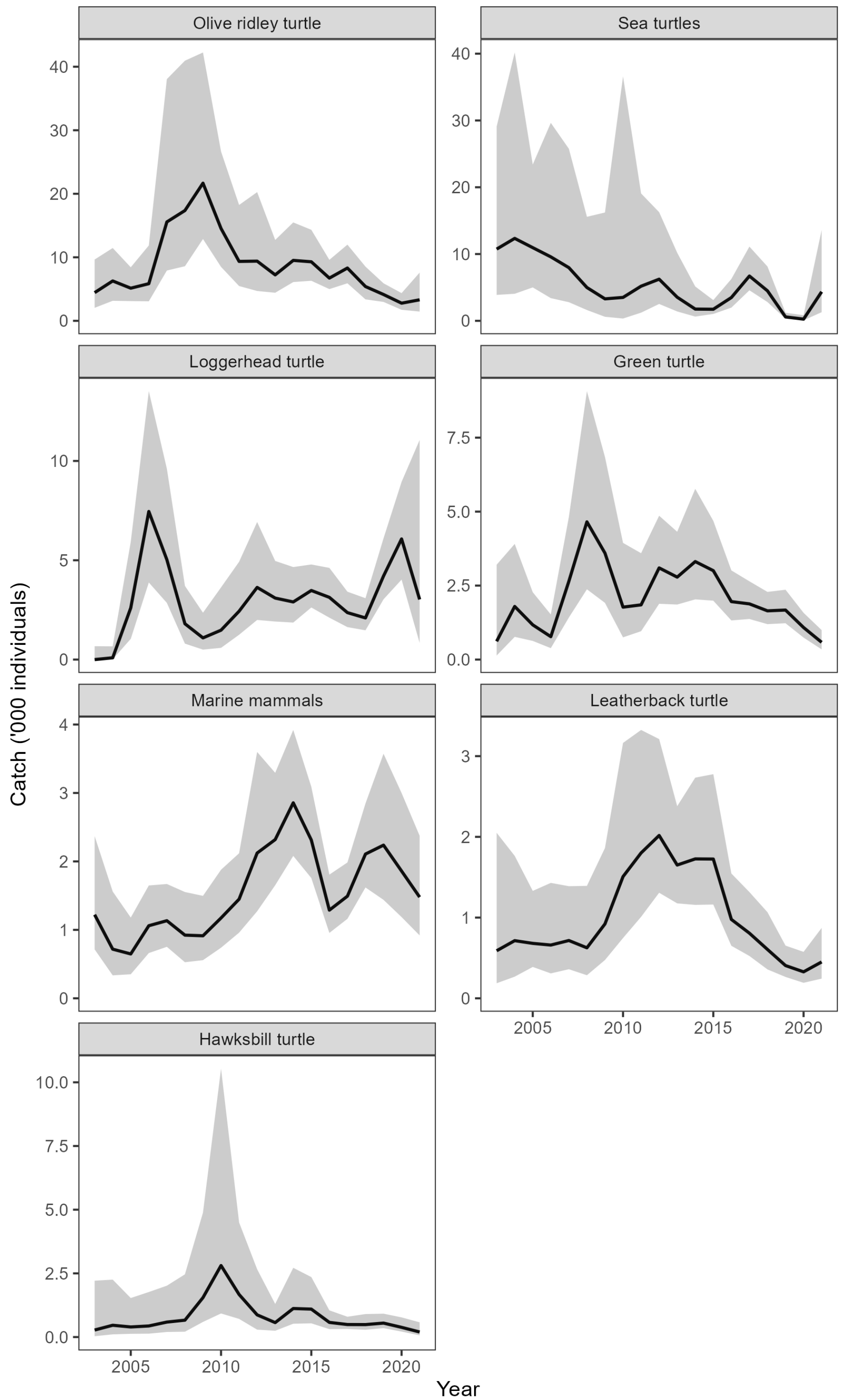


Figure 13: Total estimated annual catch for sea turtle and marine mammal estimation groups ('000 individuals; grey region provides 95% CIs) for the WCPO longline fishery. Estimated catches do not cover west-tropical domestic fisheries and former shark-targeted fisheries in the EEZs of Papua New Guinea and Solomon Islands.

Appendix

A Tables of estimated catches

Table A.1: Estimated annual catch ('000 individuals, 95% confidence intervals in parentheses) for the WCPO longline fishery by species type. Teleosts excludes tropical tuna, albacore and billfish species. Estimated catches do not cover west-tropical domestic fisheries and former shark-targeted fisheries in the EEZs of Papua New Guinea and Solomon Islands.

Year	Tropical tunas + albacore	Billfish	Teleosts	Elasmobranchs	Sea turtles	Marine mammals
2003	11,100	637 (637-637)	2,960 (2,540-3,610)	2,000 (1,840-2,220)	17.9 (9.09-37.8)	1.22 (0.715-2.37)
2004	11,600	853 (853-853)	2,640 (2,440-2,900)	2,190 (2,040-2,360)	22.8 (12.2-49.9)	0.718 (0.335-1.56)
2005	10,700	846 (846-846)	2,320 (2,180-2,490)	1,930 (1,820-2,060)	21.6 (14.5-34.4)	0.648 (0.352-1.18)
2006	10,600	692 (692-692)	2,480 (2,320-2,680)	2,020 (1,890-2,170)	26.6 (16.5-44.6)	1.06 (0.661-1.65)
2007	9,860	884 (884-884)	2,660 (2,470-2,890)	2,080 (1,930-2,270)	35.0 (22.4-61.9)	1.13 (0.753-1.67)
2008	9,110	716 (716-716)	2,620 (2,420-2,890)	1,930 (1,780-2,120)	31.8 (20.1-56.8)	0.923 (0.527-1.55)
2009	11,200	761 (761-761)	3,190 (2,920-3,540)	2,180 (1,990-2,400)	34.0 (23.5-58.2)	0.914 (0.558-1.50)
2010	12,000	692 (692-692)	3,690 (3,340-4,140)	2,150 (1,940-2,480)	28.2 (18.2-64.3)	1.17 (0.739-1.88)
2011	9,840	763 (763-763)	3,690 (3,410-4,050)	2,310 (2,090-2,620)	23.6 (16.0-39.4)	1.45 (0.959-2.12)
2012	11,500	833 (833-833)	3,380 (3,140-3,660)	2,030 (1,840-2,290)	26.5 (18.5-41.1)	2.12 (1.27-3.60)
2013	10,400	865 (865-865)	2,810 (2,660-2,980)	1,410 (1,330-1,520)	19.5 (15.1-27.9)	2.32 (1.65-3.29)
2014	11,300	856 (856-856)	2,870 (2,730-3,050)	1,560 (1,450-1,680)	21.1 (16.2-28.2)	2.86 (2.08-3.92)
2015	12,100	879 (879-879)	2,610 (2,510-2,730)	1,700 (1,610-1,810)	20.7 (16.8-26.4)	2.31 (1.76-3.09)
2016	10,100	736 (736-736)	2,180 (2,090-2,270)	1,550 (1,470-1,650)	17.2 (14.2-21.4)	1.29 (0.955-1.81)
2017	11,300	615 (615-615)	2,250 (2,180-2,330)	1,480 (1,410-1,570)	21.0 (17.5-26.0)	1.49 (1.16-1.98)
2018	9,840	633 (633-633)	2,370 (2,280-2,470)	1,540 (1,460-1,630)	15.0 (11.9-19.5)	2.11 (1.62-2.85)
2019	11,300	622 (622-622)	2,250 (2,160-2,330)	1,640 (1,560-1,720)	11.7 (9.73-14.4)	2.24 (1.44-3.57)
2020	9,890	472 (472-472)	1,780 (1,700-1,860)	1,450 (1,370-1,530)	11.1 (8.68-14.5)	1.86 (1.19-3.00)
2021	8,990	449 (449-449)	1,690 (1,590-1,810)	1,160 (1,080-1,240)	12.9 (7.30-25.0)	1.48 (0.919-2.37)

Table A.2: Estimated average catch rates (individuals per '000 hooks, 95% confidence intervals in parentheses) for the WCPO longline fishery from 2015 to 2019, by species type and set depth inferred from hooks between floats. Teleosts excludes tropical tuna, albacore and billfish species. Reported catch and effort from hook-between-floats specific aggregate data were used to calculate catch rates for tropical tuna, albacore and billfish. Catch rates do not cover west-tropical domestic fisheries and former shark-targeted fisheries in the EEZs of Papua New Guinea and Solomon Islands.

Species group	Deep set (HBF $>$ 10)	Shallow set (HBF $\leq$ 10)
Tropical tunas + albacore	13.68	4.31
Billfish	0.59	1.69
Teleosts	2.64 (2.59-2.70)	3.78 (3.41-4.29)
Elasmobranchs	1.47 (1.43-1.52)	4.91 (4.35-5.60)
Sea turtles	0.0145 (0.0128-0.0163)	0.0647 (0.0524-0.0844)
Marine mammals	0.00215 (0.00183-0.00257)	0.00309 (0.00209-0.00488)

Table A.3: Estimated annual catch of teleosts by estimation group ('000 individuals, 95% confidence intervals in parentheses where relevant) for the WCPO longline fishery. Catches of billfish species are reported separately. Estimated catches do not cover west-tropical domestic fisheries and former shark-targeted fisheries in the EEZs of Papua New Guinea and Solomon Islands.

Year	Albacore	Yellowfin	Bigeye	Mahi mahi	Escolars	Longsnouted lancetfish	Wahoo	Skipjack	Pomfrets	Opah	Great barracuda	Others
2003	5,890	2,590	2,450	589 (491-715)	381 (332-437)	237 (196-279)	312 (276-351)	131	133 (109-161)	158 (139-178)	46.0 (34.6-59.3)	1,090 (737-1,700)
2004	5,680	2,670	3,130	610 (523-721)	396 (360-438)	205 (180-233)	249 (226-274)	147	212 (185-240)	133 (120-148)	49.9 (39.8-61.0)	774 (617-1,020)
2005	6,110	2,350	2,170	538 (466-628)	370 (338-403)	227 (204-254)	268 (247-291)	105	171 (153-189)	118 (108-129)	54.7 (45.9-64.2)	571 (466-727)
2006	6,190	1,930	2,330	607 (519-729)	336 (307-368)	304 (270-341)	338 (309-367)	140	140 (127-155)	131 (120-143)	62.9 (53.4-74.3)	551 (443-718)
2007	5,620	1,980	2,150	889 (750-1,050)	346 (320-374)	306 (280-338)	317 (288-345)	110	132 (121-143)	116 (108-126)	66.7 (57.7-76.9)	485 (374-628)
2008	5,070	1,990	1,950	921 (771-1,120)	411 (378-448)	285 (257-317)	259 (234-286)	107	132 (120-145)	111 (102-121)	62.5 (52.7-73.3)	430 (320-612)
2009	6,780	2,340	1,910	1,190 (978-1,460)	499 (462-538)	318 (286-352)	277 (249-309)	134	114 (104-124)	115 (107-125)	81.2 (71.5-93.4)	586 (437-812)
2010	7,610	2,410	1,750	1,190 (990-1,440)	612 (561-669)	362 (313-418)	299 (267-337)	189	106 (93.6-120)	134 (123-146)	130 (112-151)	839 (595-1,230)
2011	5,490	2,260	1,930	1,310 (1,090-1,570)	609 (567-660)	392 (354-434)	290 (263-326)	158	135 (120-151)	129 (120-140)	111 (95.8-129)	709 (573-915)
2012	6,890	2,230	2,030	1,200 (1,010-1,430)	545 (501-597)	390 (348-445)	308 (277-347)	348	173 (153-198)	126 (114-140)	104 (85.7-126)	515 (419-661)
2013	6,600	1,870	1,710	919 (808-1,060)	457 (427-489)	371 (338-417)	299 (277-325)	221	171 (154-189)	123 (114-133)	72.0 (62.2-82.6)	390 (324-479)
2014	6,190	2,700	2,180	890 (776-1,030)	502 (467-544)	383 (346-427)	346 (318-378)	274	188 (168-211)	127 (117-138)	97.9 (85.0-111)	336 (285-408)
2015	6,460	3,070	2,200	629 (552-726)	545 (509-585)	377 (350-410)	360 (333-387)	360	209 (190-230)	119 (111-127)	110 (97.7-124)	260 (234-291)
2016	5,580	2,550	1,680	410 (357-475)	502 (467-546)	374 (336-421)	299 (280-321)	298	192 (174-213)	95.5 (89.0-102)	79.2 (70.6-88.2)	223 (203-247)
2017	6,610	2,670	1,660	393 (350-445)	522 (490-556)	402 (373-435)	317 (300-334)	327	201 (186-215)	96.7 (90.6-103)	66.0 (59.7-72.4)	255 (233-283)
2018	5,280	2,420	1,840	359 (320-404)	523 (482-565)	426 (383-476)	310 (292-331)	304	199 (180-221)	92.4 (86.3-98.9)	60.7 (53.4-68.1)	395 (352-446)
2019	5,510	3,330	1,910	288 (255-328)	479 (449-506)	449 (411-497)	315 (300-330)	556	170 (157-185)	84.8 (80.0-90.5)	68.2 (61.7-75.7)	388 (347-444)
2020	5,480	2,540	1,600	171 (150-194)	384 (357-416)	424 (383-470)	245 (230-261)	277	130 (120-142)	71.7 (66.3-76.8)	48.3 (43.3-53.8)	297 (253-361)
2021	4,970	2,370	1,410	140 (120-162)	355 (322-386)	448 (391-505)	237 (219-254)	254	118 (105-134)	44.1 (38.0-51.0)	29.0 (25.1-33.5)	313 (244-404)

Table A.4: Estimated annual catch of teleosts by estimation group ('000 tonnes, 95% confidence intervals in parentheses where relevant) for the WCPO longline fishery. Catches of billfish species are reported separately. Estimated catches do not cover west-tropical domestic fisheries and former shark-targeted fisheries in the EEZs of Papua New Guinea and Solomon Islands.

Year	Albacore	Bigeye	Yellowfin	Opah	Escolars	Wahoo	Mahi mahi	Skipjack	Longsnouted lancetfish	Great barracuda	Pomfrets	Others
2003	86.7	80.4	65.7	4.37 (3.83-4.92)	2.48 (2.17-2.84)	3.23 (2.86-3.64)	2.71 (2.27-3.30)	1.02	0.777 (0.644-0.913)	0.219 (0.163-0.283)	0.224 (0.184-0.273)	8.78 (6.77-11.7)
2004	83.1	94.8	67.8	3.69 (3.33-4.11)	2.53 (2.30-2.79)	2.56 (2.32-2.82)	2.79 (2.39-3.31)	0.995	0.656 (0.580-0.740)	0.235 (0.188-0.288)	0.369 (0.321-0.420)	7.70 (6.54-9.29)
2005	87.1	78.9	57.2	3.30 (3.02-3.59)	2.37 (2.16-2.58)	2.75 (2.54-2.98)	2.43 (2.11-2.83)	0.693	0.738 (0.665-0.823)	0.257 (0.215-0.302)	0.294 (0.261-0.331)	4.93 (4.28-5.81)
2006	88.2	81.2	54.1	3.67 (3.37-4.01)	2.23 (2.05-2.45)	3.47 (3.18-3.74)	2.70 (2.32-3.23)	0.834	0.982 (0.877-1.09)	0.295 (0.249-0.349)	0.239 (0.214-0.265)	4.61 (3.94-5.43)
2007	85.3	77.7	52.1	3.27 (3.03-3.52)	2.31 (2.13-2.50)	3.20 (2.92-3.47)	3.83 (3.25-4.52)	0.622	0.983 (0.901-1.08)	0.312 (0.269-0.362)	0.224 (0.206-0.247)	4.19 (3.66-4.86)
2008	83.8	73.9	52.6	3.13 (2.86-3.39)	2.72 (2.50-2.96)	2.60 (2.37-2.87)	3.93 (3.32-4.75)	0.617	0.921 (0.833-1.02)	0.294 (0.247-0.347)	0.227 (0.204-0.253)	4.32 (3.65-5.19)
2009	106	72.5	65.7	3.25 (3.02-3.52)	3.41 (3.15-3.68)	2.78 (2.52-3.08)	5.03 (4.17-6.17)	0.742	1.05 (0.948-1.15)	0.380 (0.333-0.438)	0.196 (0.176-0.216)	5.64 (4.70-6.81)
2010	114	67.6	64.6	3.77 (3.46-4.11)	4.16 (3.81-4.53)	3.10 (2.78-3.46)	5.37 (4.48-6.45)	1.04	1.17 (1.02-1.34)	0.611 (0.525-0.711)	0.188 (0.165-0.215)	6.32 (5.09-8.22)
2011	83.1	73.0	62.2	3.63 (3.37-3.93)	3.95 (3.68-4.27)	2.94 (2.67-3.28)	5.73 (4.81-6.87)	1.09	1.26 (1.14-1.39)	0.519 (0.448-0.609)	0.240 (0.211-0.270)	6.93 (5.97-8.14)
2012	103	81.5	58.8	3.56 (3.23-3.95)	3.59 (3.29-3.91)	3.12 (2.81-3.50)	5.07 (4.34-6.04)	2.04	1.26 (1.13-1.44)	0.487 (0.402-0.594)	0.309 (0.270-0.357)	6.21 (5.36-7.29)
2013	97.6	63.9	46.2	3.47 (3.22-3.76)	3.08 (2.87-3.29)	3.07 (2.84-3.32)	3.93 (3.47-4.51)	1.24	1.21 (1.10-1.35)	0.342 (0.294-0.394)	0.296 (0.265-0.330)	5.00 (4.38-5.73)
2014	87.1	75.1	62.4	3.59 (3.30-3.89)	3.38 (3.15-3.67)	3.53 (3.25-3.84)	3.83 (3.36-4.41)	1.49	1.24 (1.13-1.38)	0.456 (0.395-0.515)	0.314 (0.278-0.358)	5.59 (4.85-6.50)
2015	92.6	75.8	70.4	3.37 (3.15-3.60)	3.61 (3.36-3.88)	3.64 (3.39-3.91)	2.70 (2.38-3.10)	1.83	1.21 (1.12-1.31)	0.516 (0.460-0.578)	0.355 (0.321-0.397)	6.82 (6.01-7.75)
2016	82.3	59.7	60.8	2.69 (2.51-2.87)	3.40 (3.15-3.69)	3.04 (2.84-3.26)	1.76 (1.53-2.02)	1.73	1.22 (1.10-1.37)	0.380 (0.338-0.425)	0.307 (0.275-0.342)	7.27 (6.46-8.20)
2017	100	64.5	68.4	2.73 (2.56-2.90)	3.63 (3.42-3.86)	3.25 (3.08-3.43)	1.70 (1.52-1.92)	2.29	1.31 (1.21-1.41)	0.316 (0.285-0.348)	0.323 (0.297-0.350)	7.10 (6.37-7.99)
2018	85.3	70.3	65.2	2.61 (2.44-2.80)	3.43 (3.17-3.70)	3.18 (2.98-3.38)	1.55 (1.38-1.73)	1.89	1.39 (1.25-1.55)	0.288 (0.251-0.325)	0.323 (0.289-0.362)	6.16 (5.38-7.15)
2019	90.1	66.7	78.9	2.40 (2.26-2.56)	3.29 (3.09-3.48)	3.25 (3.10-3.41)	1.24 (1.10-1.41)	2.91	1.50 (1.37-1.65)	0.327 (0.295-0.365)	0.253 (0.233-0.277)	4.91 (4.28-5.69)
2020	80.0	53.7	55.3	2.03 (1.88-2.18)	2.74 (2.54-2.96)	2.56 (2.41-2.71)	0.745 (0.657-0.846)	1.94	1.43 (1.29-1.58)	0.231 (0.207-0.259)	0.190 (0.174-0.209)	4.81 (4.07-5.80)
2021	72.9	51.2	56.7	1.25 (1.07-1.44)	2.52 (2.29-2.74)	2.47 (2.28-2.64)	0.599 (0.515-0.692)	1.90	1.50 (1.31-1.68)	0.140 (0.121-0.163)	0.166 (0.144-0.190)	3.73 (3.08-4.48)

Table A.5: Estimated annual catch of billfish by estimation group ('000 individuals, 95% confidence intervals in parentheses where relevant) for the WCPO longline fishery. Estimated catches do not cover west-tropical domestic fisheries and former shark-targeted fisheries in the EEZs of Papua New Guinea and Solomon Islands.

Year	Swordfish	Blue marlin	Striped marlin	Indo-Pacific sailfish	Shortbill spearfish	Black marlin
2003	242	214	119	13.6	29.8	19.2
2004	364	323	102	9.48	29.1	26.2
2005	343	357	78.4	15.7	28.7	23.6
2006	357	203	73.1	12.9	30.3	16.2
2007	427	317	64.1	31.1	20.9	25.0
2008	333	243	73.5	20.7	24.7	21.5
2009	336	276	59.9	51.6	17.5	20.4
2010	277	292	59.0	19.6	20.0	24.4
2011	315	283	92.1	14.4	30.3	28.4
2012	345	288	82.7	65.1	25.1	27.1
2013	328	321	77.8	83.4	33.3	21.8
2014	313	330	76.9	72.7	40.2	23.4
2015	342	329	79.8	64.0	40.9	22.9
2016	268	291	60.3	64.4	33.7	19.4
2017	255	230	55.4	33.5	30.1	10.6
2018	283	215	59.8	39.0	26.0	9.90
2019	216	234	72.6	56.4	32.3	10.7
2020	203	150	67.0	24.5	19.2	9.20
2021	179	152	64.2	28.3	17.4	7.97

Table A.6: Estimated annual catch of billfish by estimation group ('000 tonnes, 95% confidence intervals in parentheses where relevant) for the WCPO longline fishery. Estimated catches do not cover west-tropical domestic fisheries and former shark-targeted fisheries in the EEZs of Papua New Guinea and Solomon Islands.

Year	Swordfish	Blue marlin	Striped marlin	Black marlin	Indo-Pacific sailfish	Shortbill spearfish
2003	13.9	11.8	5.34	0.864	0.256	0.391
2004	20.2	18.8	4.59	1.39	0.188	0.362
2005	18.9	20.8	3.72	1.33	0.282	0.371
2006	20.5	12.9	3.48	0.761	0.242	0.379
2007	24.3	17.0	3.08	1.06	0.846	0.280
2008	19.8	13.0	3.49	1.03	0.496	0.335
2009	18.3	14.2	2.73	1.01	0.866	0.224
2010	16.0	14.7	2.75	1.25	0.335	0.296
2011	17.2	14.5	3.57	1.05	0.256	0.442
2012	19.8	14.6	3.76	1.15	1.08	0.347
2013	17.7	15.2	3.22	0.970	1.21	0.459
2014	18.3	15.6	3.08	1.09	1.03	0.526
2015	20.2	16.1	3.39	0.987	1.04	0.543
2016	16.4	13.6	2.60	0.794	1.09	0.458
2017	17.5	13.0	2.52	0.494	0.680	0.429
2018	18.1	11.9	2.48	0.463	0.732	0.383
2019	13.4	11.5	2.80	0.507	0.824	0.432
2020	14.0	7.62	2.74	0.414	0.406	0.248
2021	12.4	7.35	2.60	0.337	0.441	0.216

Table A.7: Estimated annual catch of elasmobranchs by estimation group ('000 individuals, 95% confidence intervals in parentheses where relevant) for the WCPO longline fishery. Estimated catches do not cover west-tropical domestic fisheries and former shark-targeted fisheries in the EEZs of Papua New Guinea and Solomon Islands.

Year	Blue shark	Pelagic stingray	Silky shark	Shortfin mako	Oceanic whitetip shark	Bigeye thresher	Thresher sharks	Mobulid rays	Others
2003	1,190 (1,050-1,360)	250 (211-299)	179 (133-238)	83.4 (62.5-109)	101 (79.9-129)	32.3 (24.8-40.9)	42.8 (32.0-58.5)	1.70 (0.440-6.13)	112 (91.1-171)
2004	1,330 (1,200-1,490)	212 (186-243)	201 (159-260)	108 (85.3-138)	99.2 (81.3-126)	39.5 (32.9-47.2)	45.0 (33.9-57.0)	28.4 (15.1-52.3)	115 (97.1-134)
2005	1,170 (1,060-1,290)	196 (174-224)	187 (156-226)	108 (89.3-135)	74.3 (61.6-91.6)	39.3 (33.3-46.1)	35.5 (28.5-44.1)	22.3 (13.2-36.1)	93.4 (80.8-108)
2006	1,290 (1,170-1,420)	178 (157-201)	193 (163-229)	123 (103-145)	58.3 (47.7-69.9)	50.9 (43.4-59.8)	48.8 (39.4-58.8)	4.92 (2.82-8.87)	72.3 (62.3-84.3)
2007	1,280 (1,150-1,460)	164 (146-185)	244 (209-285)	144 (123-171)	55.0 (46.6-64.9)	51.2 (44.0-59.2)	57.7 (49.1-67.5)	3.33 (1.94-5.66)	78.8 (68.5-92.5)
2008	1,120 (997-1,300)	148 (130-168)	246 (204-294)	145 (123-173)	53.5 (43.0-65.0)	49.9 (41.7-59.7)	56.1 (46.6-67.8)	4.55 (2.77-8.05)	101 (85.7-121)
2009	1,190 (1,040-1,360)	198 (177-221)	343 (244-486)	159 (135-188)	61.1 (45.1-84.0)	42.6 (35.7-50.7)	54.1 (41.1-69.5)	8.44 (5.47-13.6)	114 (97.5-137)
2010	1,100 (964-1,250)	264 (226-310)	346 (193-637)	152 (127-182)	59.5 (37.5-94.3)	43.4 (35.2-53.8)	49.0 (32.9-71.8)	11.9 (6.82-21.6)	120 (102-146)
2011	1,220 (1,080-1,380)	249 (220-281)	369 (217-669)	135 (114-163)	61.5 (41.9-89.2)	65.0 (53.8-77.8)	52.9 (35.6-79.2)	13.1 (9.08-19.8)	135 (119-157)
2012	946 (846-1,060)	244 (210-281)	381 (251-610)	121 (103-147)	63.2 (44.4-91.0)	67.4 (55.3-79.8)	53.8 (36.9-78.7)	14.5 (9.86-22.4)	123 (107-143)
2013	714 (643-799)	190 (171-213)	162 (126-219)	121 (104-144)	41.3 (33.5-53.4)	48.7 (41.8-56.8)	28.4 (22.1-36.9)	13.1 (8.81-20.6)	91.2 (81.1-104)
2014	877 (776-994)	226 (203-253)	113 (92.2-138)	135 (113-161)	35.7 (29.1-44.4)	43.6 (36.8-52.4)	21.5 (17.2-26.9)	12.6 (8.59-18.6)	88.8 (76.8-104)
2015	962 (874-1,060)	267 (246-294)	152 (127-188)	91.8 (77.4-108)	42.8 (35.3-53.7)	52.2 (45.2-61.1)	24.7 (20.2-30.9)	8.61 (6.29-12.1)	93.4 (83.5-105)
2016	887 (809-978)	254 (229-280)	149 (127-177)	56.7 (47.0-68.6)	33.8 (28.7-40.4)	49.6 (43.3-57.6)	27.6 (22.9-33.4)	4.21 (2.95-5.94)	86.1 (75.0-101)
2017	813 (750-887)	272 (252-293)	134 (117-154)	55.1 (48.3-63.2)	28.2 (24.4-32.6)	50.4 (44.4-58.3)	32.0 (26.9-37.9)	5.76 (4.33-7.39)	91.2 (80.7-104)
2018	832 (765-918)	303 (276-330)	116 (99.1-141)	67.3 (57.9-77.6)	26.2 (22.1-30.9)	50.4 (42.7-60.3)	30.6 (25.0-37.3)	9.56 (7.29-12.8)	98.4 (84.4-115)
2019	898 (828-971)	341 (319-369)	123 (107-147)	73.5 (66.6-81.3)	32.3 (28.2-37.5)	40.9 (36.1-46.9)	22.2 (18.5-27.1)	8.03 (6.02-10.9)	92.8 (80.4-109)
2020	816 (750-888)	297 (272-323)	105 (87.8-131)	64.4 (56.9-73.7)	33.6 (28.7-40.3)	34.4 (29.2-40.4)	14.6 (11.4-19.2)	4.90 (3.49-6.97)	74.5 (63.5-87.2)
2021	654 (596-726)	259 (223-298)	69.7 (58.4-84.4)	46.5 (38.6-55.5)	26.7 (22.6-31.7)	29.4 (24.1-36.2)	9.91 (6.98-13.9)	4.67 (3.54-6.38)	53.5 (45.3-63.3)

Table A.8: Estimated annual catch of elasmobranchs by estimation group ('000 tonnes, 95% confidence intervals in parentheses where relevant) for the WCPO longline fishery. Estimated catches do not cover west-tropical domestic fisheries and former shark-targeted fisheries in the EEZs of Papua New Guinea and Solomon Islands.

Year	Blue shark	Bigeye thresher	Shortfin mako	Silky shark	Pelagic stingray	Mobulid rays	Thresher sharks	Oceanic whitetip shark	Others
2003	36.8 (32.4-42.0)	2.97 (2.29-3.76)	3.12 (2.34-4.05)	2.43 (1.80-3.25)	2.01 (1.69-2.41)	0.253 (0.0654-0.895)	0.966 (0.719-1.32)	1.51 (1.21-1.93)	3.81 (3.00-7.66)
2004	41.3 (37.0-46.3)	3.56 (2.97-4.25)	4.02 (3.17-5.14)	2.66 (2.11-3.39)	1.75 (1.52-2.00)	4.12 (2.19-7.51)	0.828 (0.632-1.06)	1.44 (1.20-1.80)	3.55 (2.97-4.39)
2005	37.1 (33.7-41.0)	3.57 (3.03-4.21)	3.97 (3.28-4.94)	2.51 (2.09-3.00)	1.61 (1.43-1.85)	3.26 (1.94-5.27)	0.740 (0.590-0.917)	1.09 (0.918-1.33)	2.95 (2.53-3.48)
2006	41.0 (37.1-45.1)	4.71 (4.01-5.56)	4.46 (3.72-5.29)	2.62 (2.21-3.09)	1.42 (1.26-1.61)	0.730 (0.418-1.33)	0.987 (0.801-1.21)	0.873 (0.721-1.04)	2.57 (2.17-3.15)
2007	40.3 (36.3-45.7)	4.84 (4.13-5.68)	5.22 (4.46-6.19)	3.26 (2.81-3.84)	1.29 (1.15-1.46)	0.500 (0.290-0.855)	1.16 (0.972-1.40)	0.835 (0.701-0.980)	3.10 (2.57-4.07)
2008	35.3 (31.4-40.7)	4.76 (3.97-5.76)	5.25 (4.44-6.26)	3.32 (2.75-3.96)	1.16 (1.01-1.32)	0.691 (0.418-1.20)	1.31 (1.07-1.59)	0.818 (0.666-0.986)	3.95 (3.20-5.27)
2009	37.2 (32.8-42.5)	4.16 (3.48-5.04)	5.74 (4.89-6.80)	4.55 (3.24-6.43)	1.54 (1.38-1.73)	1.27 (0.835-2.05)	1.18 (0.917-1.48)	0.937 (0.701-1.27)	4.47 (3.59-6.03)
2010	34.6 (30.4-39.5)	4.17 (3.37-5.21)	5.50 (4.59-6.60)	4.81 (2.73-8.83)	1.99 (1.71-2.32)	1.82 (1.05-3.25)	1.09 (0.742-1.60)	0.940 (0.596-1.47)	4.74 (3.81-6.19)
2011	38.9 (34.5-43.8)	6.30 (5.16-7.59)	4.89 (4.12-5.92)	5.02 (2.97-9.08)	1.92 (1.69-2.18)	1.96 (1.37-2.92)	1.12 (0.765-1.63)	0.938 (0.645-1.35)	4.93 (4.25-5.94)
2012	30.2 (27.1-33.9)	6.50 (5.30-7.74)	4.36 (3.70-5.31)	5.19 (3.41-8.22)	1.91 (1.65-2.22)	2.21 (1.49-3.41)	1.26 (0.874-1.82)	0.952 (0.672-1.37)	4.61 (3.90-5.58)
2013	22.9 (20.6-25.5)	4.57 (3.91-5.36)	4.36 (3.73-5.19)	2.21 (1.72-2.95)	1.47 (1.32-1.64)	1.99 (1.33-3.16)	0.692 (0.547-0.903)	0.625 (0.515-0.798)	3.53 (3.08-4.28)
2014	27.8 (24.6-31.5)	4.02 (3.38-4.87)	4.86 (4.07-5.83)	1.50 (1.22-1.81)	1.80 (1.61-2.00)	1.85 (1.26-2.73)	0.489 (0.386-0.631)	0.529 (0.434-0.648)	3.29 (2.80-3.99)
2015	30.4 (27.7-33.7)	4.71 (4.05-5.53)	3.32 (2.79-3.91)	1.97 (1.66-2.41)	2.16 (1.98-2.38)	1.21 (0.888-1.71)	0.533 (0.440-0.685)	0.611 (0.507-0.752)	3.18 (2.83-3.67)
2016	28.4 (25.9-31.3)	4.47 (3.89-5.24)	2.05 (1.70-2.48)	1.99 (1.70-2.36)	2.00 (1.80-2.21)	0.615 (0.433-0.863)	0.747 (0.618-0.892)	0.497 (0.425-0.590)	2.82 (2.47-3.31)
2017	26.2 (24.3-28.5)	4.50 (3.96-5.22)	1.98 (1.74-2.28)	1.83 (1.59-2.10)	2.06 (1.91-2.23)	0.882 (0.663-1.12)	0.870 (0.731-1.04)	0.429 (0.371-0.491)	3.12 (2.76-3.85)
2018	27.0 (24.9-29.8)	4.34 (3.68-5.18)	2.42 (2.08-2.79)	1.54 (1.32-1.85)	2.40 (2.19-2.64)	1.39 (1.06-1.85)	0.702 (0.571-0.860)	0.376 (0.322-0.438)	3.26 (2.80-4.04)
2019	29.2 (27.0-31.5)	3.52 (3.11-4.07)	2.63 (2.38-2.91)	1.68 (1.45-2.01)	2.66 (2.48-2.87)	1.20 (0.903-1.62)	0.599 (0.504-0.746)	0.484 (0.423-0.556)	3.19 (2.76-4.00)
2020	26.4 (24.3-28.7)	2.94 (2.48-3.46)	2.30 (2.03-2.63)	1.50 (1.24-1.86)	2.21 (2.02-2.39)	0.755 (0.538-1.08)	0.431 (0.336-0.569)	0.515 (0.443-0.610)	2.54 (2.15-3.14)
2021	21.3 (19.5-23.6)	2.51 (2.05-3.12)	1.67 (1.39-1.99)	1.00 (0.834-1.22)	1.92 (1.65-2.21)	0.731 (0.555-1.00)	0.312 (0.217-0.443)	0.411 (0.350-0.484)	1.75 (1.49-2.10)

Table A.9: Estimated annual catch of sea turtles and marine mammals by estimation group ('000 individuals, 95% confidence intervals in parentheses where relevant) for the WCPO longline fishery. Estimated catches do not cover west-tropical domestic fisheries and former shark-targeted fisheries in the EEZs of Papua New Guinea and Solomon Islands.

Year	Olive ridley turtle	Sea turtles	Loggerhead turtle	Green turtle	Marine mammals	Leatherback turtle	Hawksbill turtle
2003	4.44 (2.05-9.65)	10.7 (3.88-29.1)	¡0.001 (¡0.001-0.673)	0.616 (0.136-3.20)	1.22 (0.715-2.37)	0.589 (0.187-2.05)	0.276 (0.0328-2.21)
2004	6.28 (3.16-11.5)	12.3 (4.05-40.2)	0.0901 (0.0138-0.666)	1.80 (0.768-3.91)	0.718 (0.335-1.56)	0.714 (0.268-1.76)	0.463 (0.106-2.25)
2005	5.14 (3.11-8.43)	11.0 (5.00-23.4)	2.60 (1.04-5.93)	1.17 (0.631-2.27)	0.648 (0.352-1.18)	0.681 (0.389-1.33)	0.396 (0.128-1.53)
2006	5.84 (3.07-11.9)	9.58 (3.40-29.6)	7.46 (3.88-13.5)	0.774 (0.387-1.52)	1.06 (0.661-1.65)	0.660 (0.309-1.43)	0.435 (0.134-1.77)
2007	15.6 (7.92-38.0)	7.96 (2.79-25.8)	5.03 (2.85-9.60)	2.64 (1.42-4.82)	1.13 (0.753-1.67)	0.716 (0.360-1.39)	0.588 (0.199-2.02)
2008	17.4 (8.59-40.9)	4.99 (1.62-15.6)	1.80 (0.803-3.71)	4.65 (2.38-9.07)	0.923 (0.527-1.55)	0.626 (0.286-1.39)	0.662 (0.210-2.46)
2009	21.7 (12.9-42.2)	3.29 (0.606-16.2)	1.09 (0.502-2.36)	3.60 (1.92-6.84)	0.914 (0.558-1.50)	0.921 (0.475-1.86)	1.55 (0.594-4.88)
2010	14.5 (8.49-26.6)	3.50 (0.344-36.6)	1.48 (0.590-3.63)	1.77 (0.751-3.94)	1.17 (0.739-1.88)	1.51 (0.747-3.16)	2.81 (0.927-10.5)
2011	9.35 (5.48-18.2)	5.19 (1.22-19.1)	2.43 (1.25-4.92)	1.85 (0.959-3.59)	1.45 (0.959-2.12)	1.80 (1.01-3.32)	1.67 (0.713-4.50)
2012	9.39 (4.70-20.3)	6.23 (2.53-16.3)	3.63 (2.00-6.92)	3.10 (1.89-4.86)	2.12 (1.27-3.60)	2.02 (1.31-3.21)	0.871 (0.291-2.66)
2013	7.23 (4.42-12.7)	3.54 (1.40-10.2)	3.10 (1.92-4.96)	2.79 (1.86-4.32)	2.32 (1.65-3.29)	1.65 (1.18-2.38)	0.567 (0.248-1.30)
2014	9.51 (6.10-15.5)	1.76 (0.635-5.14)	2.90 (1.86-4.66)	3.31 (2.03-5.77)	2.86 (2.08-3.92)	1.73 (1.16-2.73)	1.12 (0.523-2.72)
2015	9.29 (6.31-14.3)	1.73 (1.03-3.10)	3.48 (2.62-4.79)	3.00 (1.99-4.69)	2.31 (1.76-3.09)	1.73 (1.16-2.78)	1.10 (0.539-2.35)
2016	6.72 (5.00-9.59)	3.48 (1.98-6.26)	3.13 (2.11-4.62)	1.96 (1.32-3.01)	1.29 (0.955-1.81)	0.977 (0.651-1.55)	0.575 (0.311-1.05)
2017	8.31 (5.91-12.0)	6.71 (4.57-11.1)	2.36 (1.63-3.42)	1.88 (1.37-2.64)	1.49 (1.16-1.98)	0.807 (0.525-1.32)	0.492 (0.317-0.797)
2018	5.40 (3.38-8.53)	4.49 (2.81-8.13)	2.10 (1.47-3.09)	1.65 (1.20-2.29)	2.11 (1.62-2.85)	0.605 (0.358-1.07)	0.489 (0.287-0.903)
2019	4.14 (2.98-5.90)	0.585 (0.299-1.21)	4.21 (3.03-6.10)	1.67 (1.23-2.36)	2.24 (1.44-3.57)	0.406 (0.265-0.653)	0.548 (0.350-0.917)
2020	2.78 (1.74-4.36)	0.254 (0.0812-0.837)	6.07 (4.03-8.94)	1.08 (0.743-1.58)	1.86 (1.19-3.00)	0.328 (0.192-0.575)	0.381 (0.215-0.772)
2021	3.31 (1.46-7.59)	4.35 (1.29-13.6)	3.03 (0.839-11.1)	0.583 (0.345-0.995)	1.48 (0.919-2.37)	0.450 (0.244-0.871)	0.199 (0.0678-0.578)