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Summary Of Bycatch In WCPFC Purse Seine Fisheries At A Regional Scale, 2003–2022

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Tom Peatman[1], Nick Hill[2], Joanne Potts[2], Simon Nicol[2]

[1]Independent Consultant for the Oceanic Fisheries Programme (OFP), The Pacific Community
[2]Oceanic Fisheries Programme (OFP), The Pacific Community, Nouméa, New Caledonia

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 large-scale equatorial purse seine fishery operating in the WCPFC Convention Area for the period 2003 to 2022. These large vessels, typically with greater than 500 tonnes carrying capacity, have been responsible for approximately 85% of the purse seine catch of tropical tunas in the WCPFC Convention Area in recent years, with an average annual catch of 1.6 million tonnes since 2010.

The estimates cover the full range of finfish, billfish, elasmobranch, marine mammal and sea turtle species that have been recorded in purse seine observer data. The estimates do not cover domestic purse seine fisheries in the western sector of the WCPFC Convention Area, or purse seine fisheries in temperate waters off Japan and New Zealand.

In this iteration, a spatiotemporal modelling framework was used to estimate catch rates. These catch rate models should allow better separation of temporal effects from other covariates, improving the utility of the catch rate models for screening of species that may warrant more targeted analyses due to unexplained temporal trends. The inclusion of spatial effects also allows consideration of the spatial distribution of estimated catches. The taxonomic resolution of catch estimates was also improved for marine mammals, to allow more meaningful monitoring of catch and catch rate estimates for these species.

The report concludes with recommendations to the Scientific Committee:

- Note the estimates of bycatch of the large-scale equatorial purse seine fishery in the WCPFC Convention Area;
- Note that the bycatch estimates should be interpreted as the bycatch that would have been recorded by observers with 100% coverage of fishing events;
- Note that other studies suggest that shark bycatch estimates are likely to be underestimates, due to underestimation of captures by observers;
- Note the refinements to the estimation approach, including the implementation of spatially-explicit catch rate models. This should improve the utility of catch rate models for identification of species that may warrant additional targeted analyses;
- Note the impacts of recent reductions in observer coverage on the precision of catch rate and catch estimates, and the extent to which they can be used to monitor for temporal trends;
- Note the refinements to the taxonomic resolution of catch estimates for marine mammals.

1 Introduction

The Western and Central Pacific Fisheries Commission (WCPFC) has the responsibility 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). Additionally, there are requirements to minimise the catch of non-target species (Article 5e), 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 and quantitative risk assessments have been undertaken for a range of species that are incidentally caught in purse seine fisheries in the WCPFC Convention Area, including silky shark (*Carcharhinus falciformis*, Carcharhinidae; Clarke et al., 2018), oceanic whitetip shark (*Carcharhinus longimanus*, Carcharhinidae; Tremblay-Boyer et al., 2019) and whale shark (*Rhincodon typus*, Rhincodontidae; Neubauer et al., 2018). The WCPFC has also contributed 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 by the WCPFC for non-target species: including sea turtles (Chelonioidea; CMM 2008–03, 2018–04); sharks (Elasmobranchii; 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); mobulid rays (Mobulidae; CMM 2019–05); marine mammals (Cetacea & pinnipeds; CMM 2011–03); seabirds (CMM 2018–03), and striped marlin (*Tetrapturus audax*, Istiophoridae; CMM 2006–04 and CMM 2010–01 for striped marlin in the southwest and north Pacific, respectively). Most of these CMMs encourage better reporting of catches for non-target species. Additionally Resolution 2005–03 encourages avoiding the capture of all non-target fish species, as well as the prompt release of captured individuals to the water unharmed.

CMM 2008–01 introduced a requirement for 100% observer coverage for purse seine operations between 10°S and 10°N from 2010 onwards, with CMM 2007–01 requiring a minimum of 5% observer coverage for purse seine fishing elsewhere. The high rates of available observer coverage offer the possibility of robust estimates of catch rates and quantities for non-target species caught in WCPO purse seine fisheries, which are typically not included in reported catches from vessel logbook data. Estimates of comprehensive purse seine catch estimates have routinely been generated for the large-scale equatorial purse seine fishery operating in the WCPFC Convention Area (Peatman and Nicol, 2021). These estimates of purse seine bycatch complement equivalent estimates for longline fisheries (Peatman and Nicol, 2023).

In this report, we estimate purse seine catch of teleosts, elasmobranchs, marine mammals and sea turtles for the period 2003 to 2022. Estimates of seabird bycatch have been generated separately through WCPFC Project 68 (Peatman et al., 2019). This iteration includes a new approach to catch rate estimation, using spatially explicit catch rate models, as well improvements to the taxonomic resolution of catch estimates for marine mammals.

2 Data and methods

2.1 Analysed datasets

WCPFC's aggregated catch and effort dataset provides total sets and catches of selected tuna species for purse seine fisheries operating in the WCPFC Convention Area based on vessel logbooks. We refer to this dataset throughout as reported catch and effort data. The reported catch and effort data are held at a resolution of year, month, flag-fleet, set type and 1° spatial cell. Set types include sets on free schools, and schools associated with anchored fish aggregating devices (FADs), drifting FADs, logs and other natural floating objects, whale sharks and whales. Reported effort data for the large-scale equatorial purse seine fishery were extracted from the reported catch and effort dataset for the period 2003 to 2022. This excludes effort from purse seine fisheries operating in temperate waters off Japan and New Zealand, as well as domestic fisheries in the western sector of the WCPFC Convention Area, for which the Pacific Community holds limited representative observer data. The large-scale equatorial purse seine fishery accounted for 86% of total reported purse seine catch in the WCPFC Convention Area from 2003 to 2022.

Observer data collected on purse seine vessels from 2003 to 2023 were extracted from data held by the Pacific Community, including WCPFC regional observer programme data as well as data from other sources. The initial data extract included 499,427 sets from 20,301 observer trips. Filtering rules were applied to remove spatial outliers, the majority of which appeared to reflect errors in recorded set locations. Observed sets between the eastern boundary of the WCPFC Convention Area and 120°W were included in training datasets to fit catch rate models, to inform catch rates in the Central Pacific region. The data from an observer's first trip is considered to be less reliable than their subsequent trips (e.g., Lawson, 2012). As such, we also excluded data from each observer's first deployment. After filtering, the analysed observer dataset included 453,212 sets from 18,894 observer trips.

2.2 Estimation groups

Estimated catches were generated for 54 species, or groups of species, referred to as 'estimation groups' which cover the full range of teleost, elasmobranch, marine mammal and sea turtle species observed in purse seine catches Table 1. However, reported catches were used where available, i.e. for bigeye, skipjack and yellowfin tuna which are collectively referred to throughout as 'tropical tuna'. The estimation groups were initially defined by Peatman et al. (2017), with consideration of ease of accurate species-level identifications during fishing operations and frequency of occurrence. Where possible, species-level estimation groups were used for species of special interest, i.e., marine mammals, sea turtles and WCPFC key shark species.

In this iteration, the estimation groups of marine mammals were refined to allow treatment at finer taxonomic resolutions. The new estimation groups were defined with consideration of the recommendations from Miller (2023), along with the frequency of observation of captures. The updated estimation groups for marine mammals were: species-specific groups for false killer whale (*Pseudorca crassidens*, Delphinidae), short-finned pilot whale (*Globicephala macrorhynchus*, Delphinidae) and Risso's dolphin (*Grampus griseus*, Delphinidae); remaining 'blackfish' species, including long-finned pilot whales (*Globicephala melas*, Delphinidae) and unspecified pilot whales (Globicephala spp.), killer whales (*Orcinus orca*, Delphinidae), pygmy killer whales (*Feresa attenuata*, Delphinidae) and melon-headed whales (*Peponocephala electra*, Delphinidae); family-level groups for dolphins (Delphinidae) and beaked whales (Ziphiidae); order level groups for toothed whales (Odontoceti) and baleen whales (Mysticeti); and, a marine mammals group. The number of observed sets and caught individuals for the marine mammal estimation groups are provided by 'species code' in Table 2.

Additionally, in this iteration we grouped blue marlin (*Makaira mazara*, Istiophoridae) and black marlin (*Makaira indica*, Istiophoridae) in the same estimation group due to concerns around the accuracy of species level identifications for these species (Williams et al., 2018).

Estimation groups were not mutually exclusive, with observed catches mapped to estimation groups using the most detailed available taxonomic classification. For example, captures recorded as a false killer whale or short-finned pilot whale would be classed as members of their species-specific estimation group, rather than included in the 'blackfish' or 'Toothed whales' estimation groups.

2.3 Catch rate models

Catch rate models were fitted using the R package *sdmTMB* (version 0.6.0.9002; Anderson et al., 2024), with all analyses undertaken in R (version 4.4.0; R Core Team, 2024). The maximal specification of the catch rate models was:

$$\mathbb{E}[y_{i,\boldsymbol{s},t}] = \mu_{i,\boldsymbol{s},t} \tag{1}$$

$$\mu_{i,\boldsymbol{s},t} = f^{-1}\left(\boldsymbol{X}_{i,\boldsymbol{s},t}\boldsymbol{\beta} + O_i + \alpha_g + \omega_{\boldsymbol{s}} + \epsilon_{\boldsymbol{s},t}\right) \tag{2}$$

where: $y_{\boldsymbol{s},t}$ represents the response data for set i at point $\boldsymbol{s}$ and time t; μ represents the mean; f represents the link function and f^{-1} represents its inverse; $\boldsymbol{X}$ represents the design matrix of the main effects; $\boldsymbol{\beta}$ represents a vector of fixed-effect coefficients; O_i represents the effort offset, here the log of observed sets; α_g represents random intercepts by group g, $\alpha_g \sim \mathrm{N}(0, \sigma_\alpha^2)$; $\omega_{\boldsymbol{s}}$ represents a spatial random field, $\omega_{\boldsymbol{s}} \sim \mathrm{MVN}(\boldsymbol{0}, \boldsymbol{\Sigma}_\omega)$; and, $\epsilon_{\boldsymbol{s},t}$ represents a spatiotemporal random field, $\epsilon_{\boldsymbol{s},t} \sim \mathrm{MVN}(\boldsymbol{0}, \boldsymbol{\Sigma}_\epsilon)$.

All models were fitted to observations at a set-level with the response variable being the observed catch per set, and so the effort offset O_i was 0. Catch rates were modelled on a per set basis, as bycatch rates have been demonstrated to have a weak relationship with catch volume (Dagorn et al., 2012).The unit of observed catch for models of billfish, elasmobranch, sea turtle and marine mammal estimation groups was individuals, with metric tonnes used for the other teleost estimation groups (Table 2). These match the units of catch typically used by observers when recording observed catches. A negative binomial error structure was used where appropriate for models with response variable units of individuals per set, with a log link function. In instances where presence/absence and catch when present could not be adequately represented with negative binomial errors, we used a delta approach with a zero truncated negative binomial error structure and log link for the positive component. Model diagnostics of exploratory models supported the use of delta-lognormal models for the teleost estimation groups, with the exception of batfish (Platax spp) for which a delta-gamma structure with log link was more stable.

Whale and whale shark associated sets have been reported more frequently by observers than in vessel logbooks across the time period of interest (e.g., Neubauer et al., 2018). To avoid downwards bias in estimated catches of whale sharks and marine mammals, Peatman and Nicol (2021) treated whale and whale shark associated sets as free school sets when estimating both catch rates and catches of whale sharks and marine mammals. Catch rates typically demonstrate strong variation in catch rates between set types, and so the differences in proportions of whale and whale shark sets has the potential to impact estimates for all estimation groups. In this iteration, we treated whale and whale shark associated sets as free school sets for all estimation groups.

Effort from the Philippines purse seine fleet included both the high-seas pocket fishery, as well as the larger vessels operating more broadly in the WCPFC Convention Area. The vessel characteristics and fishing strategies differ between these two fleet segments and so the two fleets were considered as distinct fleets when estimating catch rates and catches. The high-seas pocket fishery was assigned a flag of 'PHPH', with the remaining effort from Philippines purse seiners keeping the flag 'PH'. Reported catch and effort data for the Philippines high-seas pocket fishery was separated from the remaining Philippines effort by applying a spatial filter. Observed effort was separated on the basis of observer programme code.

Initial models were fitted for all estimation groups with the following explanatory variables:

- year, included as a random intercept, to account for temporal variation;
- month, included as penalised smooth with a cyclic basis (and end points of 1 and 12), to account for seasonal variation;
- set type, included as a categorical variable ('FS' = free school, whale and whale shark sets; 'aFAD' = anchored FAD sets; 'dFAD' = drifting FAD sets; 'log' = sets on logs or other natural floating objects), to account for differences in catch rates for sets on schools displaying different

types of associative behaviour (Amandè et al., 2010);

- 'flag', included as a random intercept, to account for potential differences in catch rates between fleets due to variation in fishing strategies, operational characteristics, etc.;
- oceanic Niño index (ONI)[1], classified as 'El Niño' (five consecutive months with index values ≥ 0.5), 'La Niña' (five consecutive months with index values ≤ -0.5, or neutral;
- the depth of the 20°C isotherm, interpolated from temperate at depth[2], included as a penalised smooth;
- a spatial random field, to account for persistent spatial variation.

For delta models, these explanatory variables were included in both the presence/absence and positive components. We refer to these models as the 'base model' for each estimation group. The 20°C isotherm was included to attempt to efficiently account for potential broad-scale spatial variation in catch rates. Other environmental variables correlated to sub-mesoscale (or finer) features may have a stronger influence on the distribution of the bycatch species and so catch rates (e.g. Bertrand et al., 2014). However, the influence of these fine-scale features may not be apparent after aggregation to the coarser resolution of the analysis reported here.

For selected estimation groups, we also tested additional models with more detailed representation of spatial and/or spatiotemporal variation, including one of the following:

- quarter-specific spatiotemporal fields, to account for seasonal variation in spatial variation;
- ONI-class specific spatiotemporal fields, to account for potential changes in spatial variation resulting from prevailing El Niño or La Niña periods;
- set-type specific spatial fields, to account for potential differences in spatial variation between set types, e.g., if there is between set-type structure in size or age-classes for the estimation group.

These additional random fields were included as a spatiotemporal field and assumed to be independent and identically distributed. Species of special interest were prioritised when selecting which estimation groups to test more complex model specifications, along with consideration of both the frequency of observation and strength of spatial structure detected in model residual diagnostics. The estimation groups with testing of more detailed models were: teleosts – rainbow runner (*Elagatis bipinnulata*, Carangidae), mackerel scad (*Decapturus macarellus*, Carangidae), oceanic triggerfish (*Balistidae*, Balistidae), mahi mahi (*Coryphaena hippurus*, Coryphaenidae), wahoo (*Acanthocybium solandri*, Scombridae), frigate & bullet tunas, and, barracudas; billfish – blue & black marlin, striped marlin, and, Indo-Pacific sailfish (*Istiophorus platypterus*, Istiophoridae); elasmobranchs – silky shark, mobulid rays, oceanic whitetip shark, and, whale shark; sea turtles – olive ridley turtle (*Lepidochelys*

[1] https://www.cpc.ncep.noaa.gov/data/indices/oni.ascii.txt

[2] NCEP Global Ocean Data Assimilation System (GODAS) data provided by the NOAA PSL, Boulder, Colorado, USA, from their website at https://psl.noaa.gov

olivacea, Cheloniidae), green turtle (*Chelonia mydas*, Cheloniidae), loggerhead turtle (*Caretta caretta*, Cheloniidae), and, hawksbill turtle (*Eretmochelys imbricata*, Cheloniidae); marine mammals – false killer whale, dolphins, baleen whales, and, short-finned pilot whale. Ensemble model predictions were used for these estimation groups (Section 2.4).

The models were used to estimate catch rates for unobserved effort taken from aggregated reported effort data. As such, explanatory variables were aggregated to a consistent resolution when both fitting catch rate models and predicting catch rates (see Section 2.4). This resolution is a compromise, with finer resolutions enabling more detailed representation of relationships between covariates and catch rates, though at the expense of greater computational demands. The finest possible spatial and temporal resolution is constrained by the resolution of the reported (aggregated) effort data, i.e., year-month and 1° spatial cell. We considered that year-month and 5° spatial cell provided a sufficiently fine resolution for the estimation of catch rates and catches. The mean depth of the 20°C isotherm was calculated for each year-month and 5° spatial cell combination, and combined with observer data and reported effort data to fit catch rate models and estimate catch rates. The location of observed and reported effort was aggregated to a 5° resolution by assigning the (proxy) midpoint of the corresponding cell, and an Lambert azimuthal equal-area projection applied. For example, for effort within the 5° cell spanning 5°N to 10°N and 140°E to 145°E, the assigned location was 7.5°N, 142.5°N.

Meshes for the spatial and spatiotemporal random fields were constructed using the *fmesher* package (Lindgren, 2024). The mesh was constructed separately for each estimation group using the distribution of observed effort with positive catch records at a 5° resolution. The mesh was constructed with an inner boundary defined by a non-convex hull encompassing the locations of reported effort, with an outer extension to reduce edge effects. A maximum edge length of 900 and 1 800 km was used for inner and outer knots respectively.

Priors were used where necessary to encourage model convergence. Penalised complexity priors were used for spatial and spatiotemporal random field Matérn parameters, typically constructed with a 5% probability that the range was less than 500km, and a 5% probability that the SD was greater than 5. Normal priors were applied for the intercepts and main effects, typically $\mathcal{N}(0, 10^2)$.

Model fits were assessed using a combination of diagnostic plots of Probability Integral Transform residuals, as well as comparisons of simulated and observed proportions of zeros and summary statistics for catch when present.

2.4 Catch estimation

Observed catches were used where available, with model-based catch rate estimates used for unobserved effort. Estimated catches were stratified by year, month, flag, set-type and 5° cell. For each strata, the number of unobserved sets was calculated and used to raise from predicted catch rates to catches. For 17% of the strata, the number of observed sets exceeded the number of reported sets. In these instances, the mean observed catch rate was computed and applied to the number of reported sets to obtain the 'observed catch'.

For the estimation groups with testing of more complex model specifications, we used ensemble model predictions. A stacking approach was implemented to calculate the model weights that maximised the overall log-likelihood across the different model specifications (Yao et al., 2018), using log-likelihoods from the validation datasets with six-fold cross validation. Models with weights less than 0.1 were excluded, with weights for the remaining models normalised to sum to 1. This reduced by 40% the number of models contributing to the ensemble predictions, with minimal impact on the ensemble predictions. For the remaining estimation groups, predictions were generated from the 'base model' in isolation.

Catch rate estimates were generated for each record in the reported effort dataset by taking 256 random draws from the multivariate normal distribution defined by the parameter estimates and their covariance matrix. Estimated quantities were combined across estimation groups assuming that the estimates were independent, e.g., when generating total catch estimates for all elasmobranchs estimation groups. Summary statistics were then calculated, with the 95 % confidence interval based on the 2.5 and 97.5 percentiles.

3 Results

3.1 Summary of analysed observer and reported effort datasets

The annual effort of the large-scale equatorial purse seine fishery in the WCPFC Convention Area demonstrated a strong increasing trend from 2003 to 2014, before remaining relatively stable for the period 2015 to 2022 (Figure 2). The increase in total effort pre-2015 was largely driven by increases in free school and drifting FAD sets, which offset decreases in log sets (Figure 3). Observed sets also demonstrated an increasing trend over period 2003 to 2019, with a particularly pronounced increase in 2010 with the introduction of the requirement for 100% observer coverage (Figure 2). However, the number of observed sets demonstrated a sharp decrease from the second quarter of 2020 onwards due to the impacts of the COVID-19 pandemic.

In this, observer coverage rates are defined as the proportion of reported sets with observer data in the analysed dataset. Annual observer coverage rates were 10-15% from 2003 to 2009, increasing to 50-85% in the period 2010 to 2019, before decreasing to pre-2010 levels from the second quarter of 2020 onwards (Figure 5).

The spatial distribution of reported effort remained relatively stable through time at a decadal resolution, though this masks finer-scale shifts in effort distributions within and between years (Figure 6). The spatial distribution of observed effort was most representative of reported effort in the period from 2010 to 2019 when observer coverage was highest, whereas pre-2010 and post-2020 there was a tendency for higher rates of observer coverage in and around the EEZs of Papua New Guinea and Solomon Islands (Figure 7 & 8).

3.2 Fitted catch rate models and estimated catches

Table A.1 provides the specification of the models used to predict catch rates for unobserved effort, including the ensemble model weights. Effect plots for the 'base' catch rate models, i.e. models not including spatiotemporal random fields, are provided in Appendix B.

The overall catch composition of the large-scale equatorial purse seine fishery was dominated by tropical tunas, though acknowledging that comparisons of catch volumes between species types is complicated by the differences in catch units (Figure 9 and Table C.1). Estimated catch rates demonstrated strong variation between set types (e.g., Figure 10), with overall catch estimates influenced by both the variation in catch rates and total effort by set type (Figure 11). In recent years, anchored FAD sets had the highest catch rates of 'other teleosts' (i.e., not tropical tunas or billfish), and relatively low catch rates of billfish and elasmobranchs. Anchored FAD sets also had relatively low catch rates of tropical tunas, noting that this includes the Philippines high-seas pocket fishery which has relatively small vessels. Drifting FAD sets had relatively high catch rates of elasmobranchs and billfish, and low catch rates of 'other teleosts'. Log sets had the highest catch rates of elasmobranchs, billfish, 'other teleosts' and marine mammals. Free school sets (including whale and whale shark sets) had the lowest catch rates of 'other finfish', billfish and marine mammals, and low catch rates of elasmobranchs and turtles.

Annual estimated catches per estimation group are provided in Figures 12 - 17, with Tables provided in Appendix C. Excluding tropical tuna and billfish, the total estimated catch of teleosts was dominated by rainbow runner (37%), mackerel scad (26%), frigate & bullet tunas (14%) and mahi mahi (5.5%). Total estimated catches of billfish were dominated by blue and black marlin (80%), striped marlin (11%) and Indo-Pacific sailfish (6.1%). Silky shark accounted for 90% of the total estimated catch of elasmobranchs, with 5% accounted for by mobulid rays. The generic elasmobranchs group accounted for 3% of total elasmobranch catch, though estimated catches were relatively low from 2005 onwards. Total estimated catches of sea turtles were predominately accounted by olive ridley (25%), green (23%), loggerhead (22%) and hawksbill (17%) turtles. The generic sea turtles group accounted for 10%, the majority of which was for the period 2003-2005. Estimated marine mammal catch was dominated by dolphins (34%), false killer whale (27%) and the generic marine mammals group (19%), the majority of the latter from the period 2003-2006.

The overall catch of tropical tuna demonstrated an increasing trend from 2003 to 2014, with no clear temporal trend from 2015 onwards. In contrast, catches of 'other teleosts' (i.e., not tropical tuna or billfish) exhibited a strong declining trend throughout the time period, decreasing from 18,000 tonnes in 2004 to 2,600 tonnes in 2022. This decline was largely driven by the reduction in log sets through time, as well as decreasing trends in year effects in catch rate models, e.g., for wahoo

(Figure B.4 & B.5), pomfrets (Figure B.10), trevallies (Figure B.16), triple-tail (Figure B.37) and filefishes (Figure B.43).

There was no clear temporal trend in billfish estimated catches from 2003 to 2010. Catches then increased sharply until 2012, before demonstrating a declining trend through to 2022. This largely reflected the trend of catches for blue & black marlin, which was influenced both by changes in effort by set type, as well as the decreasing trend apparent in year effects (Figure B.66).

Estimated elasmobranch catches demonstrated a declining trend from 2003 to 2010, with an increasing but variable trend apparent from 2011 onwards. This trend was largely driven by estimated catches of silky shark, with the declines pre-2011 reflecting changes in effort by set type, and the increases from 2011 onwards largely driven by year effects (Figure B.76 & B.77). Catches of oceanic whitetip demonstrated a U-shaped profile, which largely reflected the estimated year effects in the catch rate model (Figure B.79). Trends in catches of pelagic stingray displayed the opposite trend, with an initial increase through to the early 2010s, followed by a decline, which again mirrored the estimated year effects Figure B.81. There was no clear trend in catches of whale shark over the time period.

Estimated catches of sea turtles demonstrated an increasing trend from 2003 to 2012, then with a decreasing trend through to 2020. However, the relatively high estimated catches of the generic 'sea turtles' group complicates interpretation of estimation-group specific trends at the start of the time series. Similar trends were apparent for catches of olive ridley, green, loggerhead and hawksbill turtles, which reflected similar patterns in the catch rate model year effects (Figure B.106, B.98, B.96 & B.104).

Estimated catches of marine mammals did not demonstrate clear temporal trends, though the relatively high estimated catches of the generic 'marine mammals' group complicates interpretation of estimation-group specific trends at the start of the time series. Estimates of marine mammals in the early 2010s were relatively high, primarily driven by catches of false killer whale. However, short-finned pilot whale, Risso's dolphin and 'blackfish' also exhibited similarly timed increases in catches. Estimated catches of baleen whales demonstrated a clear increasing trend through time, reflecting the increasing trend in year effects (Figure B.121).

The estimated spatial distribution of catches by species type is provided in Figure 18, with estimation group specific maps provided in Figures 19 - 25. The estimated spatial distribution of catches at a species-type resolution broadly matched the distribution of catches of tropical tuna. However, catches of 'other teleosts', and to a lesser extent those ofbillfish, elasmobranchs, sea turtles and marine mammals, were more skewed westwards relative to the distribution of tropical tuna catches. Differences in spatial distributions of catches between estimation groups were also apparent, driven by the combination of the spatial distribution of effort by set-type, as well estimated spatial and spatiotemporal random fields.

4 Discussion

This report updates bycatch estimates for the large-scale equatorial purse seine fleet operating in the WCPFC Convention Area for the period 2003 to 2022, covering finfish, billfish, elasmobranchs, sea turtles and marine mammals. Catches of seabirds were not estimated due to limited observed captures, though estimates of total seabird catch have previously been generated through WCPFC Project 68 (Peatman et al., 2019).

The estimates of bycatch presented in this report should be interpreted as the catch that would have been observed and recorded if observer data were available for all fishing events. Forget et al. (2021) compared shark catches recorded by observers with a reference dataset collected by dedicated scientists; observers underestimated shark catches for the majority of sets across the three trips, resulting in underestimation of shark catch at a trip level of between 10 and 40%. As such, it is reasonable to expect that the shark catch estimates are an underestimate. It is not clear whether catch estimates for other taxa are likely to be similarly affected.

In this iteration, the approach to modelling catch rates has been extensively revised. The use of spatially explicit modelling approaches has a number of advantages over the previous modelling approach. The inclusion of spatial and spatiotemporal effects should provide more accurate estimates of catch rates pre-2010, when observed effort was both more limited and less representative of the fishery in terms of it's coverage spatially and by fleet. The use of spatially explicit catch rate models allows estimation of the spatial distribution of catches. The inclusion of spatial effects should also allow more direct interpretation of year effects in the catch rate models, as this should mitigate against temporal shifts in the spatial coverage of observed effort being reflected in the estimated year effects. However, care should be taken when interpreting the year effects as the catch rate models are not intended to standardise catch rates in order to isolate temporal changes in abundance.

Other improvements were also made to the estimation approach. Here, we used ensemble based model predictions for a selection of estimation groups. This allows multiple models to inform estimated catch rates, with predictions weighted by the predictive skill of each model. Additionally, in earlier iterations models were used to estimate presence/absence, with the catch when present estimated using a bootstrapping procedure stratified by set type. Here, catch rate models were fitted to both presence/absence and the catch when present. The potential for the catch rate models to account for temporal variation in catch when present should enable more accurate estimation of the temporal evolution in both catch rate and catch estimates.

The use of spatially-explicit catch rate models also provides an opportunity to assess differences in the spatial distribution of estimated catches, and spatial and spatiotemporal variation in catch rates, between estimation groups. The identified differences in spatial and spatial-temporal effects may point to potential differences in the spatial distributions of the different taxa, though acknowledging that the catch rate models should not be interpreted as species distribution models. Regardless, the spatial distributions of estimated catches contribute to the growing body of information on the distributions of purse seine bycatch (Clavareau et al., 2020).

Despite the numerous improvements to the estimation approach in this iteration, the updated catch estimates are broadly consistent with those from Peatman and Nicol (2021), both in terms of absolute levels and temporal trends. However, estimates for elasmobranchs in particular do display some differences (Figure 26). The weaker temporal trends in estimates from Peatman and Nicol (2021) may result from the relatively simple approach used to estimate the numbers caught when present.

In this iteration, the taxonomic resolution of catch estimates for marine mammals was improved as requested by WCPFC SC17 (Anon., 2021). Previously, marine mammal bycatch was estimated in a single estimation group (e.g., Peatman and Nicol, 2021). Here, the marine mammal estimation groups primarily consist of species, genus or family-level groupings. These refined estimation groupings allow for more meaningful monitoring of marine mammal catches and catch rates. For example, the temporal trend in catch estimates of baleen whales differs to that of the other marine mammal estimation groups, with the clear increasing trend for baleen whales driven both by the increasing trend in free school sets pre-2012 and an increasing trend in year effects of the catch rate model (Figure B.121).

Residual diagnostics indicated a lack of fit for a range of the positive (log-normal) catch rate model components for teleost estimation groups. Fits were not improved when trying alternative error distributions for the positives component. Attempts to fit exploratory Tweedie models to both presence/absence and positives were also similarly unsuccessful due to differences in the effects of covariates on the probability of encountering the taxa, and the catch volumes when present. The reasons for this persistent lack of fit remain unclear. Patterns in quantile residuals against the set's catch of tropical tuna were detected for a number of frequently encountered teleost estimation groups, including rainbow runner and mahi mahi, raising the possibility that the lack of fit could partially be due to influential set-level variation in (potentially un-modelled) covariates that influence catch volumes more generally.

The monitoring of comprehensive catches and catch rates of the large-scale equatorial purse seine fishery provides an opportunity to screen for species that may warrant further targeted analyses, for example in cases of persistent unexplained declining trends in year effects in catch rate models. Decreasing trends in year effects were apparent for a range of estimation groups, including false killer whale (2014 onwards; Figure B.125), short-finned pilot whale (2013 onwards; Figure B.115), blue & black marlin (Figure B.66) and wahoo (Figure B.4 & B.5). Comprehensive estimates of the catch of the large scale equatorial purse seine fishery in the WCPFC Convention Area have other potential uses for WCPFC members, including as inputs to models assessing the impacts of fishing on the broader ecosystem (Griffiths et al., 2019).

Observer coverage rates in the equatorial purse seine fishery were substantially reduced in 2020 due to the impacts of the COVID-19 pandemic. This reduction in observer coverage rates has impacted the precision of estimated catch rates and catches in recent years, particularly for less frequently observed taxa, and had a material impact on the extent to which the estimates allow monitoring of temporal changes. However, we note that observer coverage rates started to increase in 2023.

The Scientific Committee is invited to:

- Note the estimates of bycatch of the large-scale equatorial purse seine fishery in the WCPFC Convention Area;
- Note that the bycatch estimates should be interpreted as the bycatch that would have been recorded by observers with 100% coverage of fishing events;
- Note that other studies suggest that shark bycatch estimates are likely to be underestimates, due to underestimation of captures by observers;
- Note the refinements to the estimation approach, including the implementation of spatially-explicit catch rate models. This should improve the utility of catch rate models for identification of species that may warrant additional targeted analyses;
- Note the impacts of recent reductions in observer coverage on the precision of catch rate and catch estimates, and the extent to which they can be used to monitor for temporal trends;
- Note the refinements to the taxonomic resolution of catch estimates for marine mammals.

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Tables

Table 1: Estimation groups with their catch unit and species type. Estimation groups are ordered by species type and then scientific name.

Estimation group	**Scientific name**	**Catch unit**	**Species type**
Skipjack	*Katsuwonus pelamis*	Metric tonnes	Tropical tunas
Yellowfin	*Thunnus albacares*	Metric tonnes	Tropical tunas
Bigeye	*Thunnus obesus*	Metric tonnes	Tropical tunas
Frigate & bullet tunas	*Auxis thazard & A. rochei*	Metric tonnes	Other teleosts
Wahoo	*Acanthocybium solandri*	Metric tonnes	Other teleosts
Oceanic triggerfish	*Balistidae*	Metric tonnes	Other teleosts
Pomfrets	*Bramidae*	Metric tonnes	Other teleosts
Carangids	*Carangidae*	Metric tonnes	Other teleosts
Trevallies	*Caranx* spp	Metric tonnes	Other teleosts
Mahi mahi	*Coryphaena hippurus*	Metric tonnes	Other teleosts
Mackerel scad	*Decapturus macarellus*	Metric tonnes	Other teleosts
Rainbow runner	*Elagatis bipinnulata*	Metric tonnes	Other teleosts
Kawakawa	*Euthynnus affinis*	Metric tonnes	Other teleosts
Golden trevally	*Gnathanodon speciosus*	Metric tonnes	Other teleosts
Sea chubs	*Kyphosidae*	Metric tonnes	Other teleosts
Triple-tail	*Lobotes surinamensis*	Metric tonnes	Other teleosts
Sunfish	*Molidae*	Metric tonnes	Other teleosts
Filefishes	*Monacanthidae*	Metric tonnes	Other teleosts
Batfishes	*Platax* spp	Metric tonnes	Other teleosts
Scombrids	*Scombridae*	Metric tonnes	Other teleosts
Amberjacks	*Seriola* spp	Metric tonnes	Other teleosts
Barracudas	*Sphyraenidae*	Metric tonnes	Other teleosts
Marine fishes	Teleosts	Metric tonnes	Other teleosts
Albacore	*Thunnus alalunga*	Metric tonnes	Other teleosts
Indo-Pacific sailfish	*Istiophorus platypterus*	Individuals	Billfish
Blue & black marlin	*Makaira nigricans & M. indica*	Individuals	Billfish
Short-billed spearfish	*Tetrapturus angustirostris*	Individuals	Billfish
Striped marlin	*Tetrapturus audax*	Individuals	Billfish
Swordfish	*Xiphias gladius*	Individuals	Billfish
Thresher sharks	*Alopiidae*	Individuals	Elasmobranchs
Silky shark	*Carcharhinus falciformis*	Individuals	Elasmobranchs
Oceanic whitetip shark	*Carcharhinus longimanus*	Individuals	Elasmobranchs
Pelagic stingray	*Dasyatis violacea*	Individuals	Elasmobranchs
Elasmobranchs	Elasmobranchii	Individuals	Elasmobranchs
Mako sharks	*Isurus* spp	Individuals	Elasmobranchs
Mobulid rays	*Mobulidae*	Individuals	Elasmobranchs
Blue shark	*Prionace glauca*	Individuals	Elasmobranchs
Whale shark	*Rhincodon typus*	Individuals	Elasmobranchs
Hammerhead sharks	*Sphyrnidae*	Individuals	Elasmobranchs
Loggerhead turtle	*Caretta caretta*	Individuals	Sea turtles
Green turtle	*Chelonia mydas*	Individuals	Sea turtles
Sea turtles	*Chelonioidea*	Individuals	Sea turtles
Leatherback turtle	*Dermochelys coriacea*	Individuals	Sea turtles
Hawksbill turtle	*Eretmochelys imbricata*	Individuals	Sea turtles
Olive ridley turtle	*Lepidochelys olivacea*	Individuals	Sea turtles
‘Blackfish’	‘Blackfish’	Individuals	Marine mammals
Marine mammals	Cetacea & pinnipeds	Individuals	Marine mammals
Dolphins	Delphinidae	Individuals	Marine mammals
Short-finned pilot whale	*Globicephala macrorhynchus*	Individuals	Marine mammals
Risso’s dolphin	*Grampus griseus*	Individuals	Marine mammals
Baleen whales	Mysticeti	Individuals	Marine mammals
Toothed whales	Odontoceti	Individuals	Marine mammals
False killer whale	*Pseudorca crassidens*	Individuals	Marine mammals
Beaked whales	*Ziphiidae*	Individuals	Marine mammals

Table 2: Sets with capture records, and total individuals caught by species code, for each marine mammal estimation group. This includes all observed sets in the initial observer data extracts (i.e., pre-filtering).

Estimation group	Species code	Common name	Scientific name	Sets	Individuals
False killer whale	FAW	False killer whale	Pseudorca crassidens	2057	8445
Short-finned pilot whale	SHW	Short-finned pilot whale	Globicephala macrorhynchus	309	1313
Risso’s dolphin	DRR	Risso’s dolphin	Grampus griseus	145	844
’Blackfish’	MEW	Melon-headed whale	Peponocephala electra	99	280
’Blackfish’	KPW	Pygmy killer whale	Feresa attenuata	55	205
’Blackfish’	KIW	Killer whale	Orcinus orca	10	36
’Blackfish’	GLO	Pilot whales nei	Globicephala spp	2	6
Dolphins	RTD	Rough-toothed dolphin	Steno bredanensis	453	2522
Dolphins	DBO	Bottlenose dolphin	Tursiops truncatus	308	1993
Dolphins	DSI	Spinner dolphin	Stenella longirostris	203	1440
Dolphins	DBZ	Indo-Pacific bottlenose dolphin	Tursiops aduncus	187	1173
Dolphins	DCO	Common dolphin	Delphinus delphis	103	1019
Dolphins	DLP	Dolphins nei	Delphinidae	38	110
Dolphins	DPN	Pantropical spotted dolphin	Stenella attenuata	36	178
Dolphins	DST	Striped dolphin	Stenella coeruleoalba	33	242
Dolphins	DCZ	Long-beaked common dolphin	Delphinus capensis	20	169
Dolphins	DSP	Spotted dolphins nei	Stenella spp	16	55
Dolphins	FRD	Fraser’s dolphin	Lagenodelphis hosei	8	42
Dolphins	RNW	Northern right whale dolphin	Lissodelphis borealis	4	5
Dolphins	DWP	Pacific white-sided dolphin	Lagenorhynchus obliquidens	2	15
Dolphins	DDU	Dusky dolphin	Lagenorhynchus obscurus	1	1
Beaked whales	MEP	Beaked whales nei	Mesoplodon spp	81	145
Beaked whales	TGW	Ginkgo-toothed beaked whale	Mesoplodon ginkgodens	39	70
Beaked whales	BCW	Cuvier’s beaked whale	Ziphius cavirostris	21	55
Beaked whales	BBW	Blainville’s beaked whale	Mesoplodon densirostris	18	43
Toothed whales	PYW	Pygmy sperm whale	Kogia breviceps	112	187
Toothed whales	SPW	Sperm whale	Physeter macrocephalus	45	52
Toothed whales	ODN	Toothed whales nei	Odontoceti	19	42
Toothed whales	DWW	Dwarf sperm whale	Kogia simus	6	23
Toothed whales	SPP	Spectacled porpoise	Australophocaena dioptrica	1	1
Baleen whales	BRW	Bryde’s whale	Balaenoptera edeni	649	939
Baleen whales	SIW	Sei whale	Balaenoptera borealis	500	767
Baleen whales	MYS	Baleen whales nei	Mysticeti	136	213
Baleen whales	MIW	Minke whale	Balaenoptera acutorostrata	78	116
Baleen whales	HUW	Humpback whale	Megaptera novaeangliae	58	79
Baleen whales	FIW	Fin whale	Balaenoptera physalus	30	42
Baleen whales	BLW	Blue whale	Balaenoptera musculus	27	33
Marine mammals	MAM	Aquatic mammals nei	Cetartiodactyla	137	580
Marine mammals	WLE	Whale (unidentified)	Cetacea	16	35
Marine mammals	CSL	California sea lion	Zalophus californianus	1	1
Marine mammals	SEC	Harbour seal	Phoca vitulina	1	1
Marine mammals	SSL	Steller sea lion	Eumetopias jubatus	1	1

Table 3: Estimated average catch by estimation group and set-type for the period 2018-2022 (95% CIs in parentheses). 'FS' includes sets on schools associated with whales and whale sharks.

(a) Teleosts (metric tonnes)

Estimation group	FS	aFAD	dFAD	log
Skipjack	654,000	27,800	576,000	27,700
Yellowfin	199,000	16,600	107,000	8,850
Bigeye	7,980	1,160	49,900	1,790
Mackerel scad	14.5 (13.8-15.2)	773 (760-785)	250 (245-256)	63.3 (62.0-64.7)
Rainbow runner	40.6 (39.9-41.7)	199 (192-215)	684 (670-698)	157 (155-159)
Frigate & bullet tunas	49.7 (48.5-51.4)	144 (136-154)	8.53 (7.98-9.32)	6.33 (6.14-6.53)
Oceanic triggerfish	3.62 (3.44-3.80)	10.9 (10.7-11.3)	113 (108-117)	36.0 (35.3-36.8)
Mahi mahi	4.68 (4.51-4.94)	27.0 (24.0-33.0)	79.1 (76.7-81.8)	13.1 (12.8-13.4)
Kawakawa	44.7 (42.9-47.5)	19.9 (18.3-21.6)	13.4 (12.4-14.8)	3.11 (2.91-3.36)
Wahoo	0.778 (0.727-0.826)	1.12 (0.956-1.46)	55.3 (53.1-57.7)	1.18 (1.13-1.22)
Albacore	41.1 (30.4-67.4)	0.801 (0.525-6.59)	10.0 (6.91-15.8)	1.49 (0.975-2.50)
Barracudas	2.89 (2.71-3.15)	3.01 (2.60-4.52)	12.1 (11.5-12.8)	1.66 (1.60-1.78)
Golden trevally	0.123 (0.101-0.157)	12.0 (11.4-12.8)	2.68 (2.36-3.01)	0.426 (0.375-0.504)
Amberjacks	0.585 (0.291-1.23)	0.283 (0.198-0.742)	10.8 (8.31-16.3)	1.11 (0.879-1.52)
Carangids	0.459 (0.286-0.771)	2.27 (1.88-3.66)	4.91 (3.76-6.48)	0.566 (0.434-0.774)
Sunfish	3.37 (2.43-5.32)	0.572 (0.262-3.15)	3.85 (2.84-5.75)	0.406 (0.361-0.503)
Sea chubs	0.101 (0.0693-0.148)	0.488 (0.393-0.841)	3.96 (3.24-4.78)	2.02 (1.86-2.20)
Scombrids	1.14 (0.845-1.85)	0.345 (0.262-0.607)	1.95 (1.09-4.30)	0.416 (0.326-0.650)
Trevallies	0.192 (0.162-0.246)	0.154 (0.0961-0.611)	2.85 (2.56-3.42)	0.378 (0.336-0.451)
Marine fishes	0.624 (0.437-1.09)	0.209 (0.150-0.484)	1.40 (0.827-2.83)	0.377 (0.303-0.515)
Pomfrets	0.101 (0.0604-0.171)	0.136 (0.0666-0.355)	1.03 (0.739-1.60)	0.226 (0.195-0.282)
Batfishes	0.0419 (0.0279-0.0701)	0.0433 (0.0347-0.0844)	0.945 (0.756-1.25)	0.381 (0.336-0.435)
Filefishes	0.0551 (0.0376-0.0864)	0.0860 (0.0710-0.144)	0.910 (0.726-1.24)	0.219 (0.195-0.255)
Triple-tail	0.103 (0.0700-0.163)	0.0869 (0.0599-0.237)	0.368 (0.226-0.656)	0.104 (0.0840-0.160)

(b) Billfish (individuals)

Estimation group	FS	aFAD	dFAD	log
Blue & black marlin	2,210 (2,150-2,300)	104 (86.0-141)	2,050 (2,000-2,120)	183 (179-188)
Striped marlin	210 (197-226)	11.5 (9.08-16.4)	206 (192-224)	19.6 (18.6-20.6)
Indo-Pacific sailfish	206 (183-229)	9.12 (7.18-14.5)	102 (89.8-115)	11.2 (10.0-12.6)
Short-billed spearfish	51.9 (41.9-67.2)	3.77 (2.91-5.43)	27.5 (21.5-38.8)	1.41 (1.01-2.06)
Swordfish	13.9 (11.5-17.9)	2.84 (2.25-4.13)	20.3 (15.9-28.8)	2.34 (2.03-2.86)

Table 3: Continued

(c) Elasmobranchs (individuals)

Estimation group	**FS**	**aFAD**	**dFAD**	**log**
Silky shark	36,200 (35,300-37,600)	4,380 (3,820-5,470)	47,400 (46,800-48,100)	6,170 (6,060-6,310)
Mobulid rays	3,090 (2,990-3,210)	93.5 (80.7-136)	1,070 (1,020-1,120)	91.0 (88.2-95.4)
Oceanic whitetip shark	295 (279-318)	9.64 (5.66-26.4)	676 (637-734)	29.8 (27.8-32.6)
Elasmobranchs	479 (405-594)	19.7 (13.3-40.5)	414 (317-592)	68.3 (59.4-82.4)
Whale shark	414 (399-428)	2.29 (1.95-2.80)	38.8 (36.9-40.9)	3.04 (2.81-3.25)
Pelagic stingray	63.3 (58.6-70.0)	2.99 (2.40-4.53)	55.7 (51.6-62.0)	7.32 (6.97-7.67)
Hammerhead sharks	30.5 (22.6-80.8)	11.9 (3.09-62.6)	35.3 (30.5-42.8)	0.895 (0.455-2.34)
Blue shark	14.8 (12.7-19.1)	0.624 (0.175-2.60)	11.2 (9.17-16.0)	0.320 (0.118-0.872)
Thresher sharks	5.98 (4.21-10.1)	2.25 (1.91-4.54)	10.9 (7.90-17.8)	1.26 (1.02-1.99)
Mako sharks	7.19 (4.86-14.7)	0.691 (0.423-1.46)	11.3 (6.99-24.0)	0.742 (0.367-1.50)

(d) Sea turtles (individuals)

Estimation group	**FS**	**aFAD**	**dFAD**	**log**
Green turtle	44.3 (38.9-50.9)	2.04 (1.53-3.60)	13.8 (11.7-16.6)	2.62 (2.31-3.06)
Olive ridley turtle	35.8 (31.9-40.6)	5.73 (4.96-7.60)	14.8 (12.5-17.7)	3.64 (3.27-4.10)
Loggerhead turtle	31.1 (26.7-37.2)	1.79 (1.42-2.70)	15.6 (13.4-19.2)	2.13 (1.92-2.45)
Hawksbill turtle	25.8 (21.9-31.6)	2.81 (2.08-4.69)	8.13 (6.80-10.3)	1.91 (1.54-2.44)
Sea turtles	6.39 (4.62-9.89)	0.620 (0.402-1.22)	2.02 (1.15-3.62)	0.379 (0.285-0.548)
Leatherback turtle	4.92 (3.80-6.31)	0.475 (0.300-0.910)	3.65 (2.59-4.90)	0.243 (0.123-0.501)

(e) Marine mammals (individuals)

Estimation group	**FS**	**aFAD**	**dFAD**	**log**
Dolphins	192 (165-233)	185 (166-234)	323 (282-381)	53.4 (48.1-60.5)
False killer whale	282 (261-314)	13.0 (9.69-21.5)	244 (217-284)	31.3 (28.1-34.9)
Baleen whales	354 (326-395)	0.994 (0.646-1.84)	4.05 (3.06-5.46)	1.06 (0.887-1.25)
Short-finned pilot whale	49.1 (41.0-63.7)	3.22 (2.09-6.84)	54.3 (39.3-78.2)	3.43 (2.69-4.64)
Risso's dolphin	17.5 (11.3-29.4)	0.985 (0.308-3.20)	23.3 (15.9-41.8)	2.37 (1.27-5.49)
'Blackfish'	15.6 (11.9-23.1)	2.78 (2.53-3.63)	17.1 (12.6-25.6)	1.22 (0.829-2.35)
Beaked whales	20.3 (16.3-31.7)	0.00342 (0.000-0.375)	0.664 (0.241-1.57)	0.00303 (0.000-0.132)
Toothed whales	16.0 (10.5-30.1)	0.0154 (0.001-0.256)	0.427 (0.259-0.995)	0.265 (0.224-0.463)
Marine mammals	5.05 (2.65-31.2)	0.0628 (0.0136-0.694)	0.468 (0.108-5.80)	0.0489 (0.0160-0.277)

Table 4: Estimated average catch rates by estimation group and set-type for the period 2018-2022 (95% CIs in parentheses). 'FS' includes sets on schools associated with whales and whale sharks.

(a) Teleosts (metric tonnes per set)

Estimation group	**FS**	**aFAD**	**dFAD**	**log**
Skipjack	19.2	7.20	38.0	28.0
Yellowfin	5.85	4.29	7.06	8.95
Bigeye	0.235	0.300	3.29	1.81
Mackerel scad	0.000 (0.000-0.000)	0.200 (0.197-0.204)	0.0165 (0.0162-0.0169)	0.0640 (0.0626-0.0654)
Rainbow runner	0.00120 (0.00117-0.00123)	0.0516 (0.0498-0.0557)	0.0451 (0.0442-0.0460)	0.158 (0.156-0.160)
Frigate & bullet tunas	0.00146 (0.00143-0.00151)	0.0373 (0.0351-0.0399)	0.001 (0.001-0.001)	0.00639 (0.00620-0.00660)
Oceanic triggerfish	0.000 (0.000-0.000)	0.00284 (0.00278-0.00293)	0.00745 (0.00715-0.00775)	0.0364 (0.0356-0.0372)
Mahi mahi	0.000 (0.000-0.000)	0.00700 (0.00621-0.00854)	0.00522 (0.00506-0.00539)	0.0132 (0.0130-0.0136)
Kawakawa	0.00132 (0.00126-0.00140)	0.00516 (0.00475-0.00561)	0.001 (0.001-0.001)	0.00314 (0.00294-0.00339)
Wahoo	0.000 (0.000-0.000)	0.000 (0.000-0.000)	0.00365 (0.00350-0.00381)	0.00119 (0.00114-0.00124)
Albacore	0.00121 (0.001-0.00198)	0.000 (0.000-0.00171)	0.001 (0.000-0.00104)	0.00151 (0.001-0.00253)
Barracudas	0.000 (0.000-0.000)	0.001 (0.001-0.00117)	0.001 (0.001-0.001)	0.00168 (0.00161-0.00180)
Golden trevally	0.000 (0.000-0.000)	0.00310 (0.00296-0.00333)	0.000 (0.000-0.000)	0.000 (0.000-0.001)
Amberjacks	0.000 (0.000-0.000)	0.000 (0.000-0.000)	0.001 (0.001-0.00107)	0.00112 (0.001-0.00154)
Carangids	0.000 (0.000-0.000)	0.001 (0.000-0.001)	0.000 (0.000-0.000)	0.001 (0.000-0.001)
Sunfish	0.000 (0.000-0.000)	0.000 (0.000-0.001)	0.000 (0.000-0.000)	0.000 (0.000-0.001)
Sea chubs	0.000 (0.000-0.000)	0.000 (0.000-0.000)	0.000 (0.000-0.000)	0.00205 (0.00188-0.00222)
Scombrids	0.000 (0.000-0.000)	0.000 (0.000-0.000)	0.000 (0.000-0.000)	0.000 (0.000-0.001)
Trevallies	0.000 (0.000-0.000)	0.000 (0.000-0.000)	0.000 (0.000-0.000)	0.000 (0.000-0.000)
Marine fishes	0.000 (0.000-0.000)	0.000 (0.000-0.000)	0.000 (0.000-0.000)	0.000 (0.000-0.001)
Pomfrets	0.000 (0.000-0.000)	0.000 (0.000-0.000)	0.000 (0.000-0.000)	0.000 (0.000-0.000)
Batfishes	0.000 (0.000-0.000)	0.000 (0.000-0.000)	0.000 (0.000-0.000)	0.000 (0.000-0.000)
Filefishes	0.000 (0.000-0.000)	0.000 (0.000-0.000)	0.000 (0.000-0.000)	0.000 (0.000-0.000)
Triple-tail	0.000 (0.000-0.000)	0.000 (0.000-0.000)	0.000 (0.000-0.000)	0.000 (0.000-0.000)

(b) Billfish (individuals per set)

Estimation group	**FS**	**aFAD**	**dFAD**	**log**
Blue & black marlin	0.0652 (0.0633-0.0678)	0.0269 (0.0223-0.0365)	0.135 (0.132-0.140)	0.185 (0.181-0.190)
Striped marlin	0.00619 (0.00581-0.00664)	0.00299 (0.00235-0.00424)	0.0136 (0.0126-0.0148)	0.0198 (0.0188-0.0208)
Indo-Pacific sailfish	0.00606 (0.00538-0.00673)	0.00236 (0.00186-0.00375)	0.00672 (0.00592-0.00760)	0.0113 (0.0101-0.0127)
Short-billed spearfish	0.00153 (0.00123-0.00198)	0.001 (0.001-0.00141)	0.00182 (0.00142-0.00256)	0.00142 (0.00102-0.00208)
Swordfish	0.000 (0.000-0.001)	0.001 (0.001-0.00107)	0.00134 (0.00105-0.00190)	0.00236 (0.00205-0.00289)

Table 4: Continued

(c) Elasmobranchs (individuals per set)

Estimation group	FS	aFAD	dFAD	log
Silky shark	1.07 (1.04-1.11)	1.13 (0.990-1.42)	3.13 (3.08-3.17)	6.24 (6.13-6.37)
Mobulid rays	0.0910 (0.0879-0.0945)	0.0242 (0.0209-0.0351)	0.0705 (0.0673-0.0736)	0.0919 (0.0892-0.0964)
Oceanic whitetip shark	0.00868 (0.00820-0.00937)	0.00250 (0.00147-0.00685)	0.0446 (0.0420-0.0484)	0.0301 (0.0281-0.0330)
Elasmobranchs	0.0141 (0.0119-0.0175)	0.00510 (0.00345-0.0105)	0.0273 (0.0209-0.0390)	0.0691 (0.0601-0.0833)
Whale shark	0.0122 (0.0117-0.0126)	0.001 (0.001-0.001)	0.00256 (0.00243-0.00270)	0.00307 (0.00284-0.00329)
Pelagic stingray	0.00186 (0.00172-0.00206)	0.001 (0.001-0.00117)	0.00367 (0.00340-0.00409)	0.00740 (0.00704-0.00775)
Hammerhead sharks	0.001 (0.001-0.00238)	0.00308 (0.001-0.0162)	0.00233 (0.00201-0.00282)	0.001 (0.000-0.00237)
Blue shark	0.000 (0.000-0.001)	0.000 (0.000-0.001)	0.001 (0.001-0.00106)	0.000 (0.000-0.001)
Thresher sharks	0.000 (0.000-0.000)	0.001 (0.000-0.00118)	0.001 (0.001-0.00117)	0.00127 (0.00103-0.00201)
Mako sharks	0.000 (0.000-0.000)	0.000 (0.000-0.000)	0.001 (0.000-0.00158)	0.001 (0.000-0.00151)

(d) Sea turtles (individuals per set)

Estimation group	FS	aFAD	dFAD	log
Green turtle	0.00130 (0.00114-0.00150)	0.001 (0.000-0.001)	0.001 (0.001-0.00109)	0.00265 (0.00233-0.00309)
Olive ridley turtle	0.00105 (0.001-0.00120)	0.00149 (0.00129-0.00197)	0.001 (0.001-0.00117)	0.00368 (0.00331-0.00415)
Loggerhead turtle	0.001 (0.001-0.00109)	0.000 (0.000-0.001)	0.00103 (0.001-0.00126)	0.00216 (0.00194-0.00248)
Hawksbill turtle	0.001 (0.001-0.001)	0.001 (0.001-0.00122)	0.001 (0.000-0.001)	0.00193 (0.00155-0.00246)
Sea turtles	0.000 (0.000-0.000)	0.000 (0.000-0.000)	0.000 (0.000-0.000)	0.000 (0.000-0.001)
Leatherback turtle	0.000 (0.000-0.000)	0.000 (0.000-0.000)	0.000 (0.000-0.000)	0.000 (0.000-0.001)

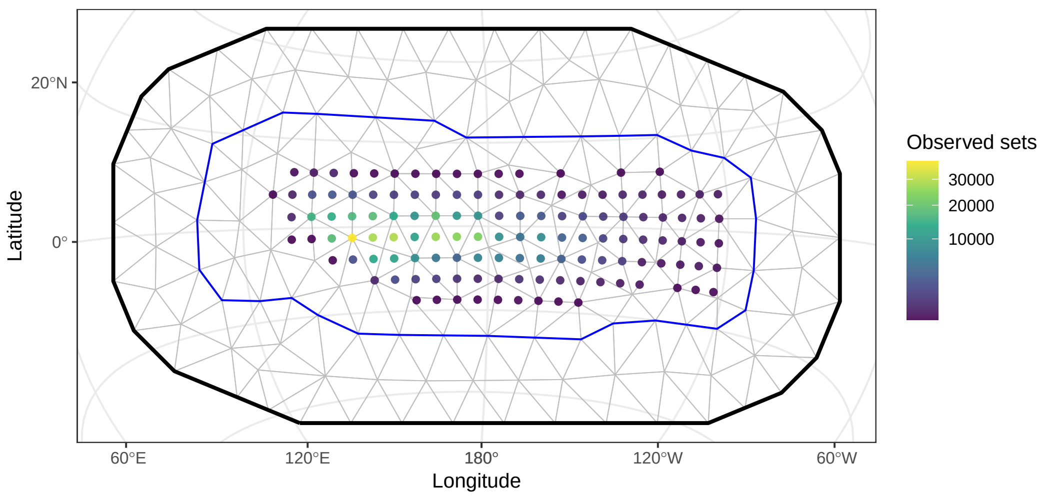
(e) Marine mammals (individuals per set)

Estimation group	FS	aFAD	dFAD	log
Dolphins	0.00565 (0.00485-0.00686)	0.0478 (0.0430-0.0605)	0.0213 (0.0186-0.0251)	0.0540 (0.0487-0.0611)
False killer whale	0.00831 (0.00769-0.00925)	0.00338 (0.00251-0.00557)	0.0161 (0.0143-0.0187)	0.0317 (0.0284-0.0352)
Baleen whales	0.0104 (0.00960-0.0116)	0.000 (0.000-0.000)	0.000 (0.000-0.000)	0.00107 (0.001-0.00126)
Short-finned pilot whale	0.00145 (0.00121-0.00187)	0.001 (0.001-0.00177)	0.00358 (0.00259-0.00516)	0.00347 (0.00272-0.00469)
Risso's dolphin	0.001 (0.000-0.001)	0.000 (0.000-0.001)	0.00154 (0.00105-0.00275)	0.00239 (0.00128-0.00555)
'Blackfish'	0.000 (0.000-0.001)	0.001 (0.001-0.001)	0.00113 (0.001-0.00169)	0.00124 (0.001-0.00238)
Beaked whales	0.001 (0.000-0.001)	0.000 (0.000-0.000)	0.000 (0.000-0.000)	0.000 (0.000-0.000)
Toothed whales	0.000 (0.000-0.001)	0.000 (0.000-0.000)	0.000 (0.000-0.000)	0.000 (0.000-0.000)
Marine mammals	0.000 (0.000-0.001)	0.000 (0.000-0.000)	0.000 (0.000-0.000)	0.000 (0.000-0.000)

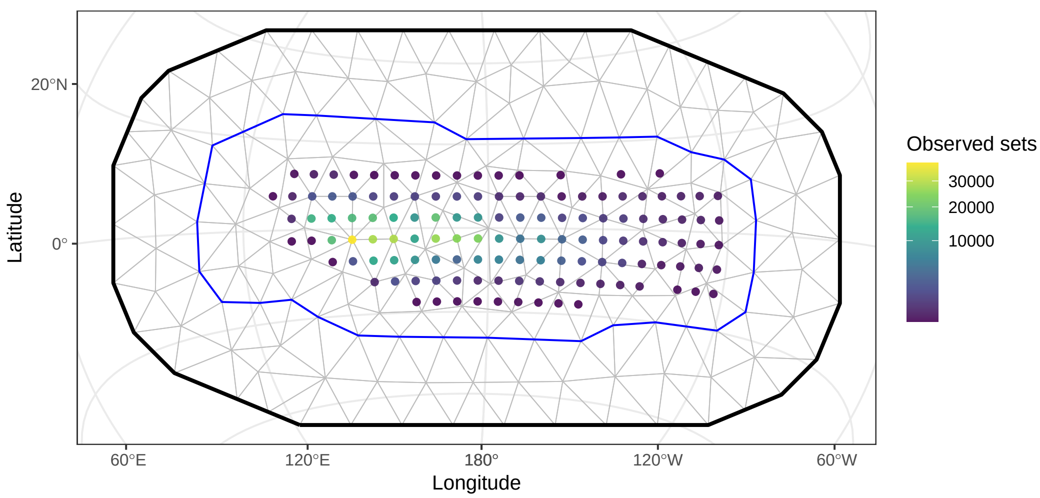
Figures

Figure 1: The mesh for catch rate models of a) silky shark and b) false killer whale. The grey lines display the mesh, with vertices indicating the knot locations. The thin blue line provides the inner boundary, based on a non-convex hull encompassing the reported effort dataset. The thick black line provides the outer boundary. The coloured points summarise the distribution of observed effort from 2003 to 2022 used to fit the catch rate models, including observed effort from outside of the WCPFC Convention Area west of 120°**W.**

(a) Silky shark



(b) False killer whale



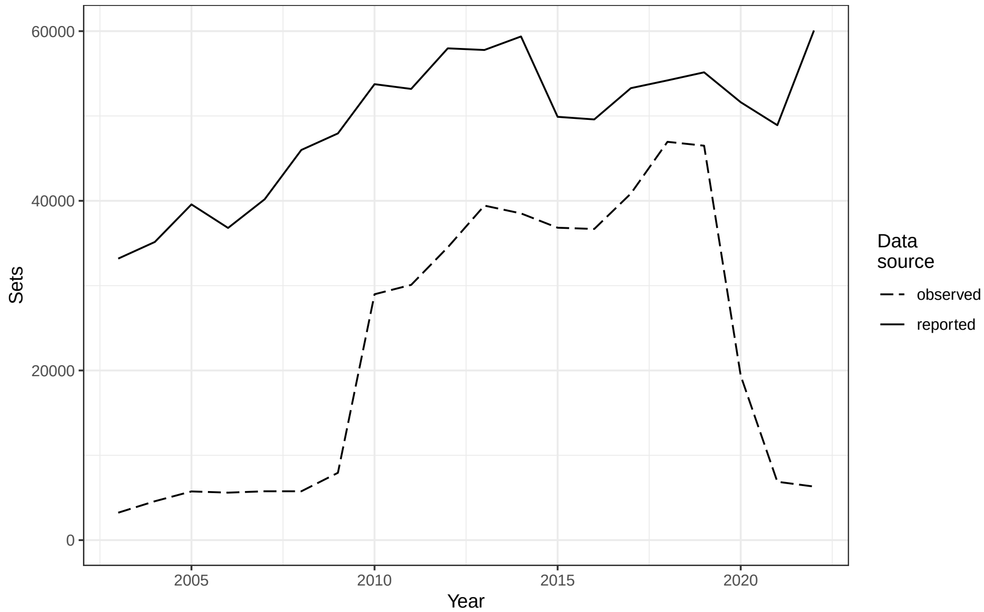


Figure 2: Annual reported and observed sets of the large-scale equatorial purse seine fishery in the WCPFC Convention Area (2003–2022). Effort from the western domestic fisheries and high latitude fisheries were excluded.

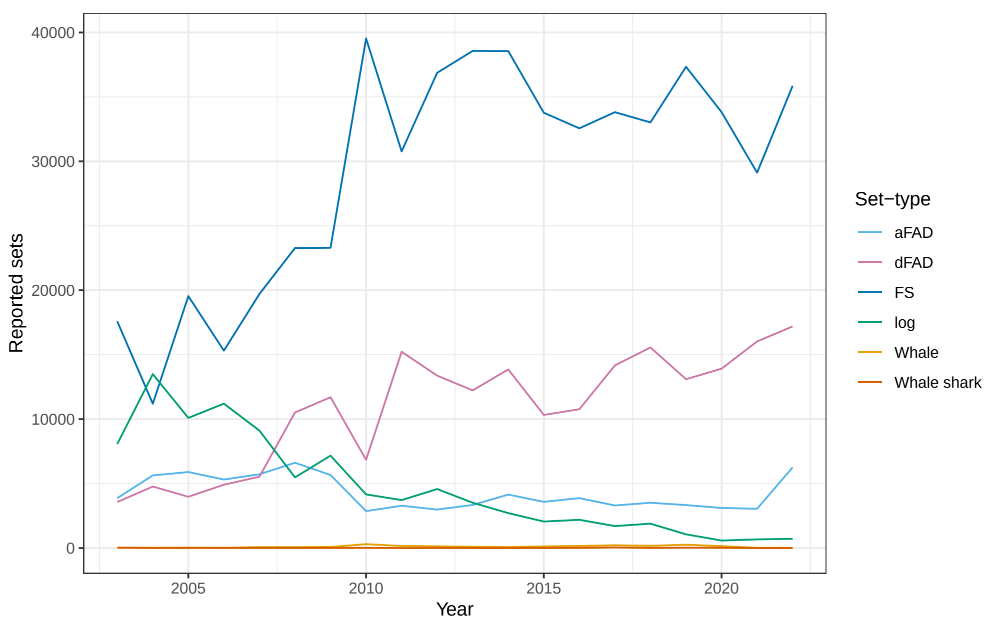


Figure 3: Annual reported sets by set-type for the large-scale equatorial purse seine fishery in the WCPFC Convention Area (2003–2022). Effort from the western domestic fisheries and high latitude fisheries were excluded.

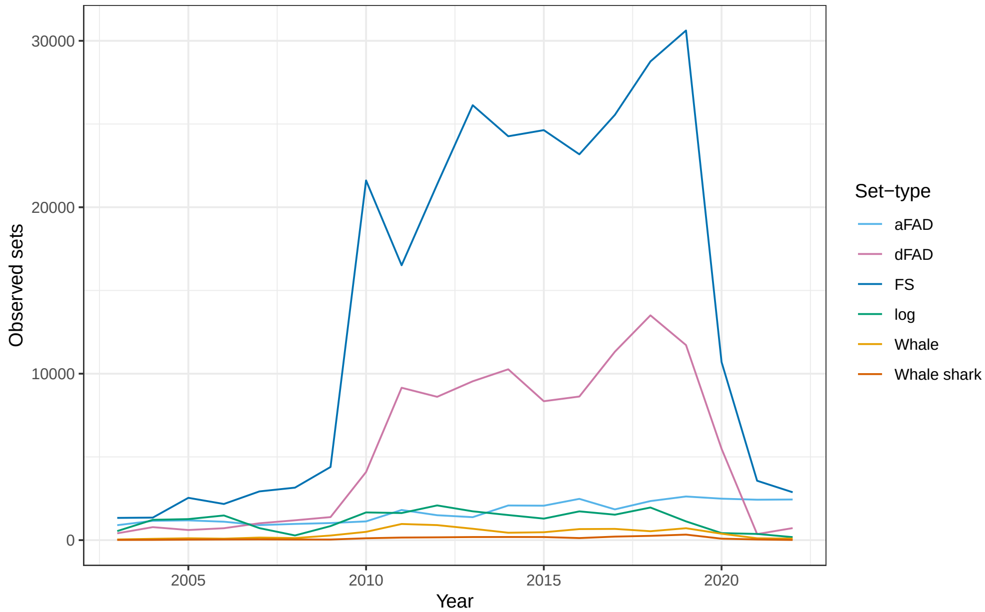


Figure 4: Annual observed sets by set-type in the analysed observer dataset for the the large-scale equatorial purse seine fishery in the WCPFC Convention Area (2003–2022).

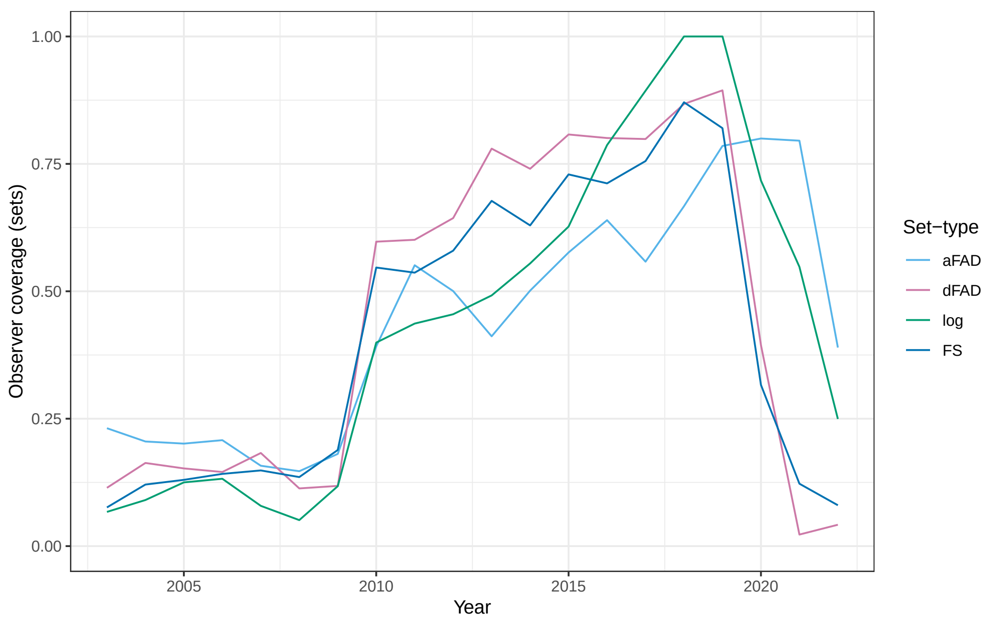


Figure 5: Annual observer coverage (proportion of total sets with an observer onboard) by set-type for the large-scale equatorial purse seine fishery in the WCPFC Convention Area (2003–2022). Whale and whale shark associated sets were excluded.

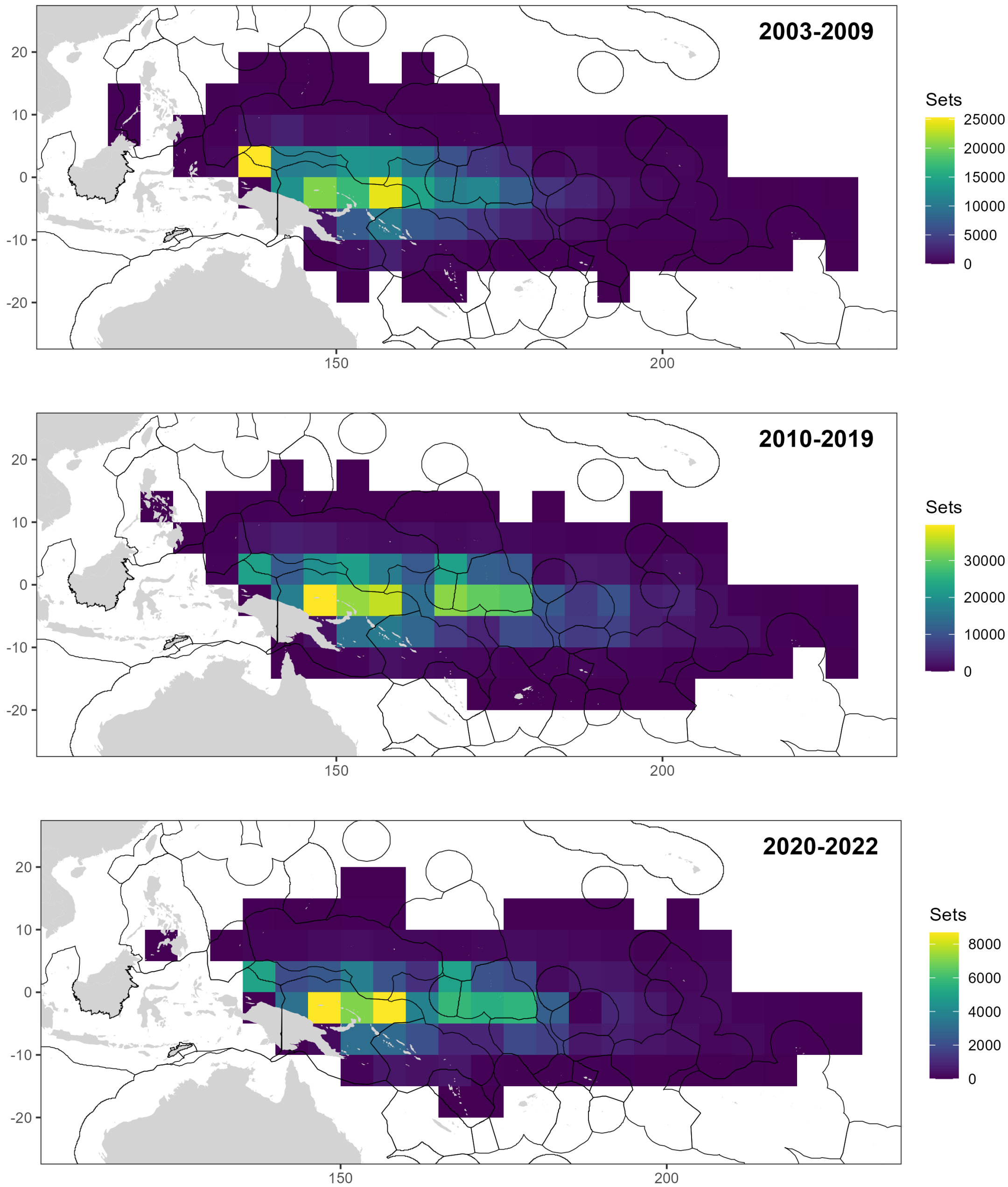


Figure 6: The spatial distribution of reported sets for the large-scale equatorial purse seine fishery in the WCPFC Convention Area, for 2003–2009 (top panel), 2010–2019 (middle) and 2020–2022 (bottom). Effort from western domestic fisheries and high latitude fisheries was excluded.

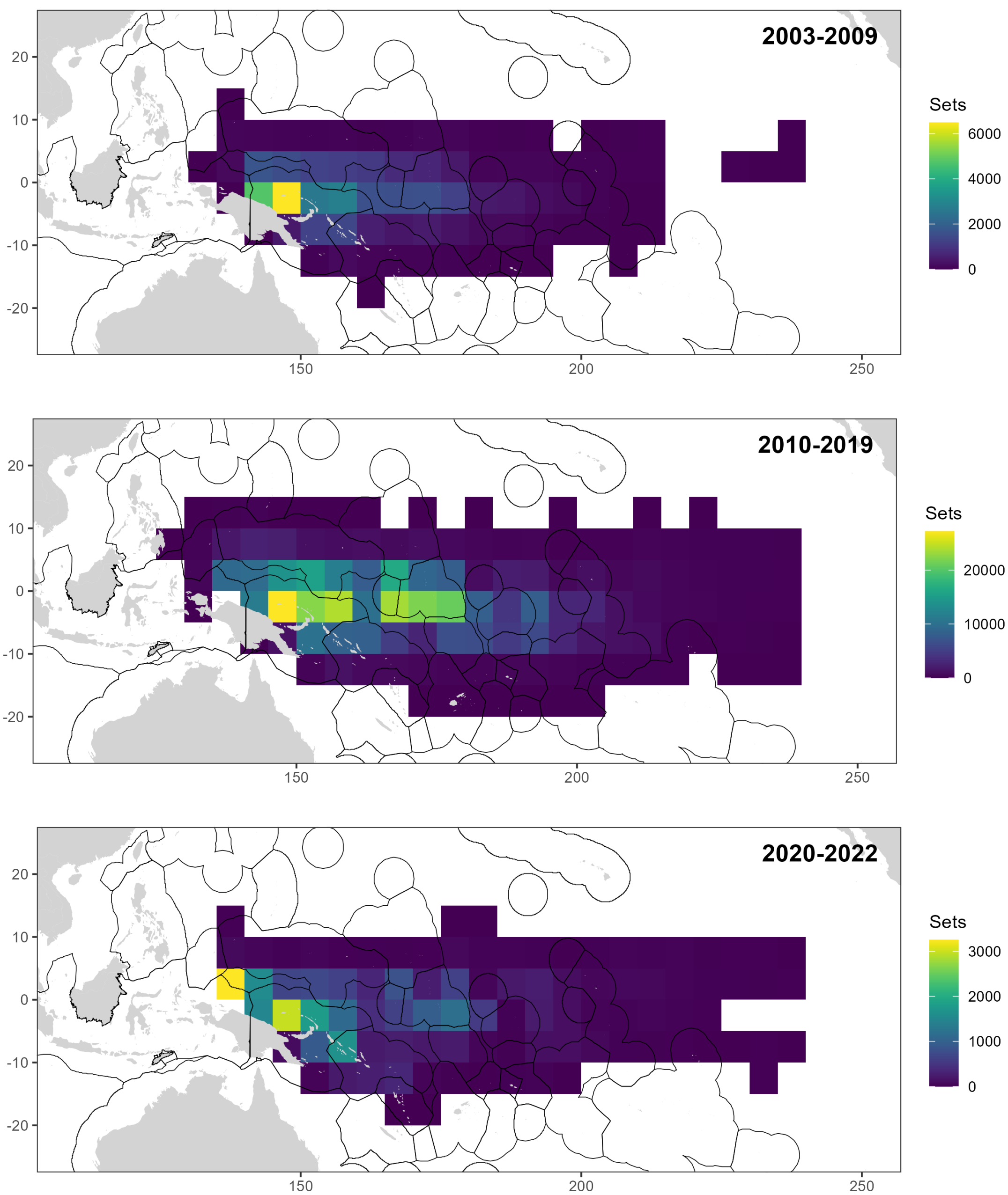


Figure 7: The spatial distribution of observed sets in the analysed observer dataset for the large-scale equatorial purse seine fishery for 2003–2009 (top panel), 2010–2019 (middle) and 2020–2022 (bottom). This includes observed effort from outside of the WCPFC Convention Area west of $120°$W.

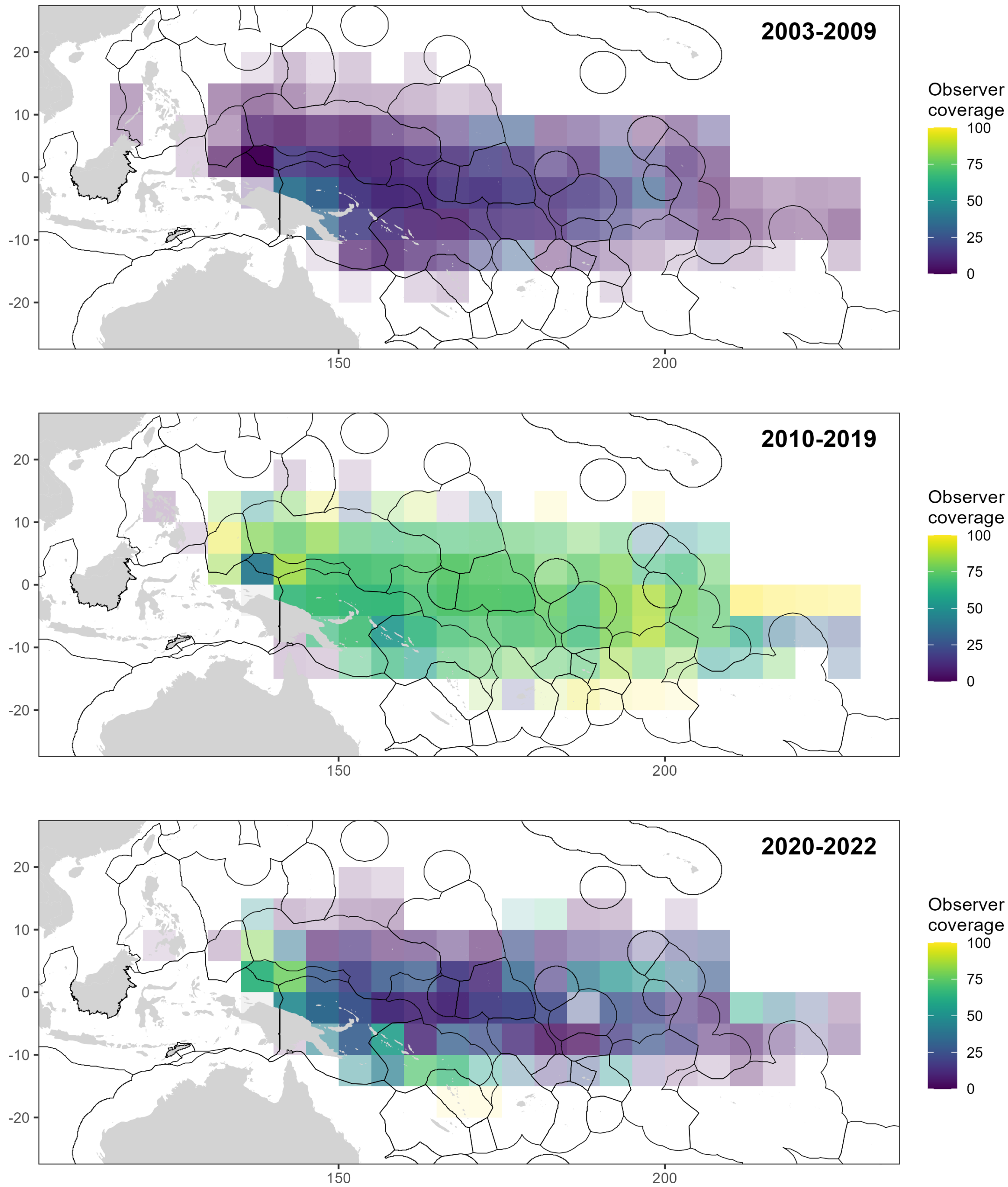


Figure 8: The spatial distribution of observer coverage (proportions of sets with an observer onboard) for the large-scale equatorial purse seine fishery in the WCPFC Convention Area for: 2003–2009 (top panel), 2010–2019 (middle) and 2020–2022 (bottom). The transparency of each cell is a function of the reported effort, with less reported effort resulting in more transparency. Effort from western domestic fisheries and high latitude fisheries was excluded.

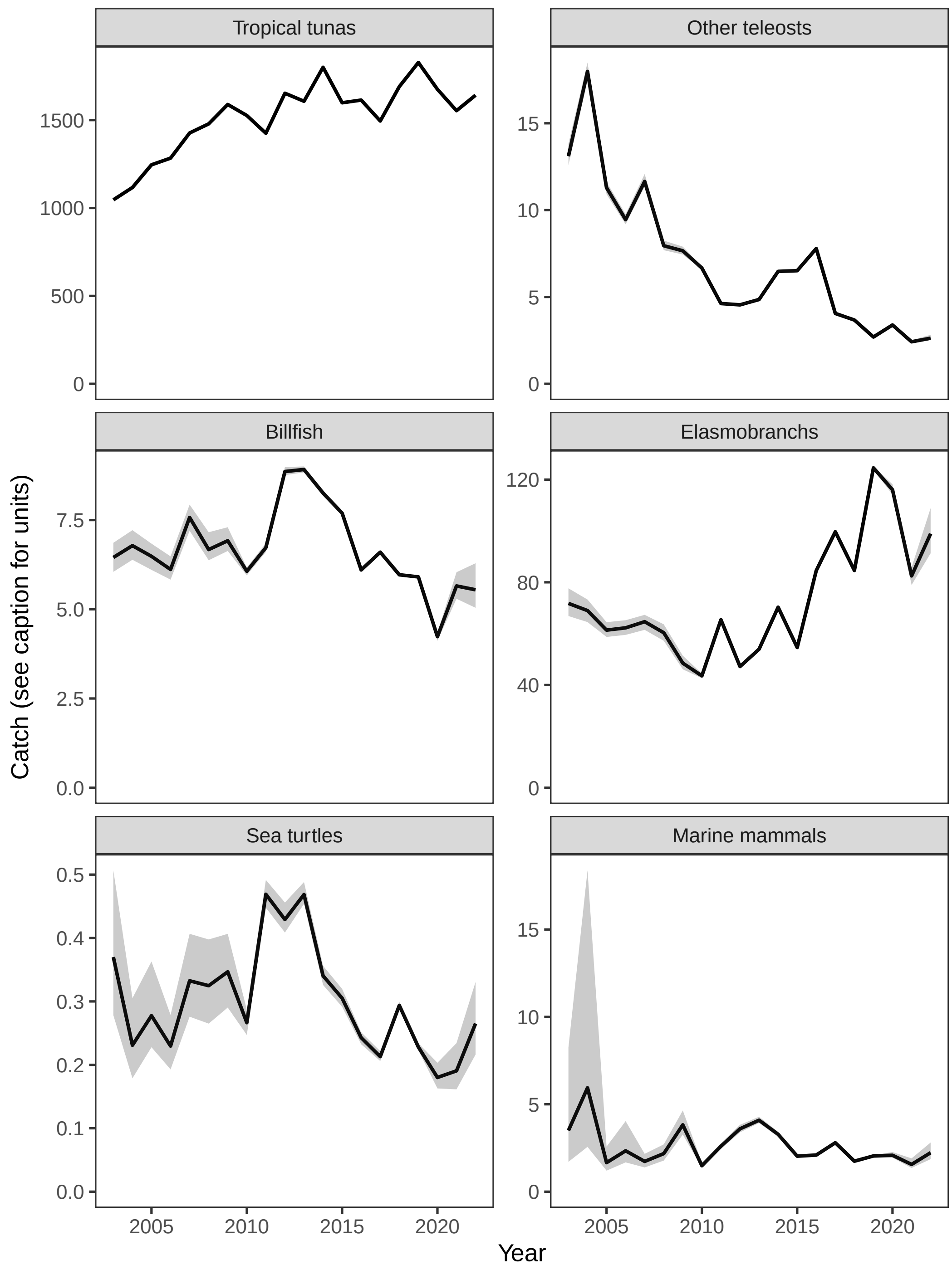


Figure 9: Estimated annual catch (with 95% confidence intervals) for the large-scale equatorial purse seine fishery in the WCPFC Convention Area by species type. 'Other teleosts' excludes tropical tuna and and billfish species. Catch units are '000 metric tonnes for tropical tuna and other finfish, and '000 individuals for billfish, elasmobranchs, marine mammals and sea turtles. Reported catches were used for tropical tuna and were assumed to be known without error.

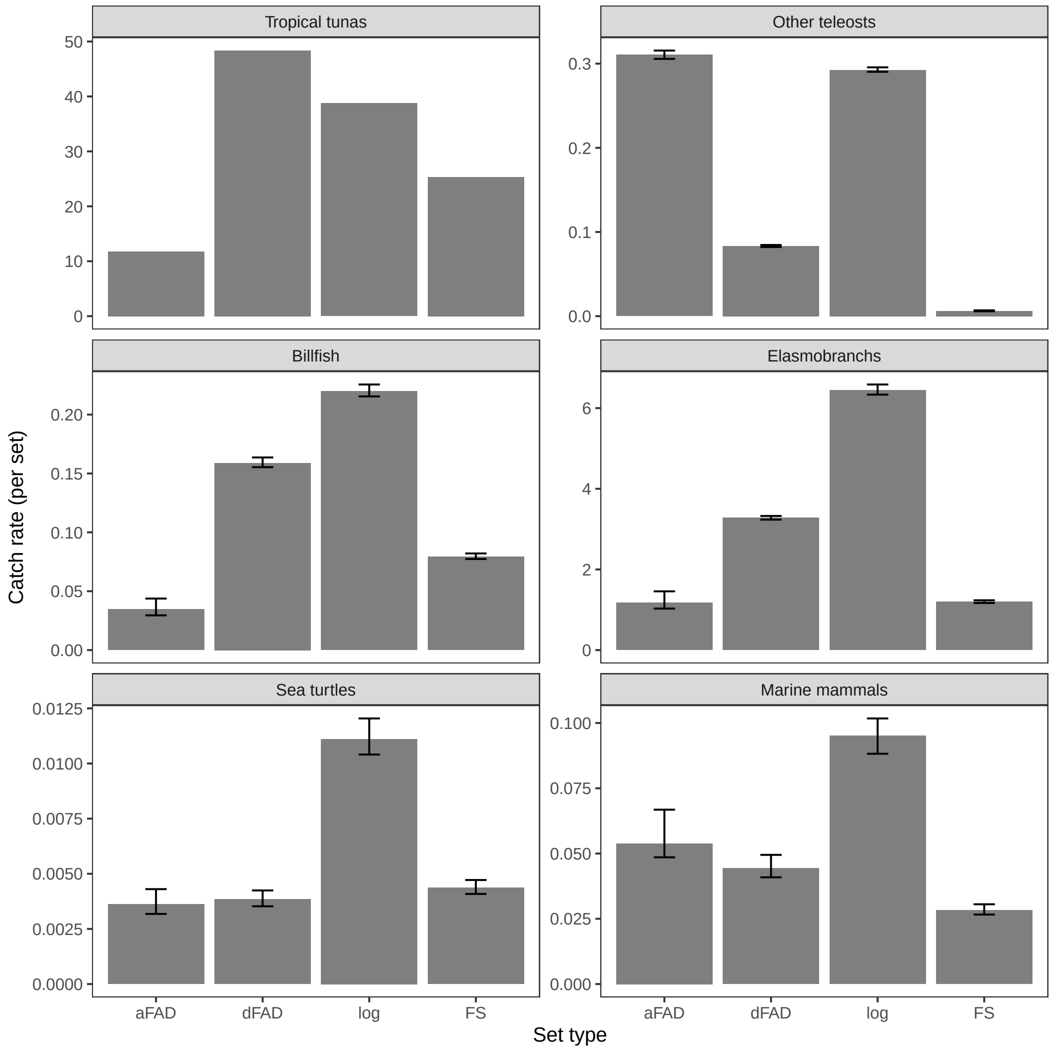


Figure 10: Mean estimated catch rates (bars provide 95% confidence intervals) for the large-scale equatorial purse seine fishery in the WCPFC Convention Area by species type for the period 2018-2022. 'Other teleosts' excludes tropical tuna and and billfish species. Catch rate units are metric tonnes per set for tropical tuna and 'other teleosts', and individuals per set for billfish, elasmobranchs, marine mammals and sea turtles. Reported catches were used for tropical tuna and were assumed to be known without error.

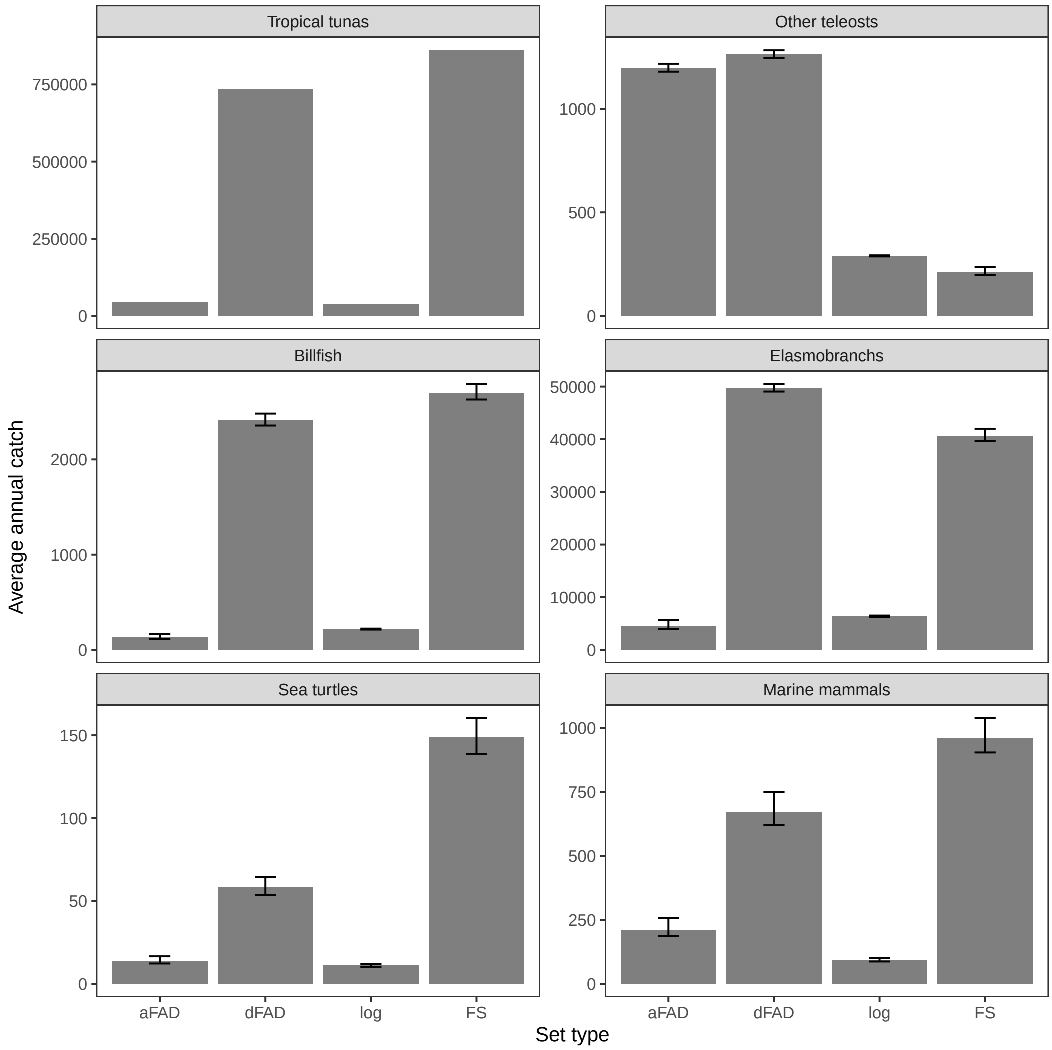


Figure 11: Mean estimated annual catch (bars provide 95% confidence intervals) for the large-scale equatorial purse seine fishery in the WCPFC Convention Area by species type for the period 2018-2022. 'Other teleosts' excludes tropical tuna and and billfish species. Catch units are metric tonnes for tropical tuna and 'other teleosts', and individuals for billfish, elasmobranchs, marine mammals and sea turtles. Reported catches were used for tropical tuna and were assumed to be known without error.

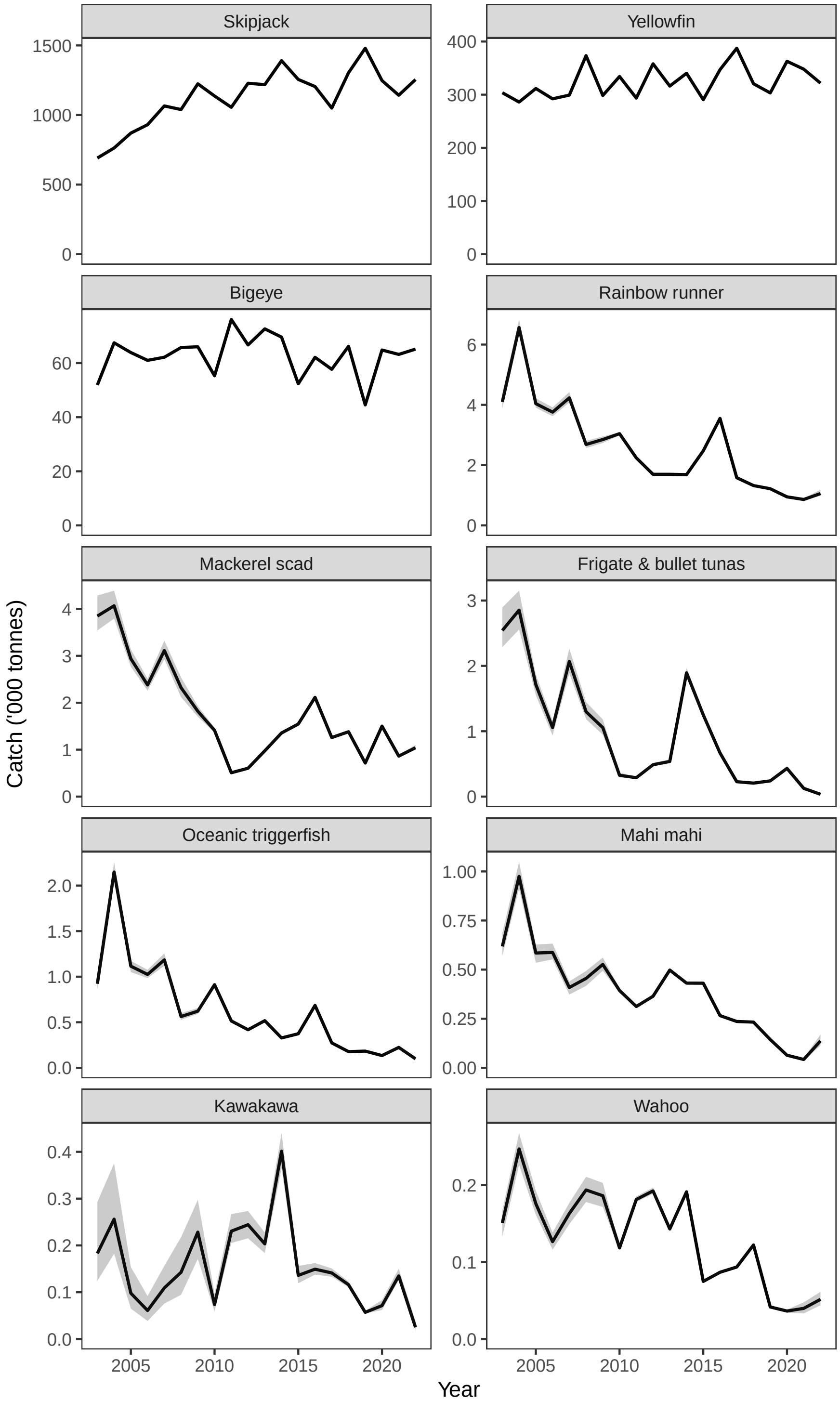


Figure 12: Estimated annual catch by teleost estimation group ('000 metric tonnes, 95% confidence intervals in parentheses) for the large-scale equatorial purse seine fishery in the WCPFC Convention Area. This figure presents catch estimates for the top ten teleost estimation groups in terms of total estimated catch over the time series (see Figure 13 for the remaining teleost estimation groups), with estimation groups ranked in descending order of catch by column (left to right) then row (top to bottom). Catches of billfish species are reported separately. Reported catches were used for tropical tuna and were assumed to be known without error.

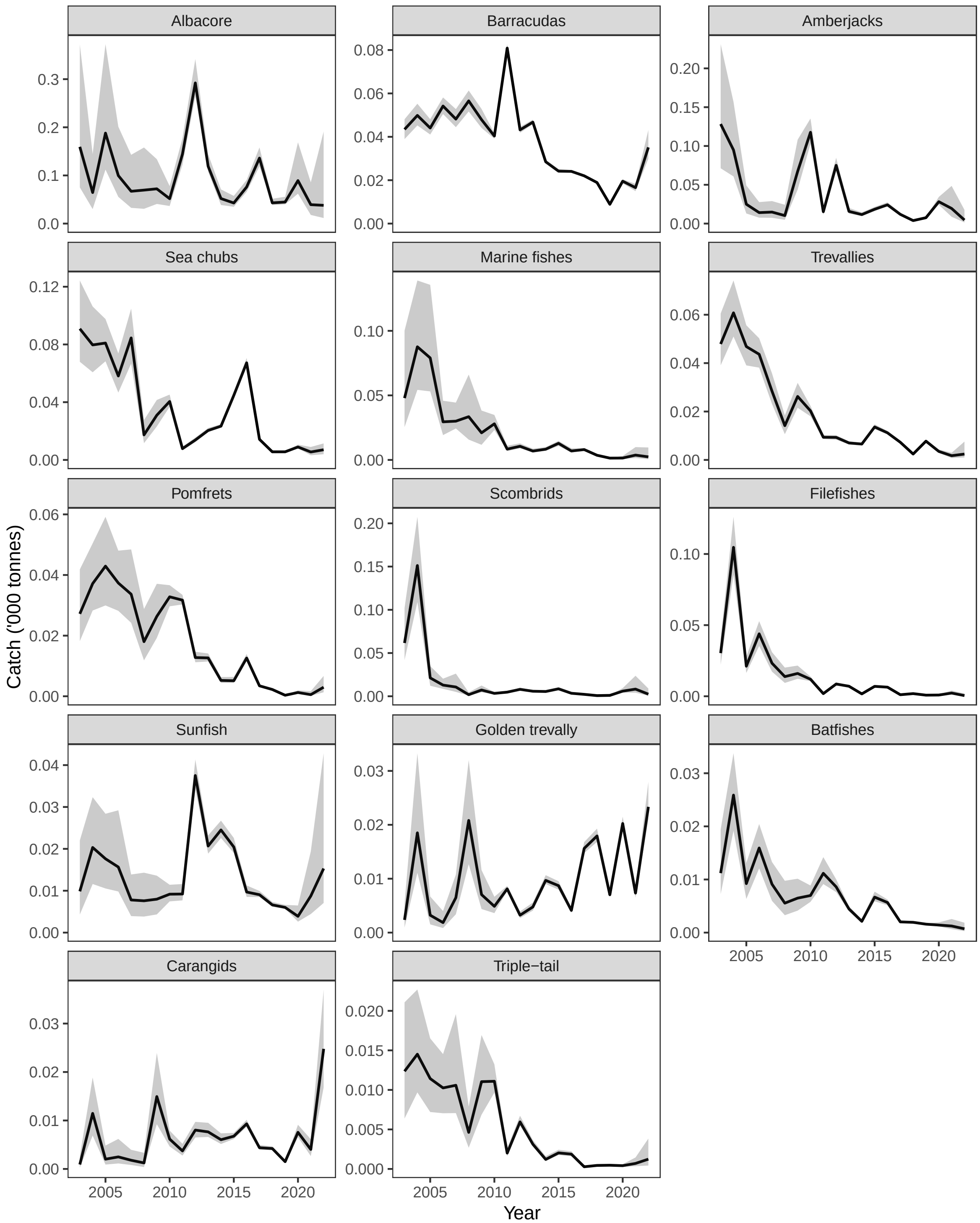


Figure 13: Estimated annual catch by teleost estimation group ('000 metric tonnes, 95% confidence intervals in parentheses) for the large-scale equatorial purse seine fishery in the WCPFC Convention Area. This table presents catch estimates for the teleost estimation groups ranked 11 to 24 in terms of total estimated catch over the time series (see Figure 12 for the remaining teleost estimation groups), with estimation groups ranked in descending order of catch by column (left to right) then row (top to bottom). Catches of billfish species are reported separately.

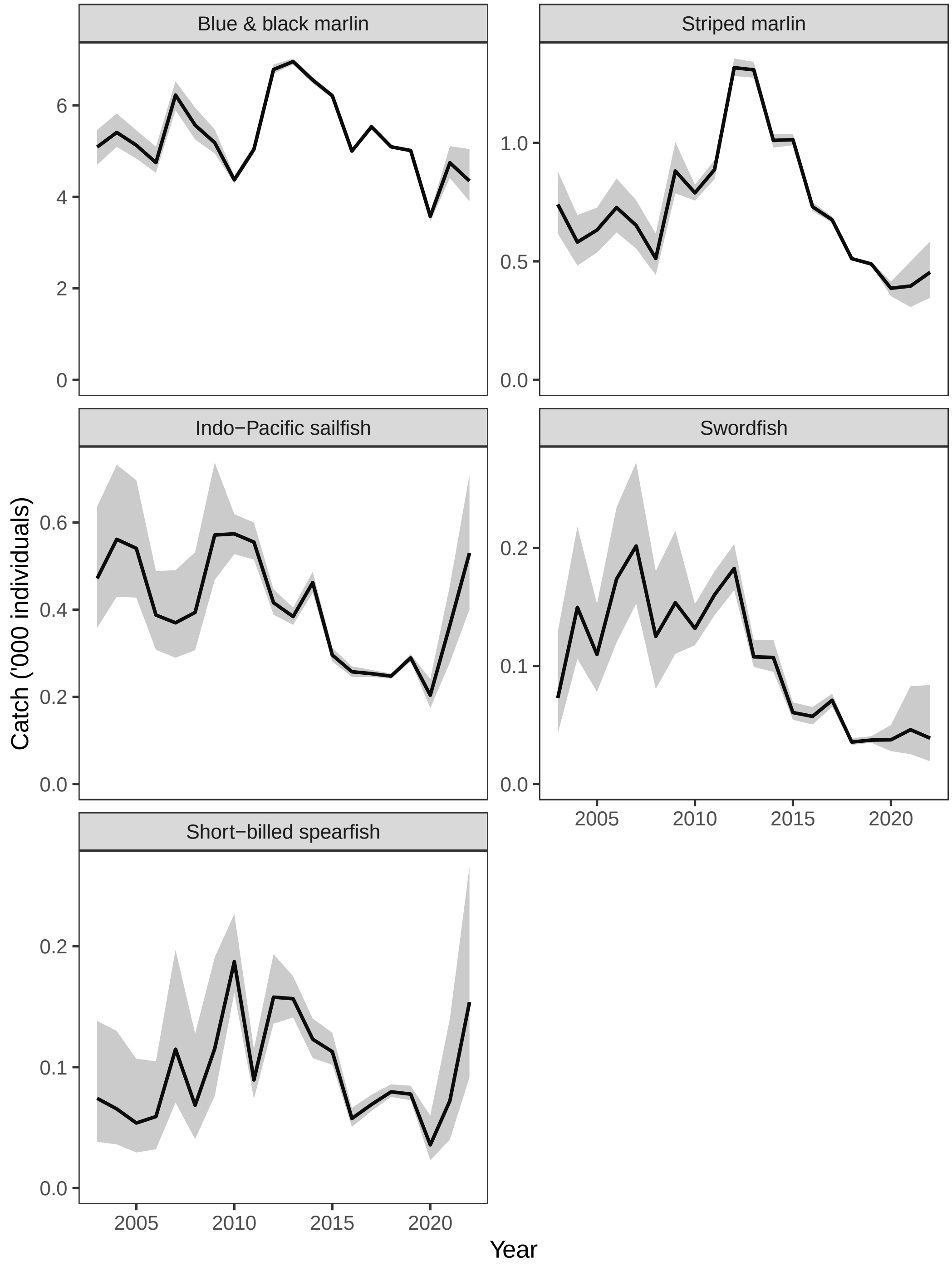


Figure 14: Estimated annual catch by billfish estimation group ('000 individuals, 95% confidence intervals in parentheses) for the large-scale equatorial purse seine fishery in the WCPFC Convention Area. Estimation groups are ranked in descending order of catch by column (left to right) then row (top to bottom).

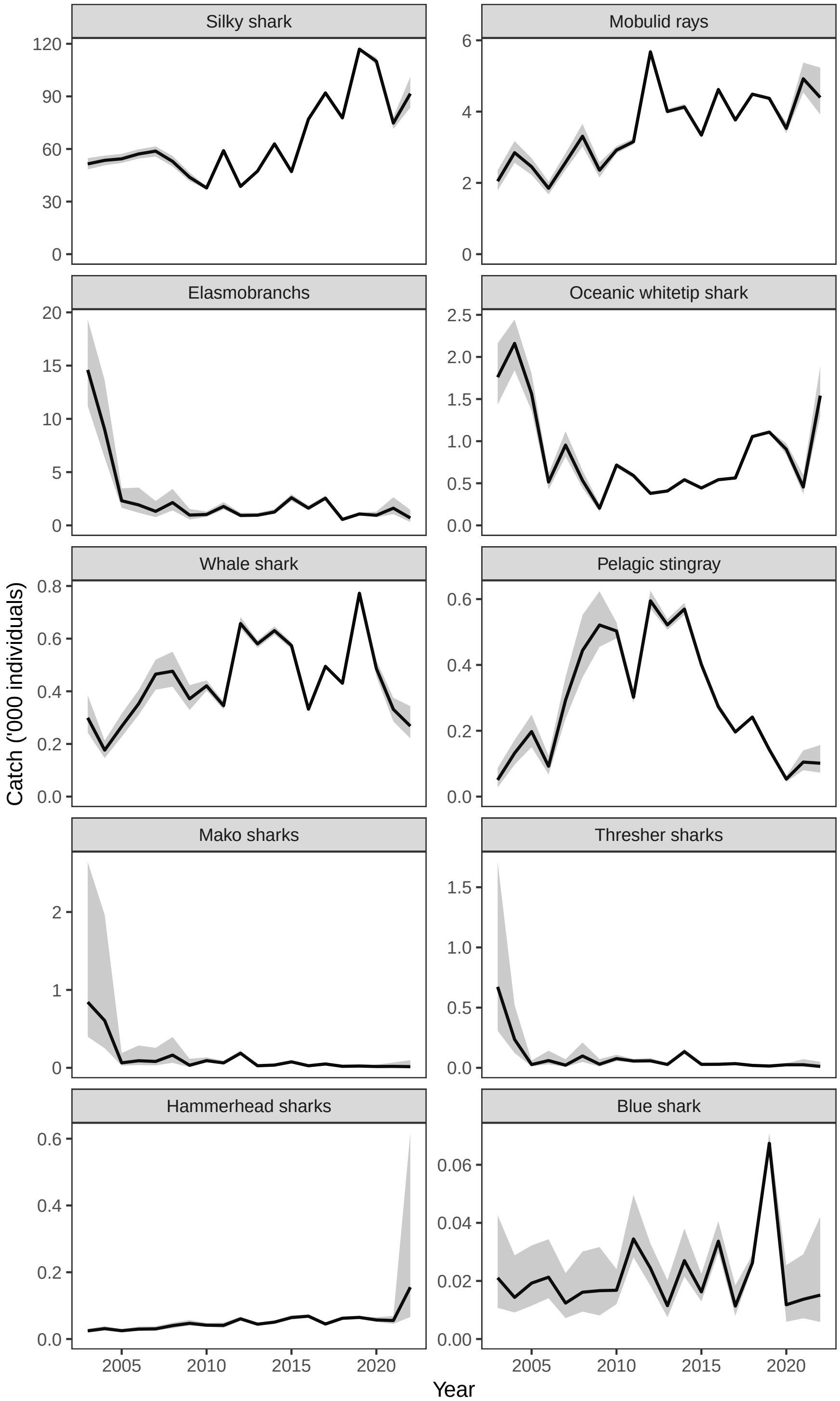


Figure 15: Estimated annual catch by elasmobranch estimation group ('000 individuals, 95% confidence intervals in parentheses) for the large-scale equatorial purse seine fishery in the WCPFC Convention Area. Estimation groups are ranked in descending order of catch by column (left to right) then row (top to bottom).

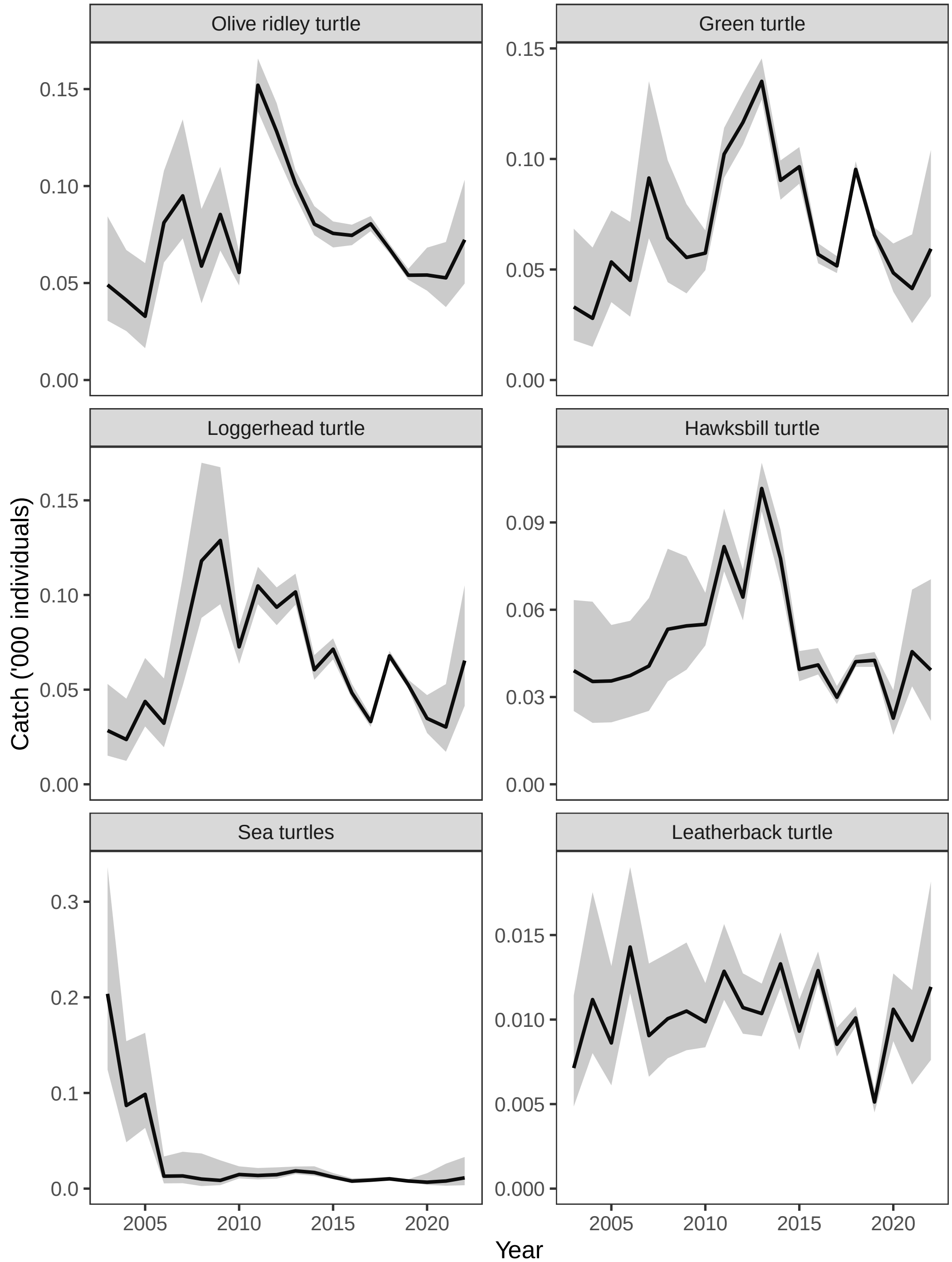


Figure 16: Estimated annual catch by sea turtle estimation group ('000 individuals, 95% confidence intervals in parentheses) for the large-scale equatorial purse seine fishery in the WCPFC Convention Area. Estimation groups are ranked in descending order of catch (left to right).

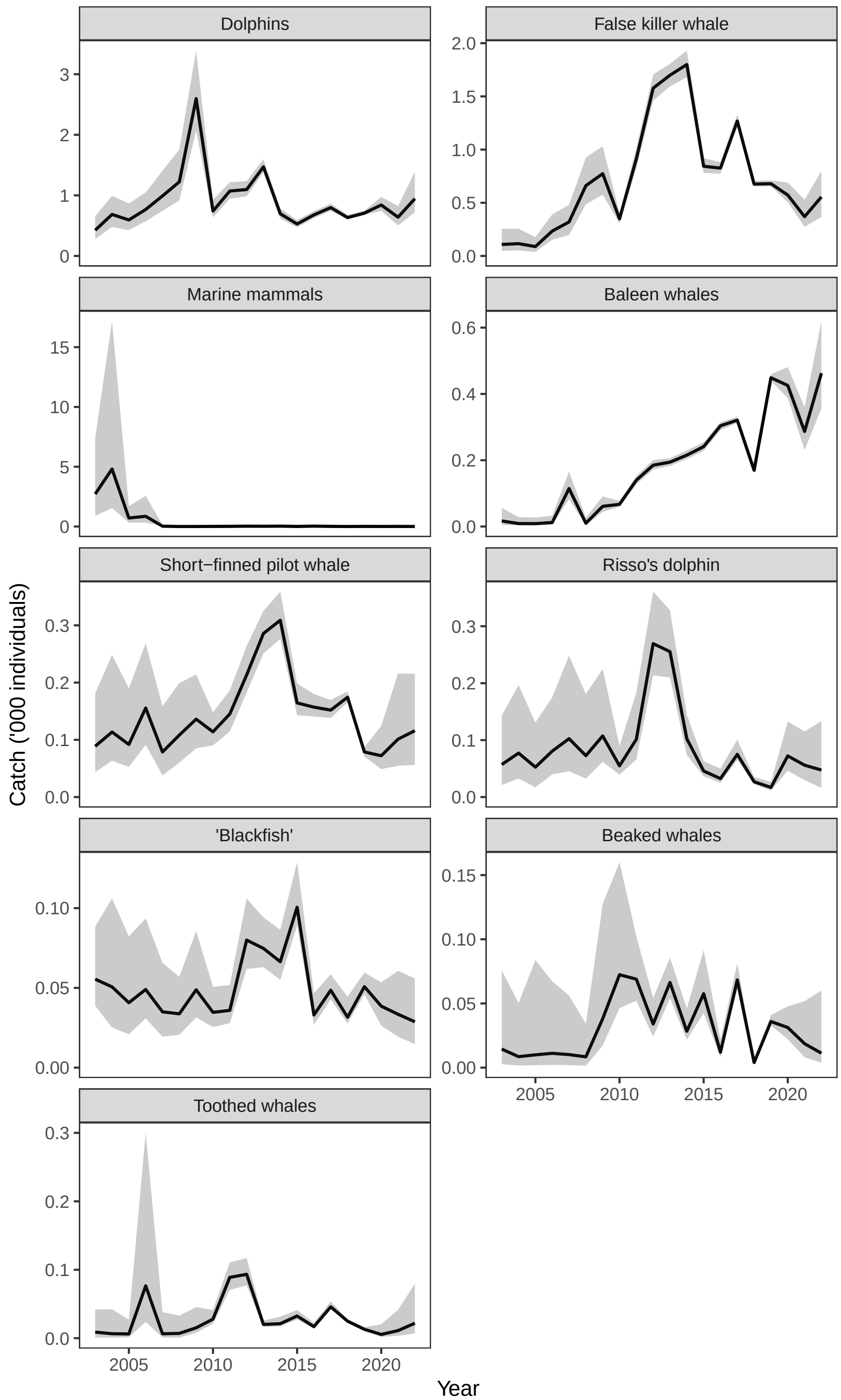


Figure 17: Estimated annual catch by marine mammal estimation group ('000 individuals, 95% confidence intervals in parentheses) for the large-scale equatorial purse seine fishery in the WCPFC Convention Area. Estimation groups are ranked in descending order of catch by column (left to right) then row (top to bottom).

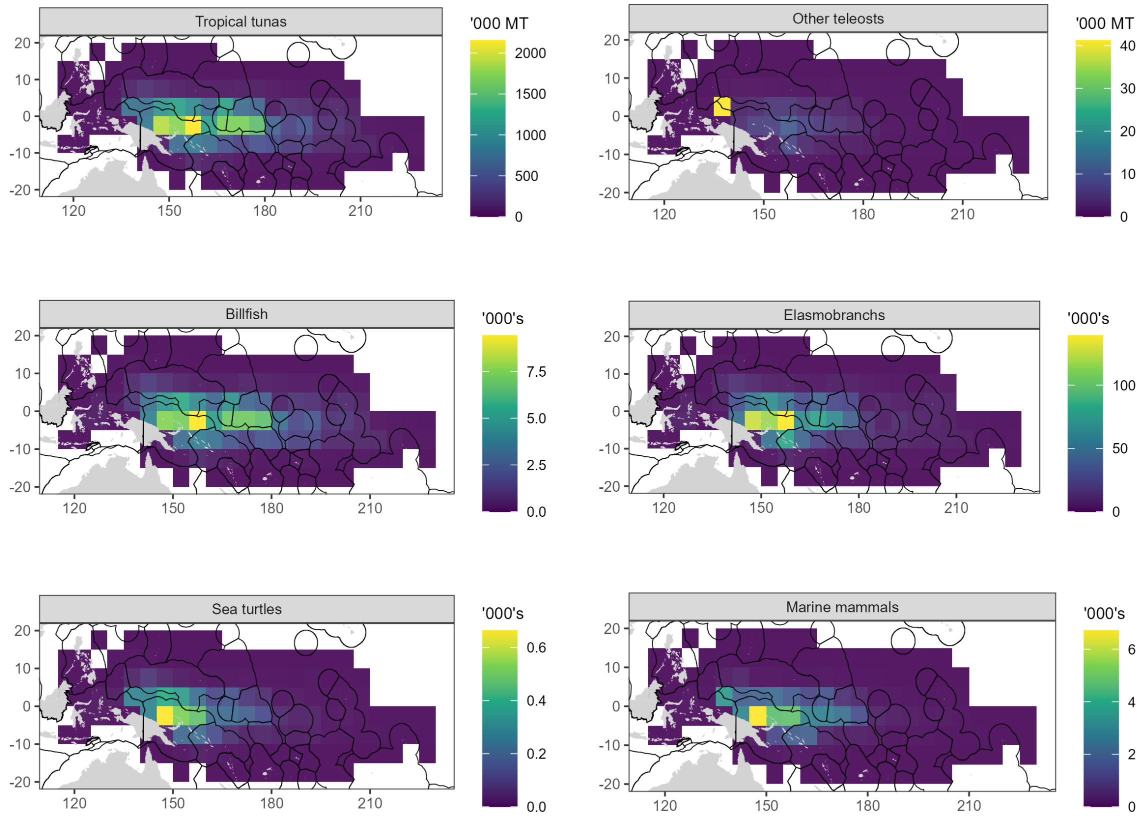


Figure 18: Estimated spatial distributions of species type specific catch of the large-scale equatorial purse seine fishery in the WCPFC Convention Area (2003 to 2022). 'Other teleosts' excludes tropical tuna and and billfish species. Reported catches were used for tropical tuna and were assumed to be known without error.

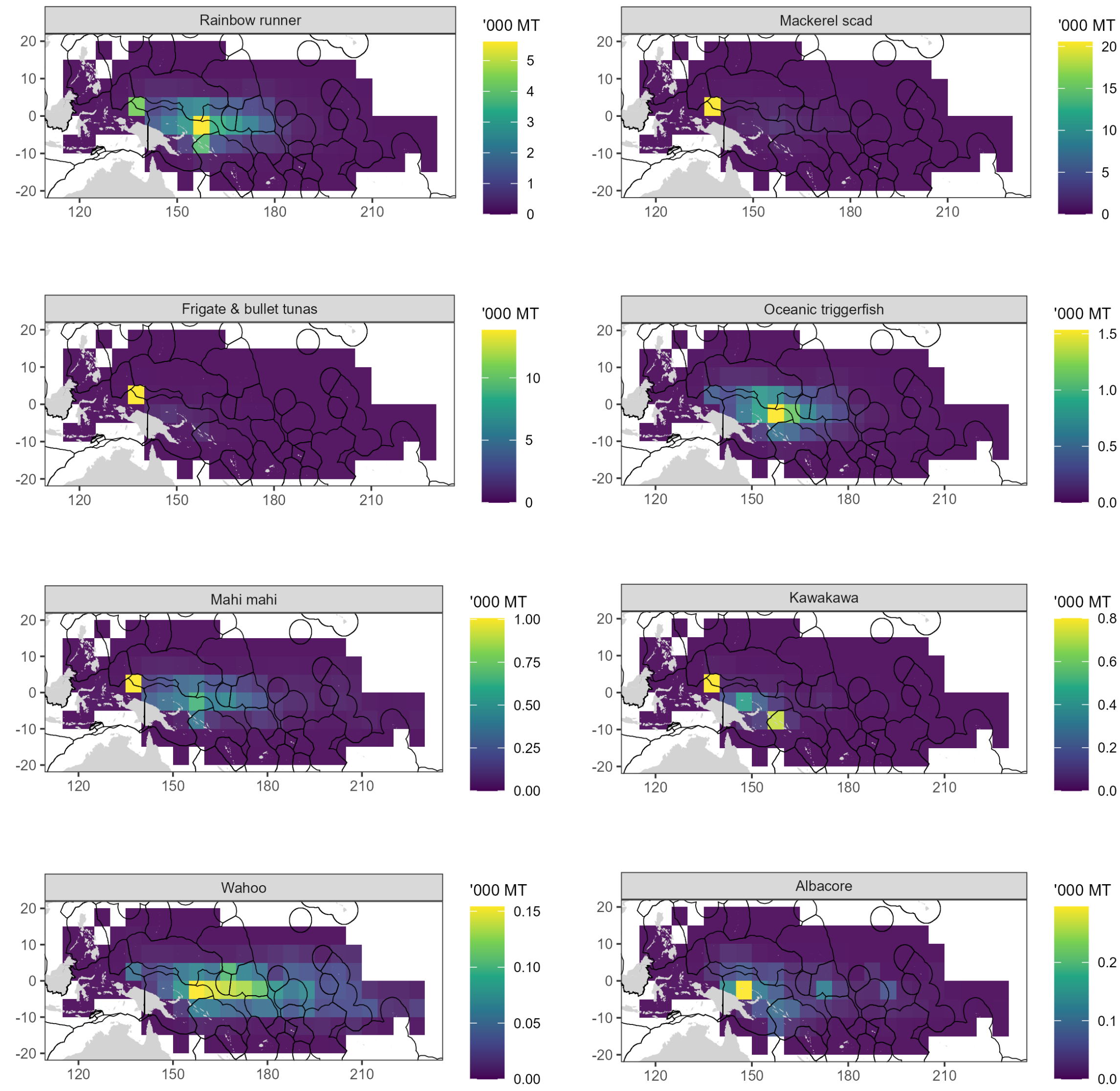


Figure 19: Estimated spatial distributions of catches of selected teleost estimation groups by the large-scale equatorial purse seine fishery in the WCPFC Convention Area (2003 to 2022). This figure presents catch estimates for the top eight teleost estimation groups in terms of total estimated catch over the time series (excluding tropical tuna, see Figure 21 & 20 for the remaining teleost estimation groups), with estimation groups ranked in descending order of catch by column (left to right) then row (top to bottom).

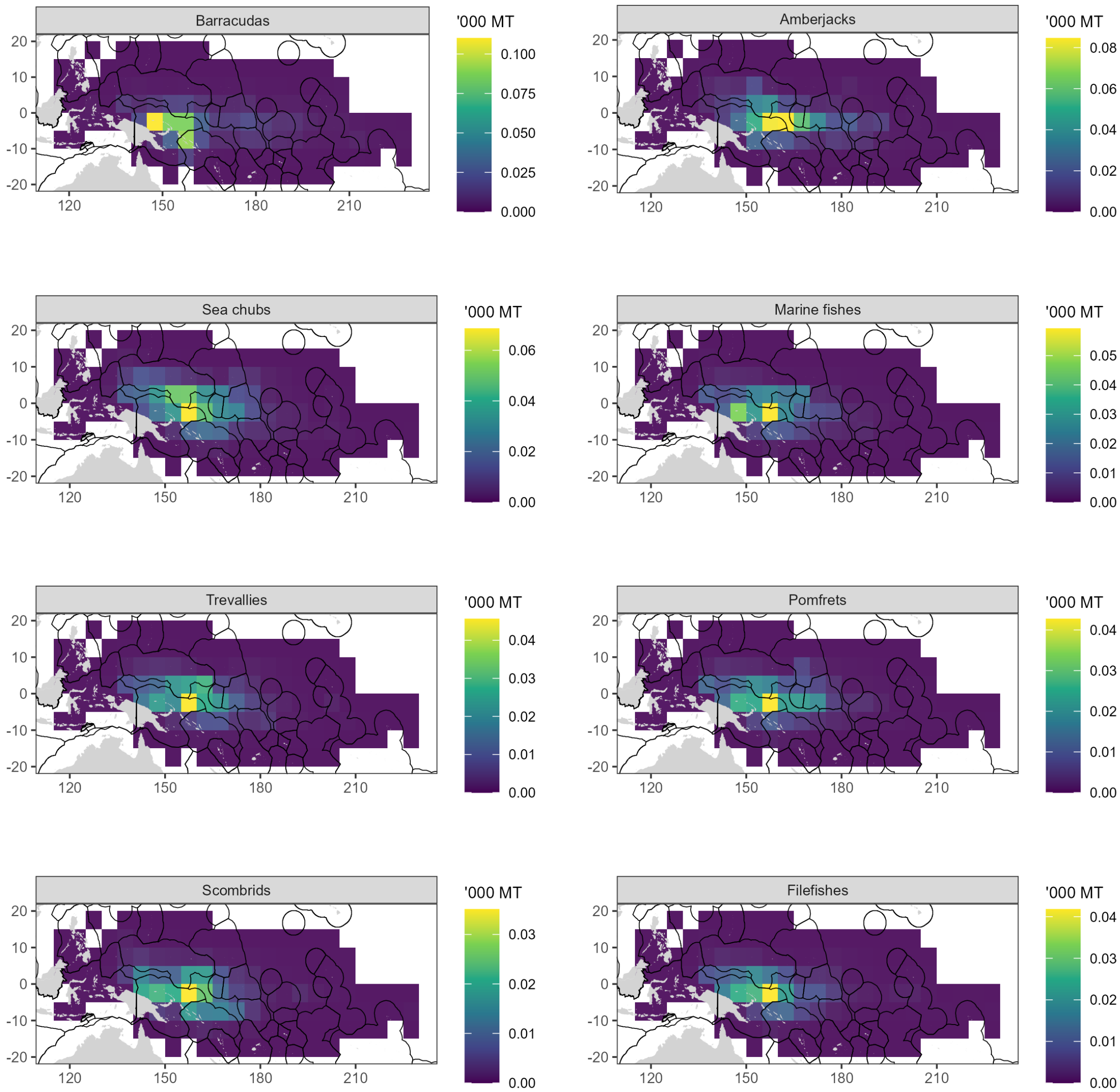


Figure 20: Estimated spatial distributions of catches of selected teleost estimation groups by the large-scale equatorial purse seine fishery in the WCPFC Convention Area (2003 to 2022). This figure presents catch estimates for the estimation groups ranked 9 to 16 in terms of total estimated catch over the time series (excluding tropical tuna, see Figure 19 & 20 for the remaining teleost estimation groups), with estimation groups ranked in descending order of catch by column (left to right) then row (top to bottom).

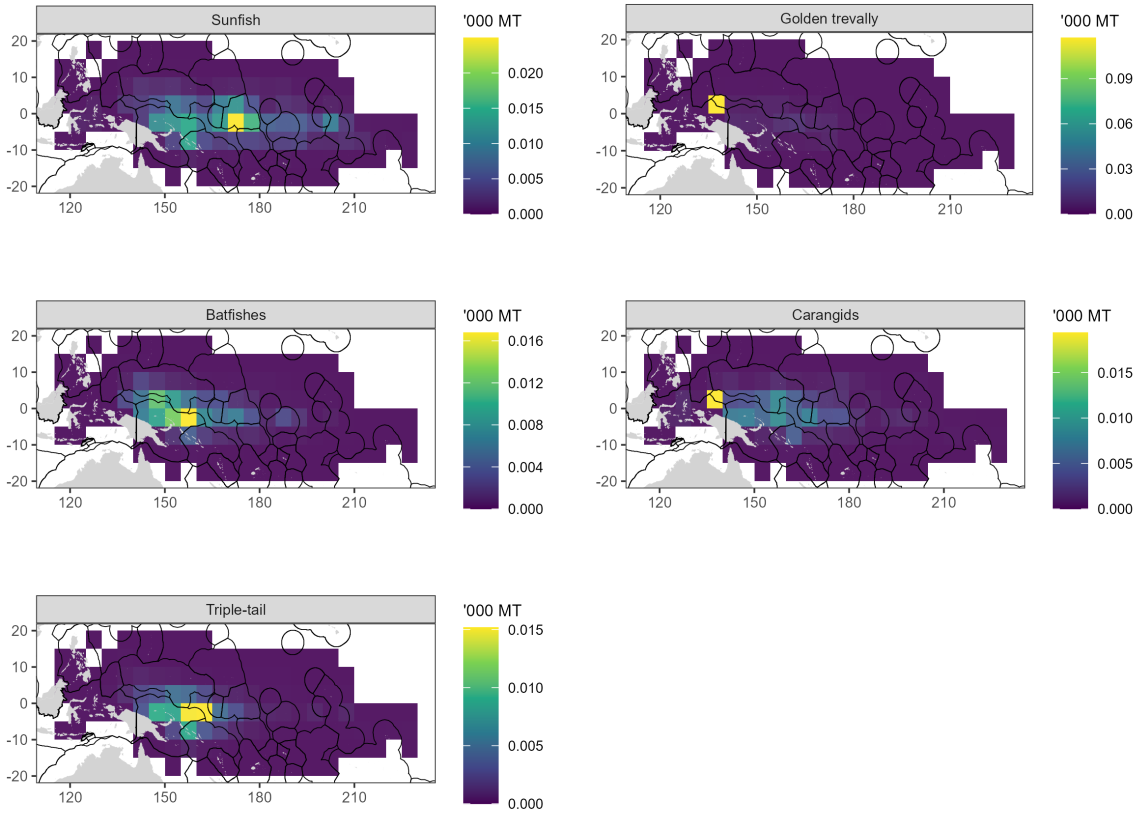


Figure 21: Estimated spatial distributions of catches of selected teleost estimation groups by the large-scale equatorial purse seine fishery in the WCPFC Convention Area (2003 to 2022). This figure presents catch estimates for the estimation groups ranked 17 to 21 in terms of total estimated catch over the time series (excluding tropical tuna, see Figure 19 & 20 for the remaining teleost estimation groups), with estimation groups ranked in descending order of catch by column (left to right) then row (top to bottom).

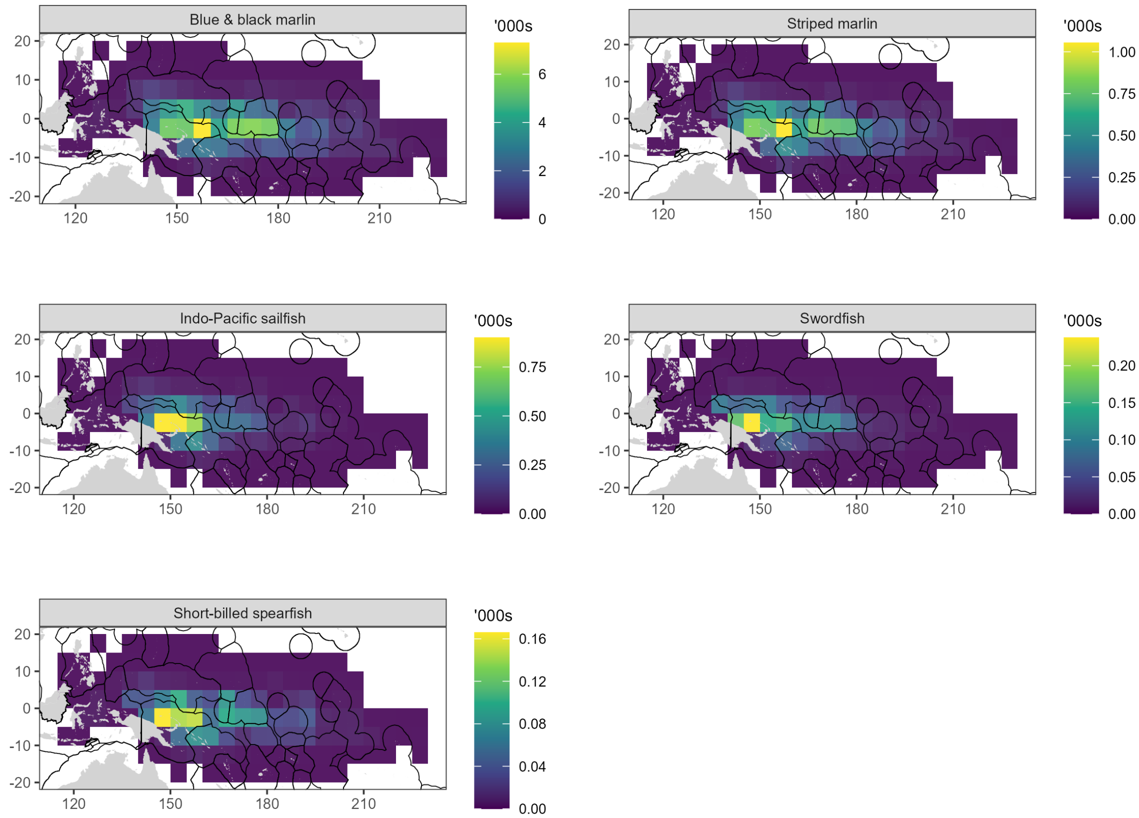


Figure 22: Estimated spatial distributions of catches of billfish estimation groups by the large-scale equatorial purse seine fishery in the WCPFC Convention Area (2003 to 2022). Estimation groups are ranked in descending order of catch by column (left to right) then row (top to bottom).

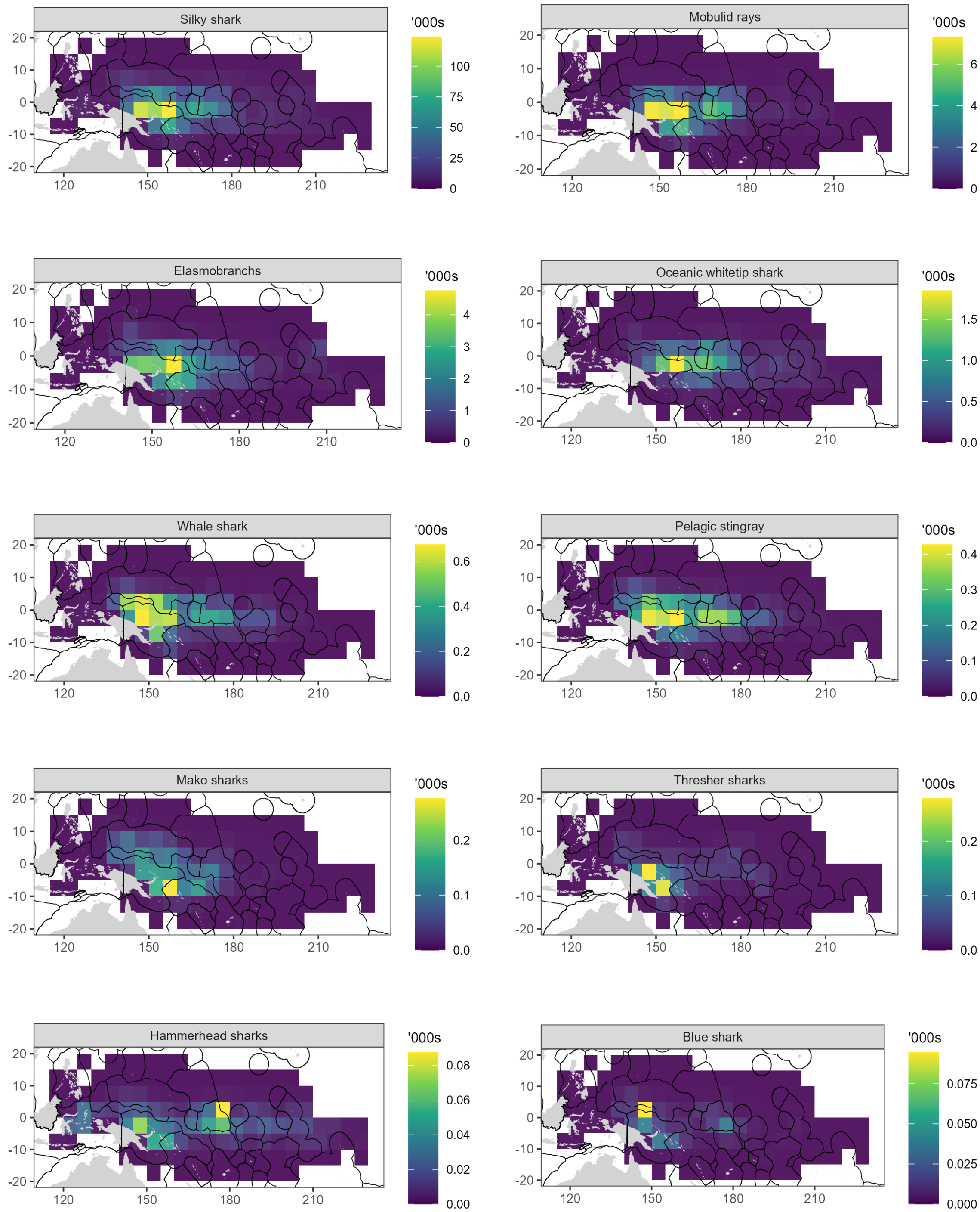


Figure 23: Estimated spatial distributions of catches of elasmobranch estimation groups by the large-scale equatorial purse seine fishery in the WCPFC Convention Area (2003 to 2022). Estimation groups are ranked in descending order of catch by column (left to right) then row (top to bottom).

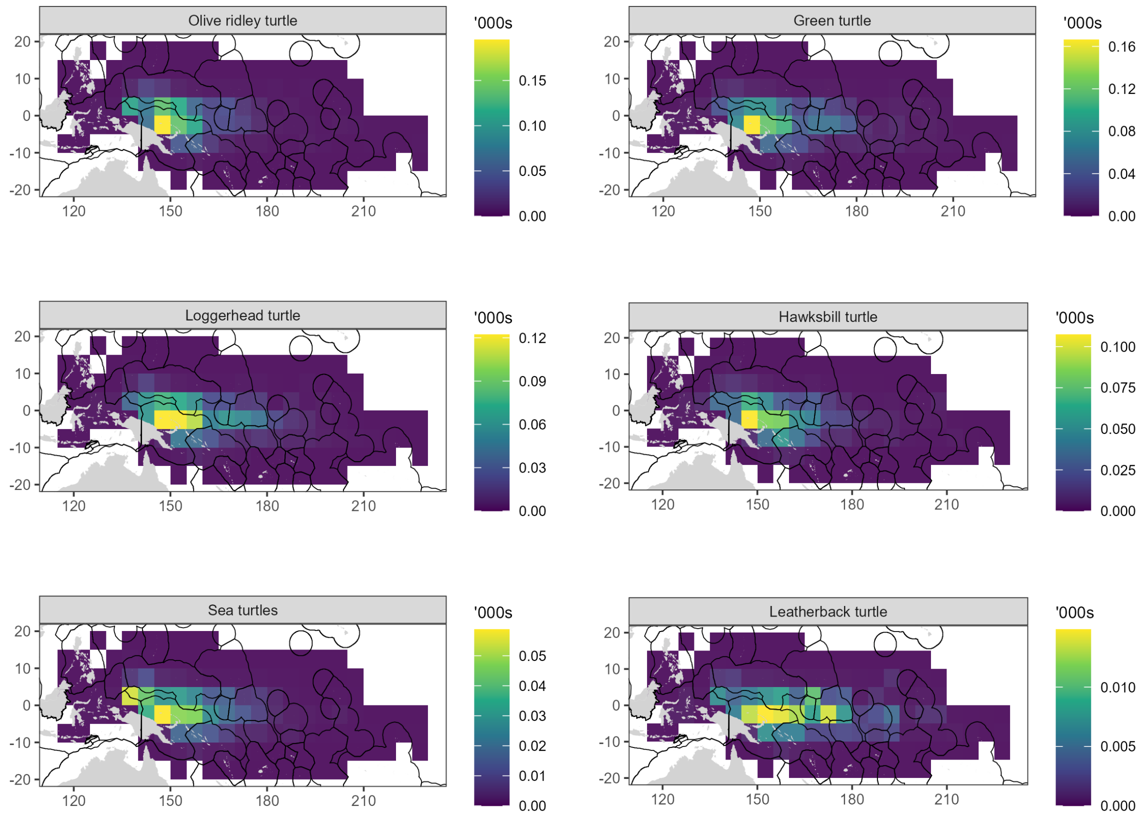


Figure 24: Estimated spatial distributions of catches of sea turtle estimation groups by the large-scale equatorial purse seine fishery in the WCPFC Convention Area (2003 to 2022). Estimation groups are ranked in descending order of catch by column (left to right) then row (top to bottom).

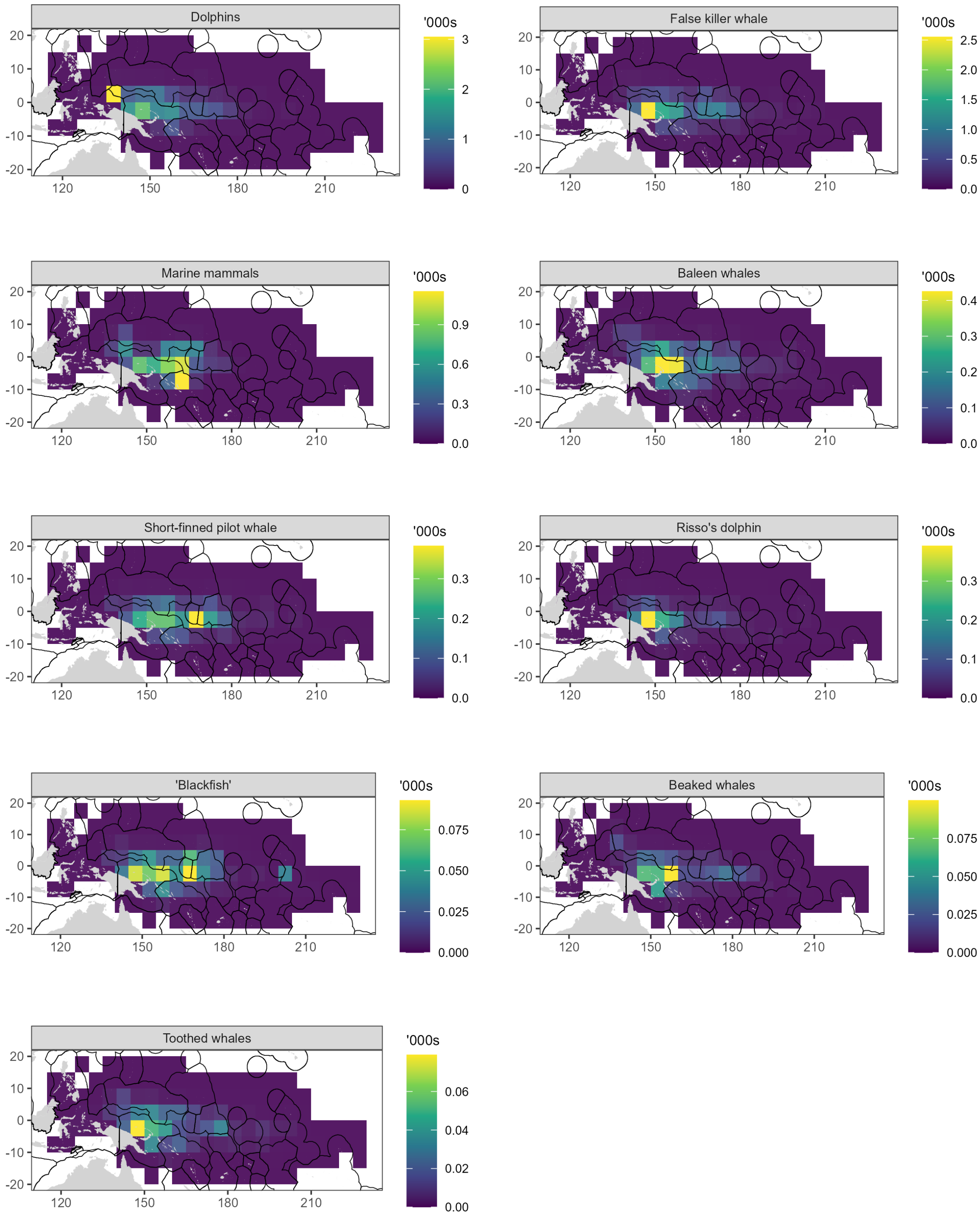


Figure 25: Estimated spatial distributions of catches of marine mammal estimation groups by the large-scale equatorial purse seine fishery in the WCPFC Convention Area (2003 to 2022). Estimation groups are ranked in descending order of catch by column (left to right) then row (top to bottom).

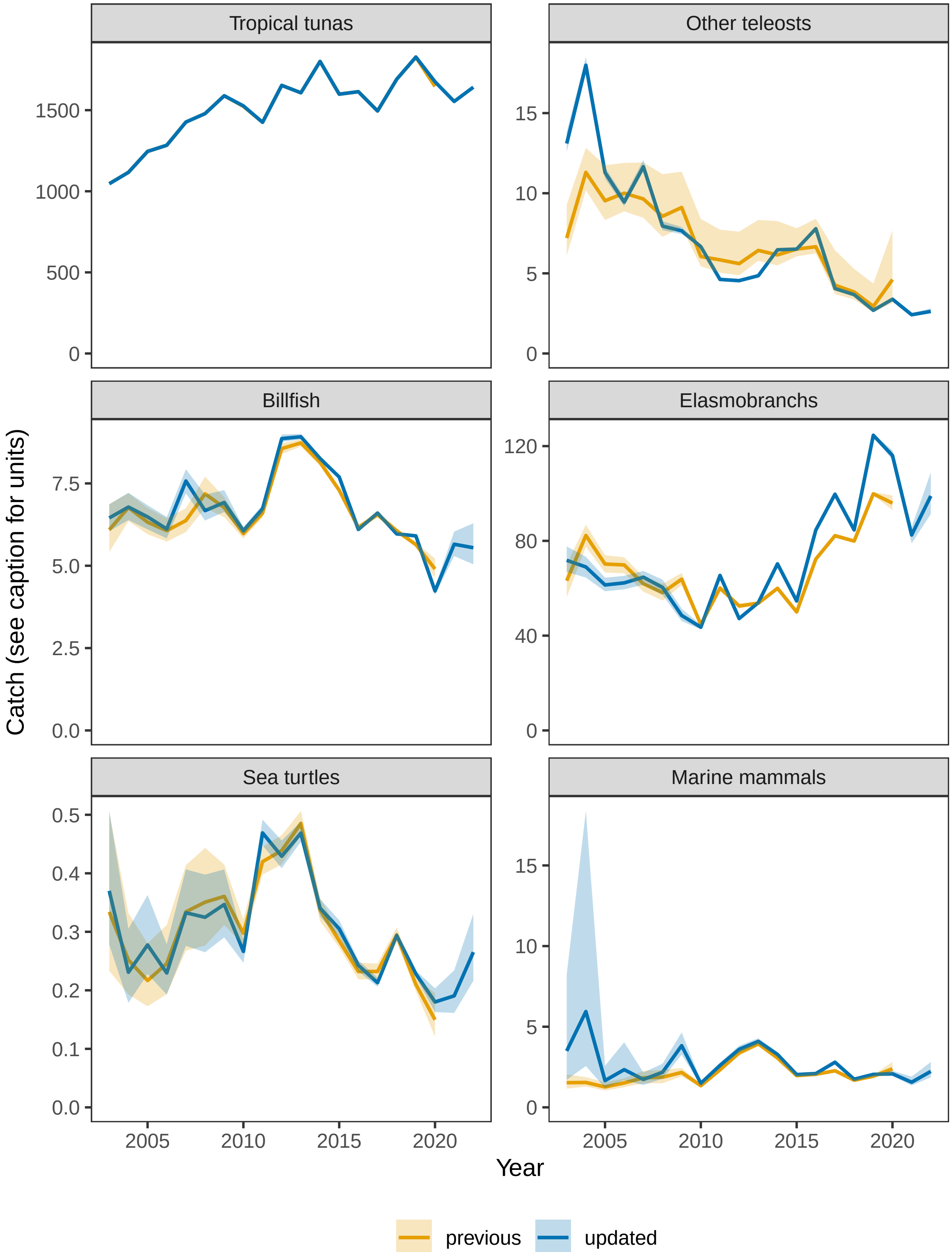


Figure 26: Comparisons of species type specific annual catch estimates ('updated') with estimates from Peatman and Nicol (2021) which cover the period 2003–2020 ('previous'). Catch units are '000 metric tonnes for tropical tuna and other finfish, and '000 individuals for billfish, elasmobranchs, marine mammals and sea turtles. Reported catches were used for tropical tuna and were assumed to be known without error.

Appendices

A Catch rate model summaries

Table A.1: Summary of the catch rate models used to predict catch rates for unobserved effort. In formulas, $(1 \mid x)$ denotes a random intercept for the 'x' variable, and s() denotes either a penalised smooth with shrinkage (bs = 'cs') or a penalised cyclic smooth (bs = 'cc'). 'Time' provides the variable that defines the spatiotemporal random field structure, where each value of the time variable has it's own random field. The spatiotemporal random fields were assumed to be independent and identically distributed. For estimation groups with ensemble model based predictions, 'Weight' gives the weight assigned to predicted values.

Estimation group	Model family	Formula	Time	Weight
Frigate & bullet tunas	delta_lognormal	set.type + oni.class + s(depth.20, bs = 'cs') + s(month, bs = 'cc') + (1 | flag.id) + (1 | yy)	oni.class	0.379
Frigate & bullet tunas	delta_lognormal	set.type + oni.class + s(depth.20, bs = 'cs') + s(month, bs = 'cc') + (1 | flag.id) + (1 | yy)	qtr	0.329
Frigate & bullet tunas	delta_lognormal	set.type + oni.class + s(depth.20, bs = 'cs') + s(month, bs = 'cc') + (1 | flag.id) + (1 | yy)	set.type	0.292
Wahoo	delta_lognormal	s(depth.20, bs = 'cs') + s(month, bs = 'cc') + (1 | set.type) + (1 | oni.class) + (1 | flag.id) + (1 | yy)	oni.class	0.312
Wahoo	delta_lognormal	s(depth.20, bs = 'cs') + s(month, bs = 'cc') + (1 | set.type) + (1 | oni.class) + (1 | flag.id) + (1 | yy)	qtr	0.688
Oceanic triggerfish	delta_lognormal	set.type + oni.class + s(depth.20, bs = 'cs') + s(month, bs = 'cc') + (1 | flag.id) + (1 | yy)	oni.class	0.377
Oceanic triggerfish	delta_lognormal	s(depth.20, bs = 'cs') + s(month, bs = 'cc') + (1 | set.type) + (1 | oni.class) + (1 | flag.id) + (1 | yy)	set.type	0.623
Pomfrets	delta_lognormal	set.type + oni.class + s(depth.20, bs = 'cs') + s(month, bs = 'cc') + (1 | flag.id) + (1 | yy)	–	1.000
Carangids	delta_lognormal	set.type + oni.class + s(depth.20, bs = 'cs') + s(month, bs = 'cc') + (1 | flag.id) + (1 | yy)	–	1.000
Trevallies	delta_lognormal	set.type + oni.class + s(depth.20, bs = 'cs') + s(month, bs = 'cc') + (1 | flag.id) + (1 | yy)	–	1.000
Mahi mahi	delta_lognormal	set.type + oni.class + s(depth.20, bs = 'cs') + s(month, bs = 'cc') + (1 | flag.id) + (1 | yy)	oni.class	0.180
Mahi mahi	delta_lognormal	set.type + oni.class + s(depth.20, bs = 'cs') + s(month, bs = 'cc') + (1 | flag.id) + (1 | yy)	qtr	0.820
Mackerel scad	delta_lognormal	set.type + oni.class + s(depth.20, bs = 'cs') + s(month, bs = 'cc') + (1 | flag.id) + (1 | yy)	oni.class	0.612
Mackerel scad	delta_lognormal	set.type + oni.class + s(depth.20, bs = 'cs') + s(month, bs = 'cc') + (1 | flag.id) + (1 | yy)	qtr	0.183
Mackerel scad	delta_lognormal	set.type + oni.class + s(depth.20, bs = 'cs') + s(month, bs = 'cc') + (1 | flag.id) + (1 | yy)	set.type	0.205
Rainbow runner	delta_lognormal	set.type + oni.class + s(depth.20, bs = 'cs') + s(month, bs = 'cc') + (1 | flag.id) + (1 | yy)	oni.class	0.244
Rainbow runner	delta_lognormal	set.type + oni.class + s(depth.20, bs = 'cs') + s(month, bs = 'cc') + (1 | flag.id) + (1 | yy)	qtr	0.168
Rainbow runner	delta_lognormal	set.type + oni.class + s(depth.20, bs = 'cs') + s(month, bs = 'cc') + (1 | flag.id) + (1 | yy)	set.type	0.587
Kawakawa	delta_lognormal	set.type + oni.class + s(depth.20, bs = 'cs') + s(month, bs = 'cc') + (1 | flag.id) + (1 | yy)	–	1.000
Golden trevally	delta_lognormal	set.type + oni.class + s(depth.20, bs = 'cs') + s(month, bs = 'cc') + (1 | flag.id) + (1 | yy)	–	1.000
Sea chubs	delta_lognormal	set.type + oni.class + s(depth.20, bs = 'cs') + s(month, bs = 'cc') + (1 | flag.id) + (1 | yy)	–	1.000
Triple-tail	delta_lognormal	s(depth.20, bs = 'cs') + s(month, bs = 'cc') + (1 | set.type) + (1 | oni.class) + (1 | flag.id) + (1 | yy)	–	1.000
Sunfish	delta_lognormal	set.type + oni.class + s(depth.20, bs = 'cs') + s(month, bs = 'cc') + (1 | flag.id) + (1 | yy)	–	1.000
Filefishes	delta_lognormal	s(depth.20, bs = 'cs') + s(month, bs = 'cc') + (1 | set.type) + (1 | oni.class) + (1 | flag.id) + (1 | yy)	–	1.000
Batfishes	delta_gamma	s(depth.20, bs = 'cs') + s(month, bs = 'cc') + (1 | set.type) + (1 | oni.class) + (1 | flag.id) + (1 | yy)	–	1.000
Scombrids	delta_lognormal	s(month, bs = 'cc') + (1 | set.type) + (1 | oni.class) + (1 | flag.id) + (1 | yy)	–	1.000
Amberjacks	delta_lognormal	set.type + oni.class + s(depth.20, bs = 'cs') + s(month, bs = 'cc') + (1 | flag.id) + (1 | yy)	–	1.000
Barracudas	delta_lognormal	set.type + oni.class + s(depth.20, bs = 'cs') + s(month, bs = 'cc') + (1 | flag.id) + (1 | yy)	qtr	0.385

Table A.1: ***(continued)***

Estimation group	**Model family**	**Formula**	**Time**	**Weight**
Barracudas	delta_lognormal	set.type + oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	set.type	0.615
Marine fishes	delta_lognormal	set.type + oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	–	1.000
Albacore	delta_lognormal	set.type + oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	–	1.000
Indo-Pacific sailfish	nbinom2	set.type + oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	qtr	0.376
Indo-Pacific sailfish	nbinom2	set.type + oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	set.type	0.624
Blue & black marlin	nbinom2	set.type + oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	oni.class	0.197
Blue & black marlin	nbinom2	set.type + oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	qtr	0.109
Blue & black marlin	nbinom2	set.type + oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	set.type	0.694
Short-billed spearfish	nbinom2	set.type + oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	–	1.000
Striped marlin	nbinom2	set.type + oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	qtr	0.441
Striped marlin	nbinom2	set.type + oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	set.type	0.559
Swordfish	poisson	set.type + oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	–	1.000
Thresher sharks	nbinom2	set.type + oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	–	1.000
Silky shark	delta_truncated_nbinom2	set.type + oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	qtr	0.243
Silky shark	delta_truncated_nbinom2	set.type + oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	set.type	0.757
Oceanic whitetip shark	nbinom2	s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | set.type) + (1 | oni.class) + (1 | flag.id) + (1 | yy)	oni.class	0.198
Oceanic whitetip shark	nbinom2	s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | set.type) + (1 | oni.class) + (1 | flag.id) + (1 | yy)	qtr	0.348
Oceanic whitetip shark	nbinom2	s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | set.type) + (1 | oni.class) + (1 | flag.id) + (1 | yy)	set.type	0.454
Pelagic stingray	nbinom2	set.type + oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	oni.class	0.487
Pelagic stingray	nbinom2	set.type + oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	qtr	0.279
Pelagic stingray	nbinom2	set.type + oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	set.type	0.234
Elasmobranchs	delta_truncated_nbinom2	set.type + oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	–	1.000
Mako sharks	nbinom2	set.type + oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	–	1.000
Mobulid rays	nbinom2	set.type + oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	oni.class	0.238
Mobulid rays	nbinom2	set.type + oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	qtr	0.598
Mobulid rays	nbinom2	set.type + oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	set.type	0.164
Blue shark	nbinom2	oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | set.type) + (1 | flag.id) + (1 | yy)	–	1.000
Whale shark	nbinom2	set.type + oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	oni.class	0.358
Whale shark	nbinom2	set.type + oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	qtr	0.481
Whale shark	nbinom2	set.type + oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	set.type	0.161
Hammerhead sharks	nbinom2	oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | set.type) + (1 | flag.id) + (1 | yy)	–	1.000
Loggerhead turtle	nbinom2	set.type + oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	qtr	0.511
Loggerhead turtle	nbinom2	set.type + oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	set.type	0.489

Table A.1: ***(continued)***

Estimation group	Model family	Formula	Time	Weight
Green turtle	nbinom2	set.type + oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	–	0.207
Green turtle	nbinom2	set.type + oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	qtr	0.793
Sea turtles	nbinom2	set.type + oni.class + s(depth.20, bs = ‘cs’) + (1 | flag.id) + (1 | yy)	–	1.000
Leatherback turtle	nbinom2	set.type + oni.class + (1 | flag.id) + (1 | yy)	–	1.000
Hawksbill turtle	nbinom2	set.type + oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	qtr	0.734
Hawksbill turtle	nbinom2	set.type + oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	set.type	0.266
Olive ridley turtle	nbinom2	set.type + oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	qtr	0.506
Olive ridley turtle	nbinom2	set.type + oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	set.type	0.494
‘Blackfish’	nbinom2	set.type + oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	–	1.000
Marine mammals	nbinom2	set.type + oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	–	1.000
Dolphins	delta_truncated_nbinom2	set.type + oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	oni.class	0.708
Dolphins	delta_truncated_nbinom2	set.type + oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	set.type	0.292
Short-finned pilot whale	delta_truncated_nbinom2	set.type + oni.class + (1 | flag.id) + (1 | yy)	–	0.597
Short-finned pilot whale	delta_truncated_nbinom2	set.type + oni.class + (1 | flag.id) + (1 | yy)	qtr	0.403
Risso’s dolphin	delta_truncated_nbinom2	set.type + oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	–	1.000
Baleen whales	nbinom2	set.type + oni.class + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	–	0.587
Baleen whales	nbinom2	set.type + oni.class + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	oni.class	0.180
Baleen whales	nbinom2	set.type + oni.class + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	qtr	0.233
Toothed whales	nbinom2	oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | set.type) + (1 | flag.id) + (1 | yy)	–	1.000
False killer whale	delta_truncated_nbinom2	set.type + oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	oni.class	0.526
False killer whale	delta_truncated_nbinom2	set.type + oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | flag.id) + (1 | yy)	set.type	0.474
Beaked whales	nbinom2	oni.class + s(depth.20, bs = ‘cs’) + s(month, bs = ‘cc’) + (1 | set.type) + (1 | flag.id) + (1 | yy)	–	1.000

B Catch rate model effects

B.1 Teleosts - catch rate models

Frigate & bullet tunas (*Auxis thazard* & *A. rochei*)

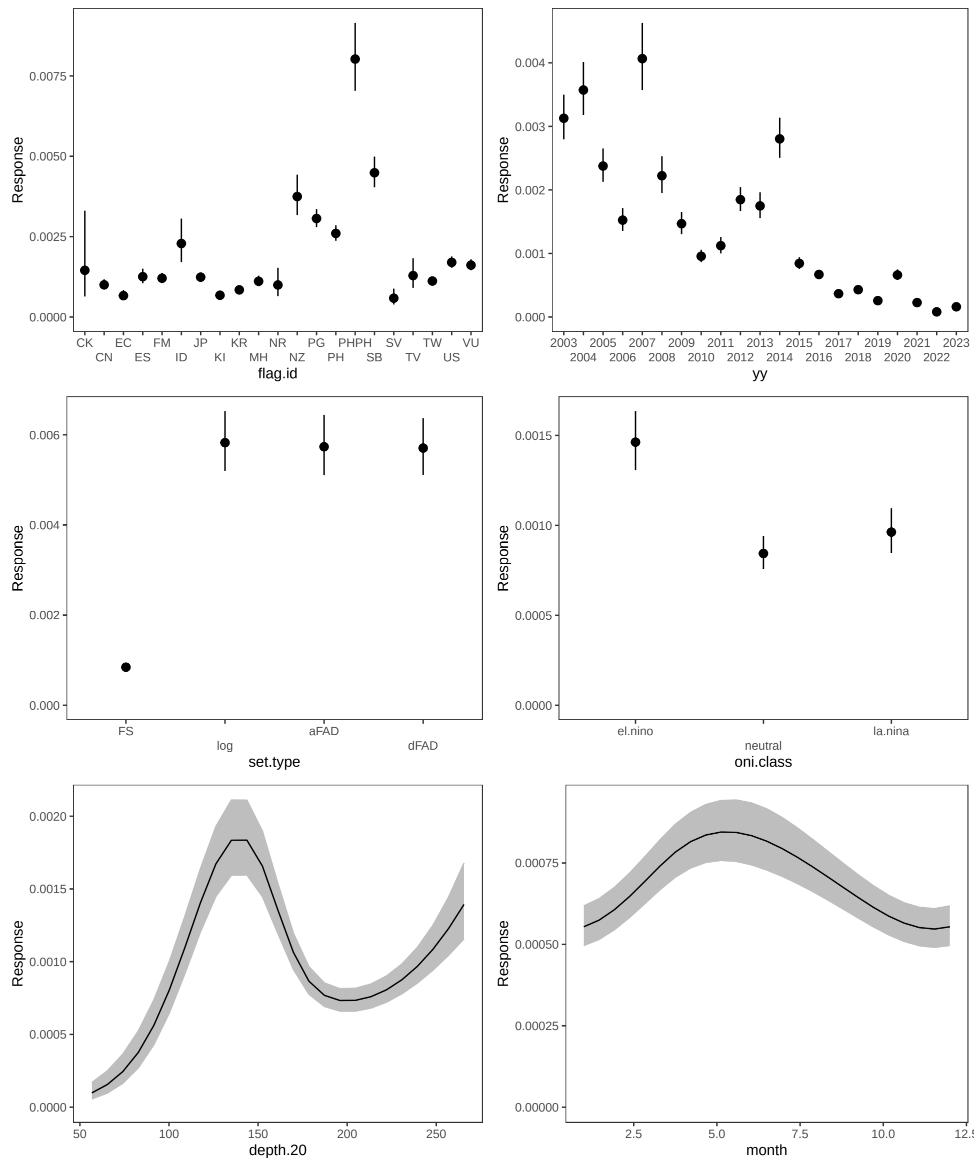


Figure B.1: Effects for the delta component of the Frigate & bullet tunas catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels': year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the $20°$C isotherm = 180m, latitude = $175°$E, longitude = $2.5°$S. See Figure B.3 for spatial effects.

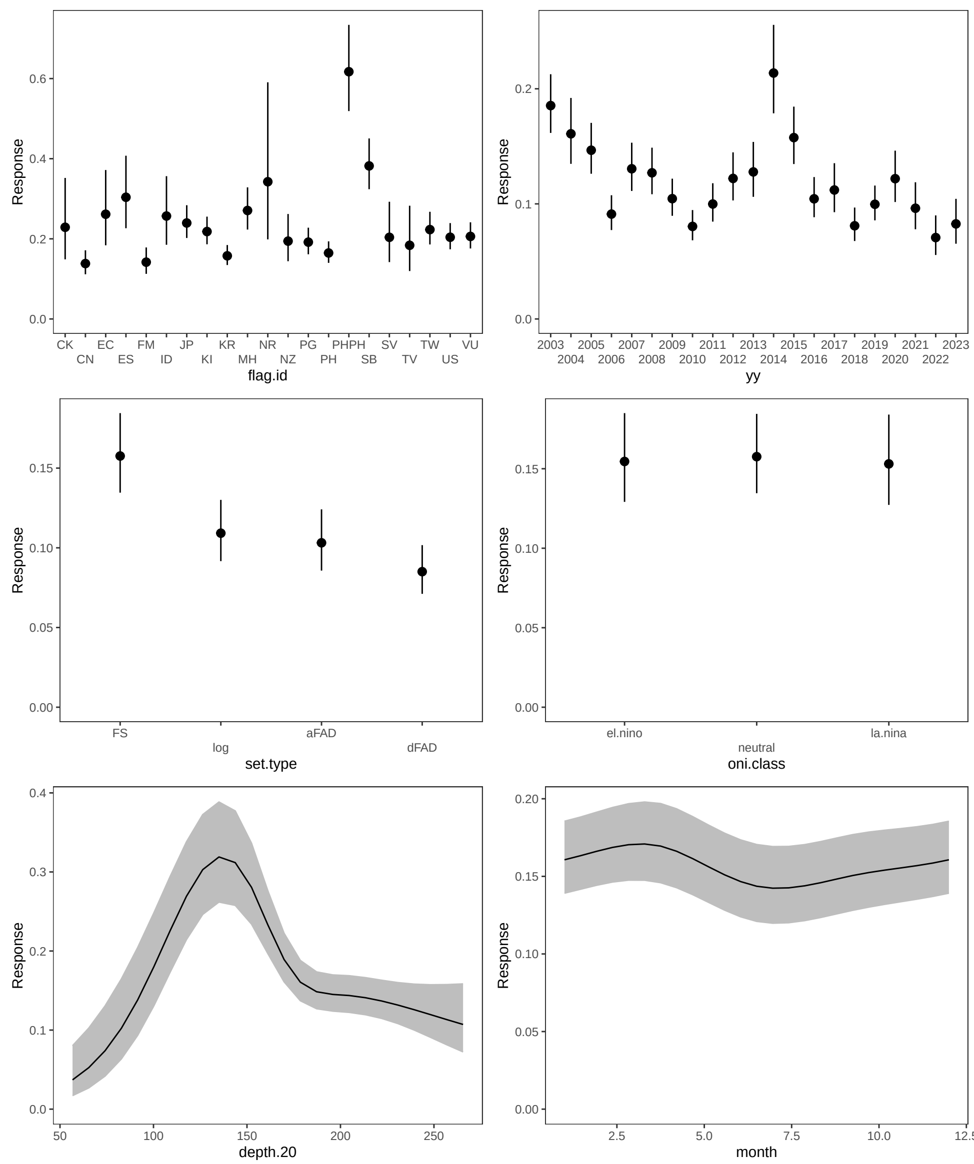


Figure B.2: Effects for the positives component of the Frigate & bullet tunas catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the remaining explanatory variables held constant at reference levels (see caption of Figure B.1). See Figure B.3 for spatial effects.

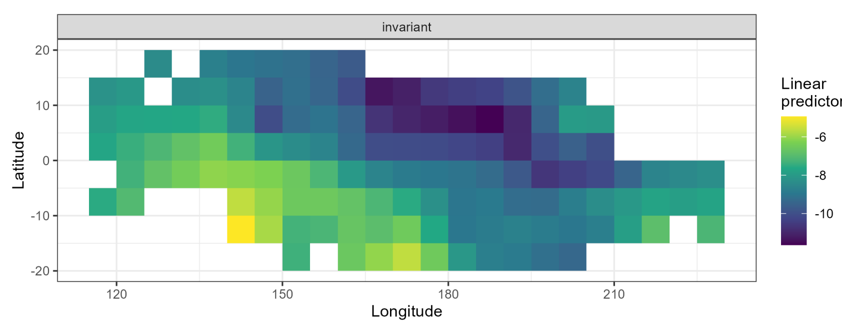


Figure B.3: Combined spatial effect for the delta and positives components of the Frigate & bullet tunas catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.1).

Wahoo (*Acanthocybium solandri*)

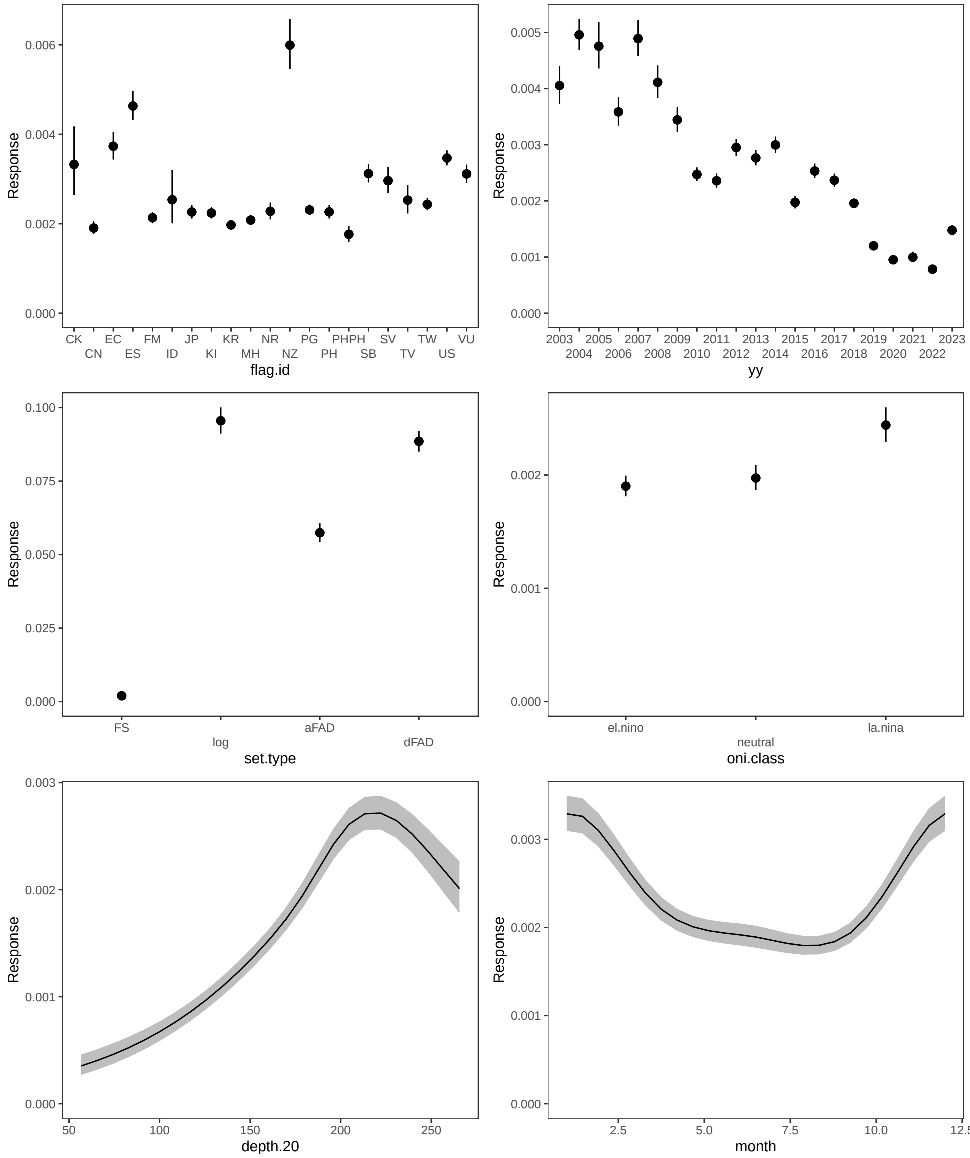


Figure B.4: Effects for the delta component of the Wahoo catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels': year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the $20°$C isotherm = 180m, latitude = $175°$E, longitude = $2.5°$S. See Figure B.6 for spatial effects.

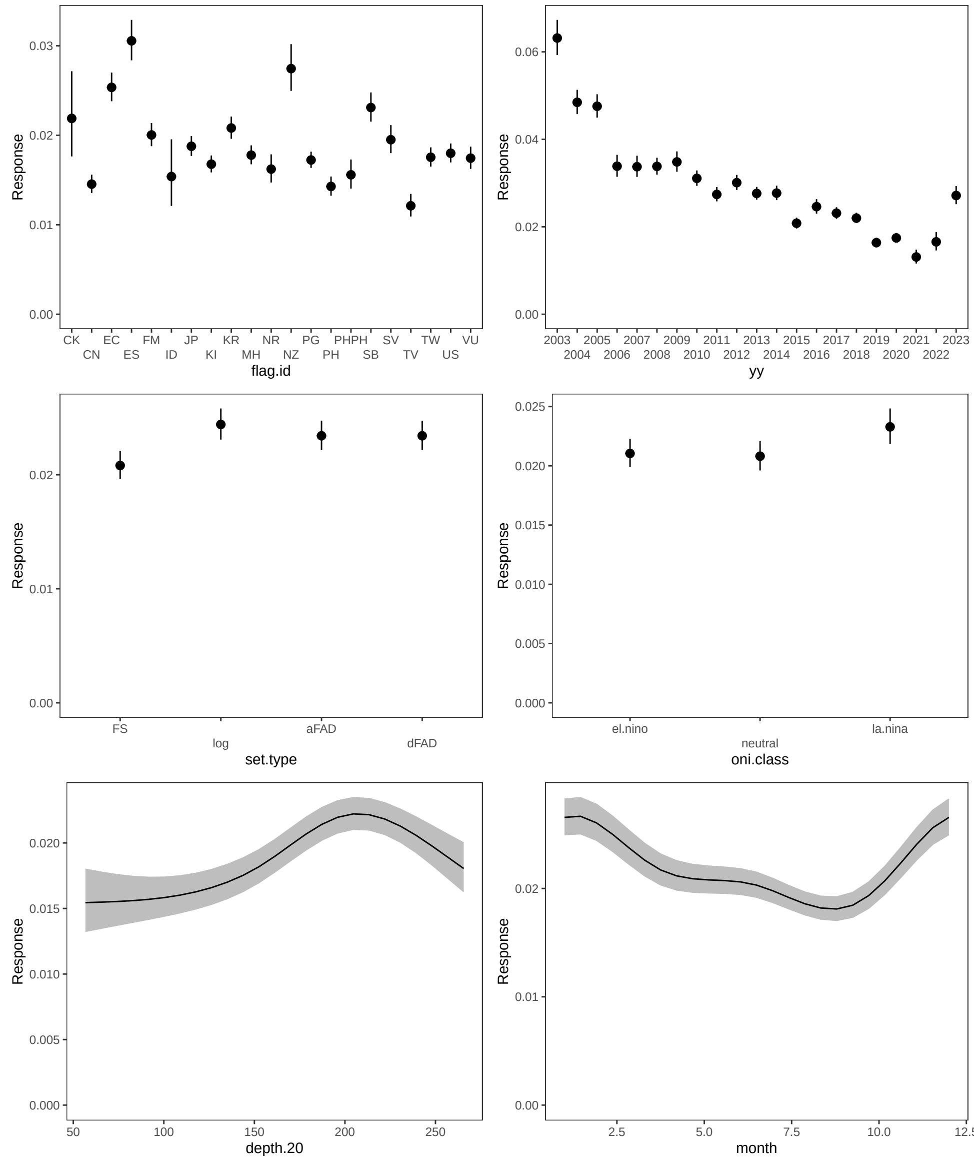


Figure B.5: Effects for the positives component of the Wahoo catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the remaining explanatory variables held constant at reference levels (see caption of Figure B.4). See Figure B.6 for spatial effects.

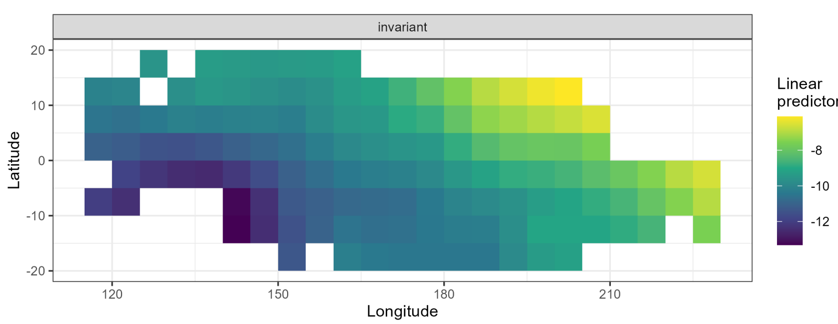


Figure B.6: Combined spatial effect for the delta and positives components of the Wahoo catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.4).

Oceanic triggerfish (*Balistidae*)

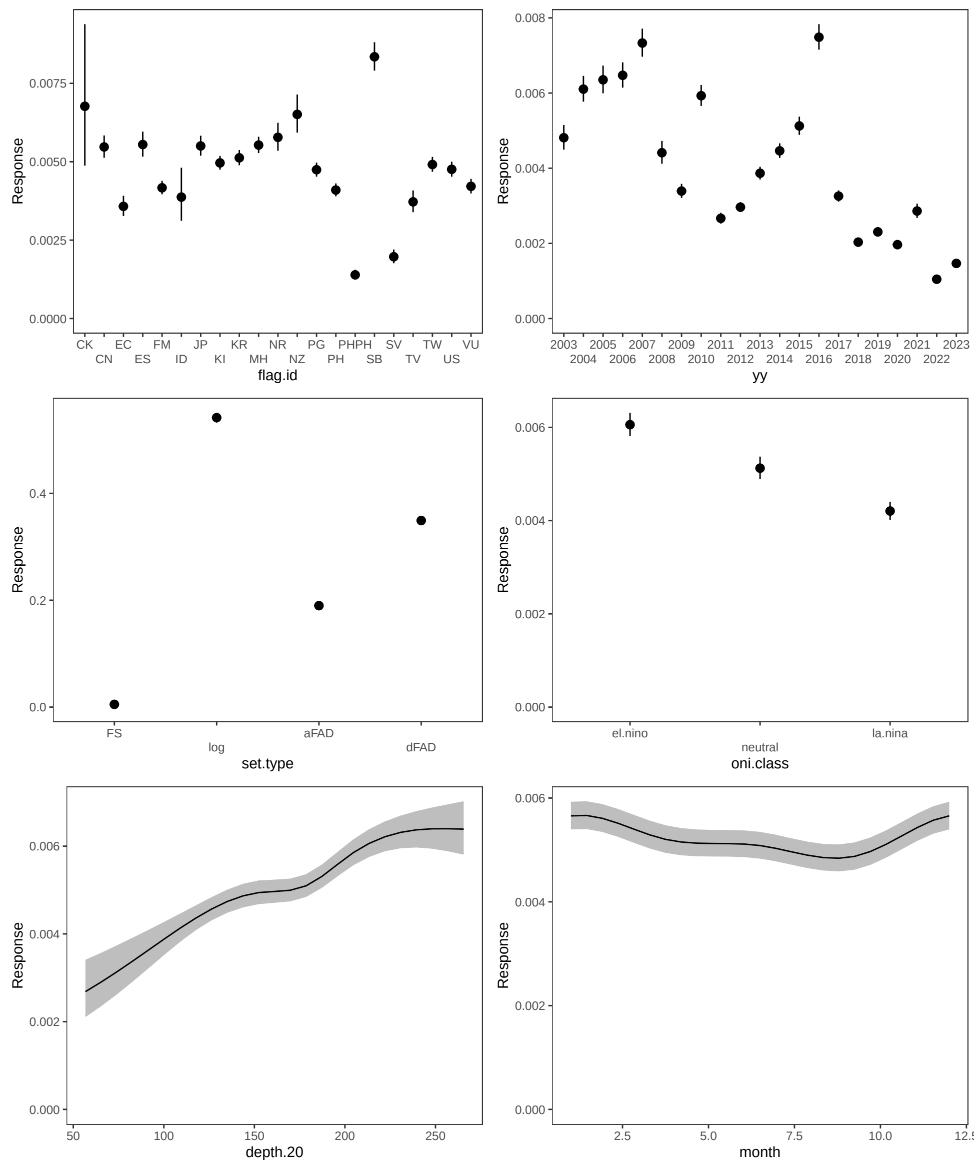


Figure B.7: Effects for the delta component of the Oceanic triggerfish catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels': year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the $20°$C isotherm = 180m, latitude = $175°$E, longitude = $2.5°$S. See Figure B.9 for spatial effects.

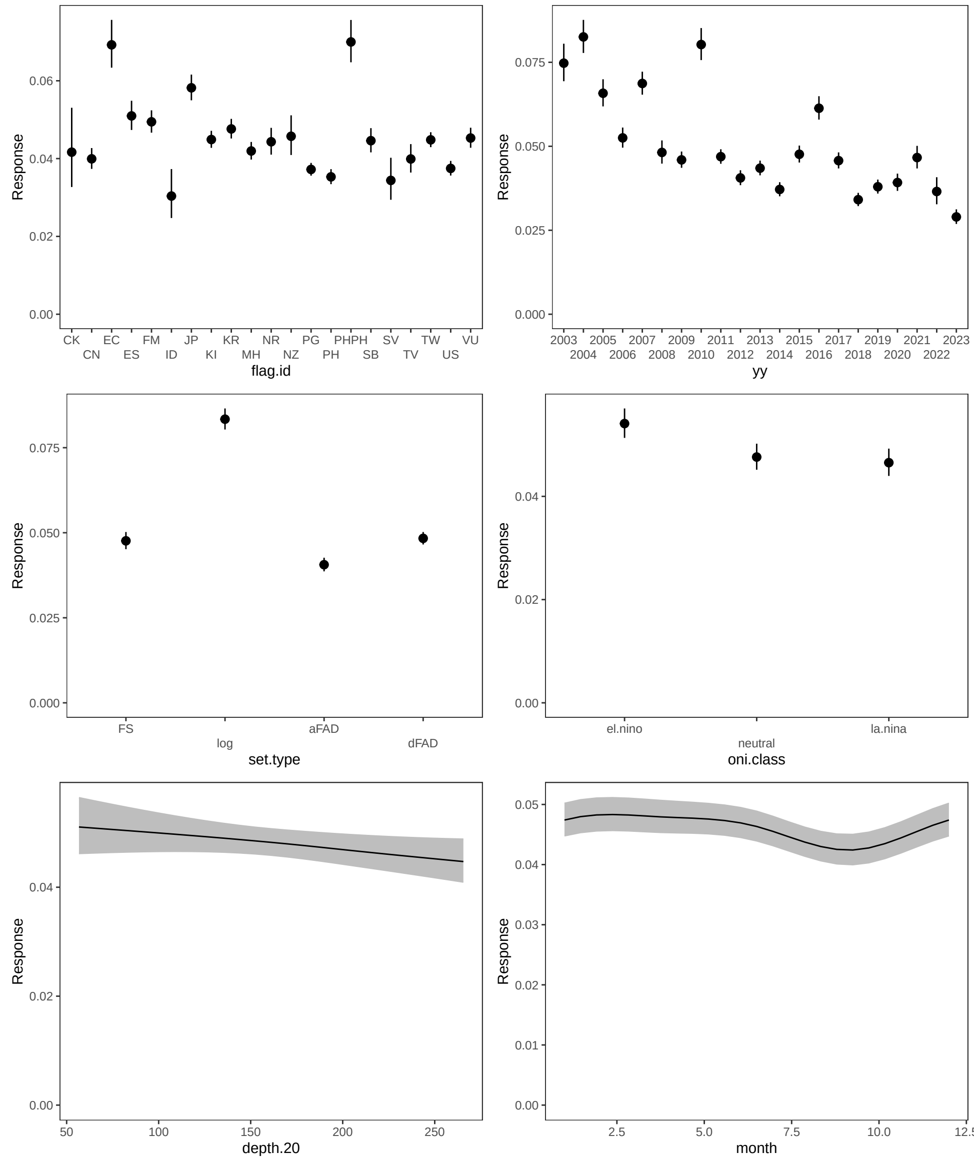


Figure B.8: Effects for the positives component of the Oceanic triggerfish catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the remaining explanatory variables held constant at reference levels (see caption of Figure B.7). See Figure B.9 for spatial effects.

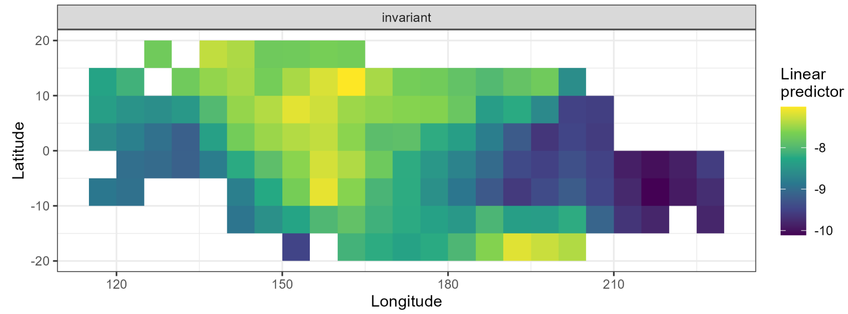


Figure B.9: Combined spatial effect for the delta and positives components of the Oceanic triggerfish catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.7).

Pomfrets (*Bramidae*)

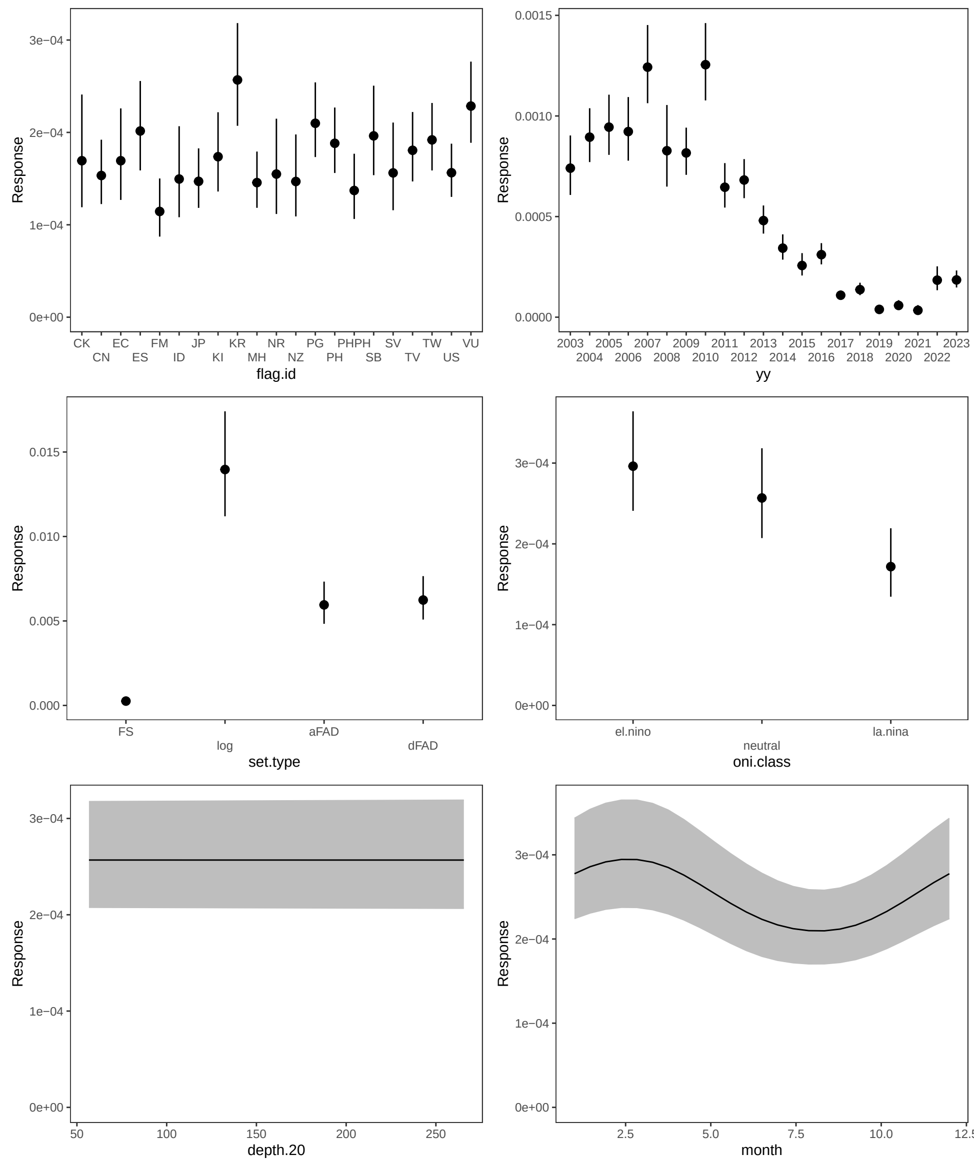


Figure B.10: Effects for the delta component of the Pomfrets catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels': year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the $20°$C isotherm = 180m, latitude = $175°$E, longitude = $2.5°$S. See Figure B.12 for spatial effects.

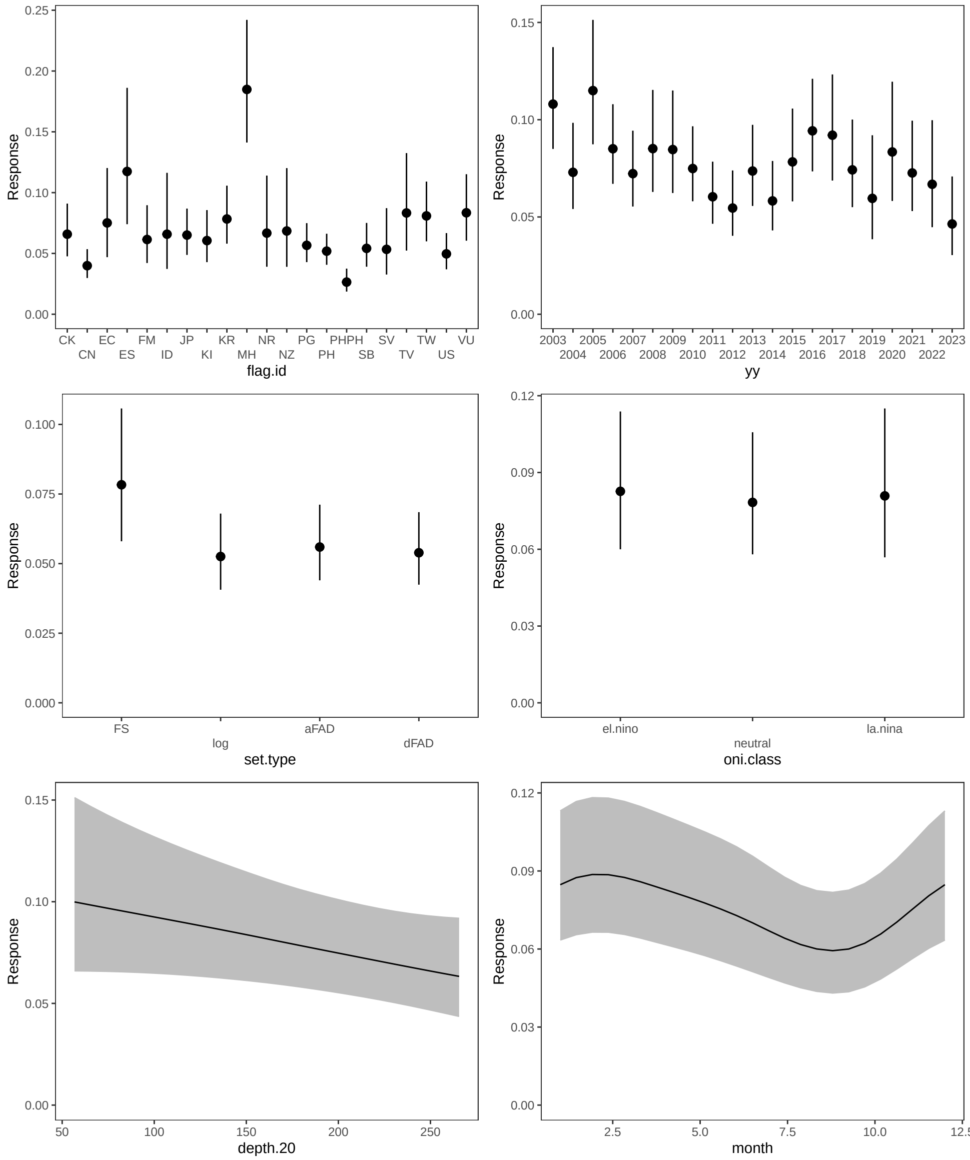


Figure B.11: Effects for the positives component of the Pomfrets catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the remaining explanatory variables held constant at reference levels (see caption of Figure B.10). See Figure B.12 for spatial effects.

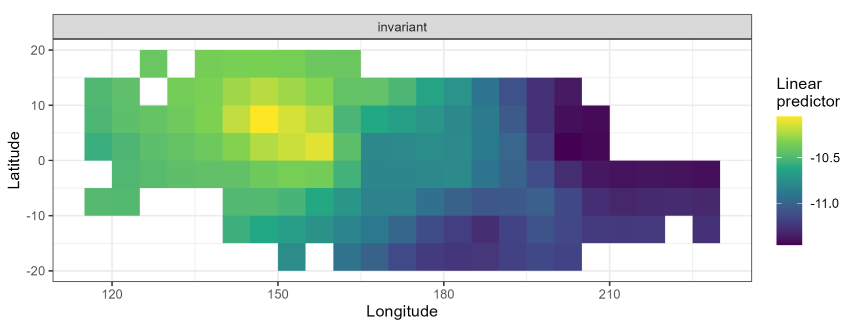


Figure B.12: Combined spatial effect for the delta and positives components of the Pomfrets catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.10).

Carangids (*Carangidae*)

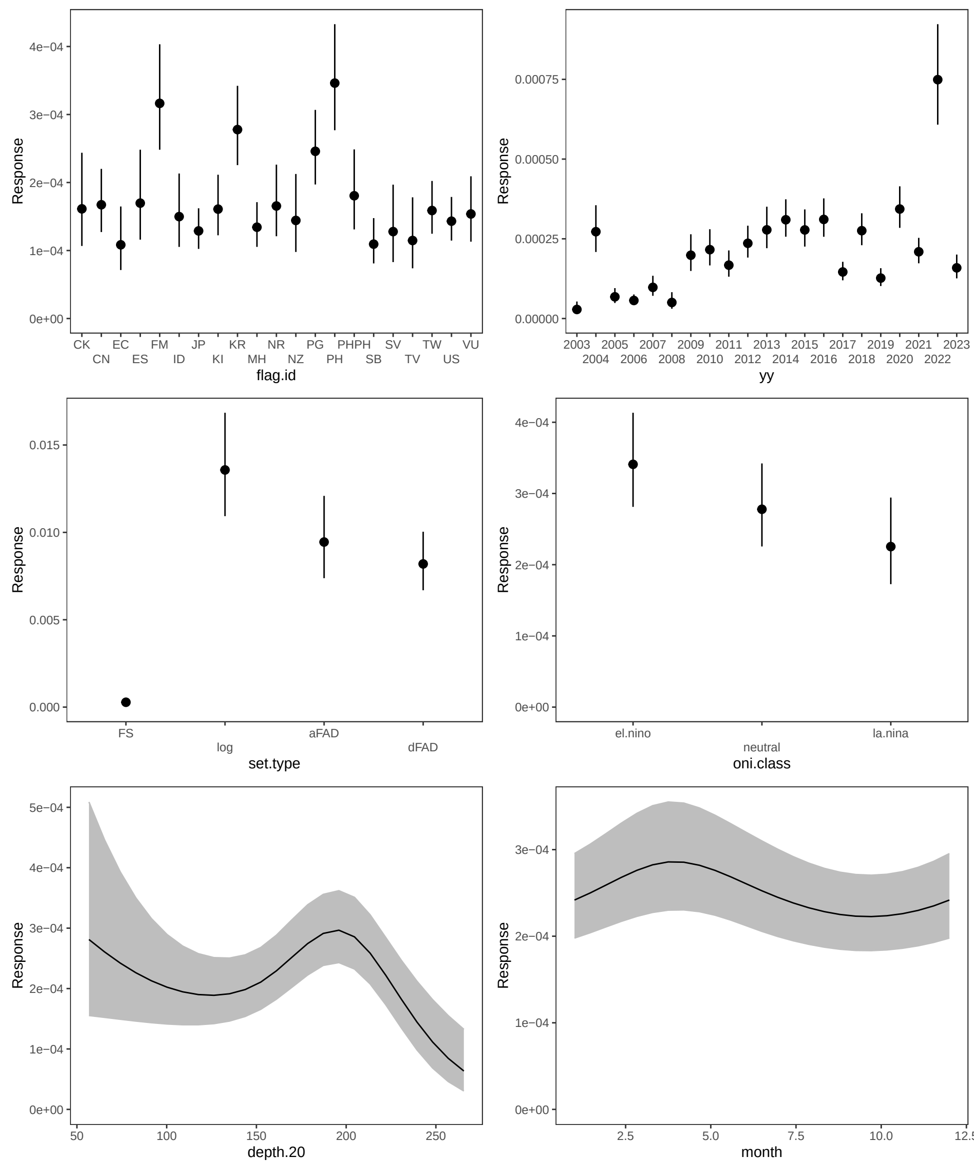


Figure B.13: Effects for the delta component of the Carangids catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels': year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the $20°$C isotherm = 180m, latitude = $175°$E, longitude = $2.5°$S. See Figure B.15 for spatial effects.

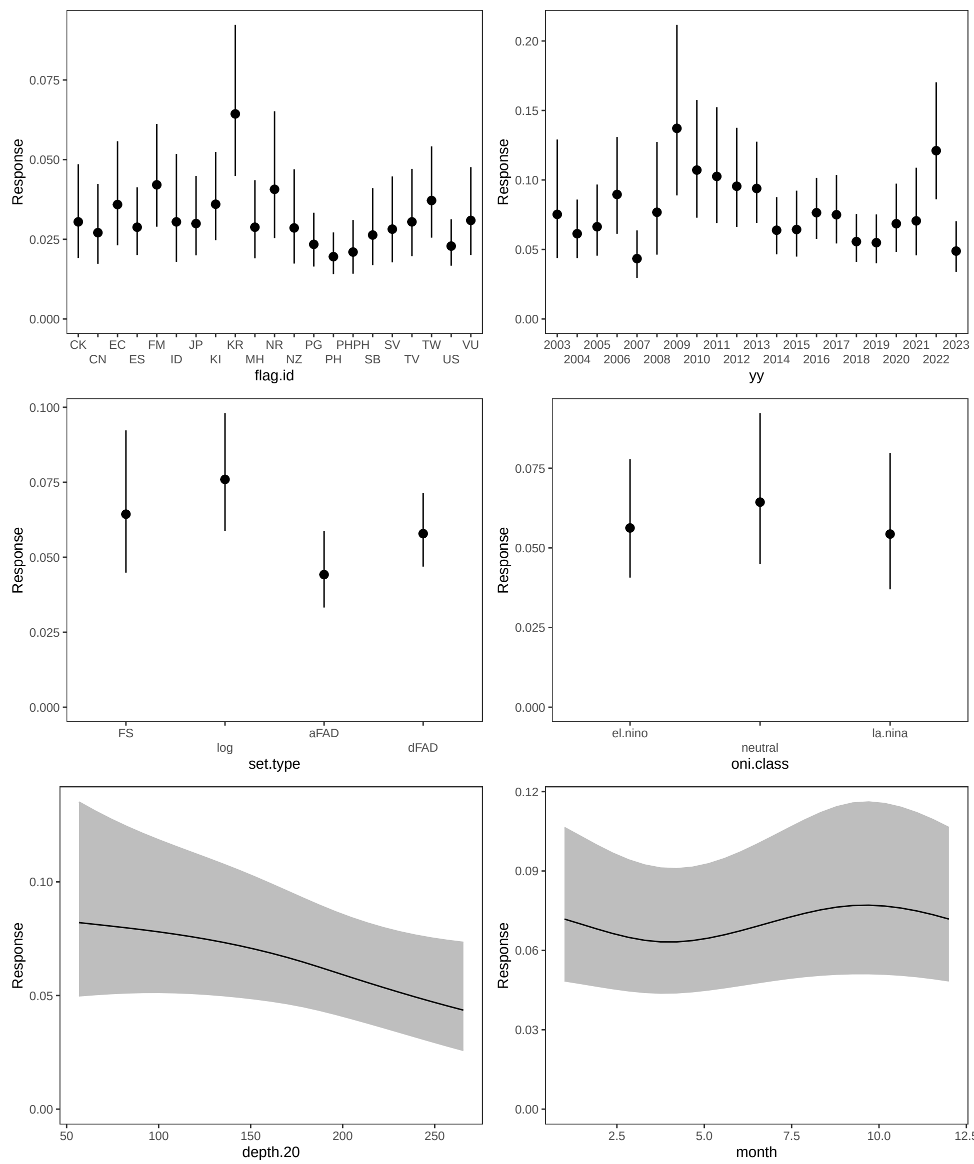


Figure B.14: **Effects for the positives component of the Carangids catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the remaining explanatory variables held constant at reference levels (see caption of Figure B.13). See Figure B.15 for spatial effects.**

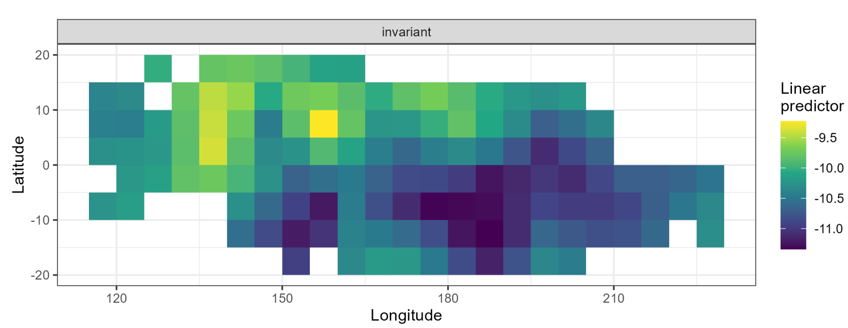


Figure B.15: Combined spatial effect for the delta and positives components of the Carangids catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.13).

Trevallies (*Caranx* spp)

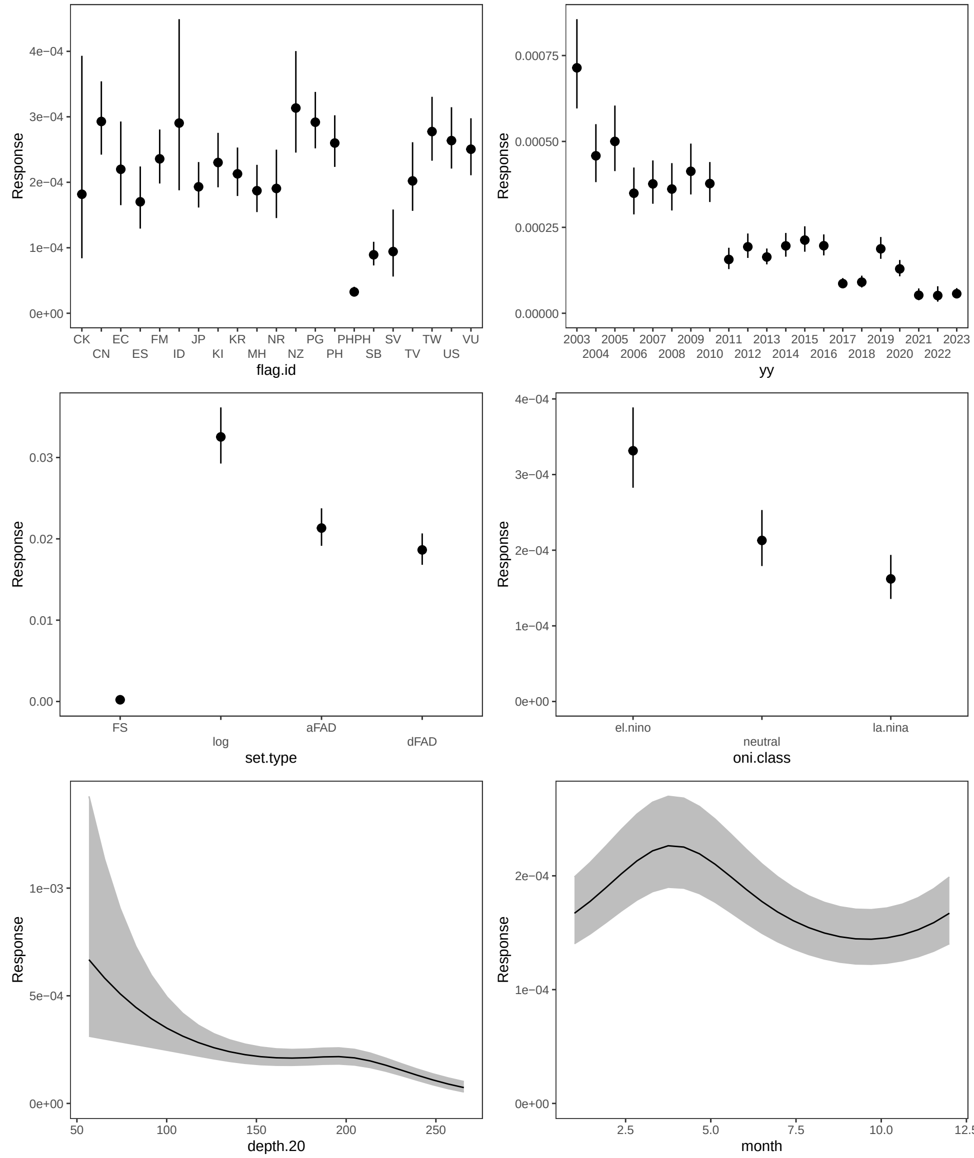


Figure B.16: Effects for the delta component of the Trevallies catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels': year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the 20°C isotherm = 180m, latitude = 175°E, longitude = 2.5°S. See Figure B.18 for spatial effects.

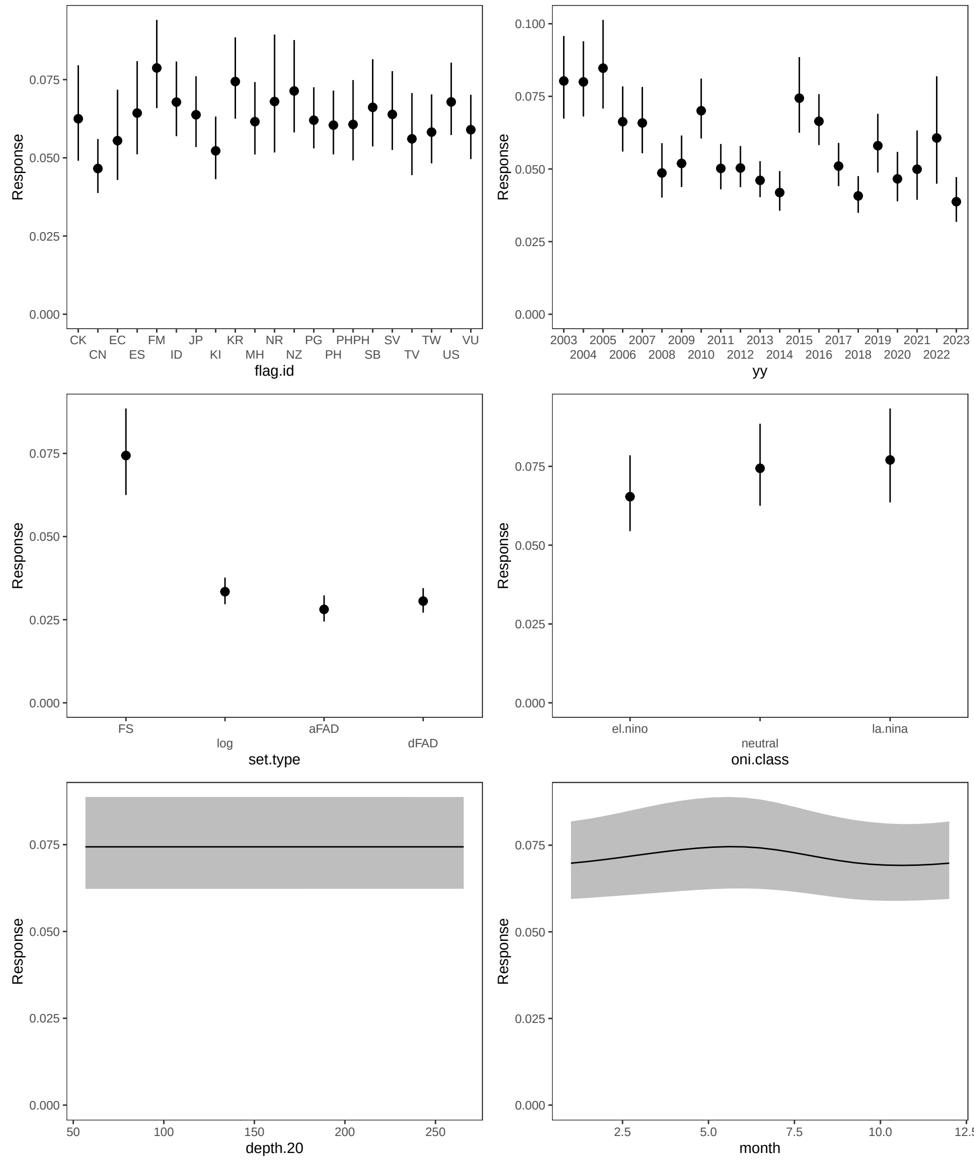


Figure B.17: Effects for the positives component of the Trevallies catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the remaining explanatory variables held constant at reference levels (see caption of Figure B.16). See Figure B.18 for spatial effects.

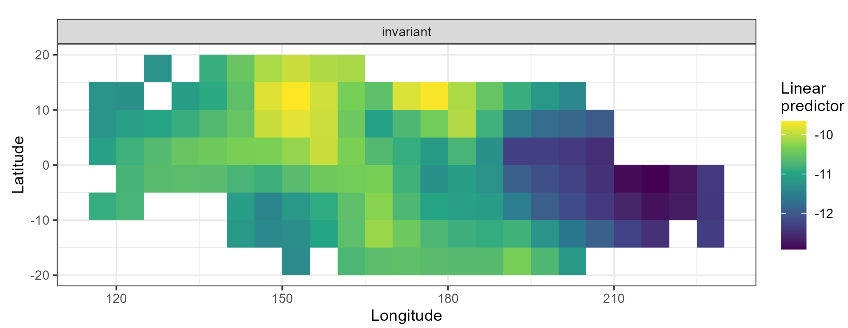


Figure B.18: Combined spatial effect for the delta and positives components of the Trevallies catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.16).

Mahi mahi (*Coryphaena hippurus*)

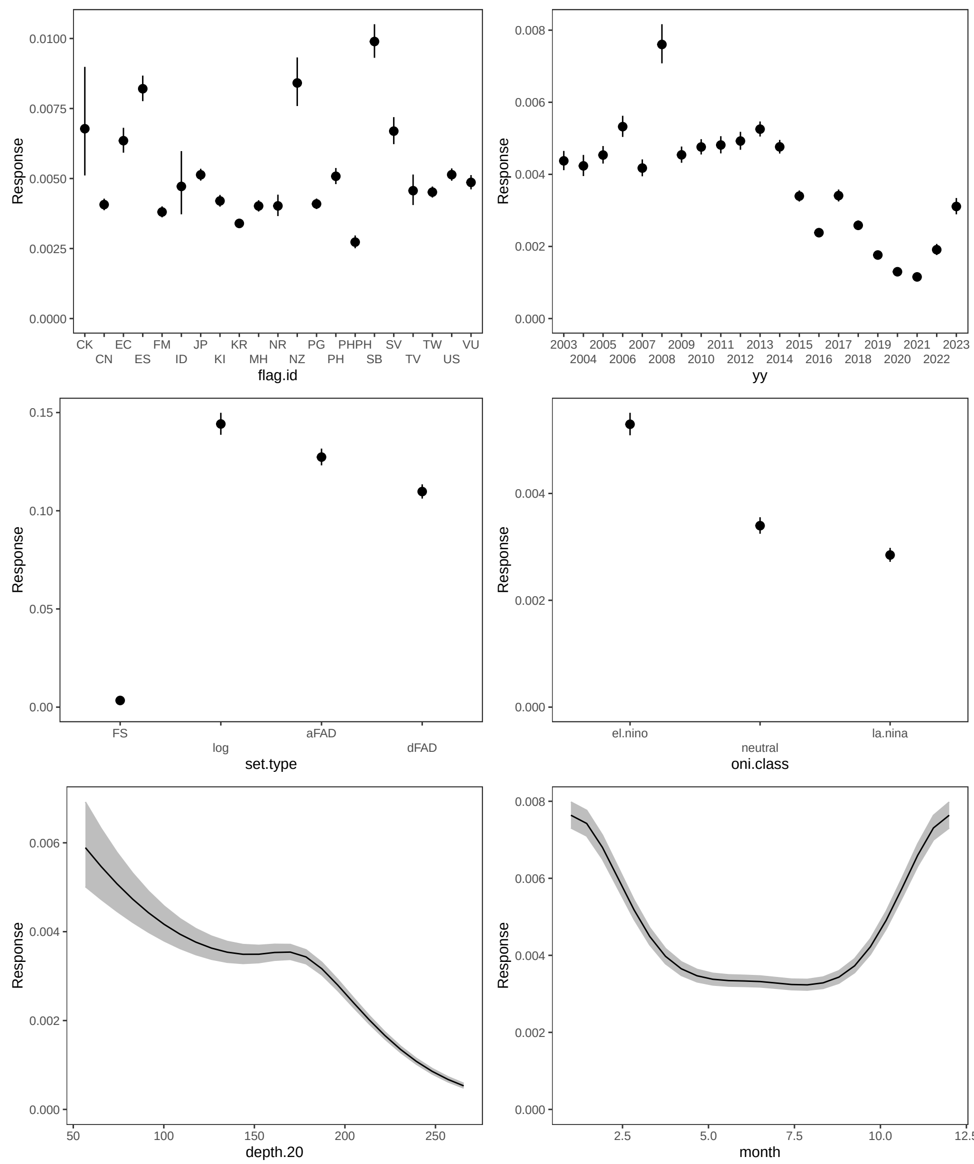


Figure B.19: Effects for the delta component of the Mahi mahi catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels': year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the $20°$C isotherm = 180m, latitude = $175°$E, longitude = $2.5°$S. See Figure B.21 for spatial effects.

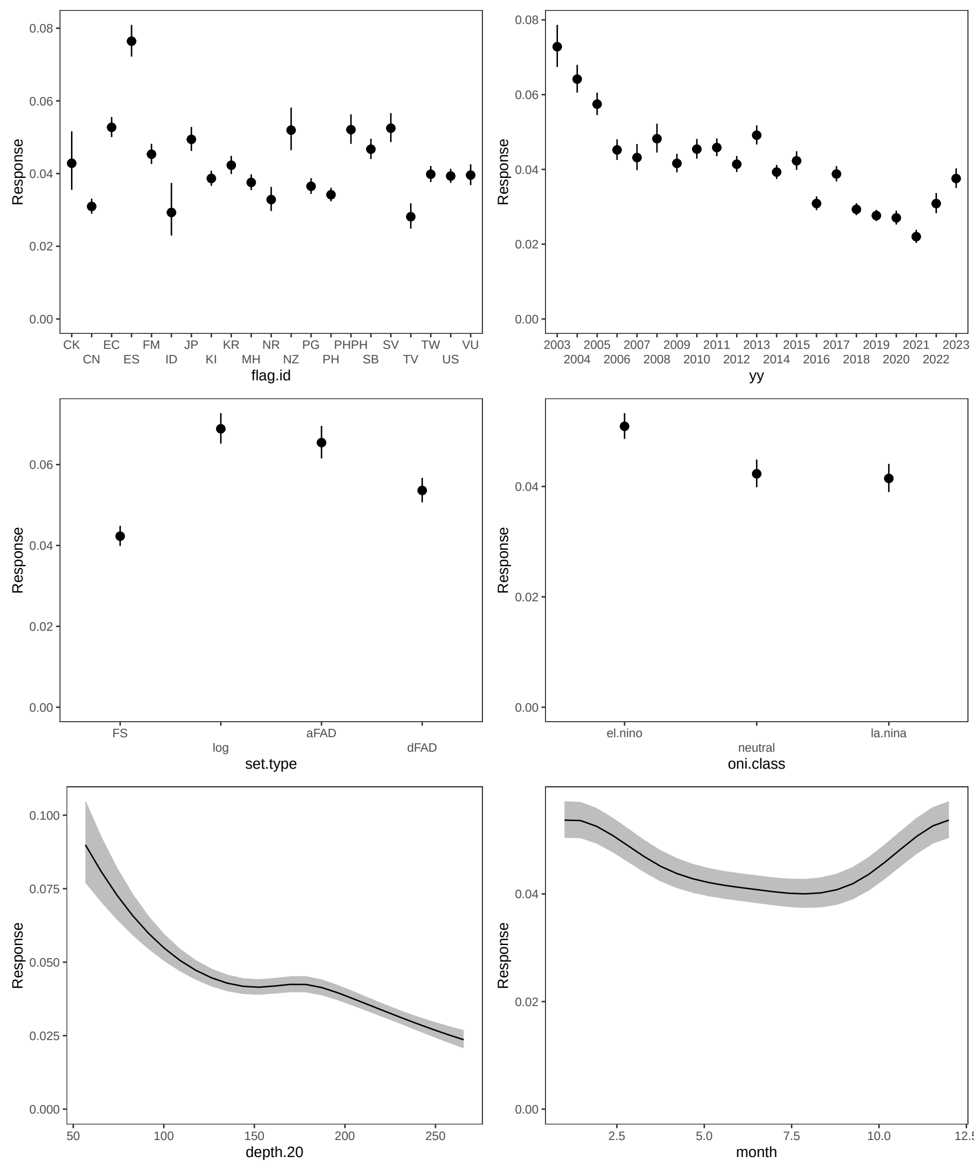


Figure B.20: Effects for the positives component of the Mahi mahi catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the remaining explanatory variables held constant at reference levels (see caption of Figure B.19). See Figure B.21 for spatial effects.

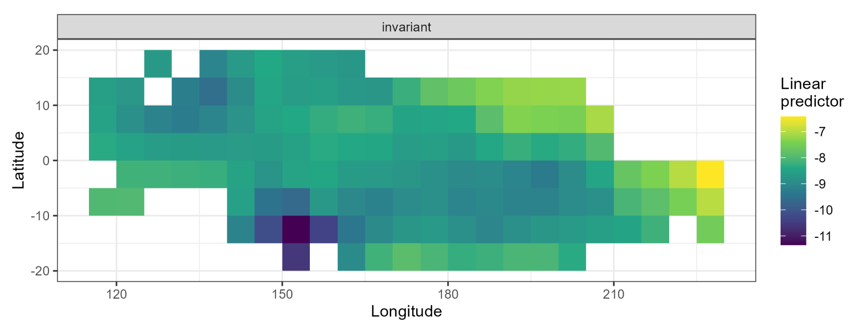


Figure B.21: Combined spatial effect for the delta and positives components of the Mahi mahi catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.19).

Mackerel scad (*Decapturus macarellus*)

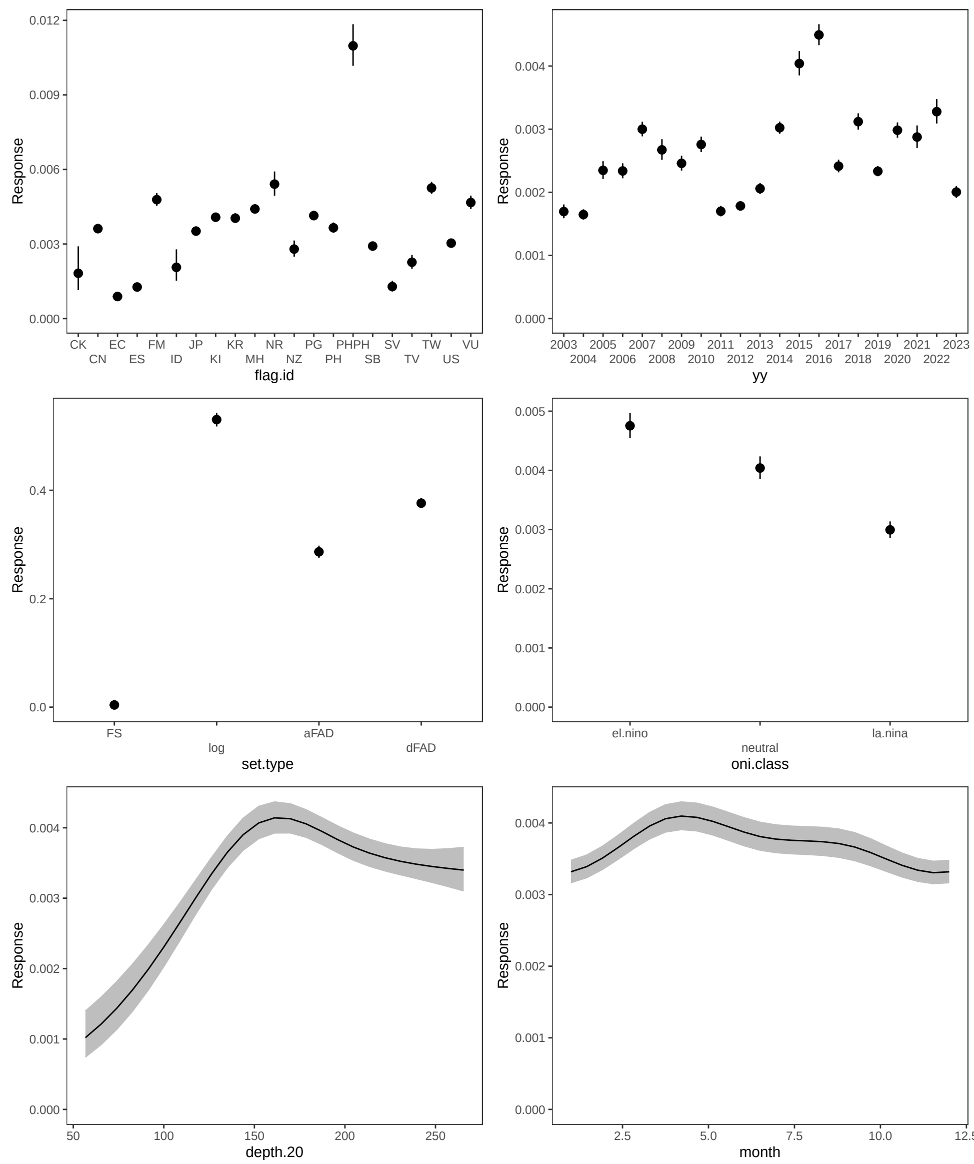


Figure B.22: Effects for the delta component of the Mackerel scad catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels': year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the $20°$C isotherm = 180m, latitude = $175°$E, longitude = $2.5°$S. See Figure B.24 for spatial effects.

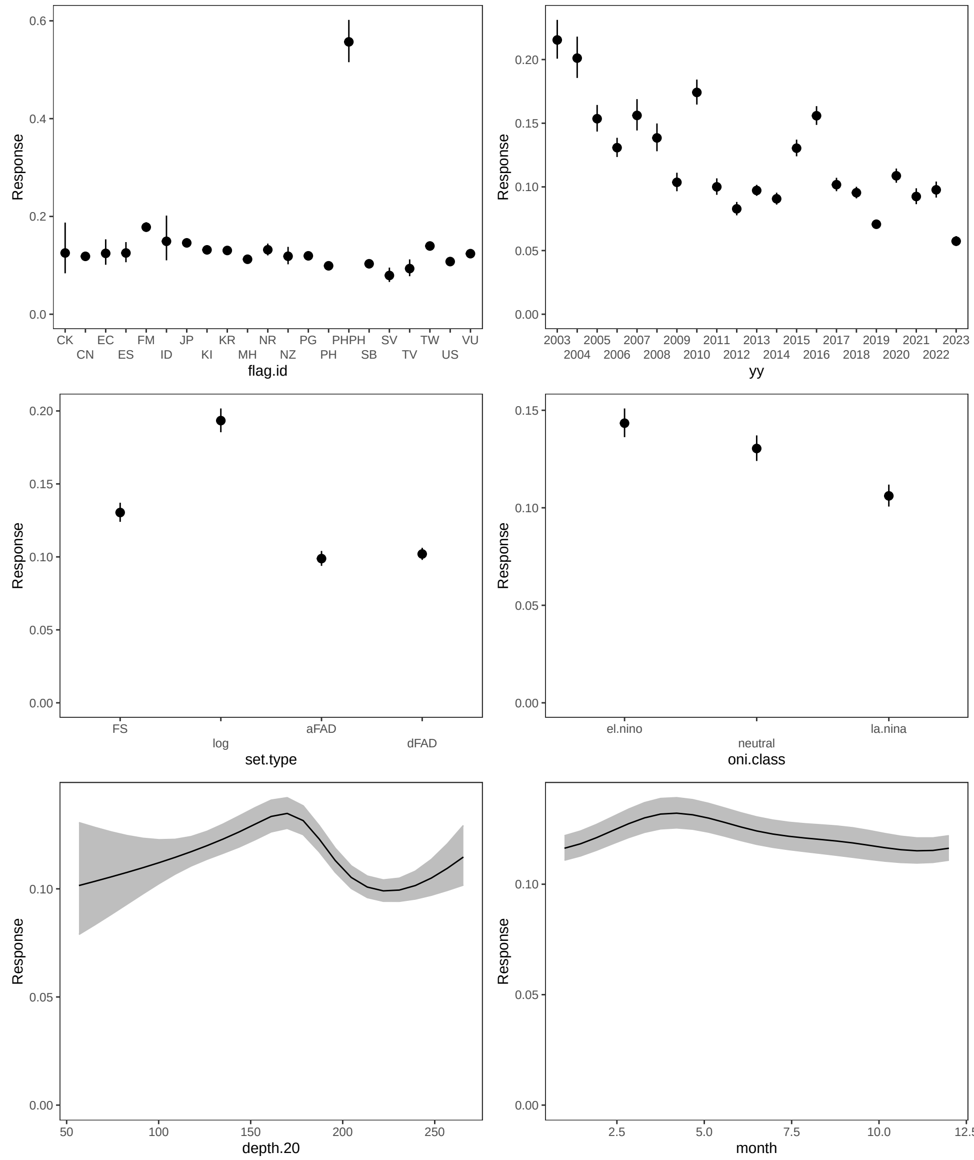


Figure B.23: Effects for the positives component of the Mackerel scad catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the remaining explanatory variables held constant at reference levels (see caption of Figure B.22). See Figure B.24 for spatial effects.

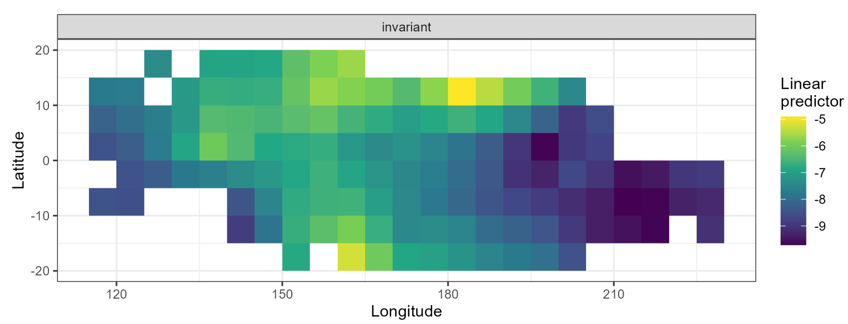


Figure B.24: Combined spatial effect for the delta and positives components of the Mackerel scad catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.22).

Rainbow runner (*Elagatis bipinnulata*)

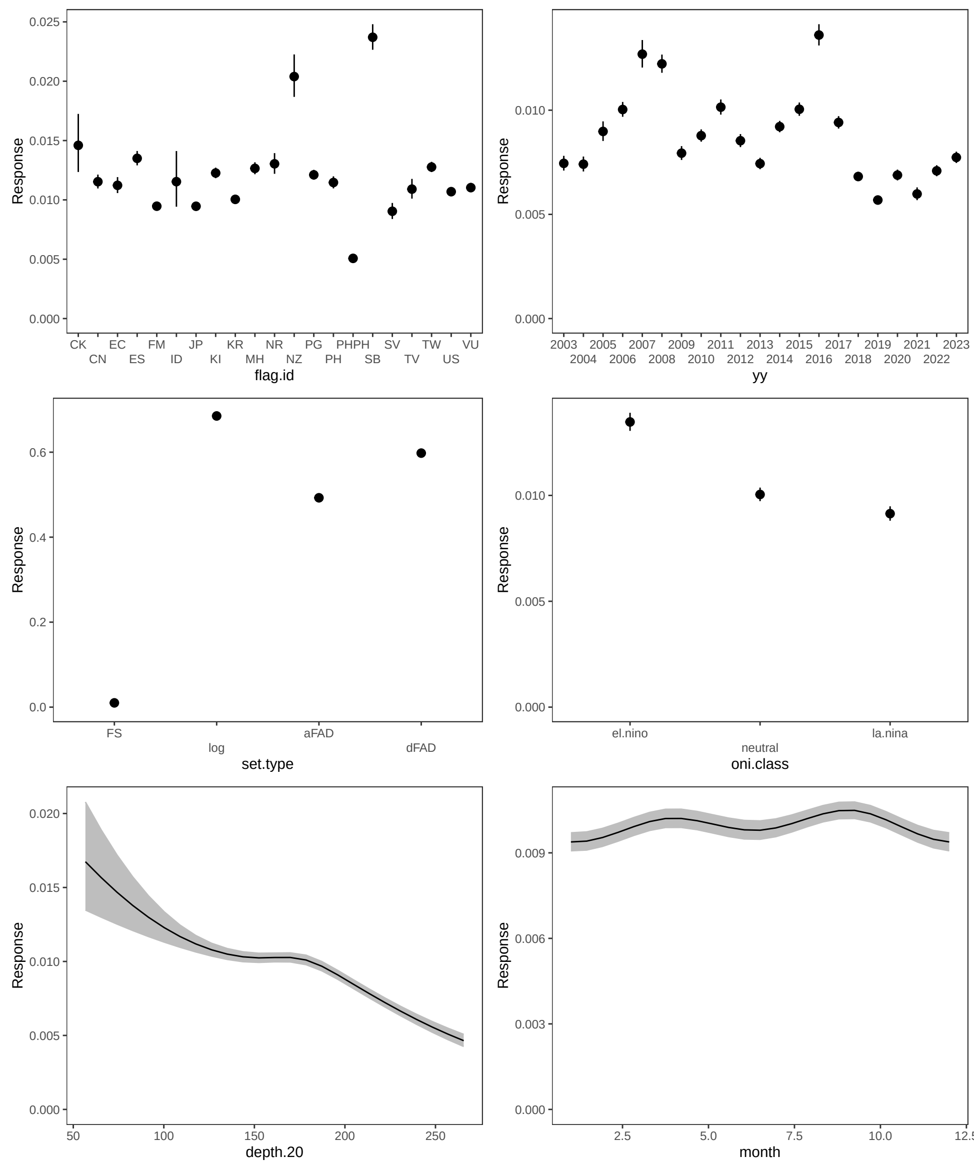


Figure B.25: Effects for the delta component of the Rainbow runner catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels': year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the $20°$C isotherm = 180m, latitude = $175°$E, longitude = $2.5°$S. See Figure B.27 for spatial effects.

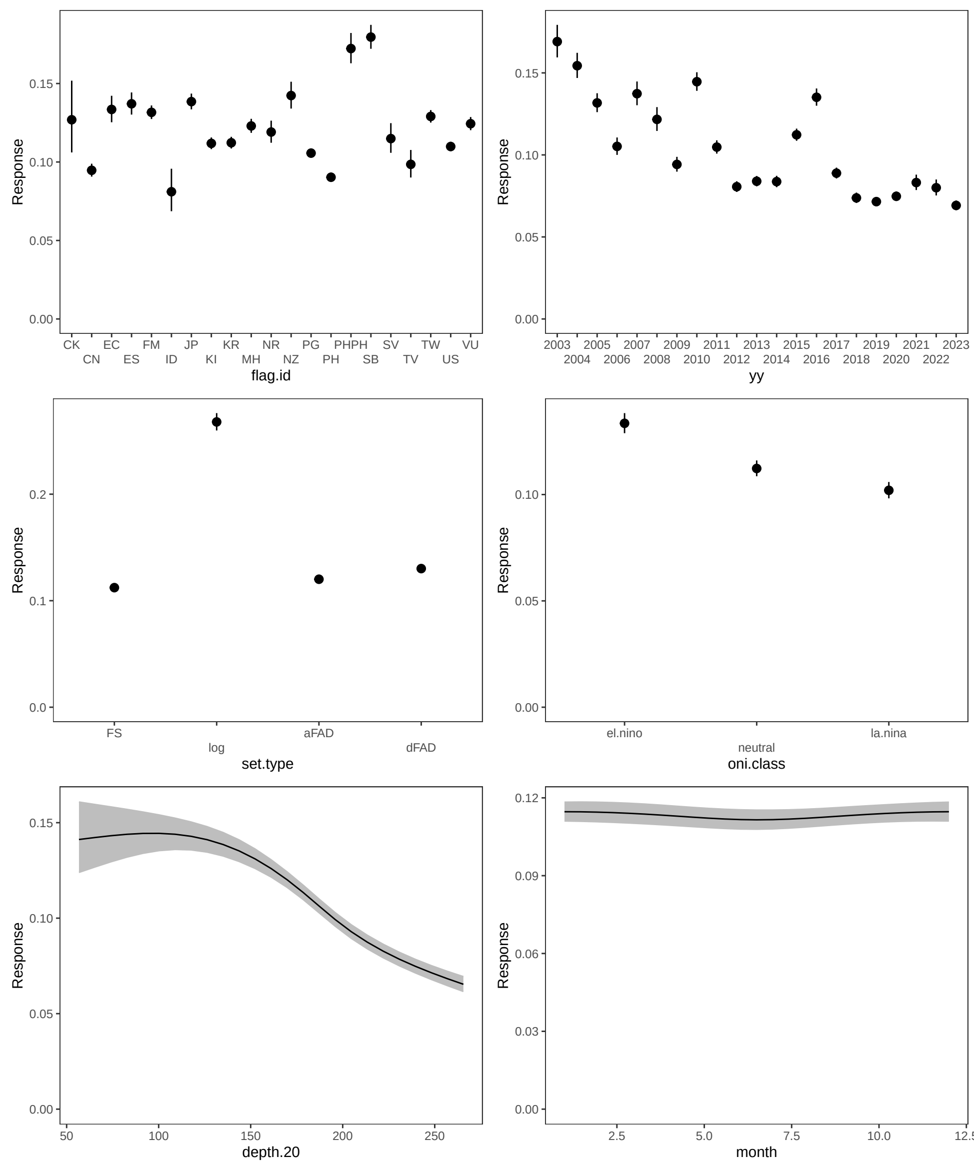


Figure B.26: Effects for the positives component of the Rainbow runner catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the remaining explanatory variables held constant at reference levels (see caption of Figure B.25). See Figure B.27 for spatial effects.

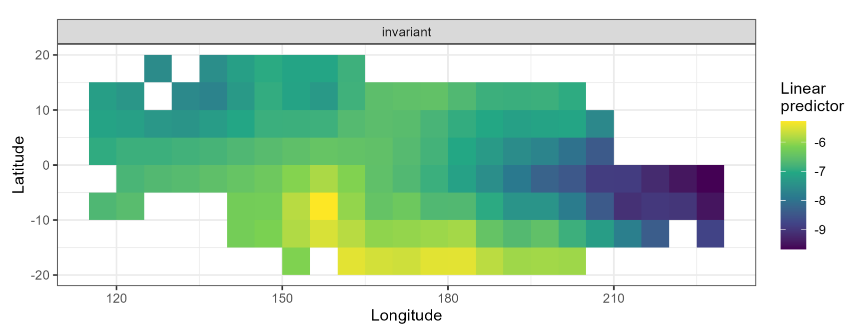


Figure B.27: Combined spatial effect for the delta and positives components of the Rainbow runner catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.25).

Kawakawa (*Euthynnus affinis*)

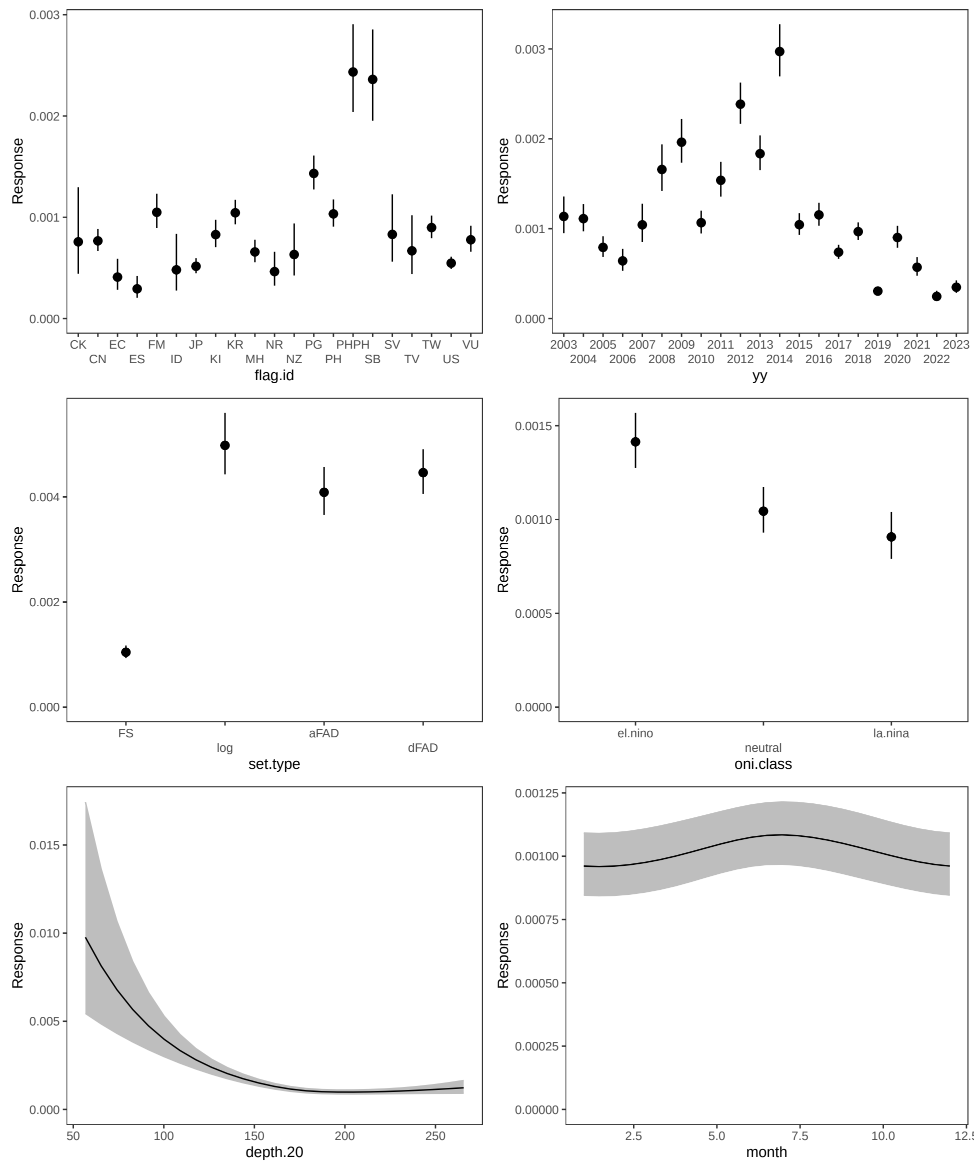


Figure B.28: Effects for the delta component of the Kawakawa catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels': year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the $20°$C isotherm = 180m, latitude = $175°$E, longitude = $2.5°$S. See Figure B.30 for spatial effects.

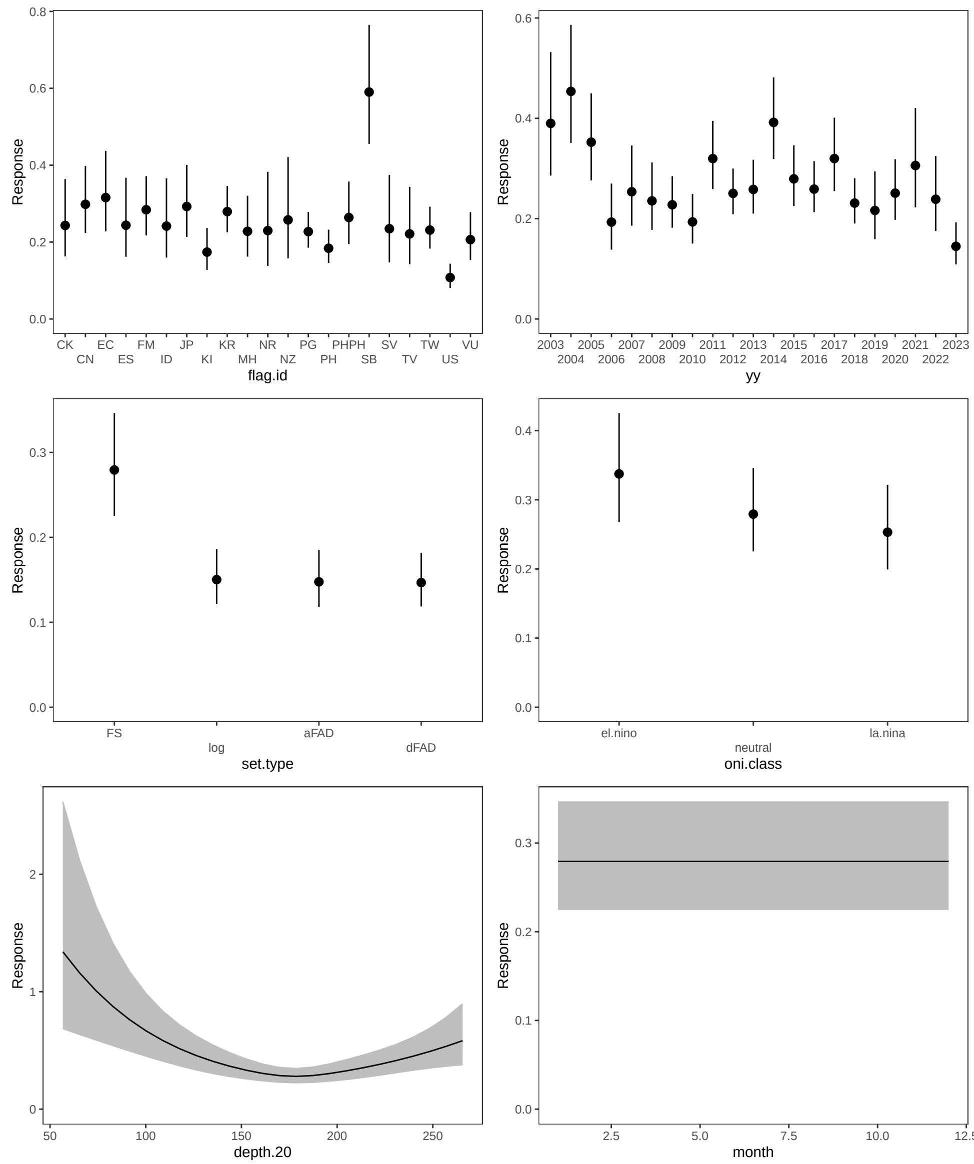


Figure B.29: Effects for the positives component of the Kawakawa catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the remaining explanatory variables held constant at reference levels (see caption of Figure B.28). See Figure B.30 for spatial effects.

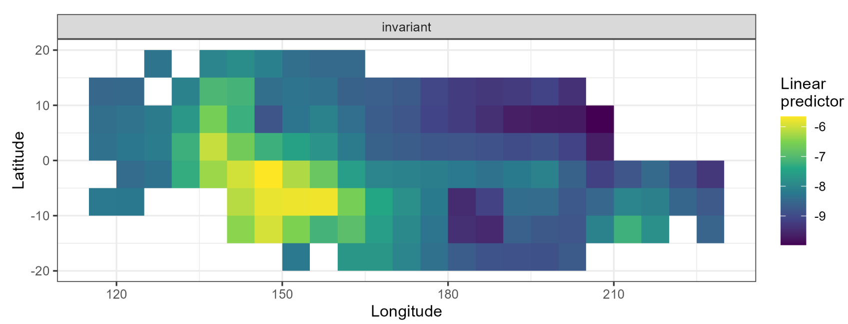


Figure B.30: Combined spatial effect for the delta and positives components of the Kawakawa catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.28).

Golden trevally (*Gnathanodon speciosus*)

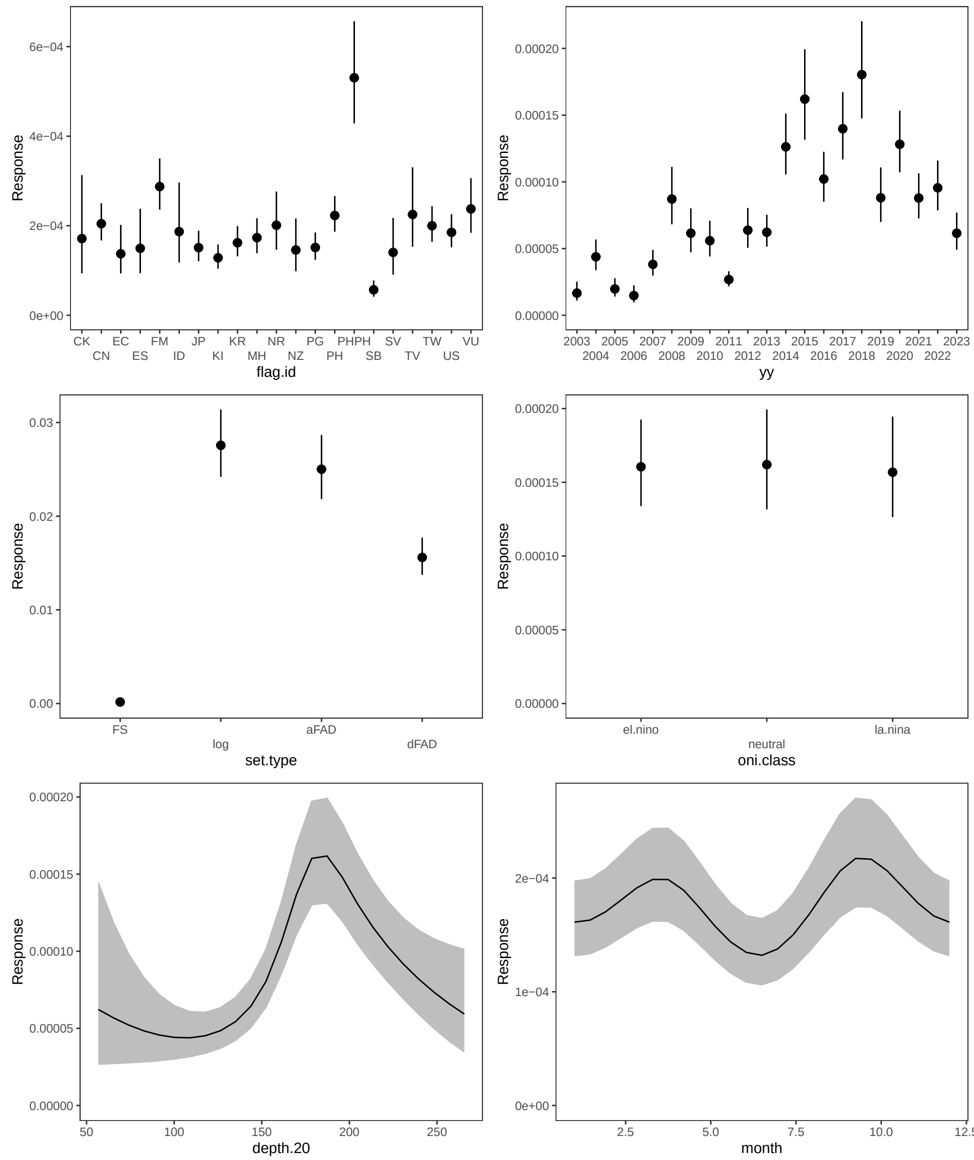


Figure B.31: Effects for the delta component of the Golden trevally catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels': year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the $20°$C isotherm = 180m, latitude = $175°$E, longitude = $2.5°$S. See Figure B.33 for spatial effects.

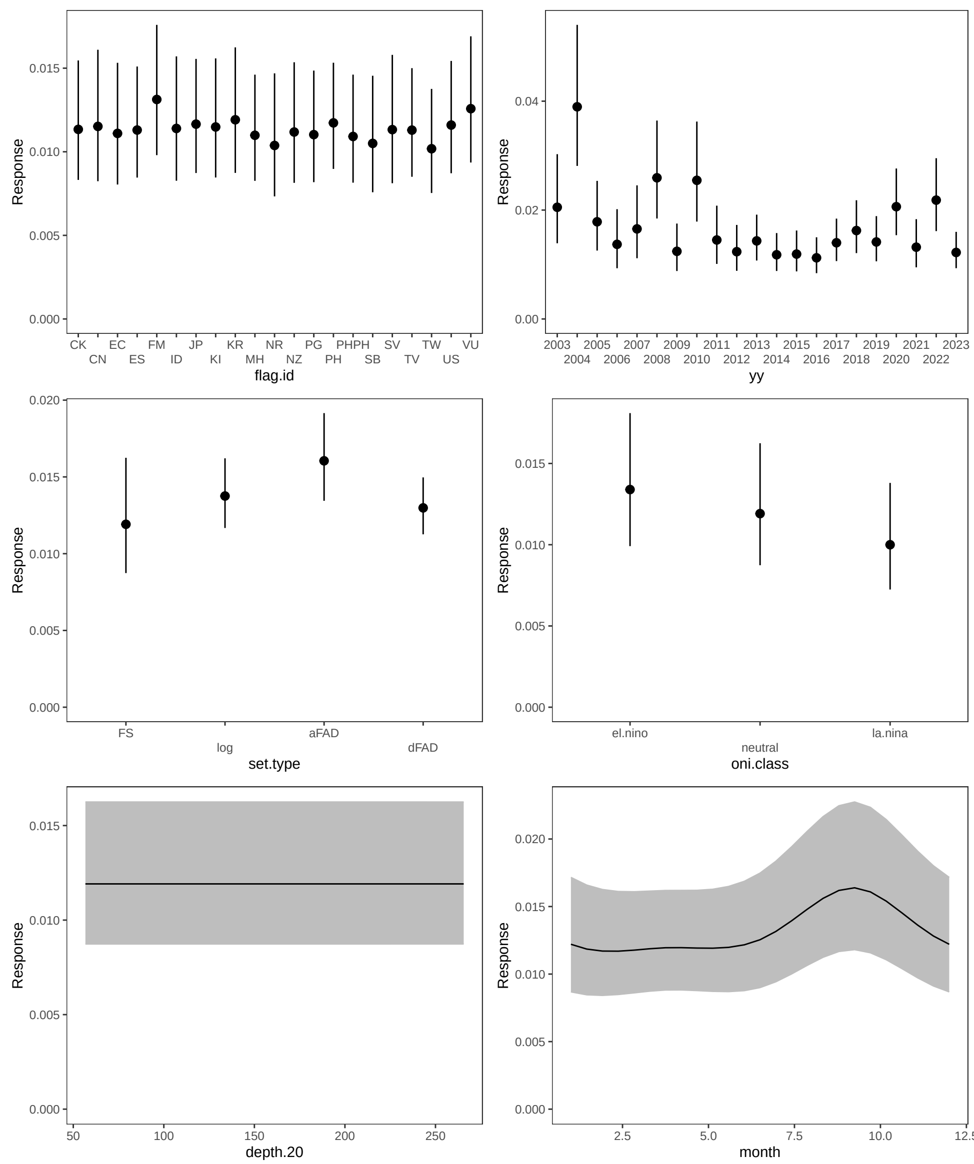


Figure B.32: Effects for the positives component of the Golden trevally catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the remaining explanatory variables held constant at reference levels (see caption of Figure B.31). See Figure B.33 for spatial effects.

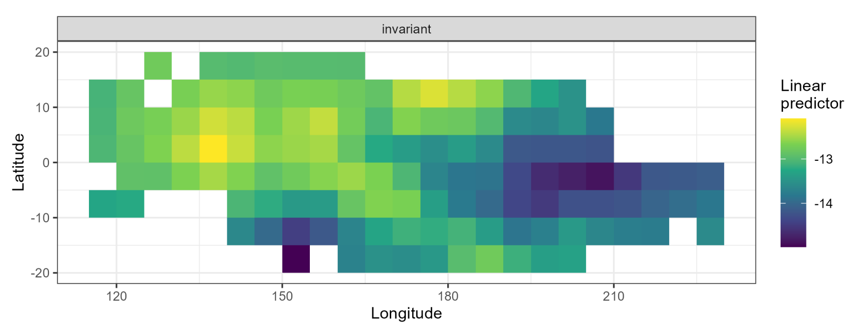


Figure B.33: Combined spatial effect for the delta and positives components of the Golden trevally catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.31).

Sea chubs (*Kyphosidae*)

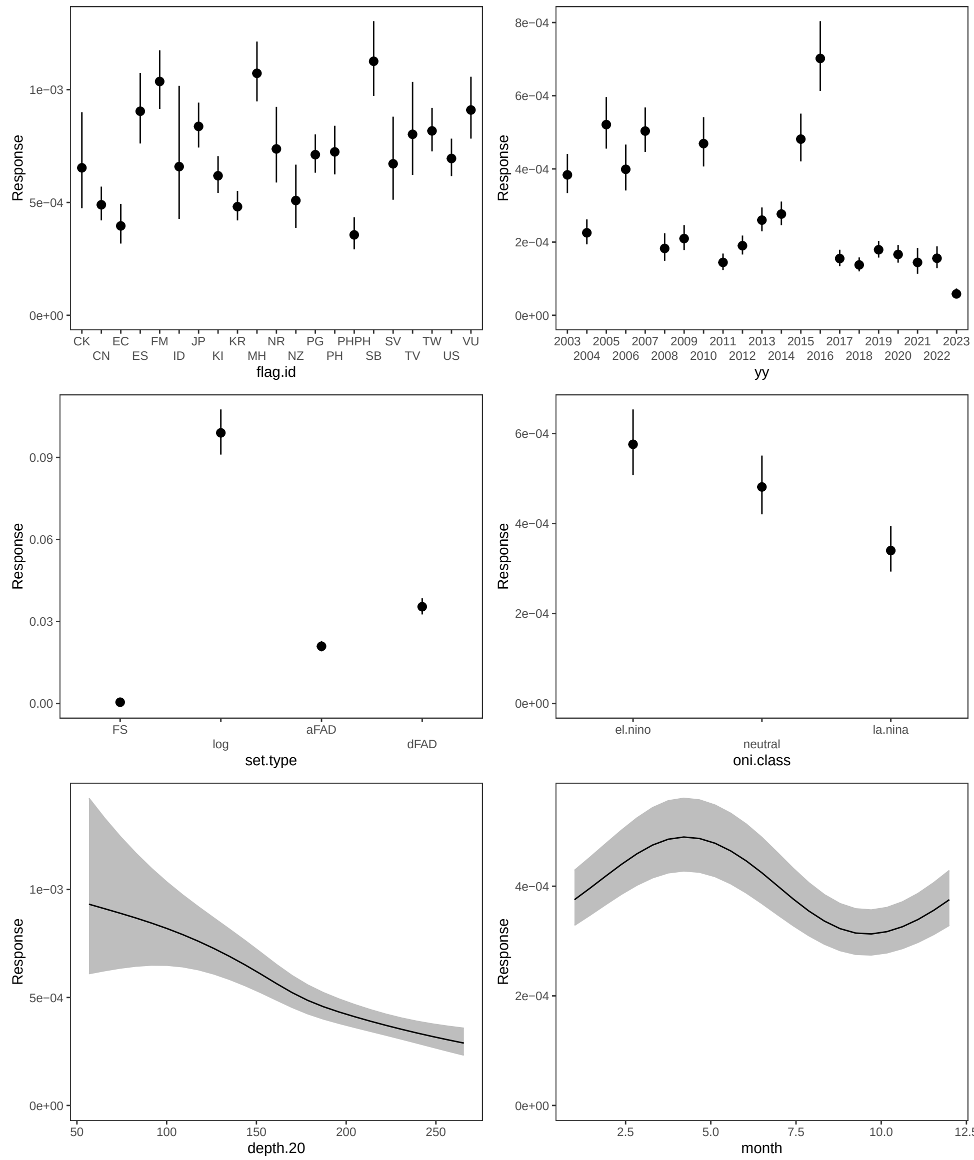


Figure B.34: Effects for the delta component of the Sea chubs catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels': year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the $20°$C isotherm = 180m, latitude = $175°$E, longitude = $2.5°$S. See Figure B.36 for spatial effects.

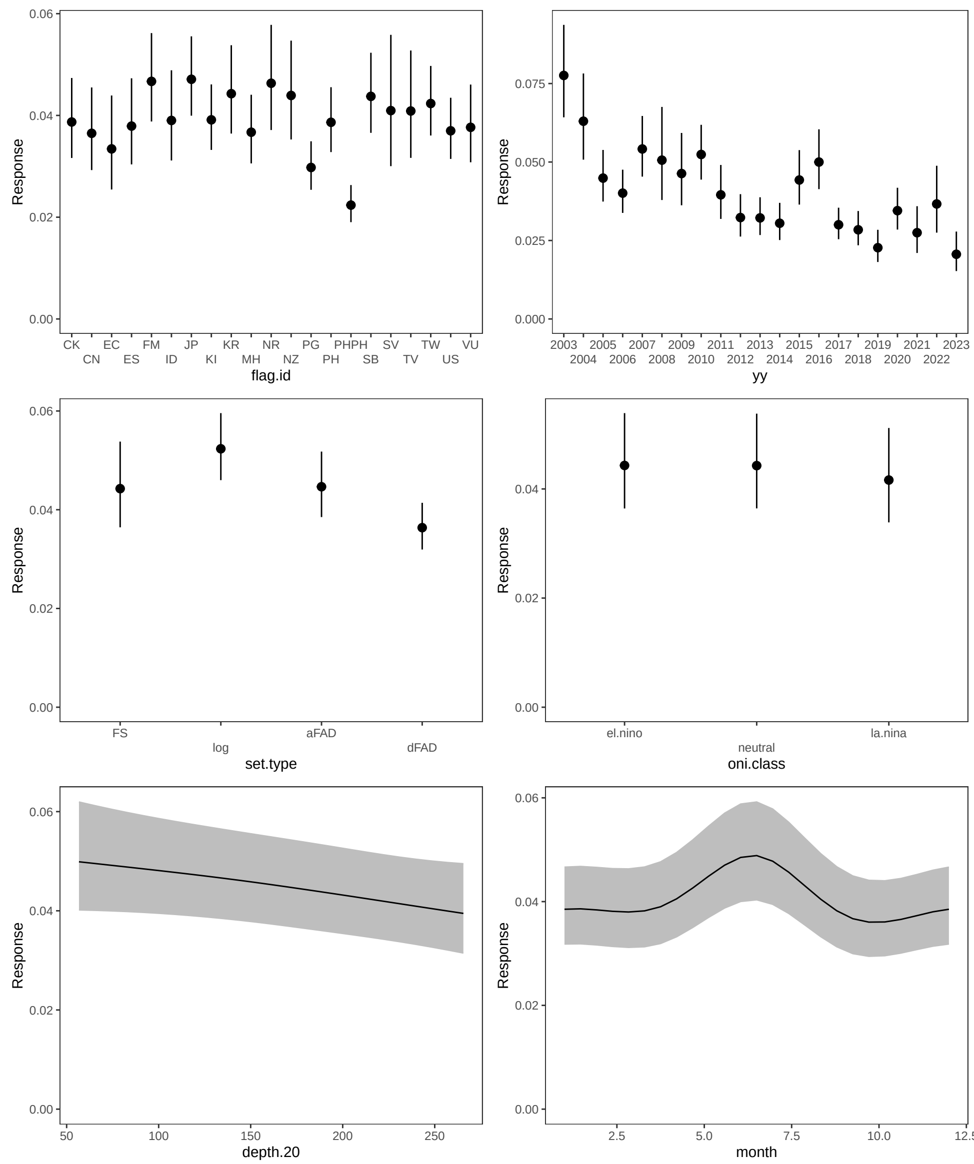


Figure B.35: Effects for the positives component of the Sea chubs catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the remaining explanatory variables held constant at reference levels (see caption of Figure B.34). See Figure B.36 for spatial effects.

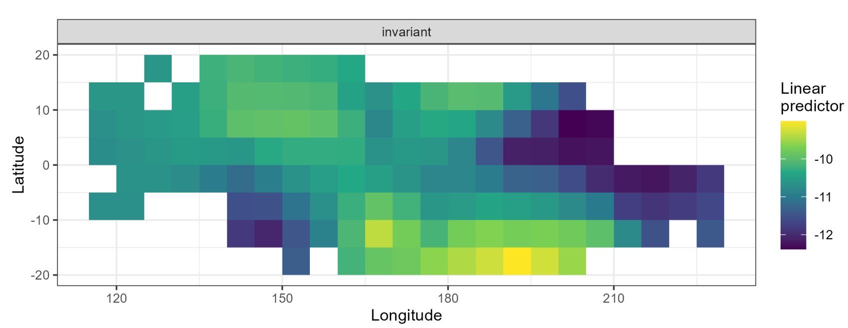


Figure B.36: Combined spatial effect for the delta and positives components of the Sea chubs catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.34).

Triple-tail (*Lobotes surinamensis*)

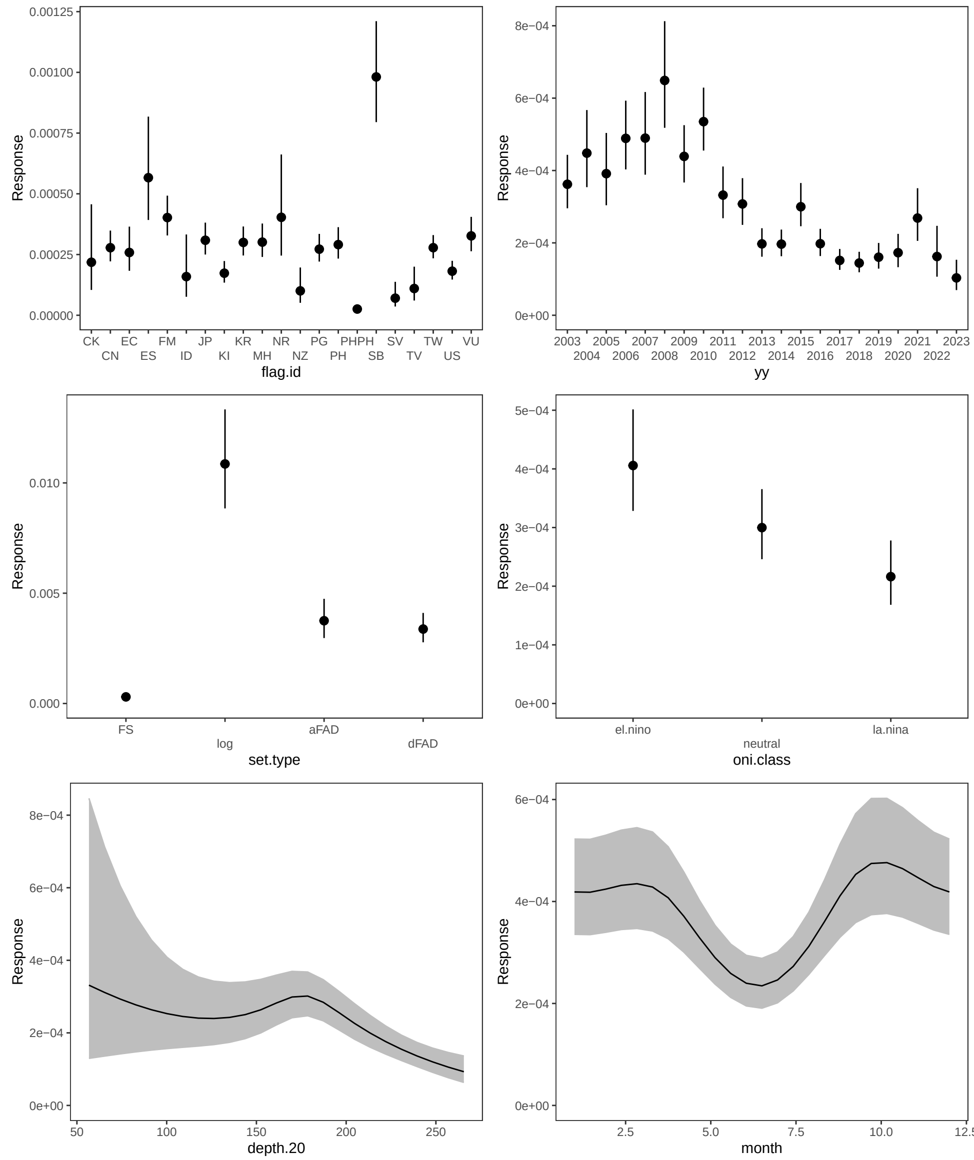


Figure B.37: Effects for the delta component of the Triple-tail catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels': year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the $20°$C isotherm = 180m, latitude = $175°$E, longitude = $2.5°$S. See Figure B.39 for spatial effects.

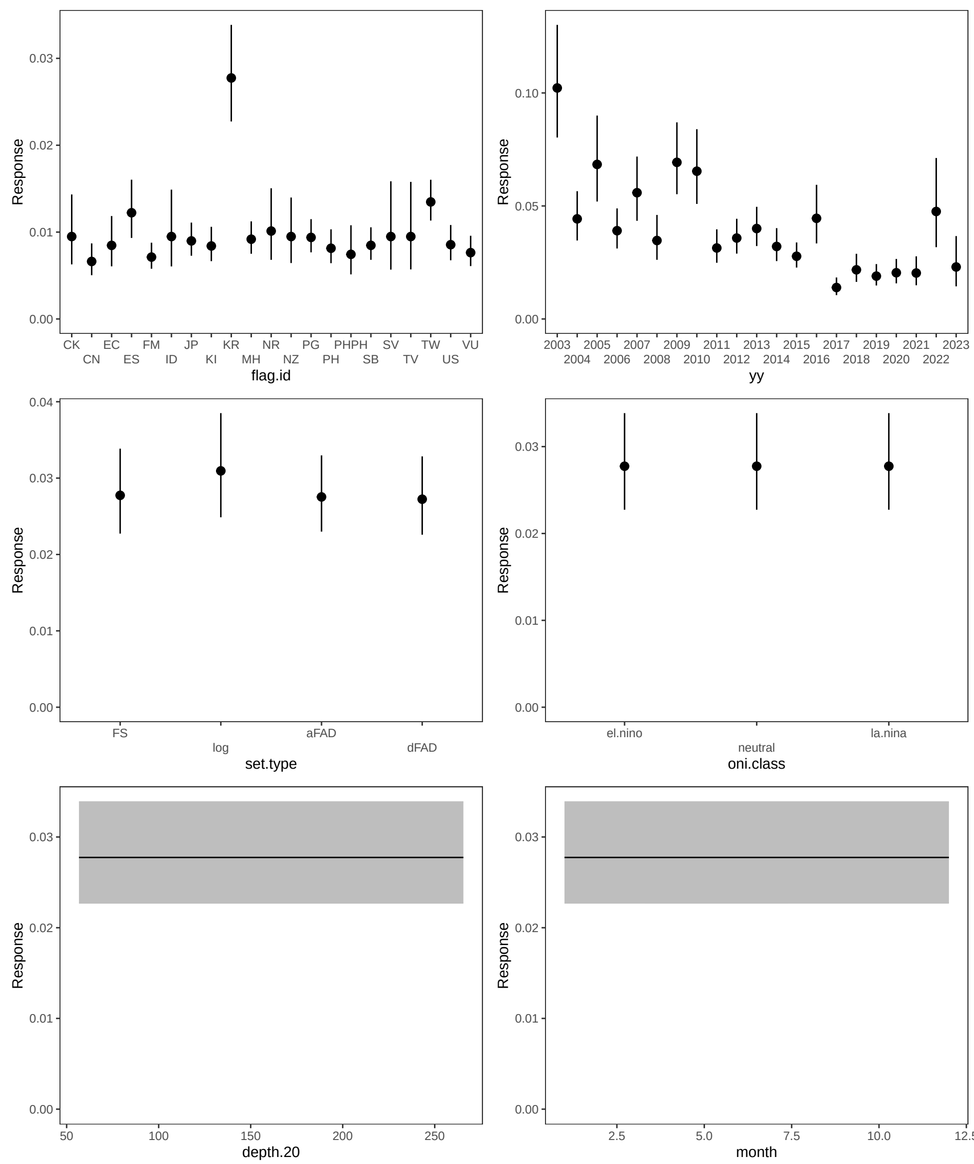


Figure B.38: Effects for the positives component of the Triple-tail catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the remaining explanatory variables held constant at reference levels (see caption of Figure B.37). See Figure B.39 for spatial effects.

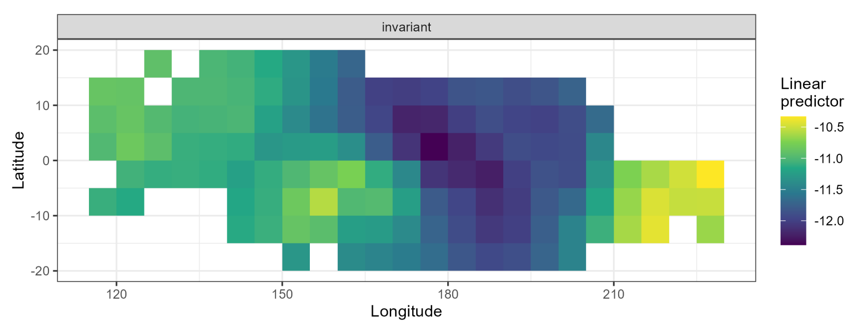


Figure B.39: Combined spatial effect for the delta and positives components of the Triple-tail catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.37).

Sunfish (*Molidae*)

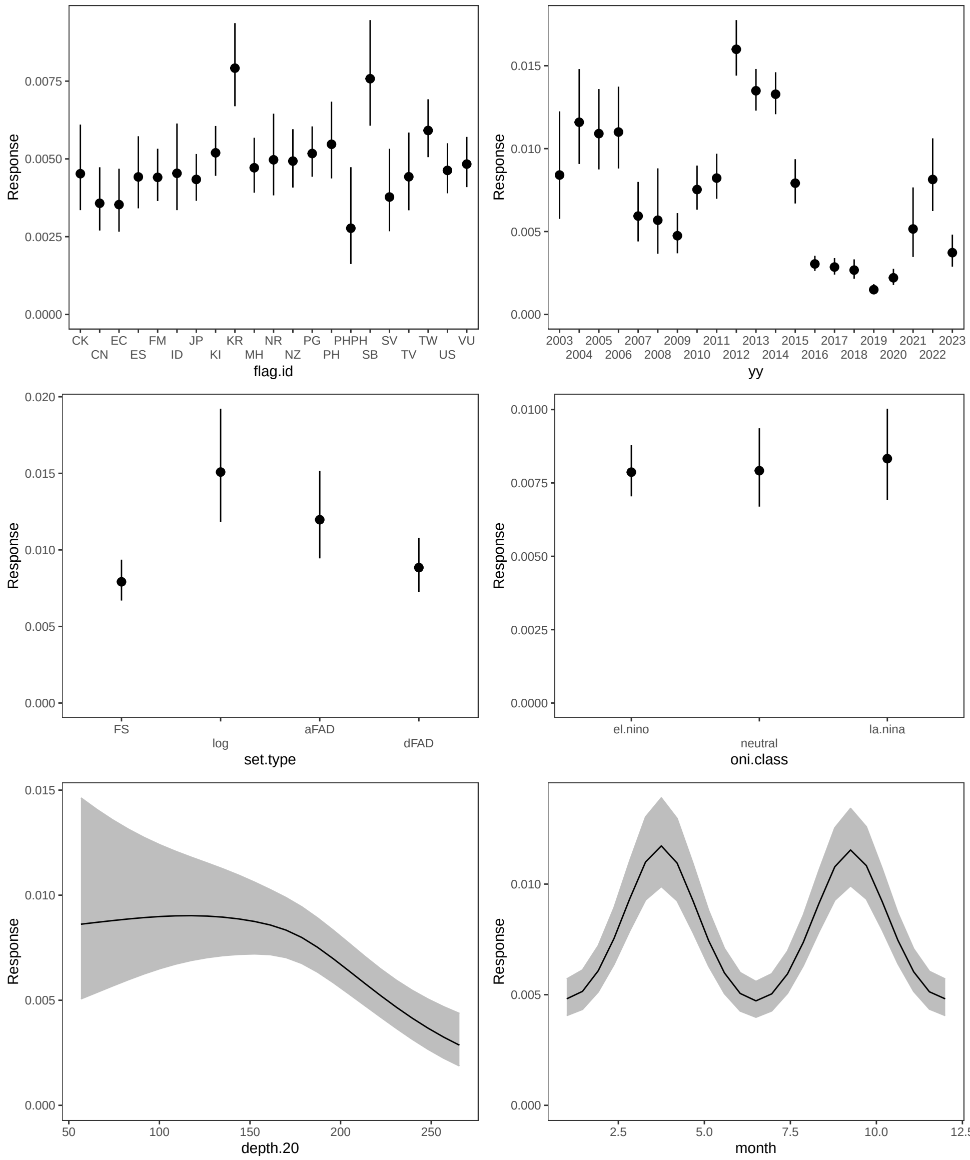


Figure B.40: Effects for the delta component of the Sunfish catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels': year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the $20°$**C isotherm = 180m, latitude =** $175°$**E, longitude =** $2.5°$**S. See Figure B.42 for spatial effects.**

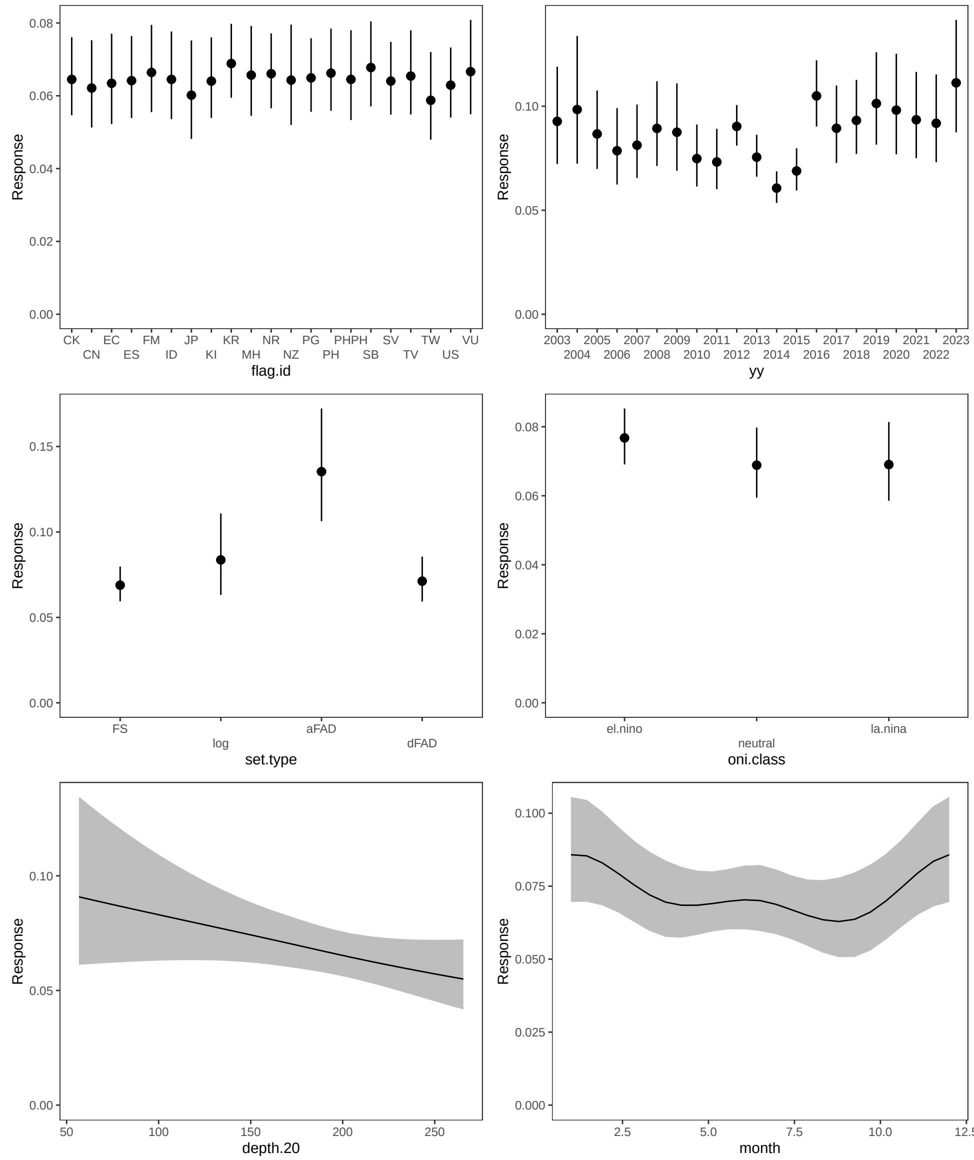


Figure B.41: Effects for the positives component of the Sunfish catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the remaining explanatory variables held constant at reference levels (see caption of Figure B.40). See Figure B.42 for spatial effects.

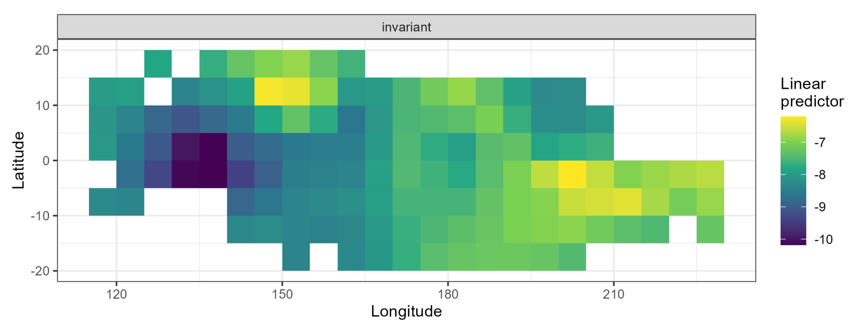


Figure B.42: Combined spatial effect for the delta and positives components of the Sunfish catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.40).

Filefishes (*Monacanthidae*)

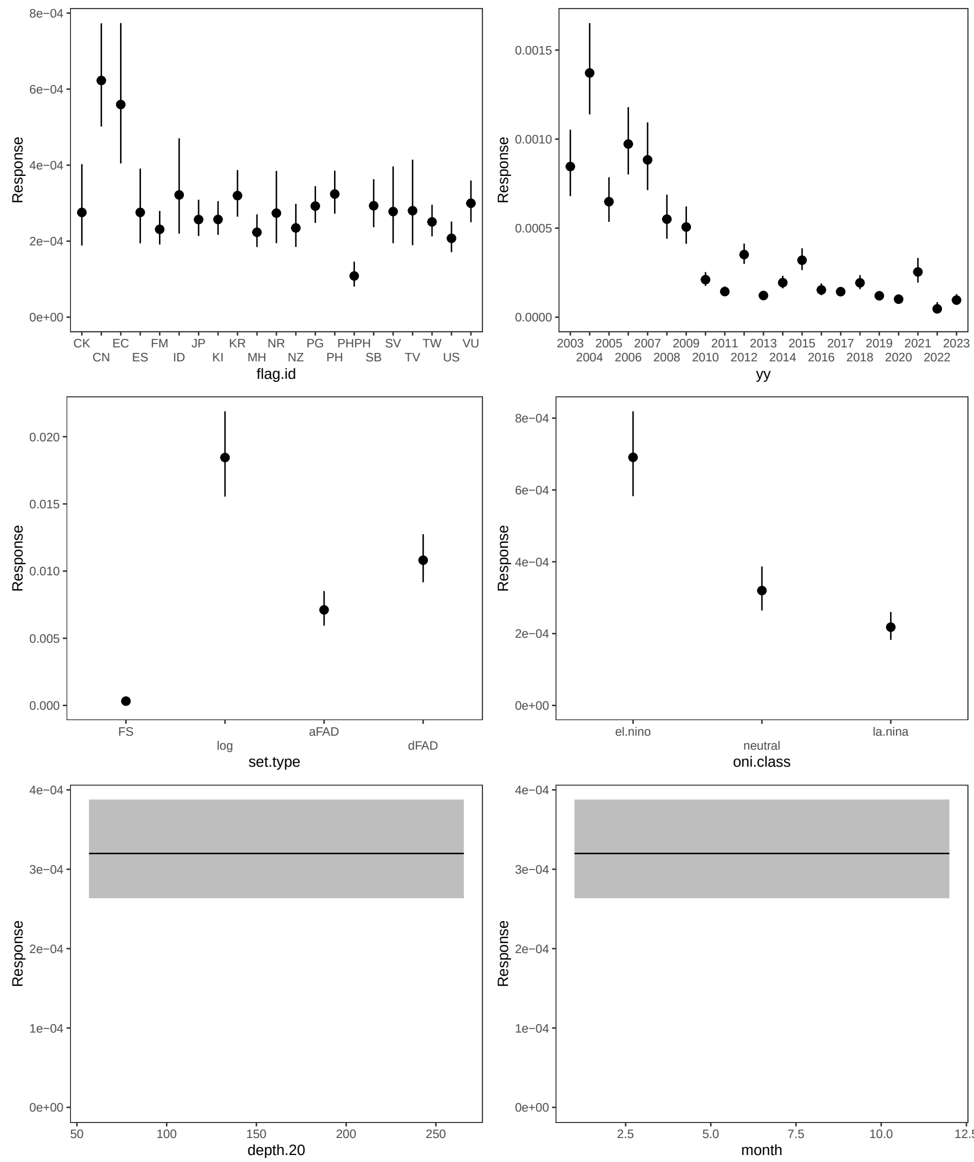


Figure B.43: Effects for the delta component of the Filefishes catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels': year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the $20°$C isotherm = 180m, latitude = $175°$E, longitude = $2.5°$S. See Figure B.45 for spatial effects.

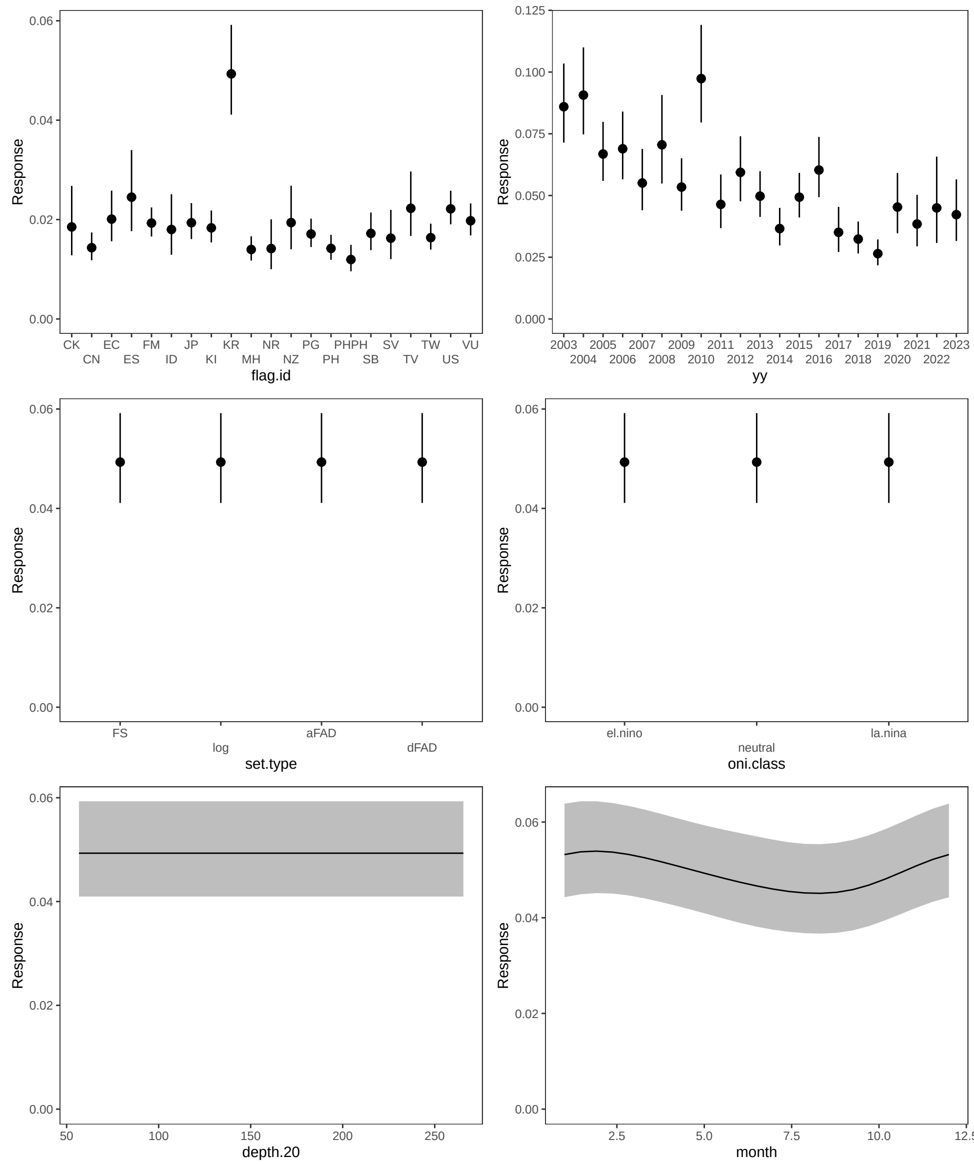


Figure B.44: Effects for the positives component of the Filefishes catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the remaining explanatory variables held constant at reference levels (see caption of Figure B.43). See Figure B.45 for spatial effects.

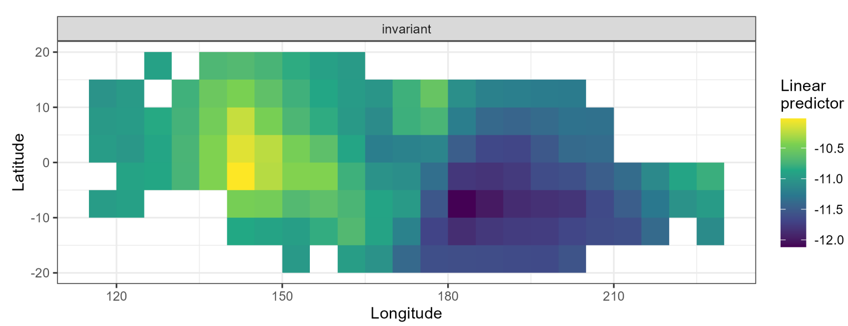


Figure B.45: Combined spatial effect for the delta and positives components of the Filefishes catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.43).

Batfishes (*Platax* spp)

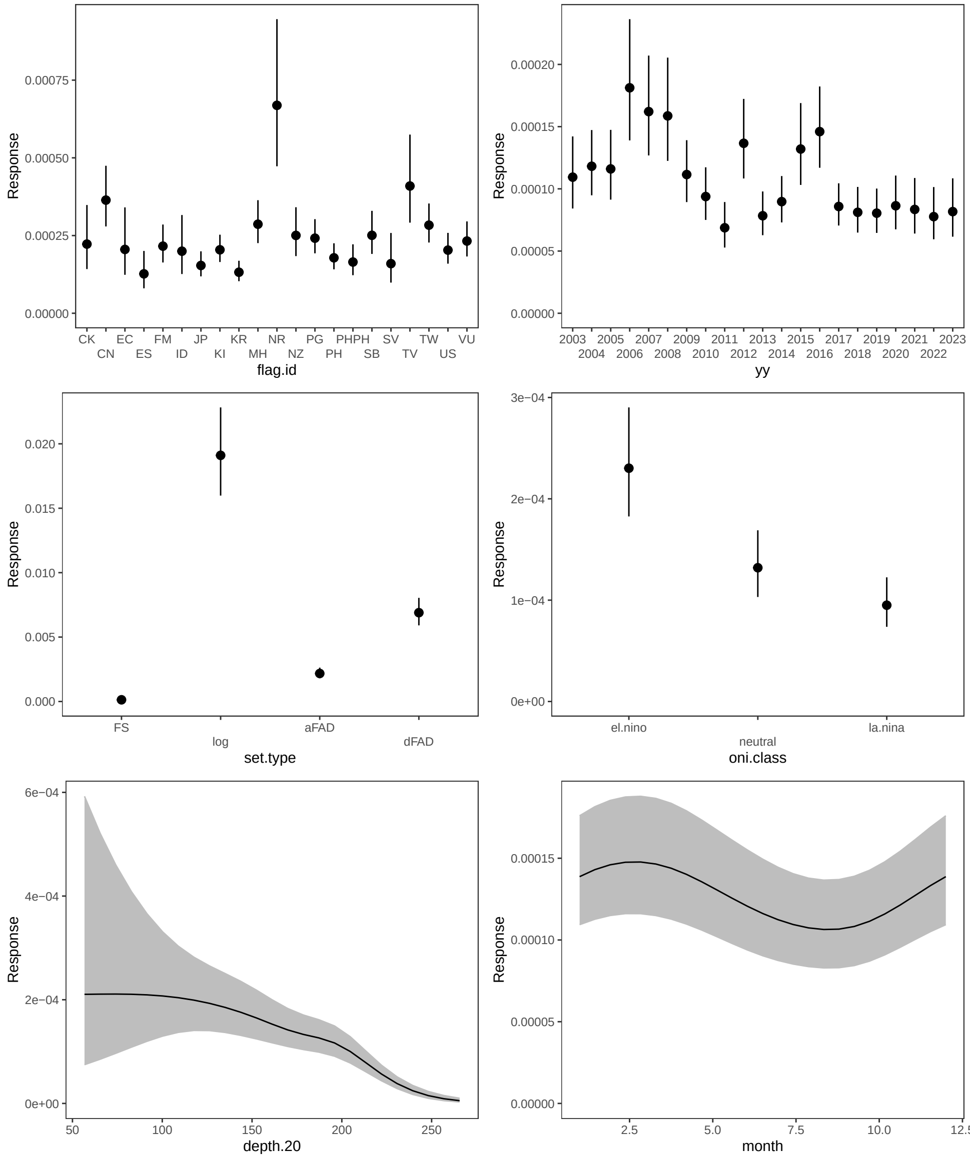


Figure B.46: Effects for the delta component of the Batfishes catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels': year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the 20°C isotherm = 180m, latitude = 175°E, longitude = 2.5°S. See Figure B.48 for spatial effects.

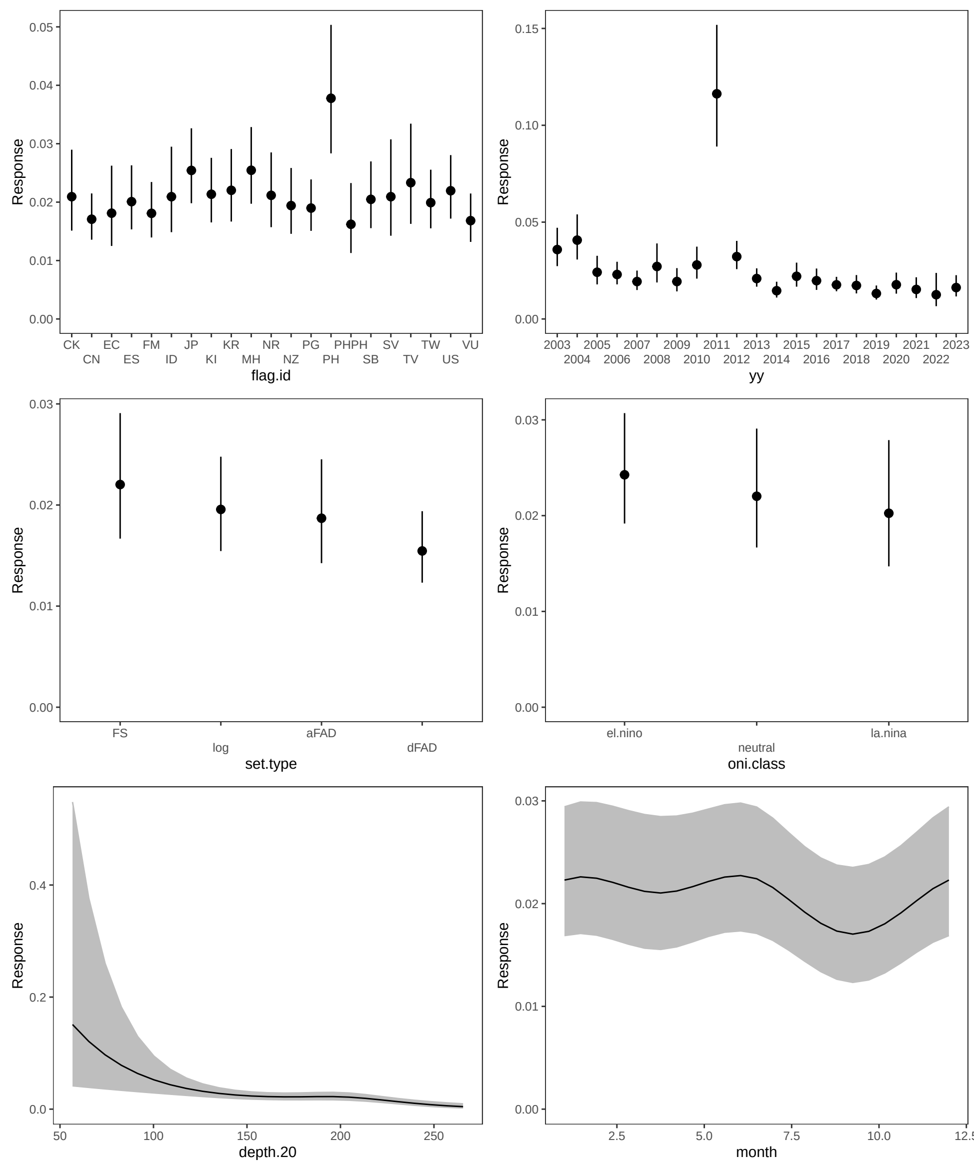


Figure B.47: Effects for the positives component of the Batfishes catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the remaining explanatory variables held constant at reference levels (see caption of Figure B.46). See Figure B.48 for spatial effects.

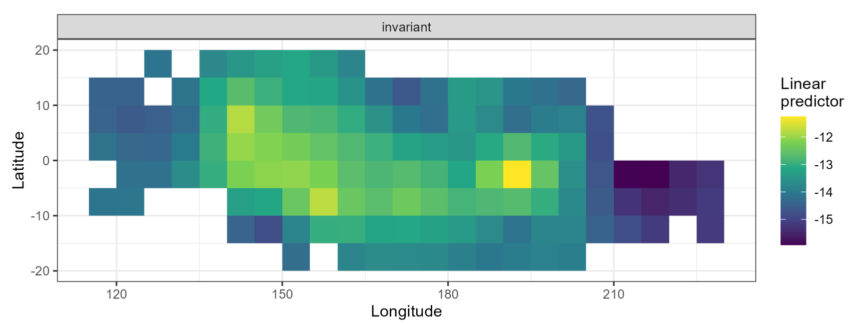


Figure B.48: Combined spatial effect for the delta and positives components of the Batfishes catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.46).

Scombrids (*Scombridae*)

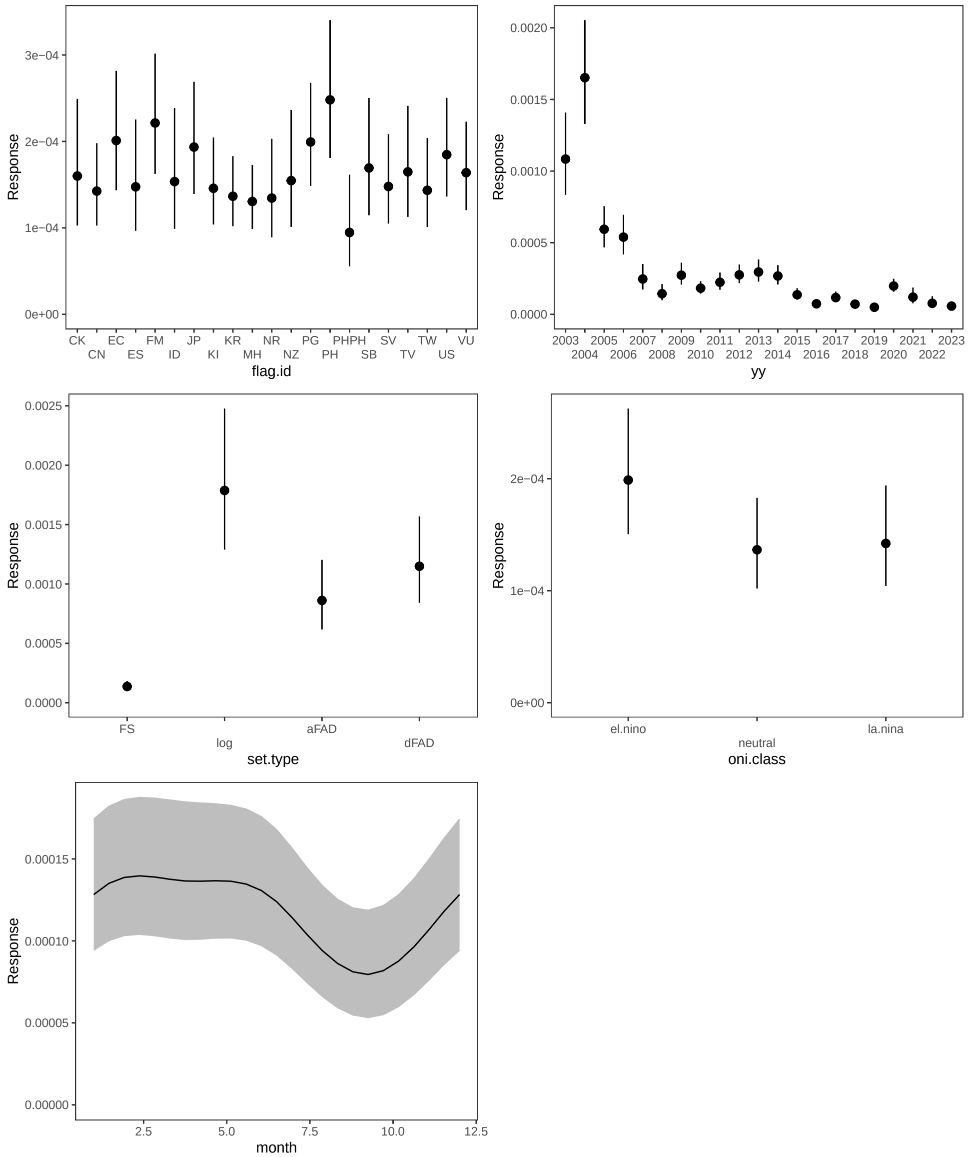


Figure B.49: Effects for the delta component of the Scombrids catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels': year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the $20°$C isotherm = 180m, latitude = $175°$E, longitude = $2.5°$S. See Figure B.51 for spatial effects.

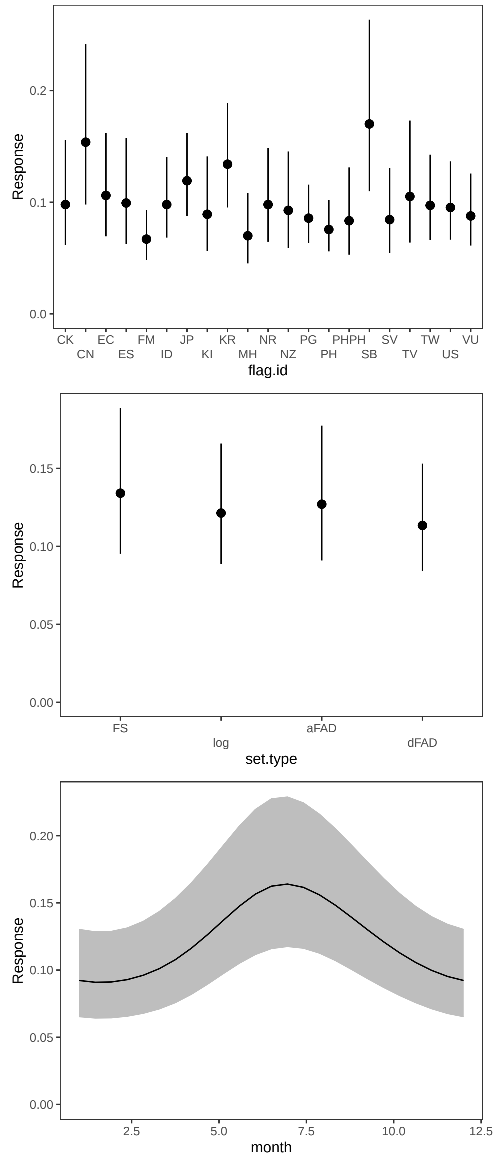


Figure B.50: Effects for the positives component of the Scombrids catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the remaining explanatory variables held constant at reference levels (see caption of Figure B.49). See Figure B.51 for spatial effects.

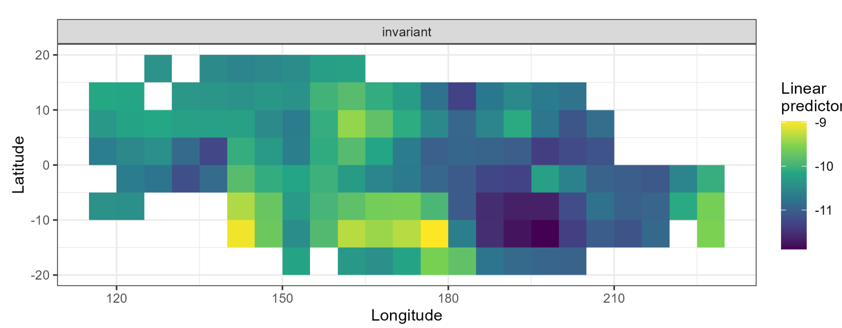


Figure B.51: Combined spatial effect for the delta and positives components of the Scombrids catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.49).

Amberjacks (*Seriola* spp)

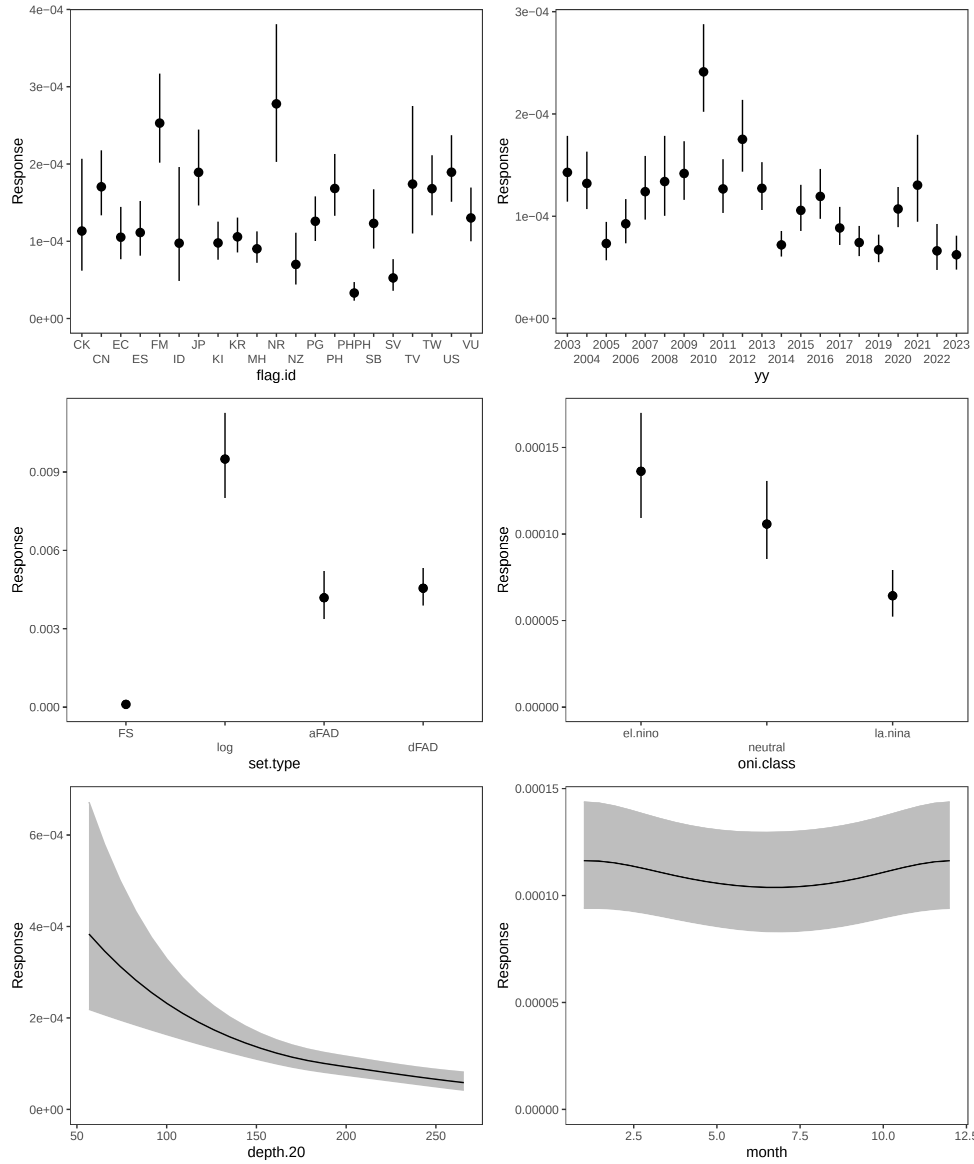


Figure B.52: Effects for the delta component of the Amberjacks catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels': year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the $20°$C isotherm = 180m, latitude = $175°$E, longitude = $2.5°$S. See Figure B.54 for spatial effects.

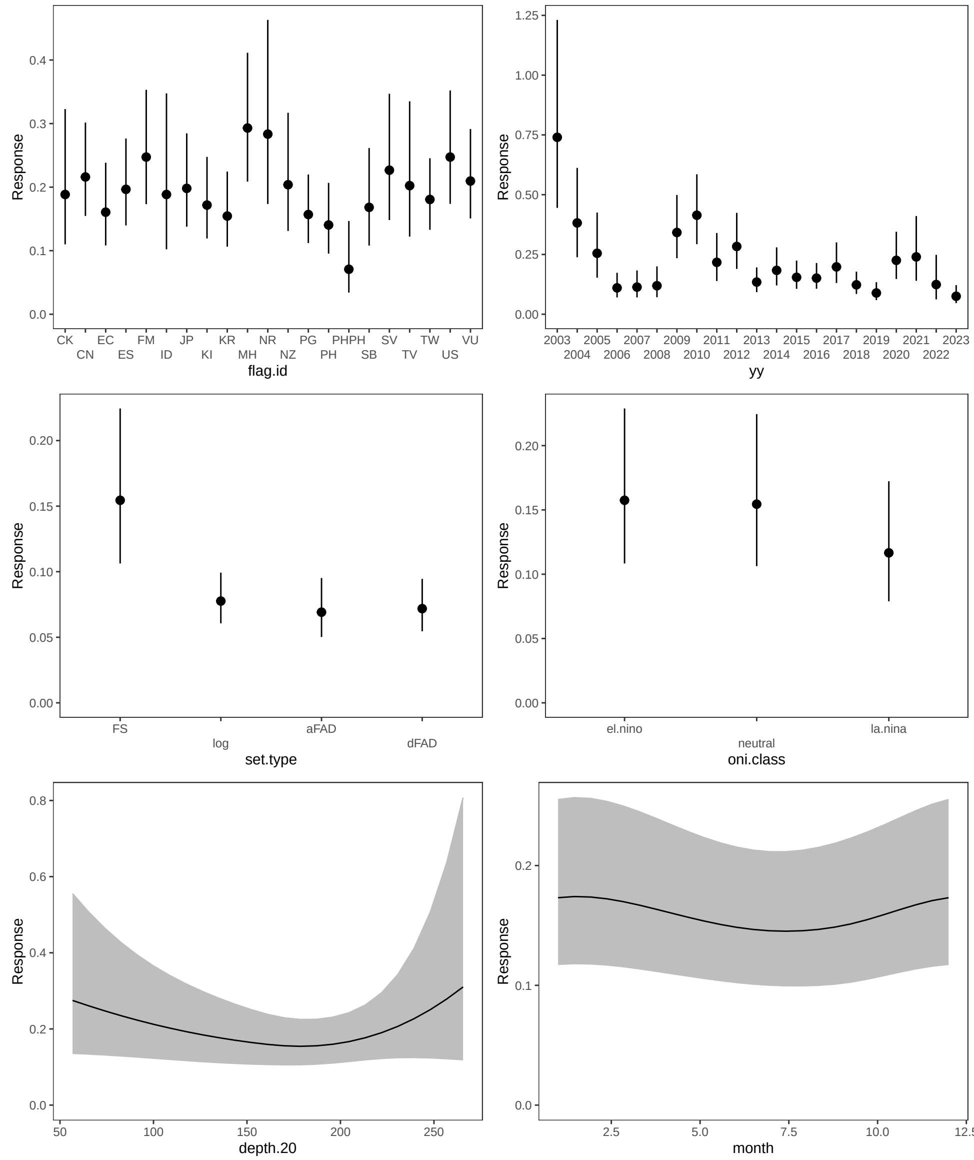


Figure B.53: Effects for the positives component of the Amberjacks catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the remaining explanatory variables held constant at reference levels (see caption of Figure B.52). See Figure B.54 for spatial effects.

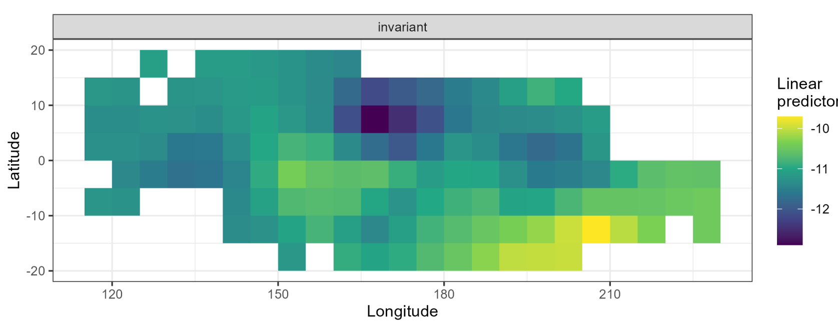


Figure B.54: Combined spatial effect for the delta and positives components of the Amberjacks catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.52).

Barracudas (*Sphyraenidae*)

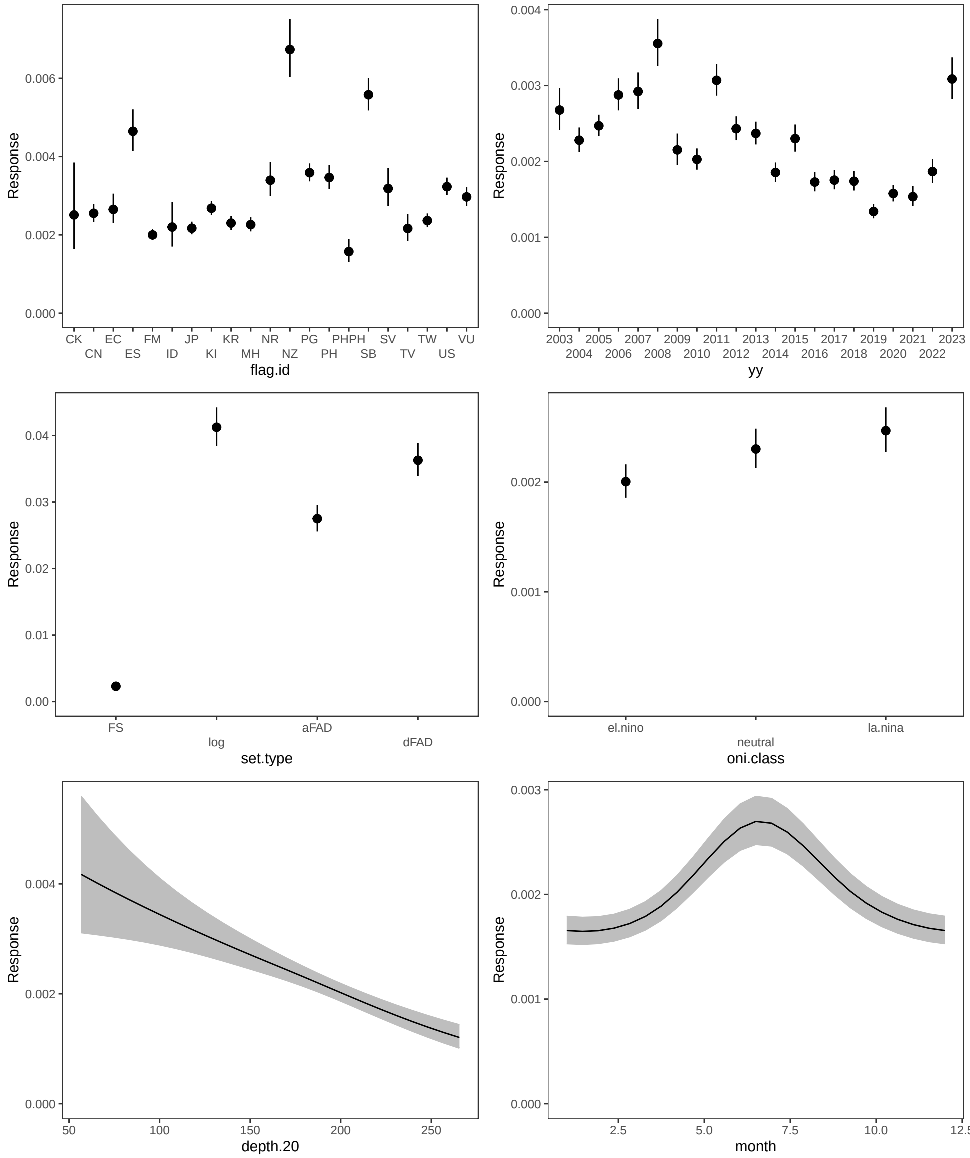


Figure B.55: Effects for the delta component of the Barracudas catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels': year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the $20°$C isotherm = 180m, latitude = $175°$E, longitude = $2.5°$S. See Figure B.57 for spatial effects.

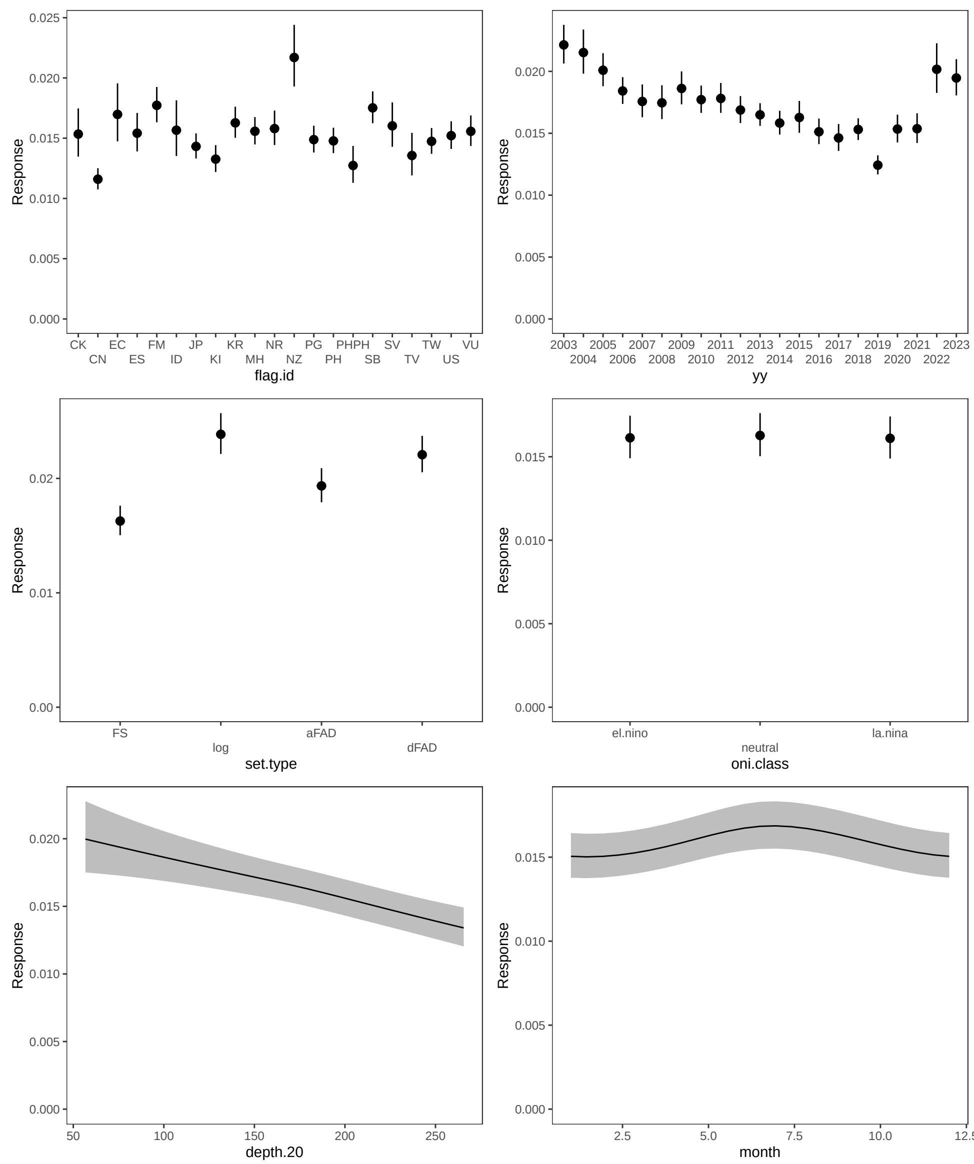


Figure B.56: Effects for the positives component of the Barracudas catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the remaining explanatory variables held constant at reference levels (see caption of Figure B.55). See Figure B.57 for spatial effects.

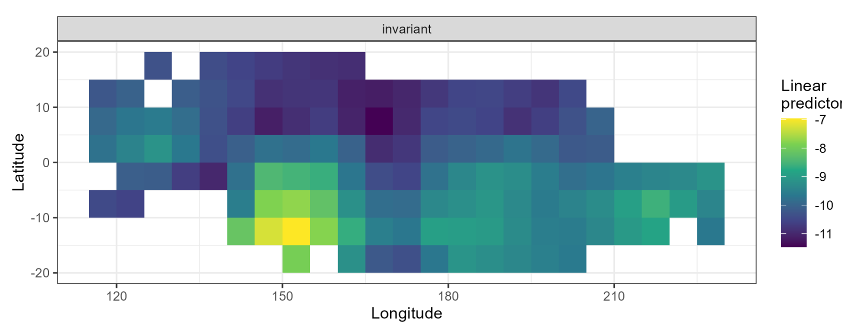


Figure B.57: Combined spatial effect for the delta and positives components of the Barracudas catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.55).

Marine fishes (Teleosts)

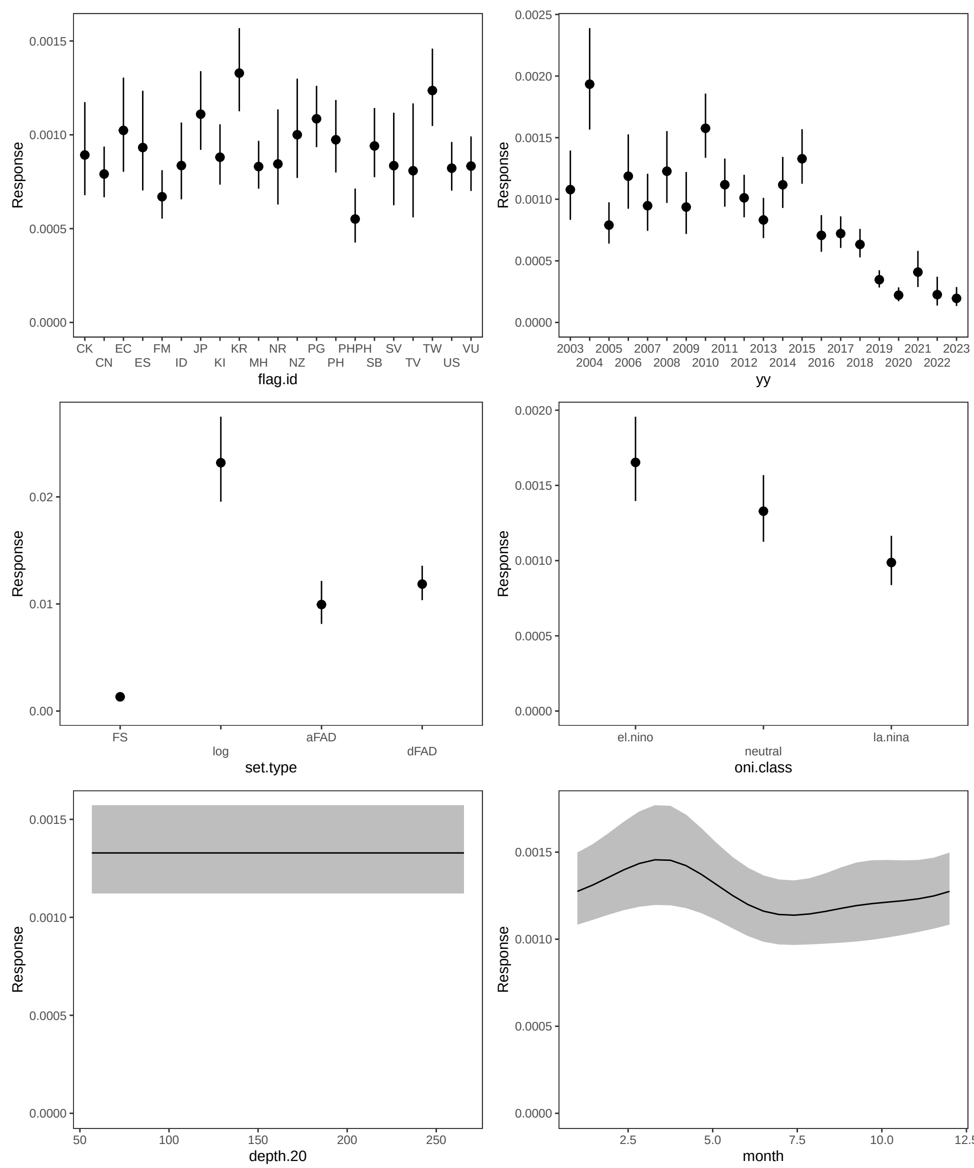


Figure B.58: Effects for the delta component of the Marine fishes catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels': year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the $20°$**C isotherm = 180m, latitude =** $175°$**E, longitude =** $2.5°$**S. See Figure B.60 for spatial effects.**

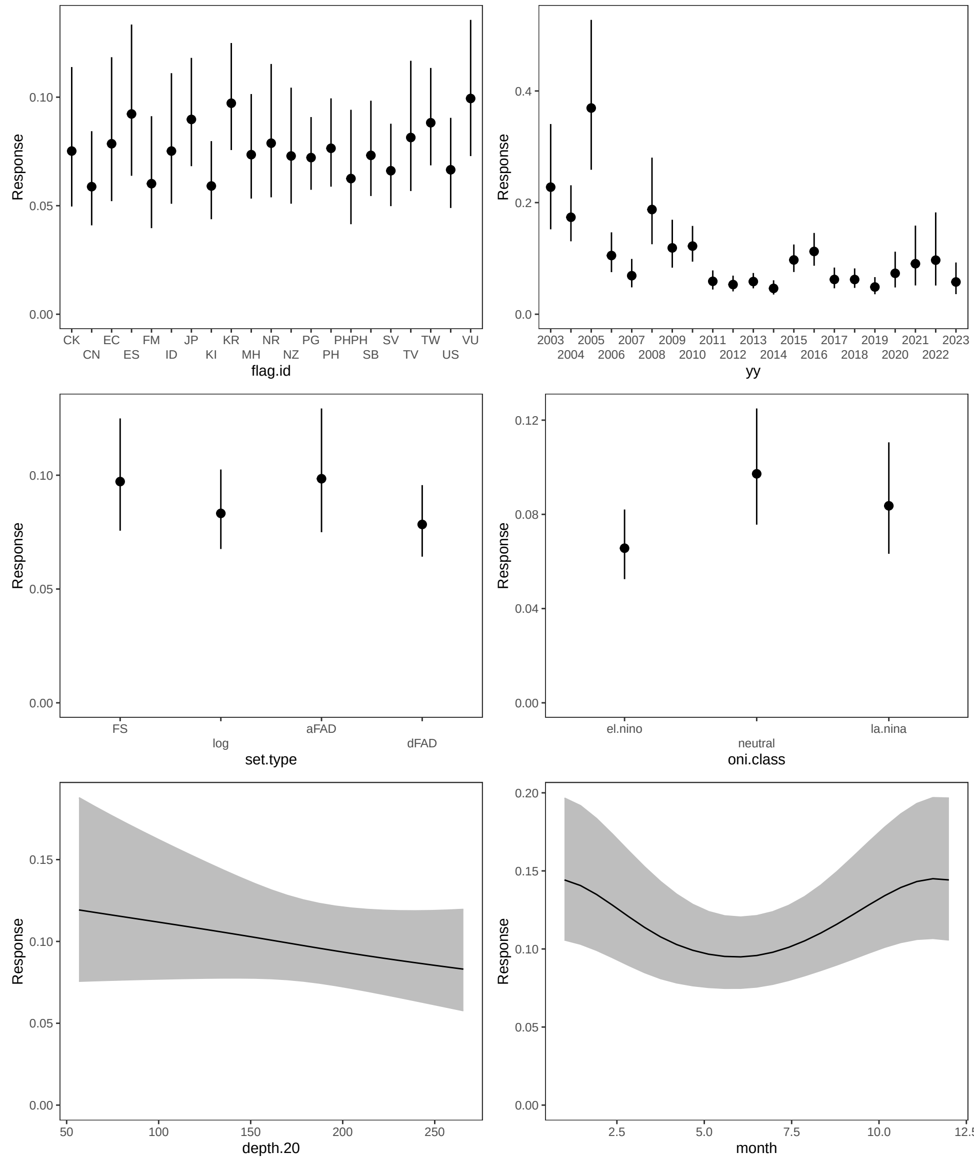


Figure B.59: Effects for the positives component of the Marine fishes catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the remaining explanatory variables held constant at reference levels (see caption of Figure B.58). See Figure B.60 for spatial effects.

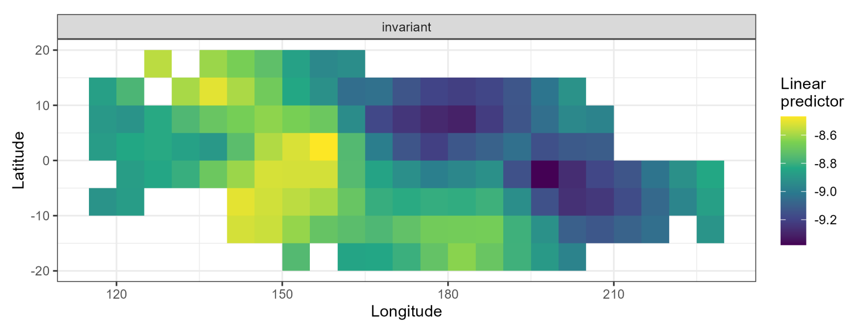


Figure B.60: Combined spatial effect for the delta and positives components of the Marine fishes catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.58).

Albacore (*Thunnus alalunga*)

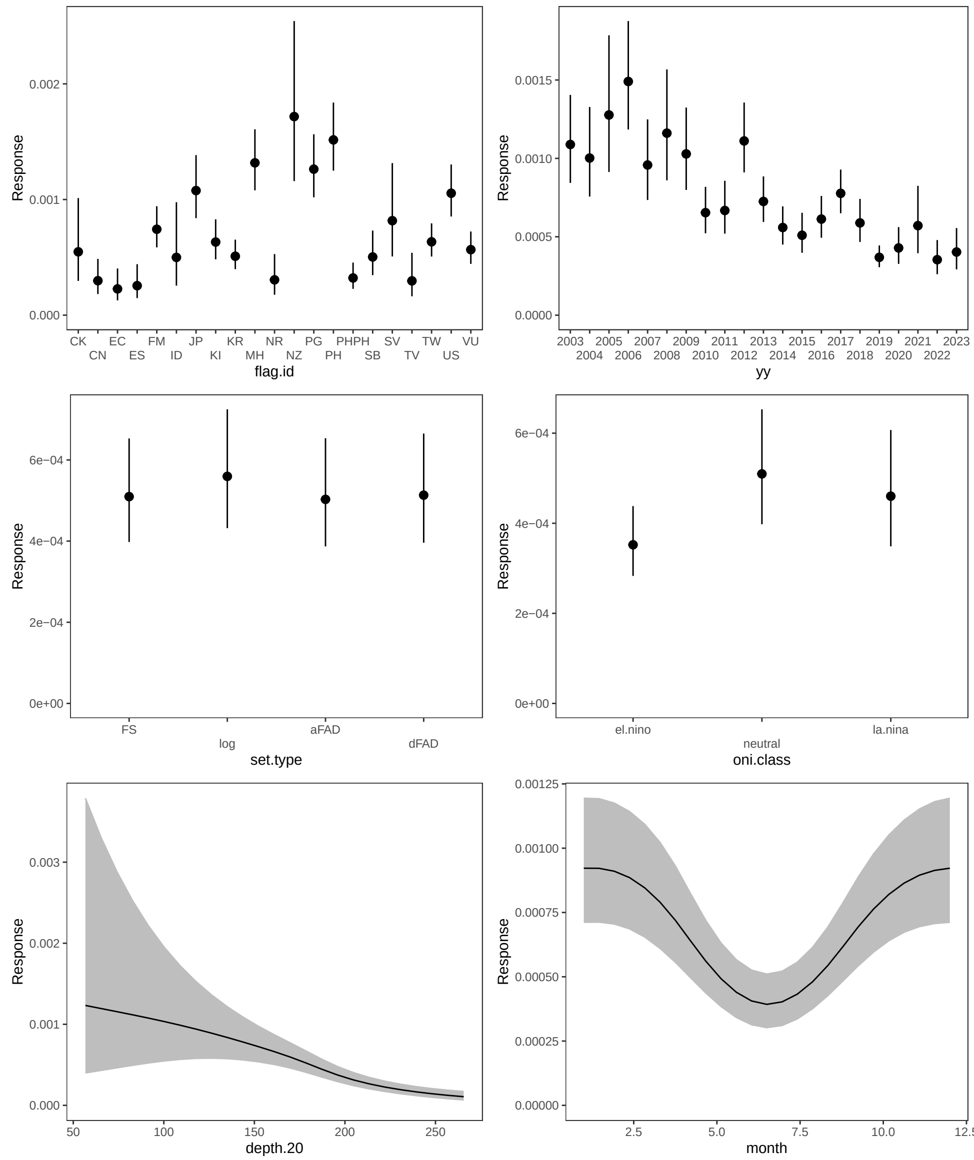


Figure B.61: Effects for the delta component of the Albacore catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels': year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the $20°$**C isotherm = 180m, latitude =** $175°$**E, longitude =** $2.5°$**S. See Figure B.63 for spatial effects.**

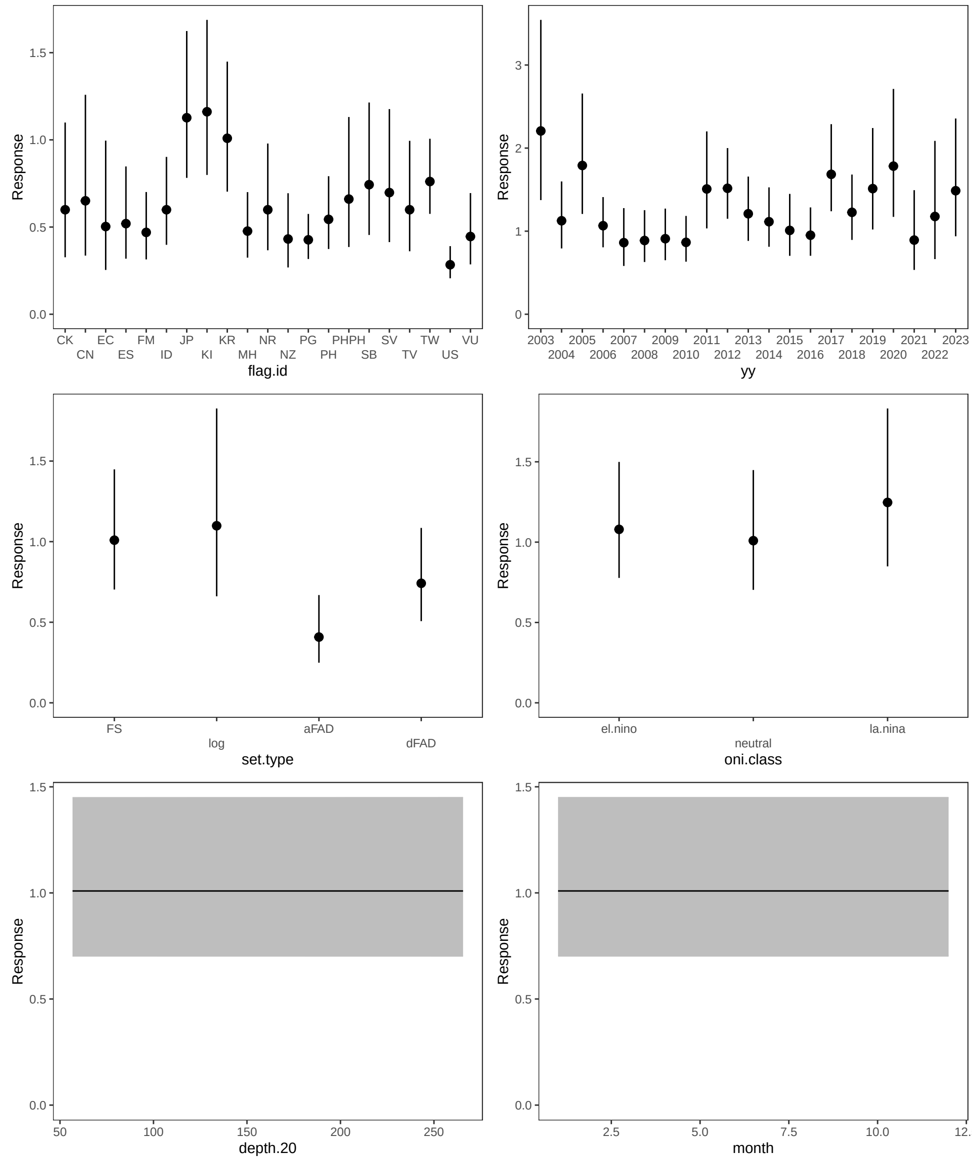


Figure B.62: Effects for the positives component of the Albacore catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the remaining explanatory variables held constant at reference levels (see caption of Figure B.61). See Figure B.63 for spatial effects.

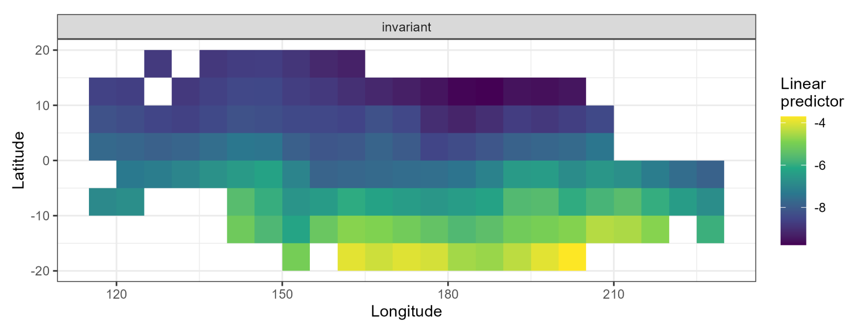


Figure B.63: Combined spatial effect for the delta and positives components of the Albacore catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.61).

B.2 Billfish - catch rate models

Indo-Pacific sailfish (*Istiophorus platypterus*)

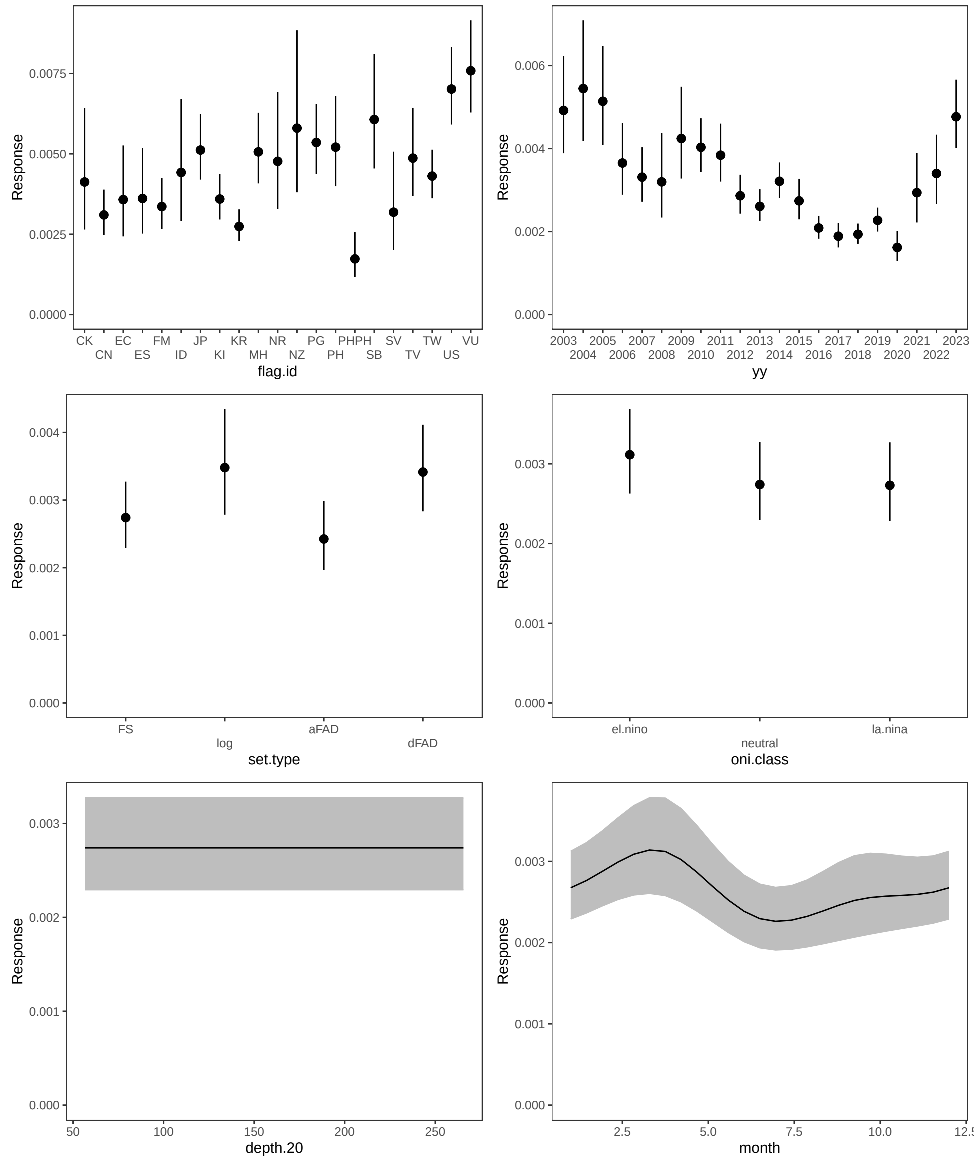


Figure B.64: Effects for the Indo-Pacific sailfish catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels' (year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the 20°C isotherm = 180m, latitude = 175°E, longitude = 2.5°S). See Figure B.65 for spatial effects.

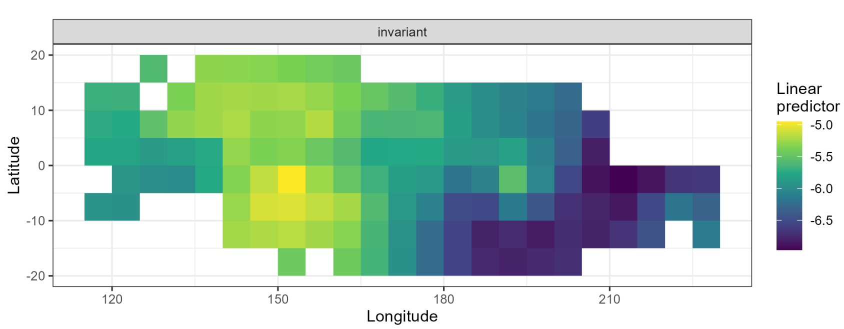


Figure B.65: Combined spatial effect for the Indo-Pacific sailfish catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.64).

Blue & black marlin (*Makaira nigricans* & *M. indica*)

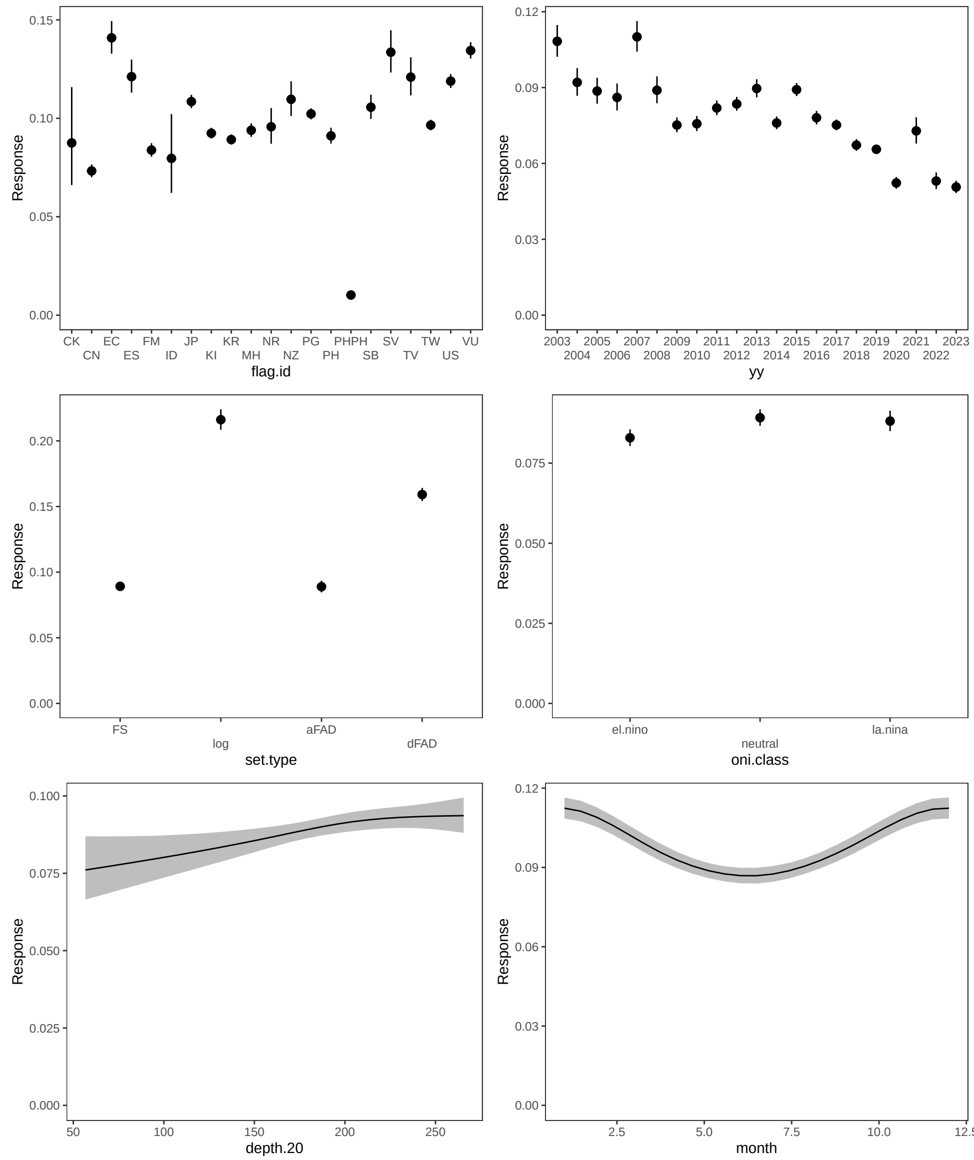


Figure B.66: Effects for the Blue & black marlin catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at ‘reference levels’ (year = 2015, month = 5, set-type = ‘FS’, flag = ‘KR’, ONI = ‘neutral’, depth of the $20°$C isotherm = 180m, latitude = $175°$E, longitude = $2.5°$S). See Figure B.67 for spatial effects.

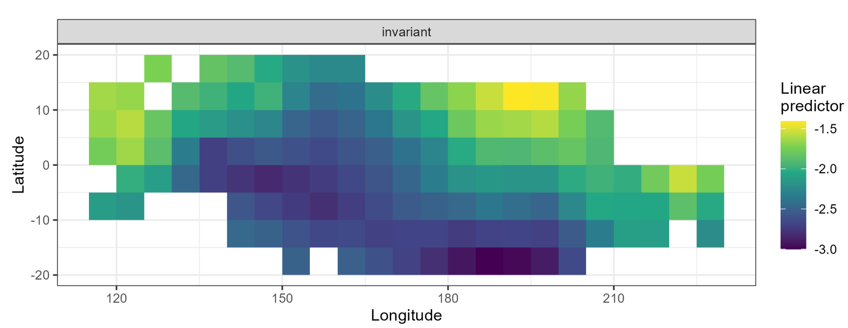


Figure B.67: Combined spatial effect for the Blue & black marlin catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.66).

Short-billed spearfish (*Tetrapturus angustirostris*)

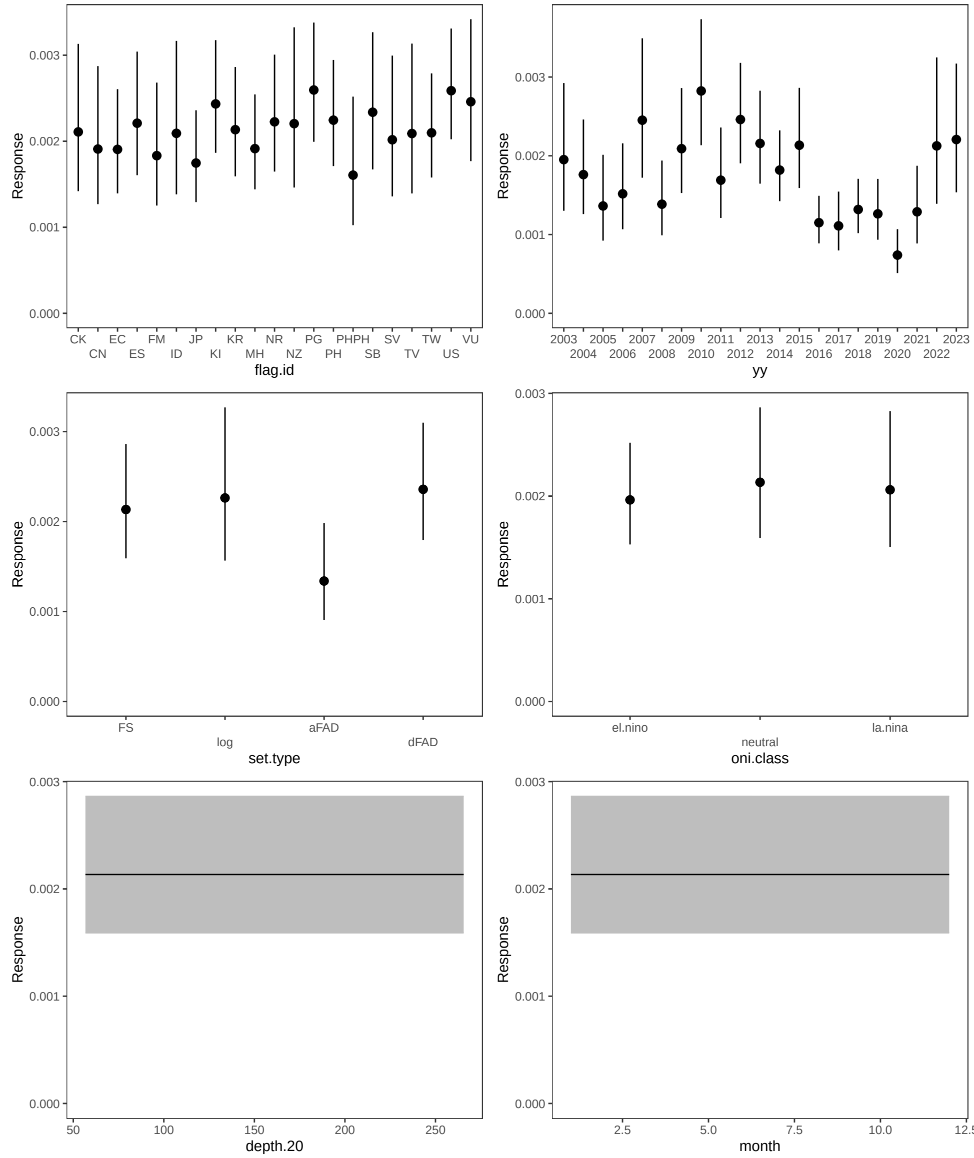


Figure B.68: Effects for the Short-billed spearfish catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels' (year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the 20°C isotherm = 180m, latitude = 175°E, longitude = 2.5°S). See Figure B.69 for spatial effects.

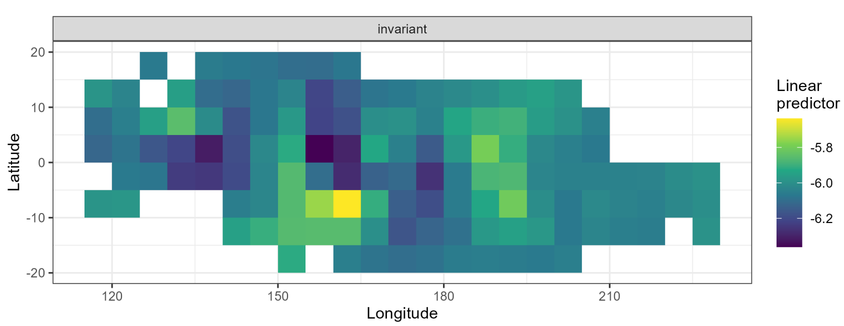


Figure B.69: Combined spatial effect for the Short-billed spearfish catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.68).

Striped marlin (*Tetrapturus audax*)

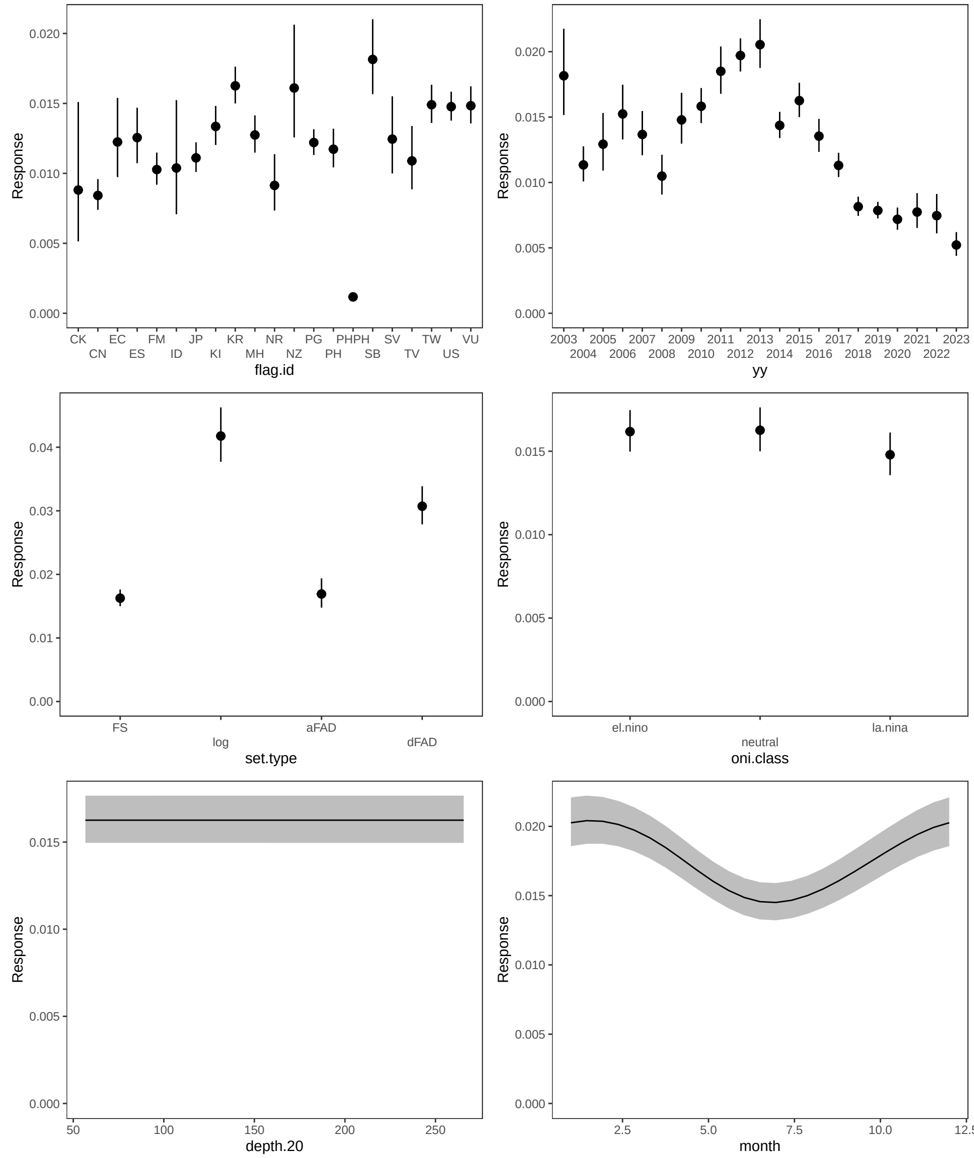


Figure B.70: Effects for the Striped marlin catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels' (year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the $20°$C isotherm = 180m, latitude = $175°$E, longitude = $2.5°$S). See Figure B.71 for spatial effects.

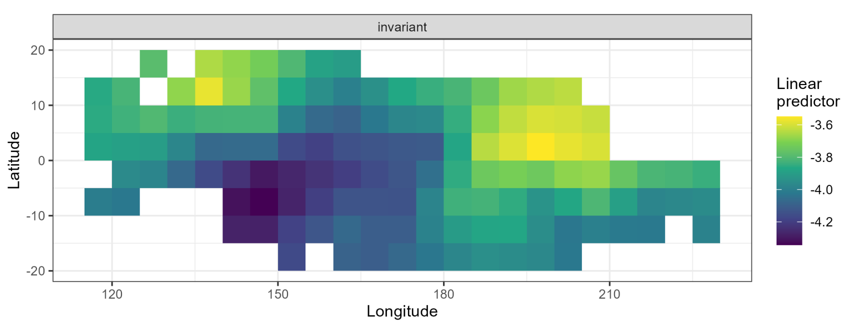


Figure B.71: Combined spatial effect for the Striped marlin catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.70).

Swordfish (*Xiphias gladius*)

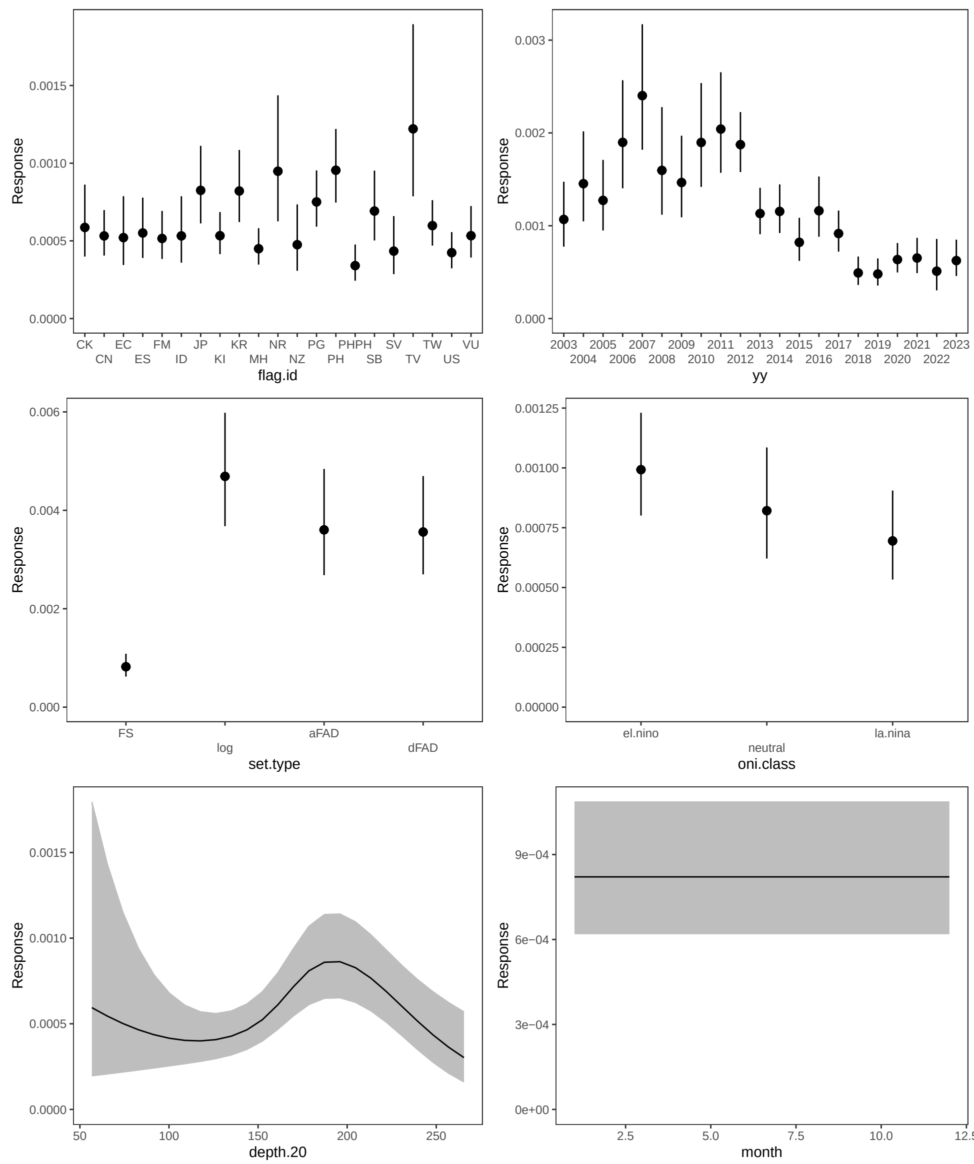


Figure B.72: Effects for the Swordfish catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels' (year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the $20°$C isotherm = 180m, latitude = $175°$E, longitude = $2.5°$S). See Figure B.73 for spatial effects.

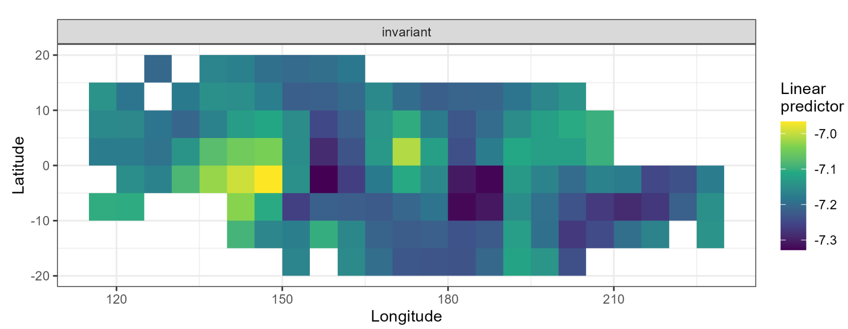


Figure B.73: Combined spatial effect for the Swordfish catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.72).

B.3 Elasmobranchs - catch rate models

Thresher sharks (*Alopiidae*)

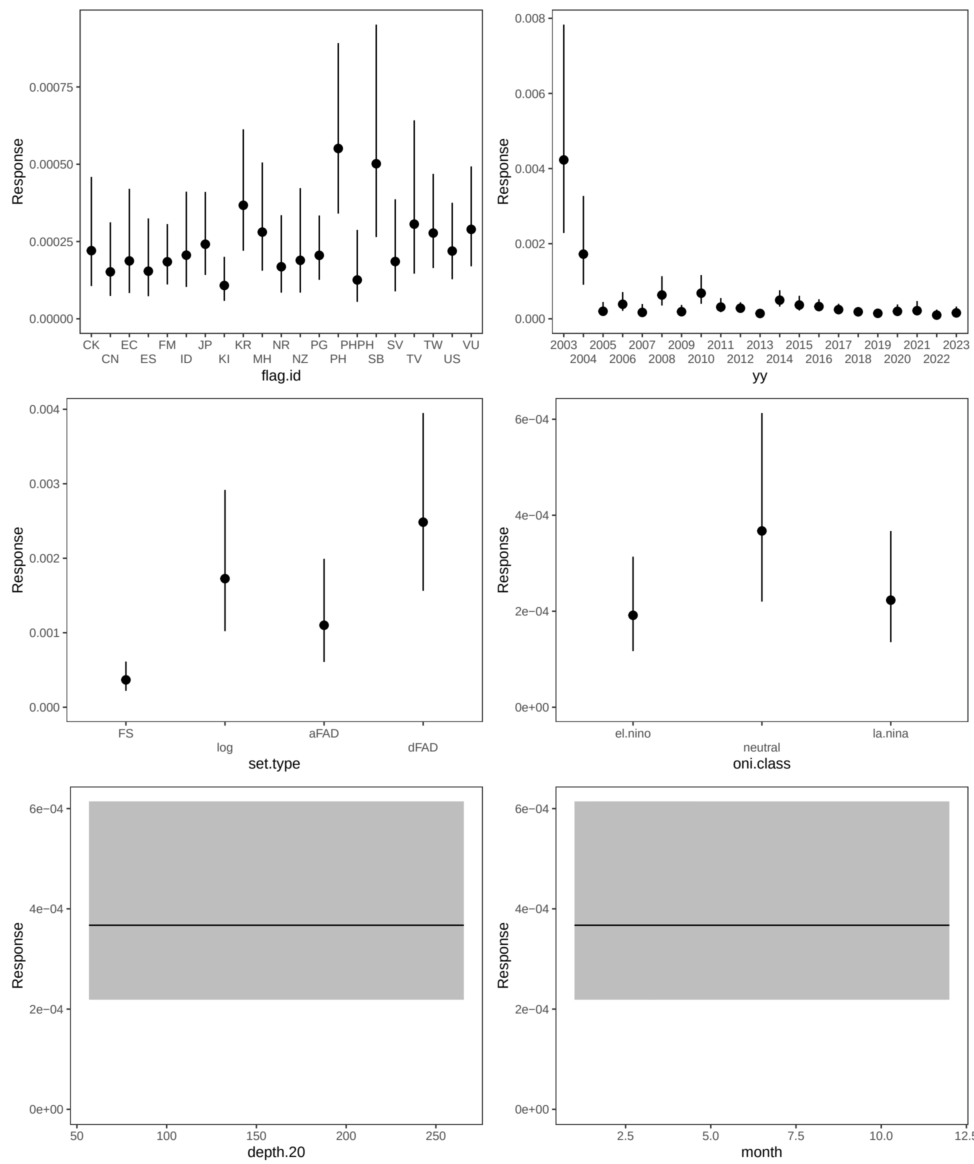


Figure B.74: Effects for the Thresher sharks catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels' (year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the 20°C isotherm = 180m, latitude = 175°E, longitude = 2.5°S). See Figure B.75 for spatial effects.

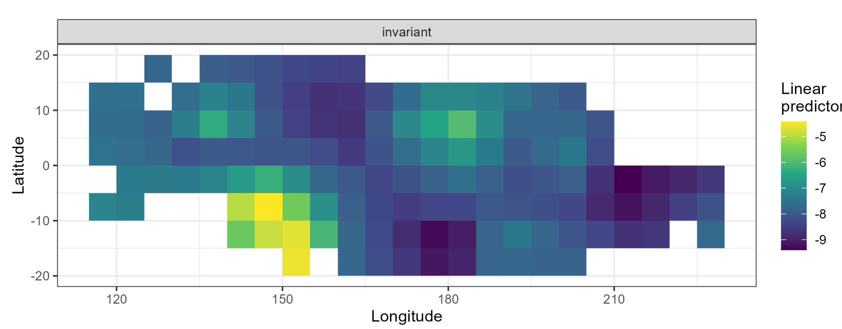


Figure B.75: Combined spatial effect for the Thresher sharks catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.74).

Silky shark (*Carcharhinus falciformis*)

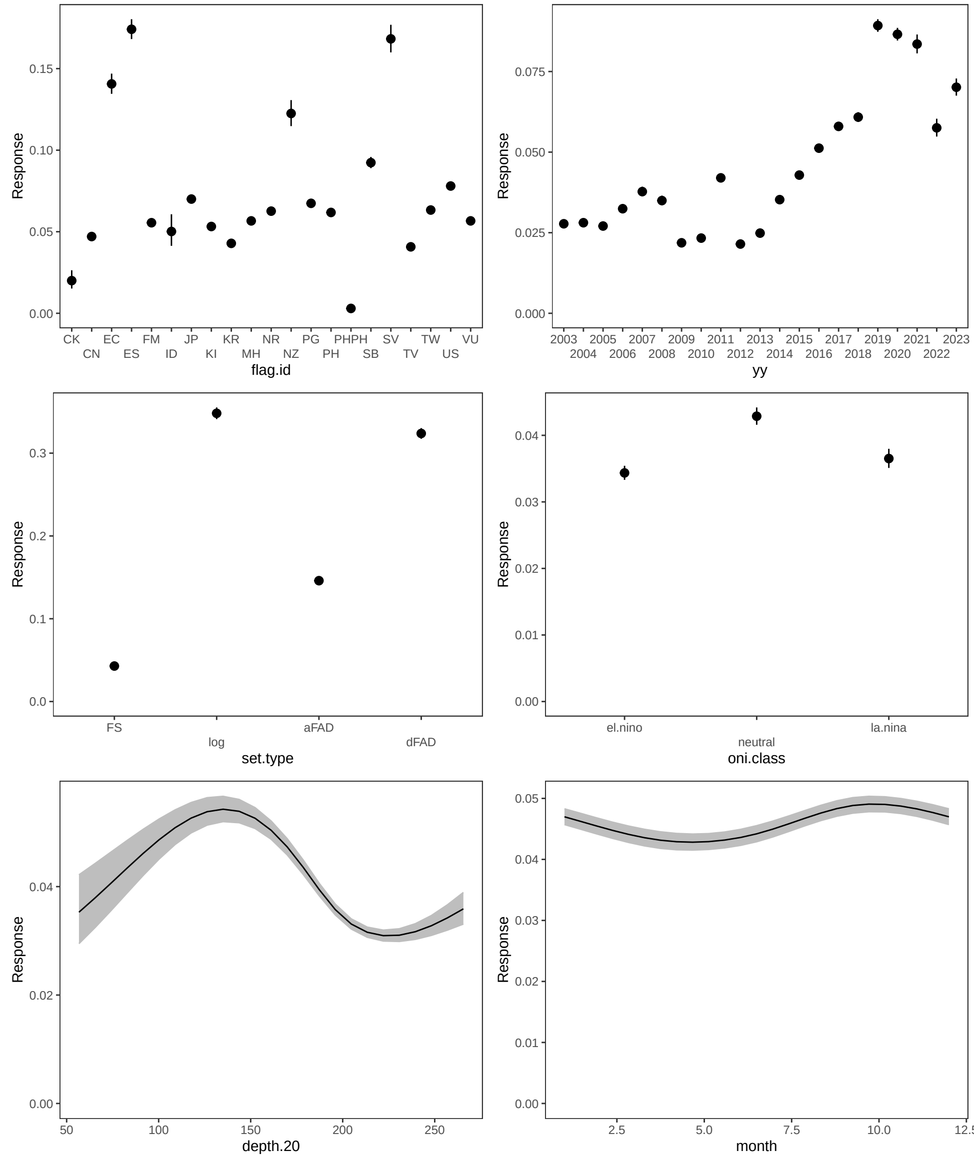


Figure B.76: Effects for the delta component of the Silky shark catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels': year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the $20°$C isotherm = 180m, latitude = $175°$E, longitude = $2.5°$S. See Figure B.78 for spatial effects.

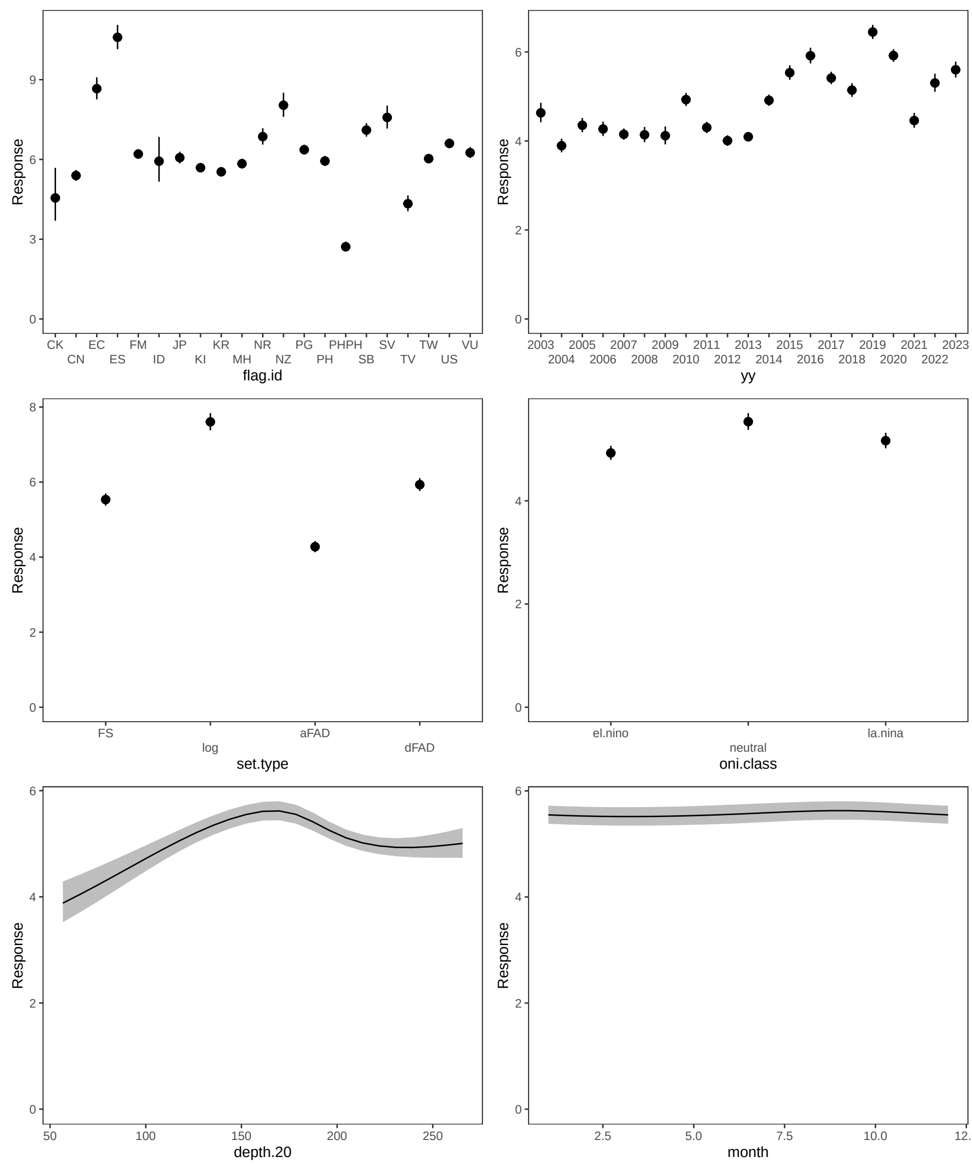


Figure B.77: Effects for the positives component of the Silky shark catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the remaining explanatory variables held constant at reference levels (see caption of Figure B.76). See Figure B.78 for spatial effects.

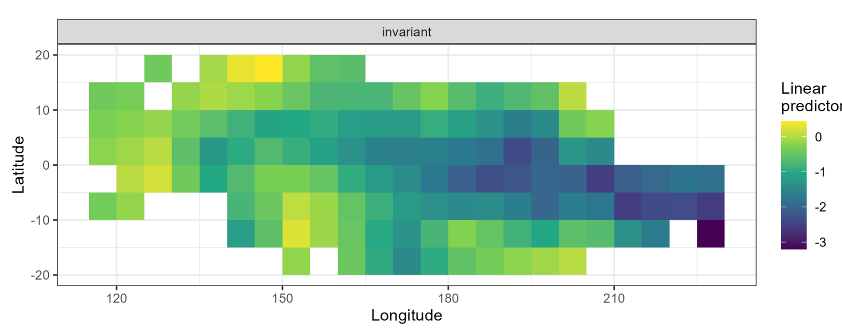


Figure B.78: Combined spatial effect for the delta and positives components of the Silky shark catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.76).

Oceanic whitetip shark (*Carcharhinus longimanus*)

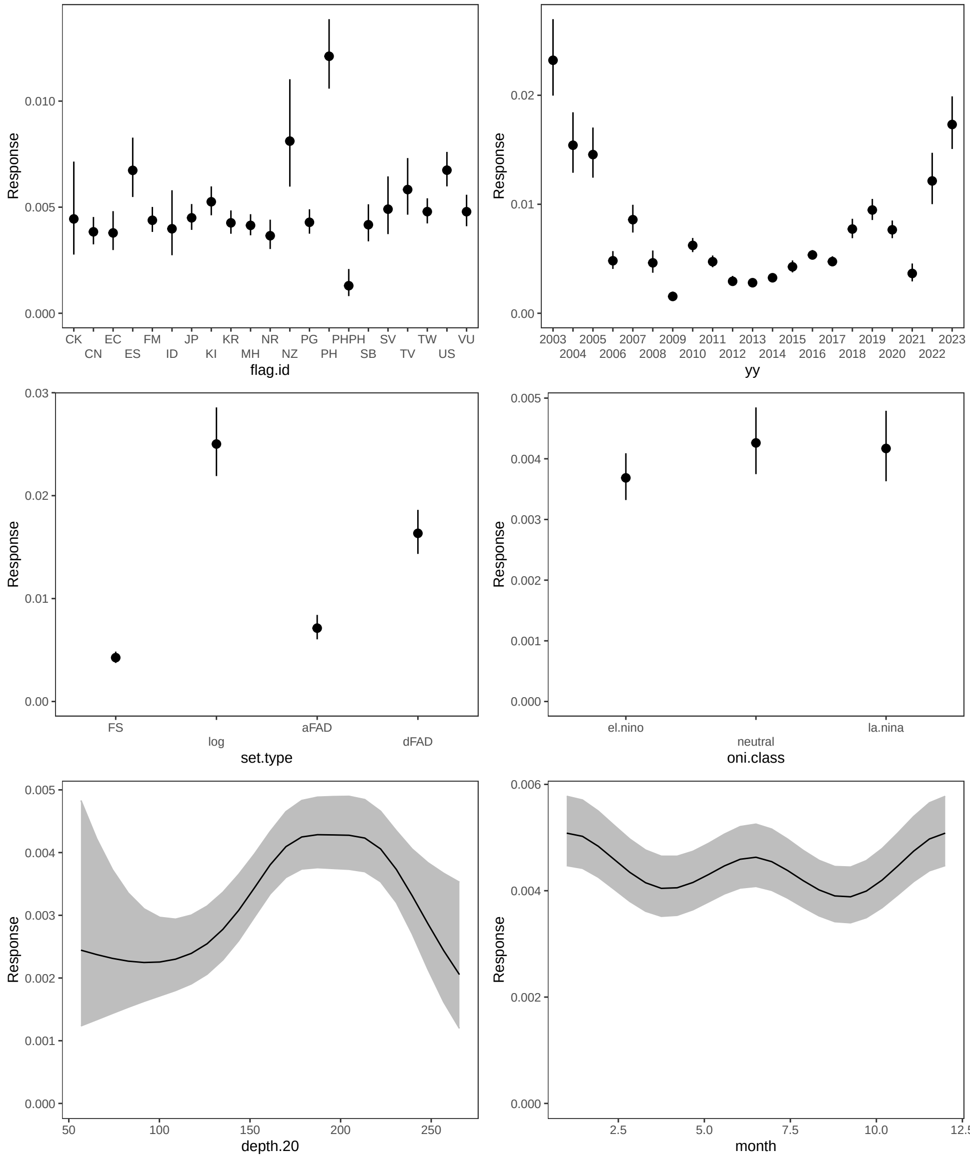


Figure B.79: Effects for the Oceanic whitetip shark catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels' (year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the 20°C isotherm = 180m, latitude = 175°E, longitude = 2.5°S). See Figure B.80 for spatial effects.

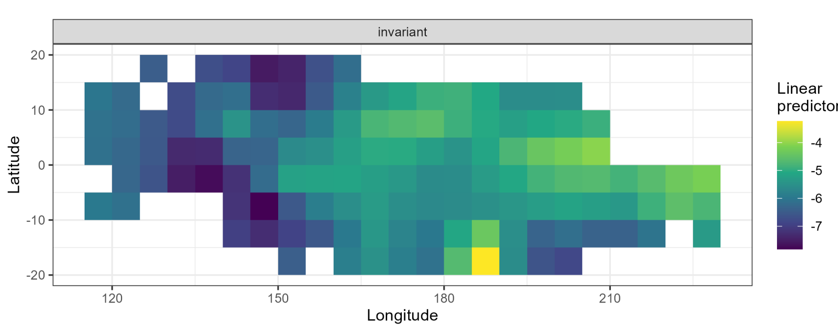


Figure B.80: Combined spatial effect for the Oceanic whitetip shark catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.79).

Pelagic stingray (*Dasyatis violacea*)

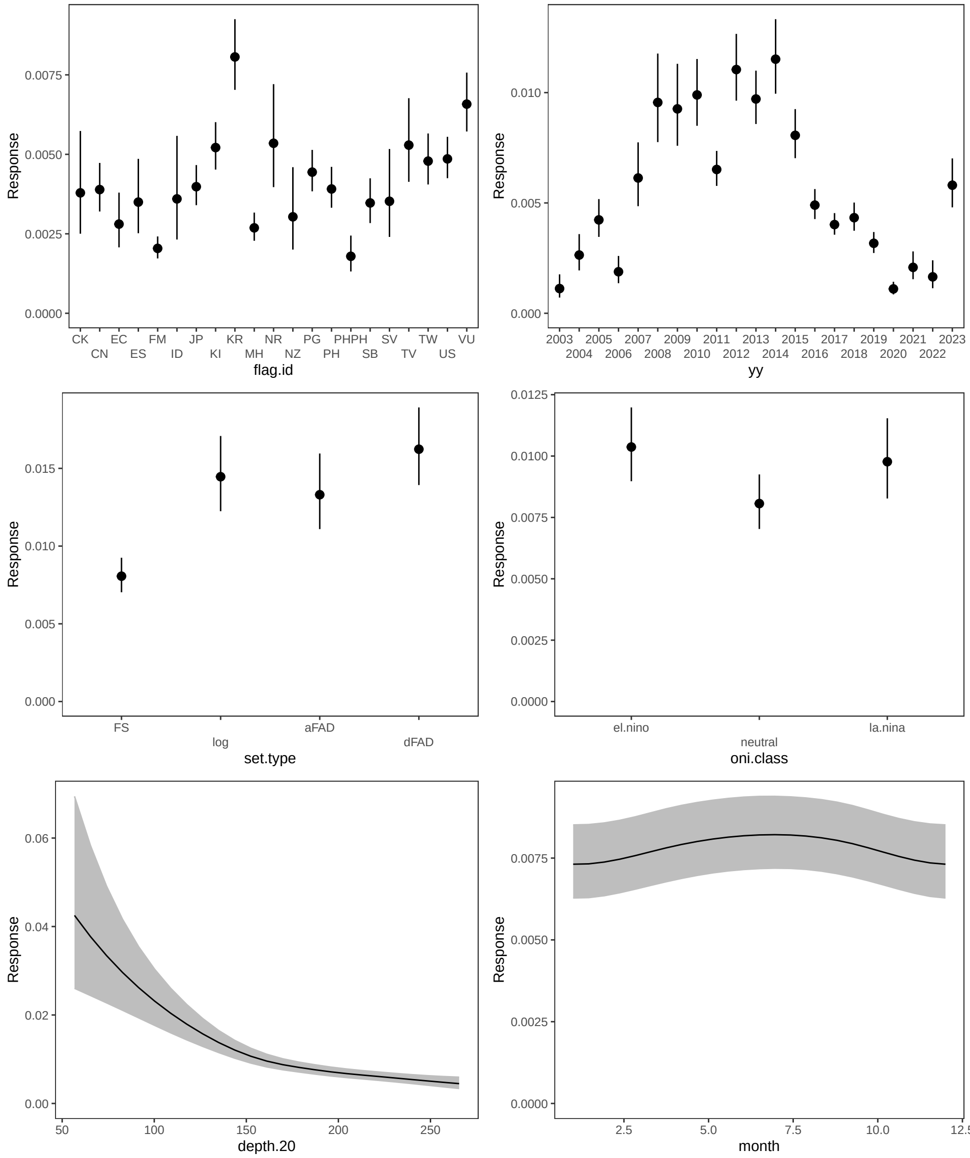


Figure B.81: Effects for the Pelagic stingray catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels' (year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the $20°$C isotherm = 180m, latitude = $175°$E, longitude = $2.5°$S). See Figure B.82 for spatial effects.

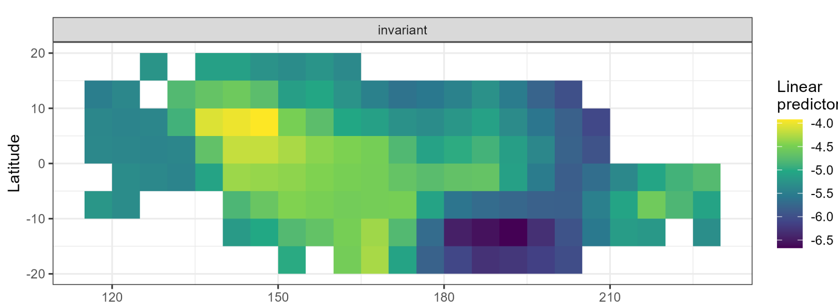


Figure B.82: Combined spatial effect for the Pelagic stingray catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.81).

Elasmobranchs (Elasmobranchii)

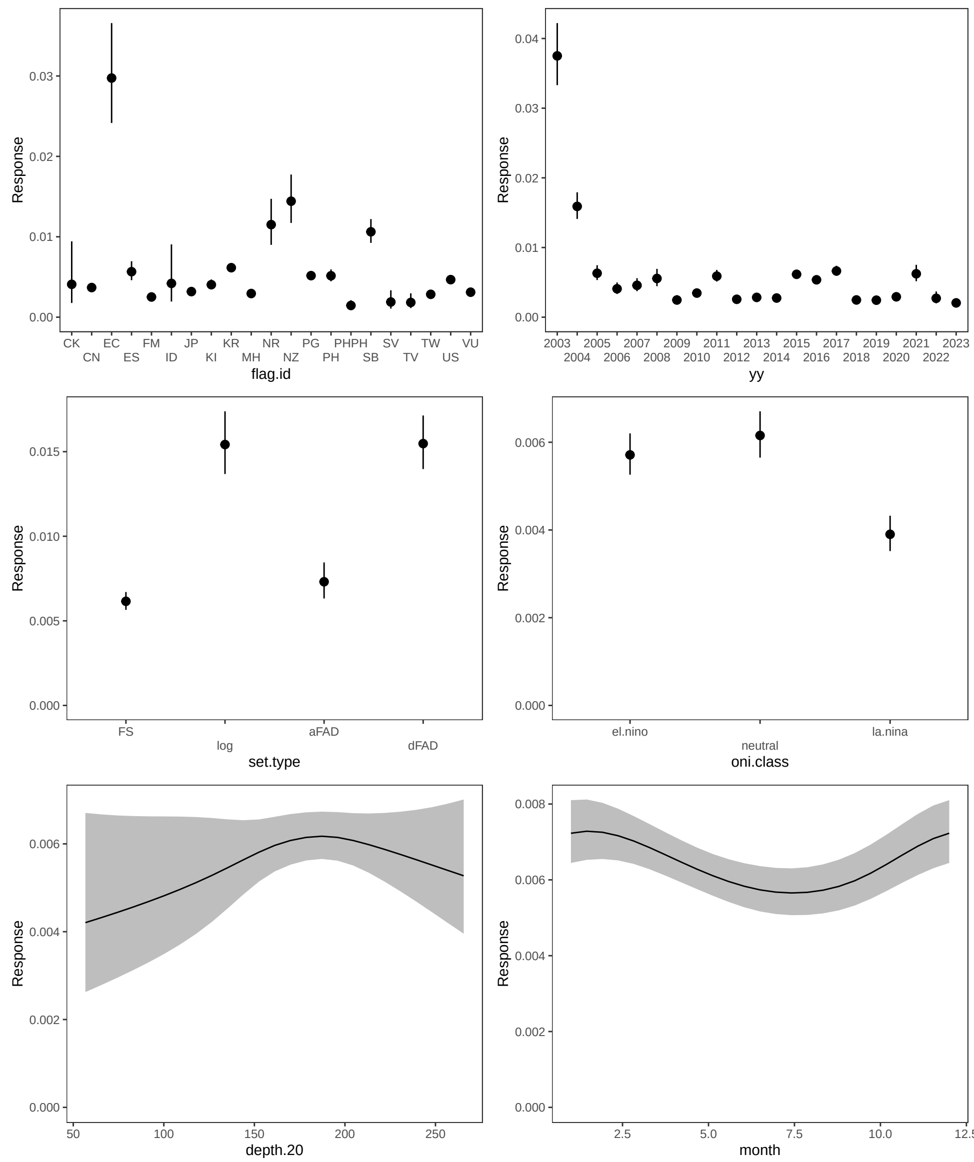


Figure B.83: Effects for the delta component of the Elasmobranchs catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels': year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the $20°$C isotherm = 180m, latitude = $175°$E, longitude = $2.5°$S. See Figure B.85 for spatial effects.

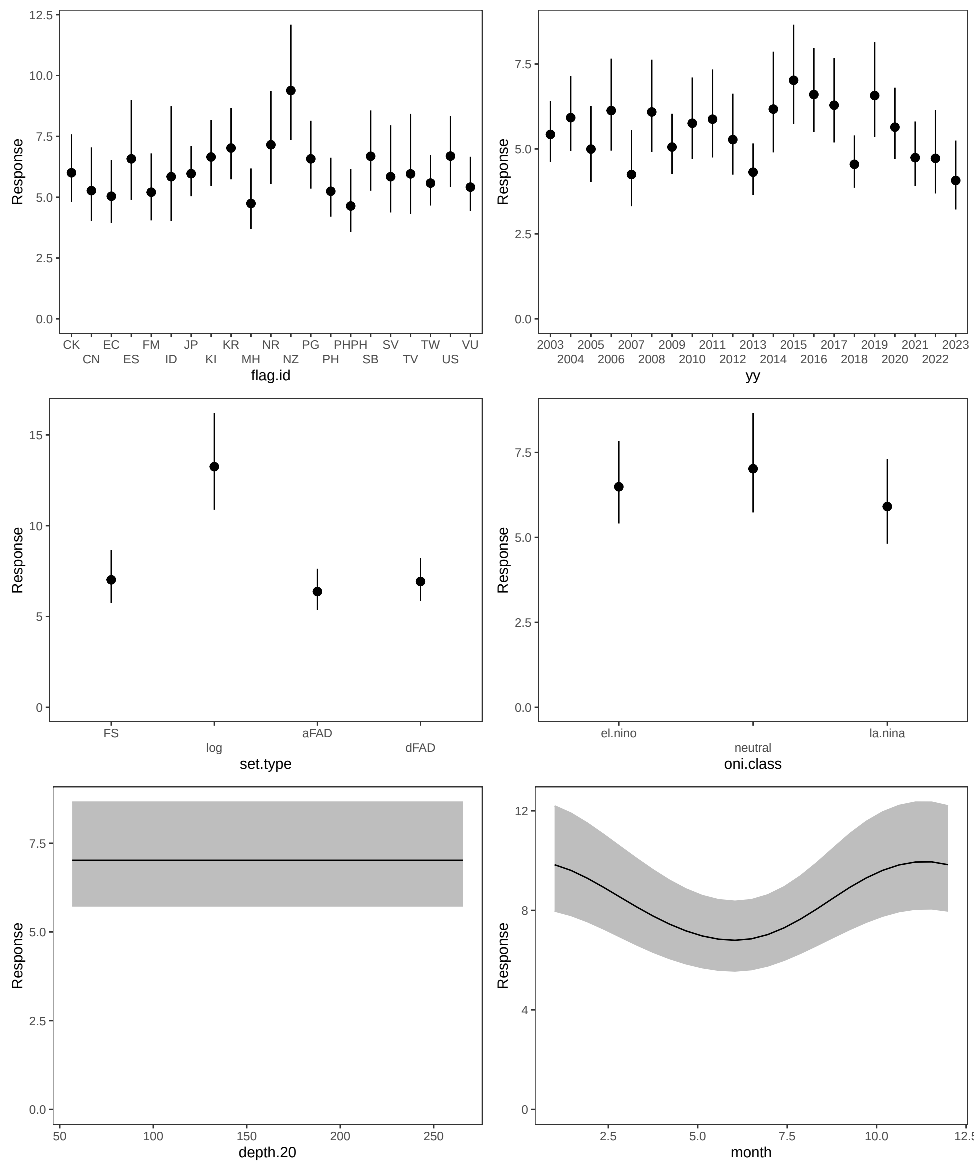


Figure B.84: Effects for the positives component of the Elasmobranchs catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the remaining explanatory variables held constant at reference levels (see caption of Figure B.83). See Figure B.85 for spatial effects.

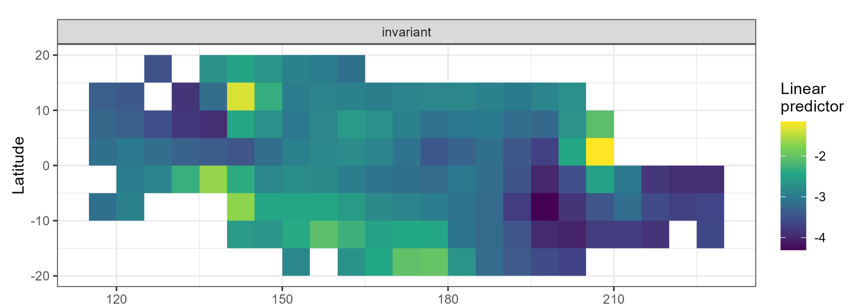


Figure B.85: Combined spatial effect for the delta and positives components of the Elasmobranchs catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.83).

Mako sharks (*Isurus* spp)

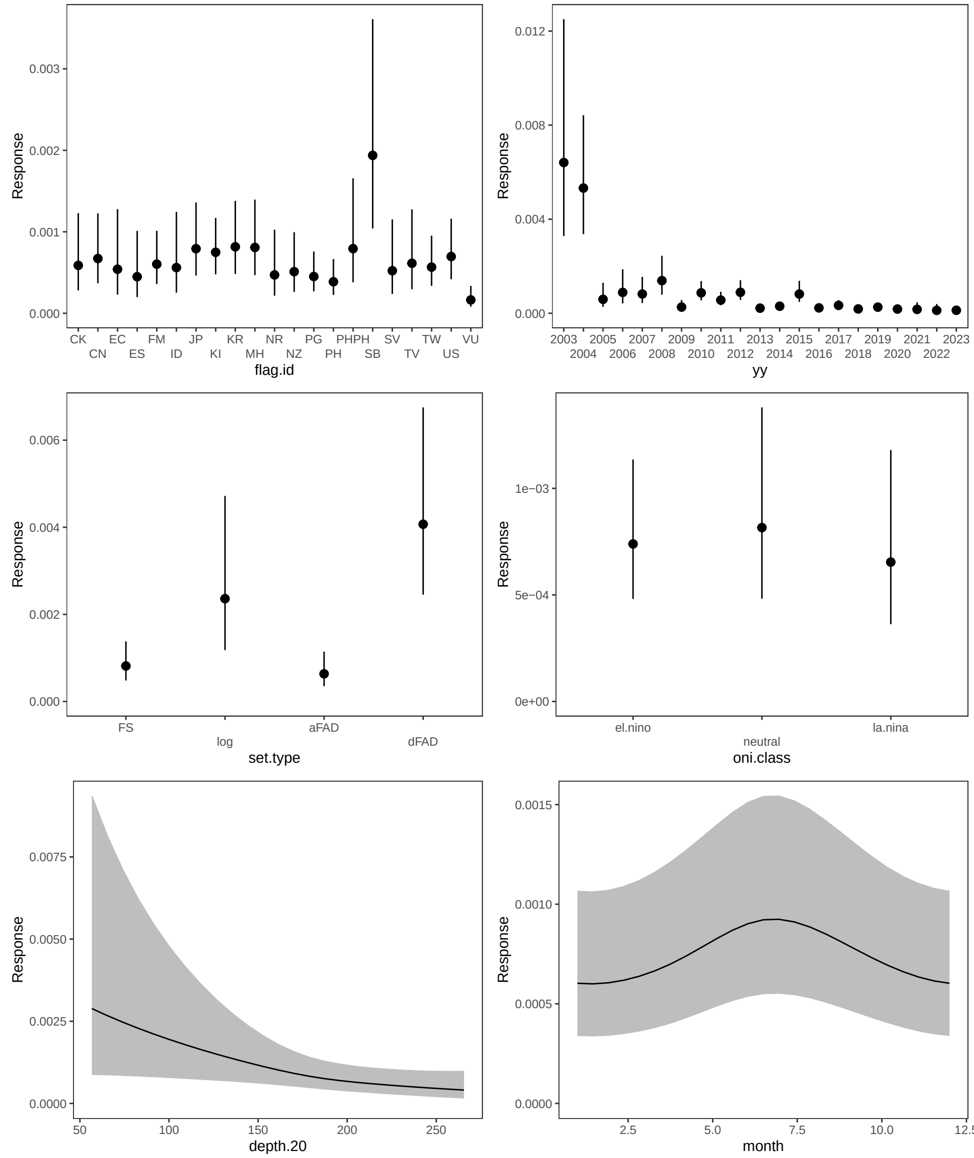


Figure B.86: Effects for the Mako sharks catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels' (year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the 20°C isotherm = 180m, latitude = 175°E, longitude = 2.5°S). See Figure B.87 for spatial effects.

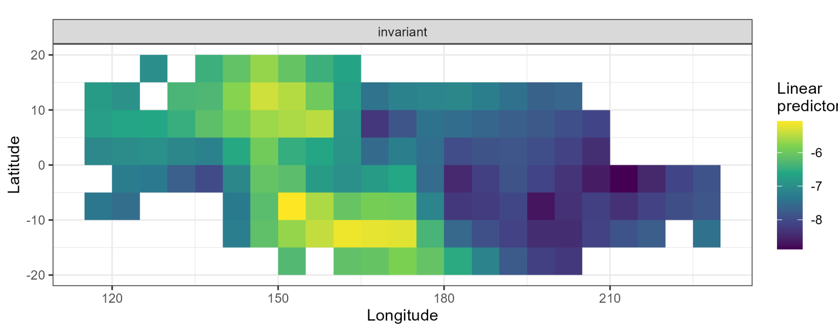


Figure B.87: Combined spatial effect for the Mako sharks catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.86).

Mobulid rays (*Mobulidae*)

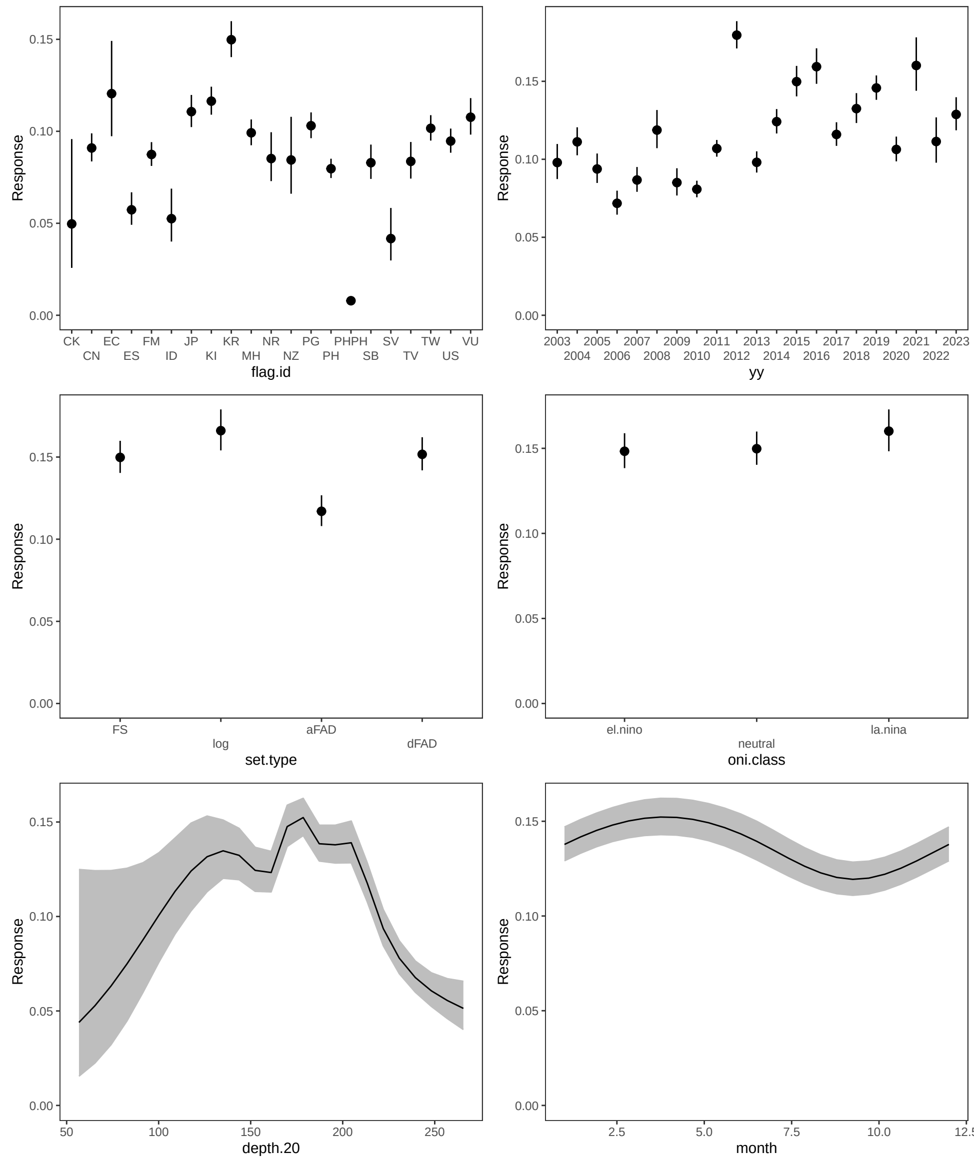


Figure B.88: Effects for the Mobulid rays catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels' (year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the 20°C isotherm = 180m, latitude = 175°E, longitude = 2.5°S). See Figure B.89 for spatial effects.

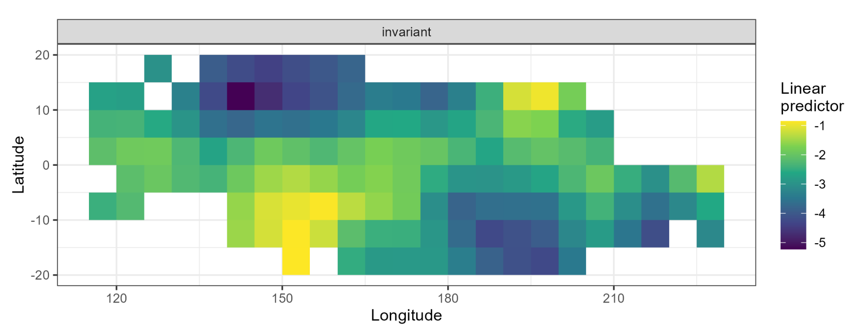


Figure B.89: Combined spatial effect for the Mobulid rays catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.88).

Blue shark (*Prionace glauca*)

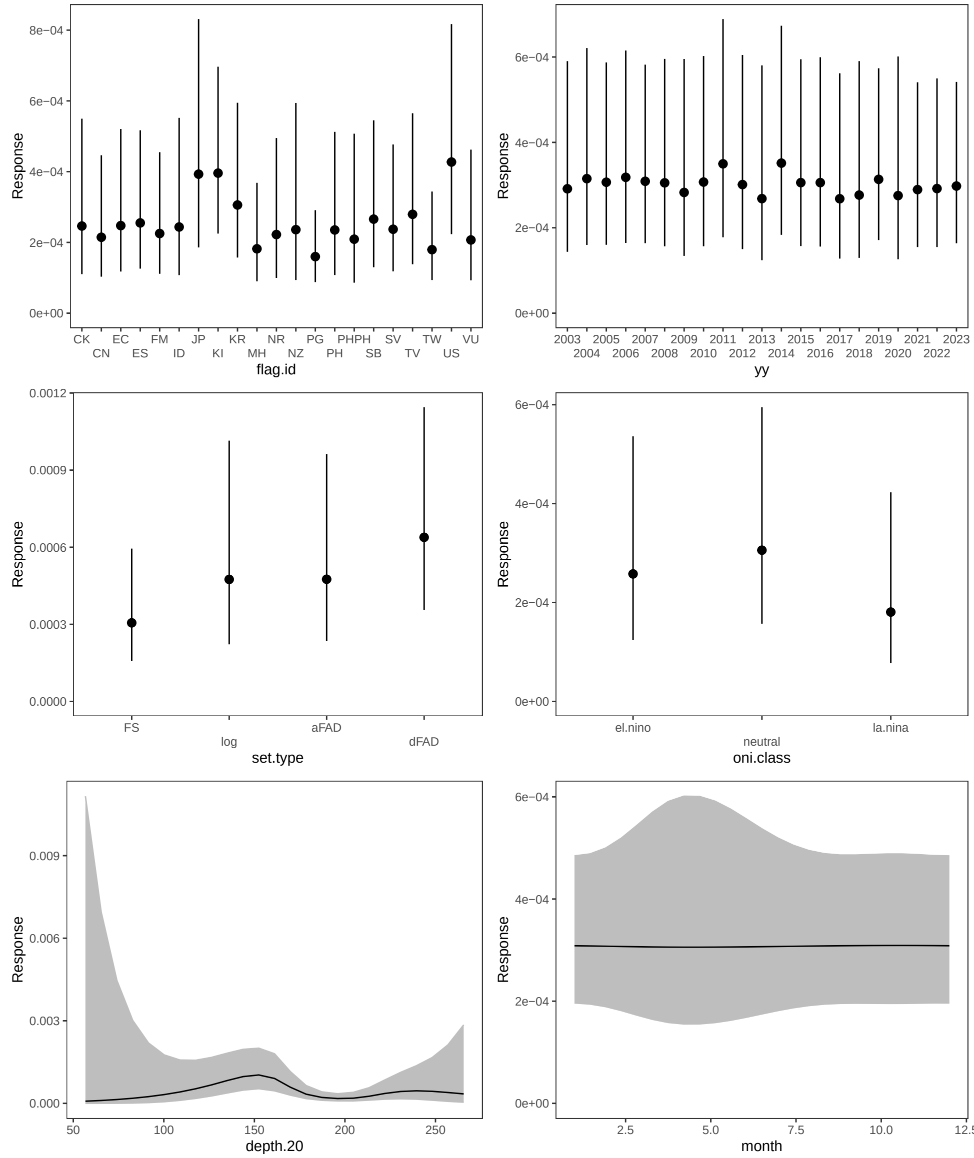


Figure B.90: Effects for the Blue shark catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels' (year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the $20°$C isotherm = 180m, latitude = $175°$E, longitude = $2.5°$S). See Figure B.91 for spatial effects.

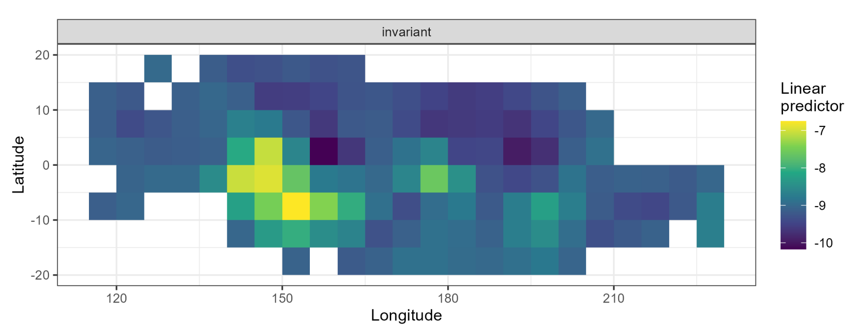


Figure B.91: Combined spatial effect for the Blue shark catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.90).

Whale shark (*Rhincodon typus*)

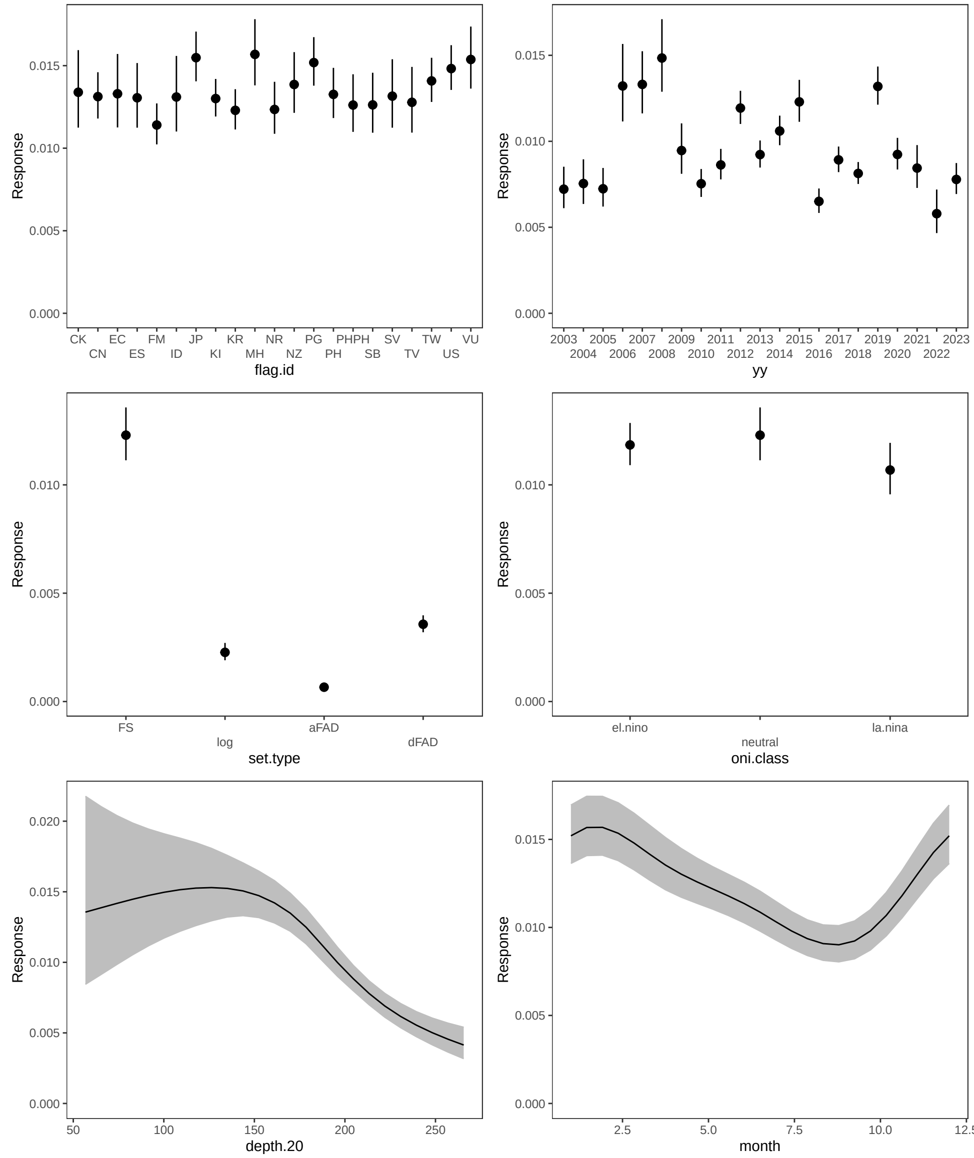


Figure B.92: Effects for the Whale shark catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels' (year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the 20°C isotherm = 180m, latitude = 175°E, longitude = 2.5°S). See Figure B.93 for spatial effects.

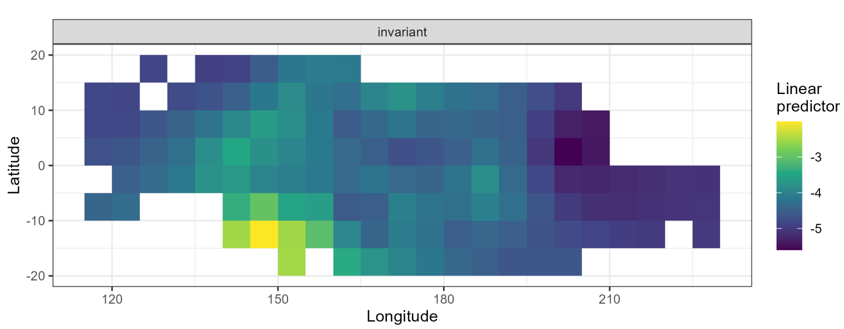


Figure B.93: Combined spatial effect for the Whale shark catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.92).

Hammerhead sharks (*Sphyrnidae*)

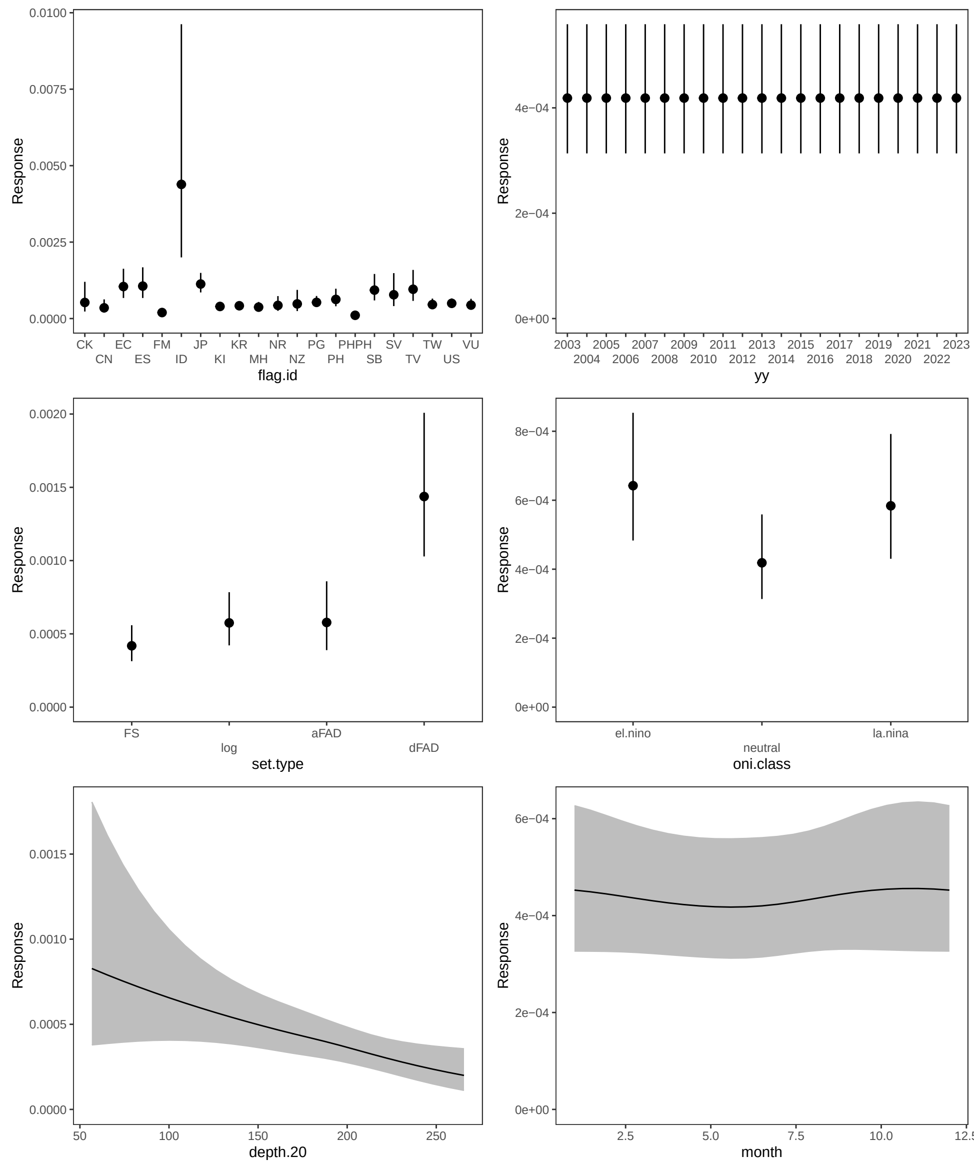


Figure B.94: Effects for the Hammerhead sharks catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels' (year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the $20°$C isotherm = 180m, latitude = $175°$E, longitude = $2.5°$S). See Figure B.95 for spatial effects.

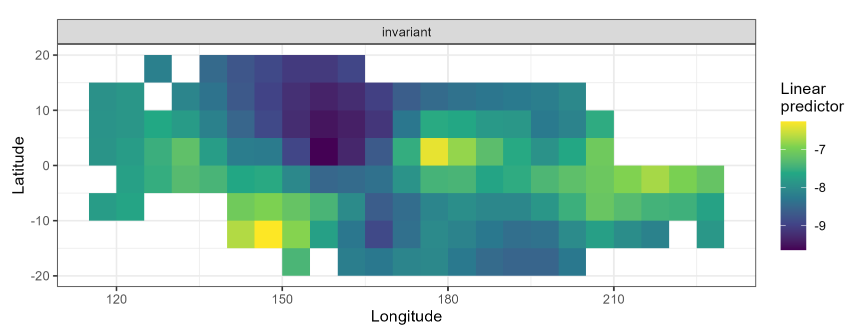


Figure B.95: Combined spatial effect for the Hammerhead sharks catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.94).

B.4 Sea turtles - catch rate models

Loggerhead turtle (*Caretta caretta*)

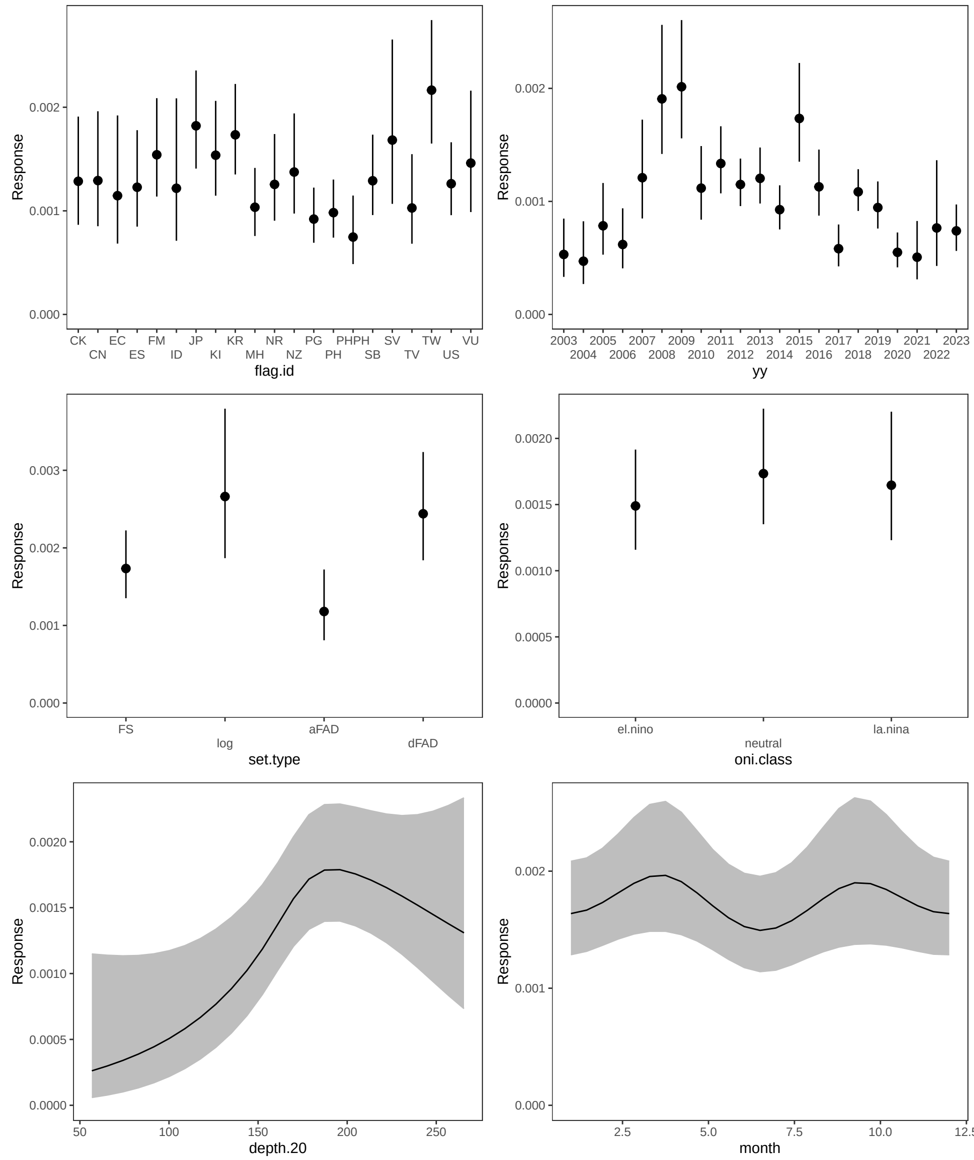


Figure B.96: Effects for the Loggerhead turtle catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels' (year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the $20°$C isotherm = 180m, latitude = $175°$E, longitude = $2.5°$S). See Figure B.97 for spatial effects.

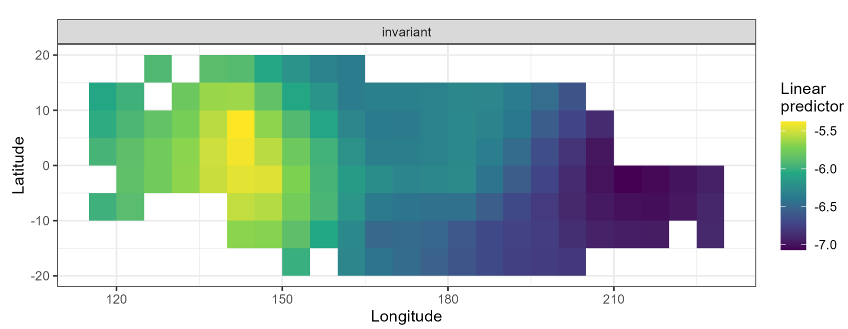


Figure B.97: Combined spatial effect for the Loggerhead turtle catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.96).

Green turtle (*Chelonia mydas*)

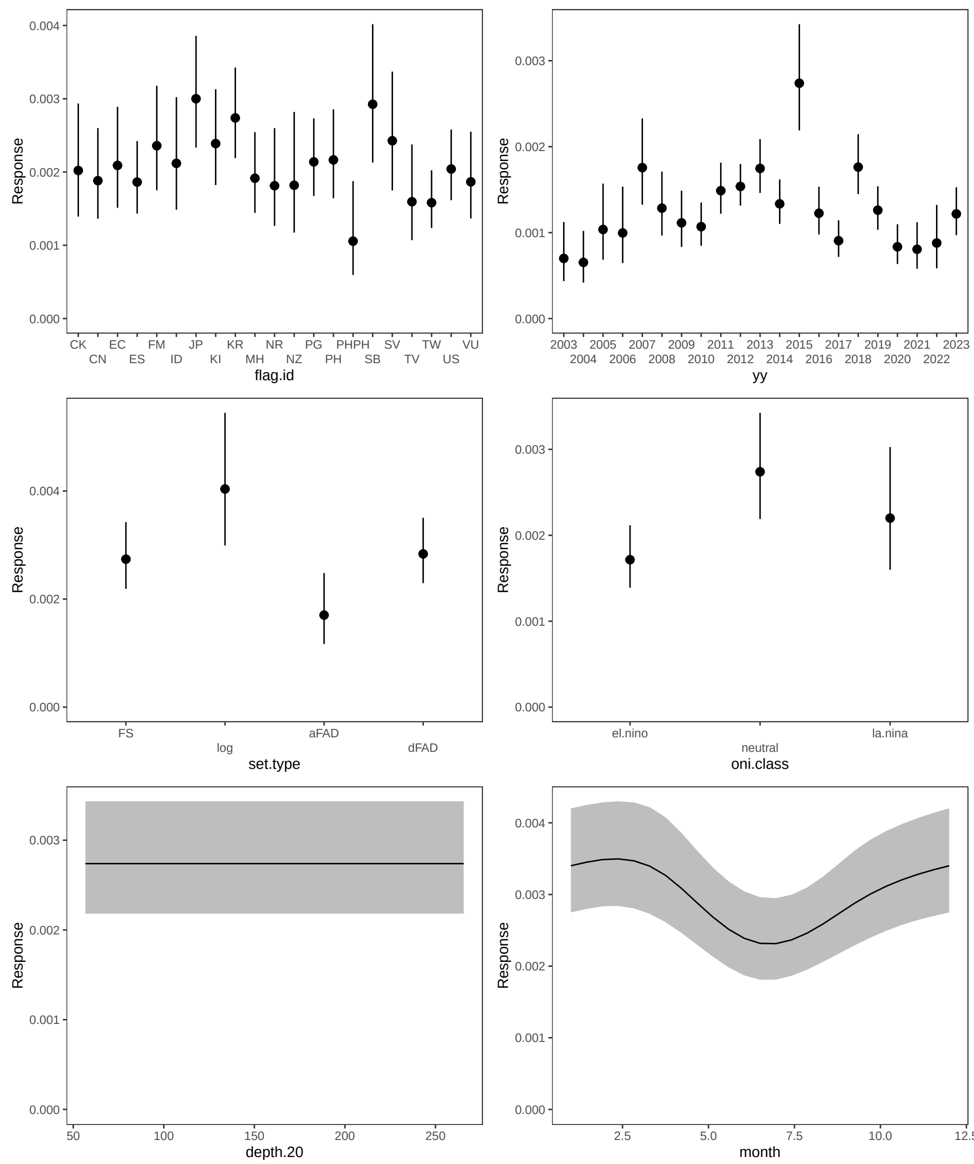


Figure B.98: Effects for the Green turtle catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels' (year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the $20°$C isotherm = 180m, latitude = $175°$E, longitude = $2.5°$S). See Figure B.99 for spatial effects.

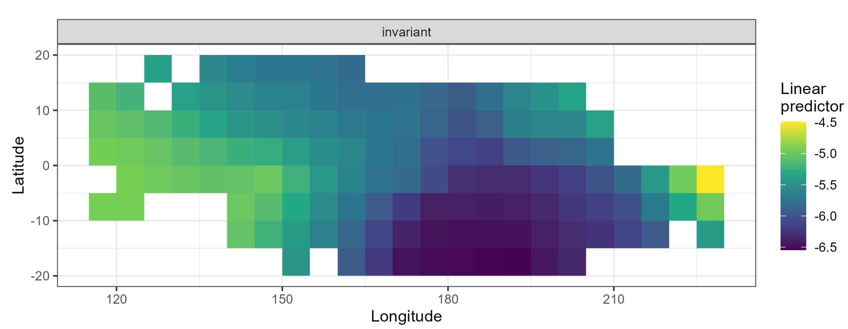


Figure B.99: Combined spatial effect for the Green turtle catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.98).

Sea turtles (*Chelonioidea*)

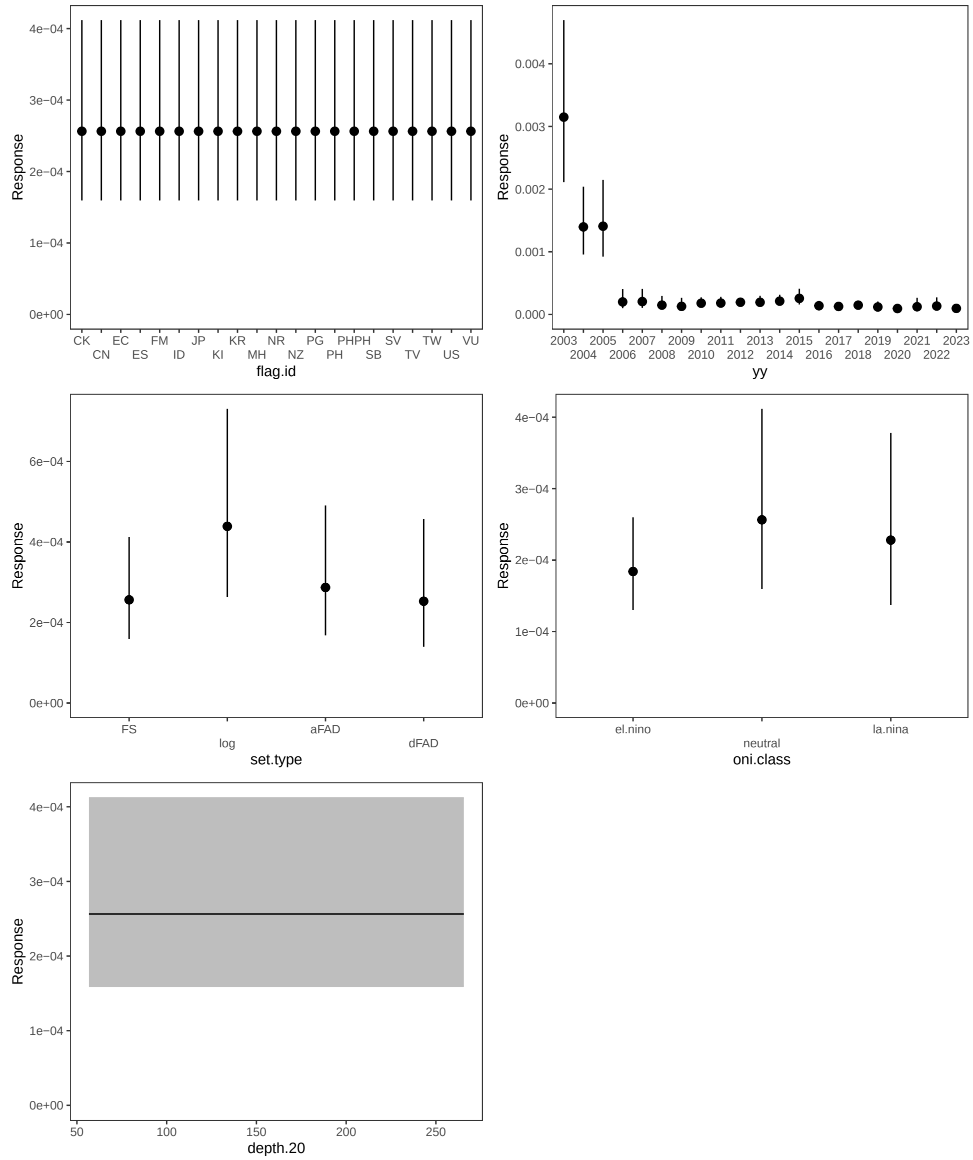


Figure B.100: Effects for the Sea turtles catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels' (year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the 20°C isotherm = 180m, latitude = 175°E, longitude = 2.5°S). See Figure B.101 for spatial effects.

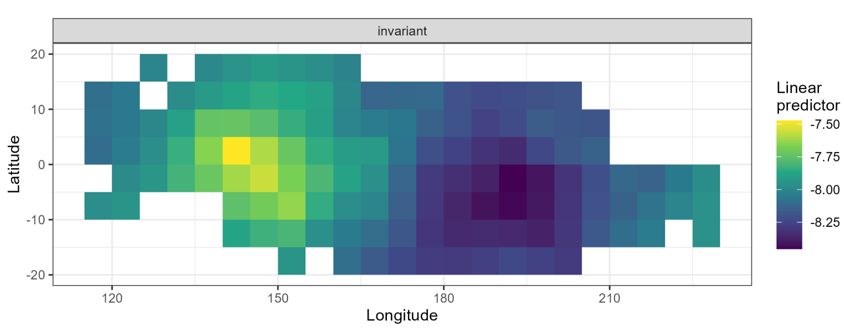


Figure B.101: Combined spatial effect for the Sea turtles catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.100).

Leatherback turtle (*Dermochelys coriacea*)

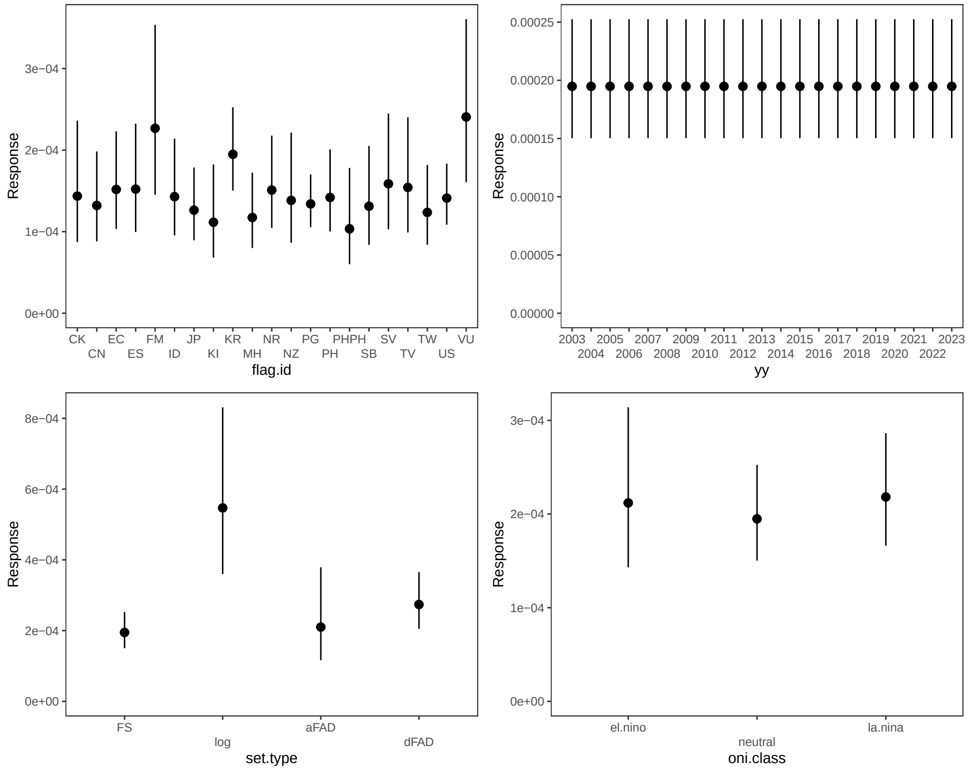


Figure B.102: Effects for the Leatherback turtle catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels' (year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the 20°C isotherm = 180m, latitude = 175°E, longitude = 2.5°S). See Figure B.103 for spatial effects.

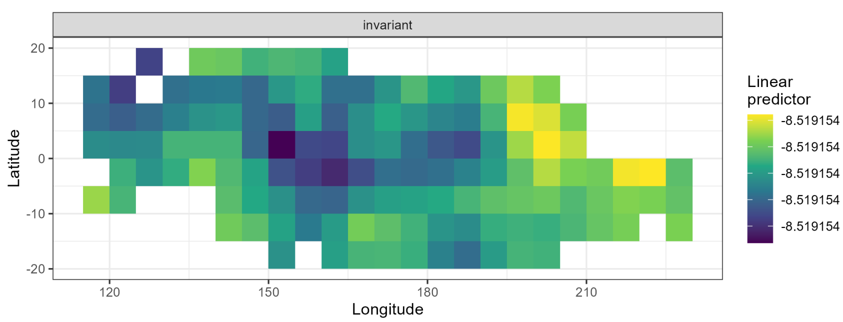


Figure B.103: Combined spatial effect for the Leatherback turtle catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.102).

Hawksbill turtle (*Eretmochelys imbricata*)

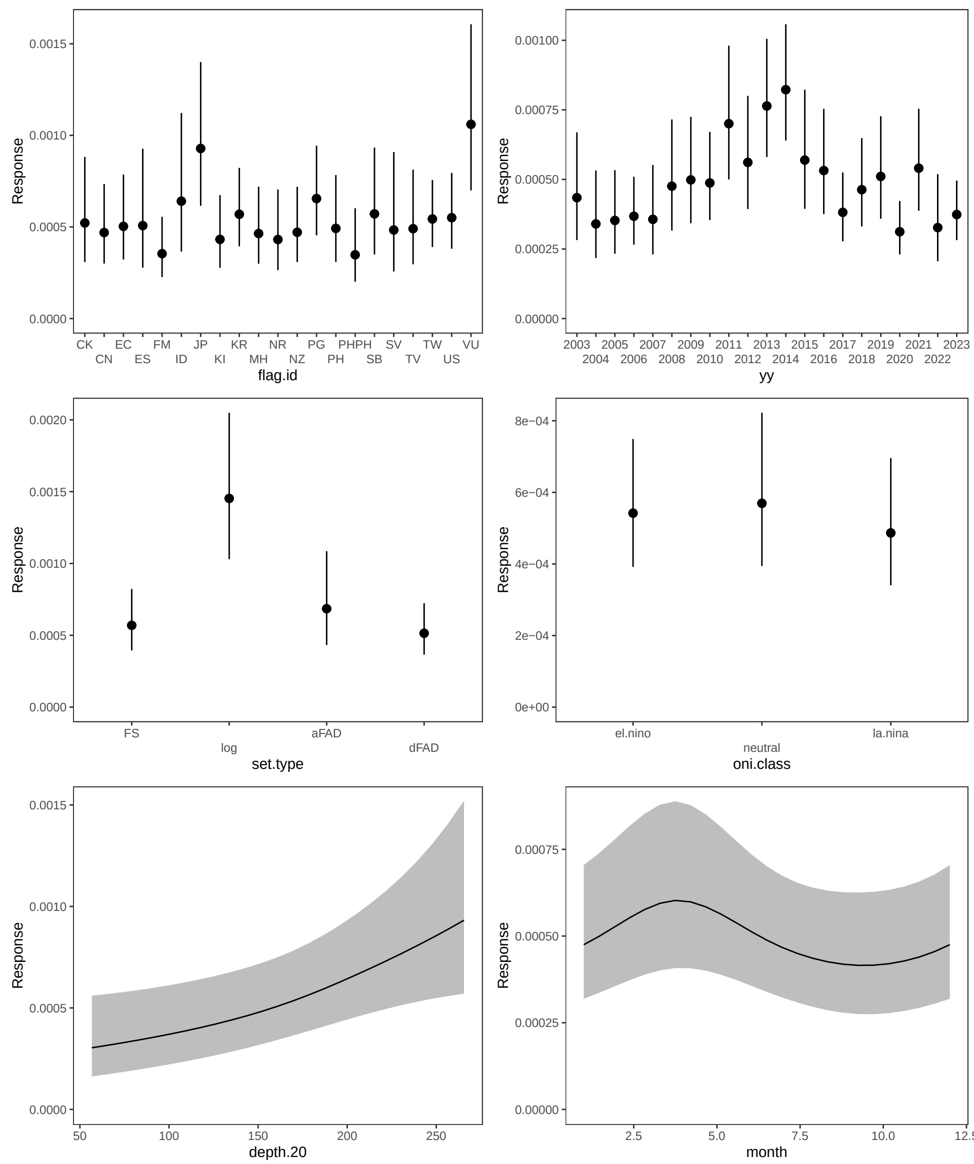


Figure B.104: Effects for the Hawksbill turtle catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels' (year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the 20°C isotherm = 180m, latitude = 175°E, longitude = 2.5°S). See Figure B.105 for spatial effects.

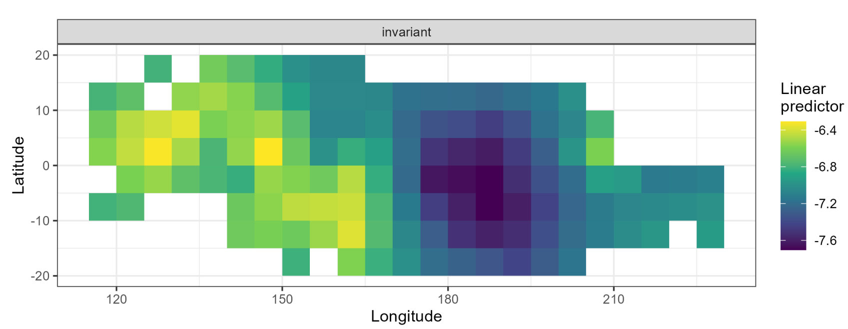


Figure B.105: Combined spatial effect for the Hawksbill turtle catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.104).

Olive ridley turtle (*Lepidochelys olivacea*)

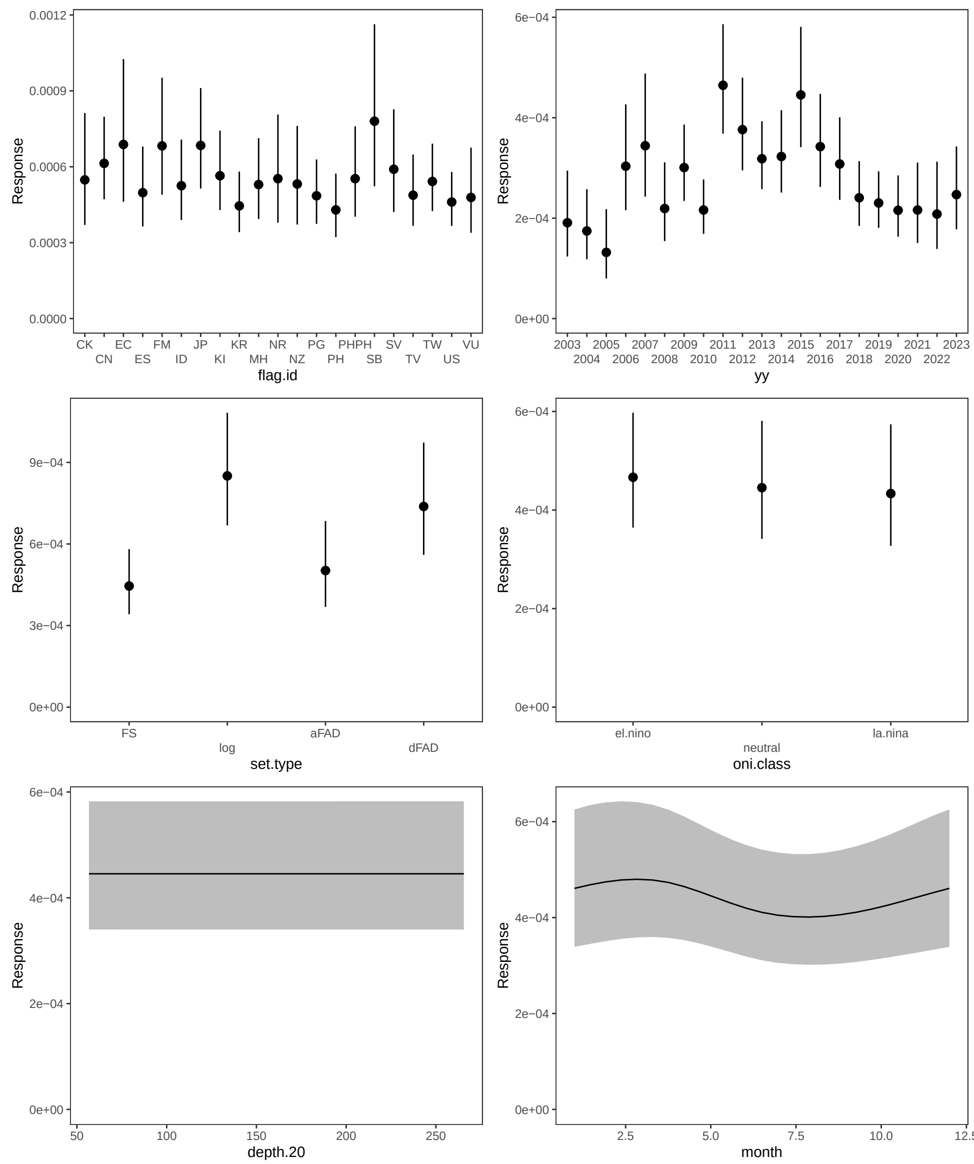


Figure B.106: Effects for the Olive ridley turtle catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels' (year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the $20°$C isotherm = 180m, latitude = $175°$E, longitude = $2.5°$S). See Figure B.107 for spatial effects.

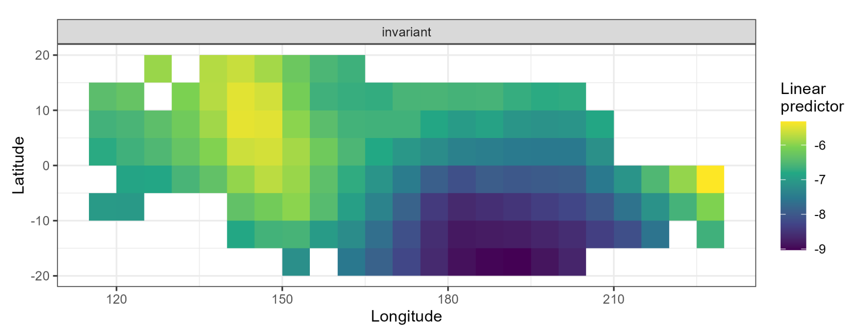


Figure B.107: Combined spatial effect for the Olive ridley turtle catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.106).

B.5 Marine mammals - catch rate models

‘Blackfish’ (‘Blackfish’)

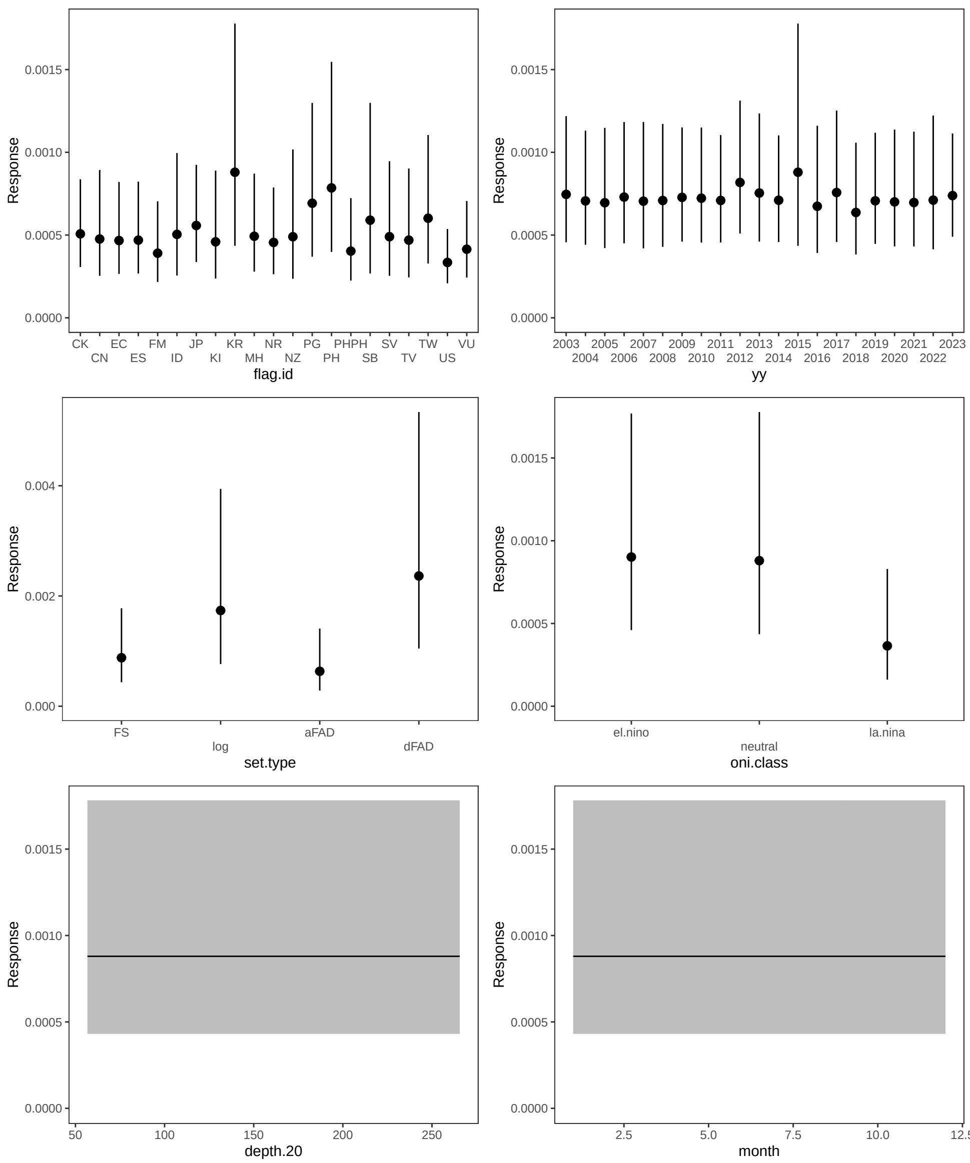


Figure B.108: Effects for the ‘Blackfish’ catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at ‘reference levels’ (year = 2015, month = 5, set-type = ‘FS’, flag = ‘KR’, ONI = ‘neutral’, depth of the 20°C isotherm = 180m, latitude = 175°E, longitude = 2.5°S). See Figure B.109 for spatial effects.

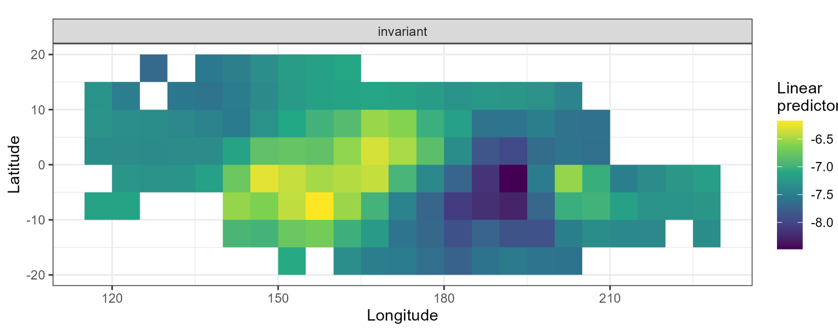


Figure B.109: Combined spatial effect for the ‘Blackfish’ catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.108).

Marine mammals (Cetacea & pinnipeds)

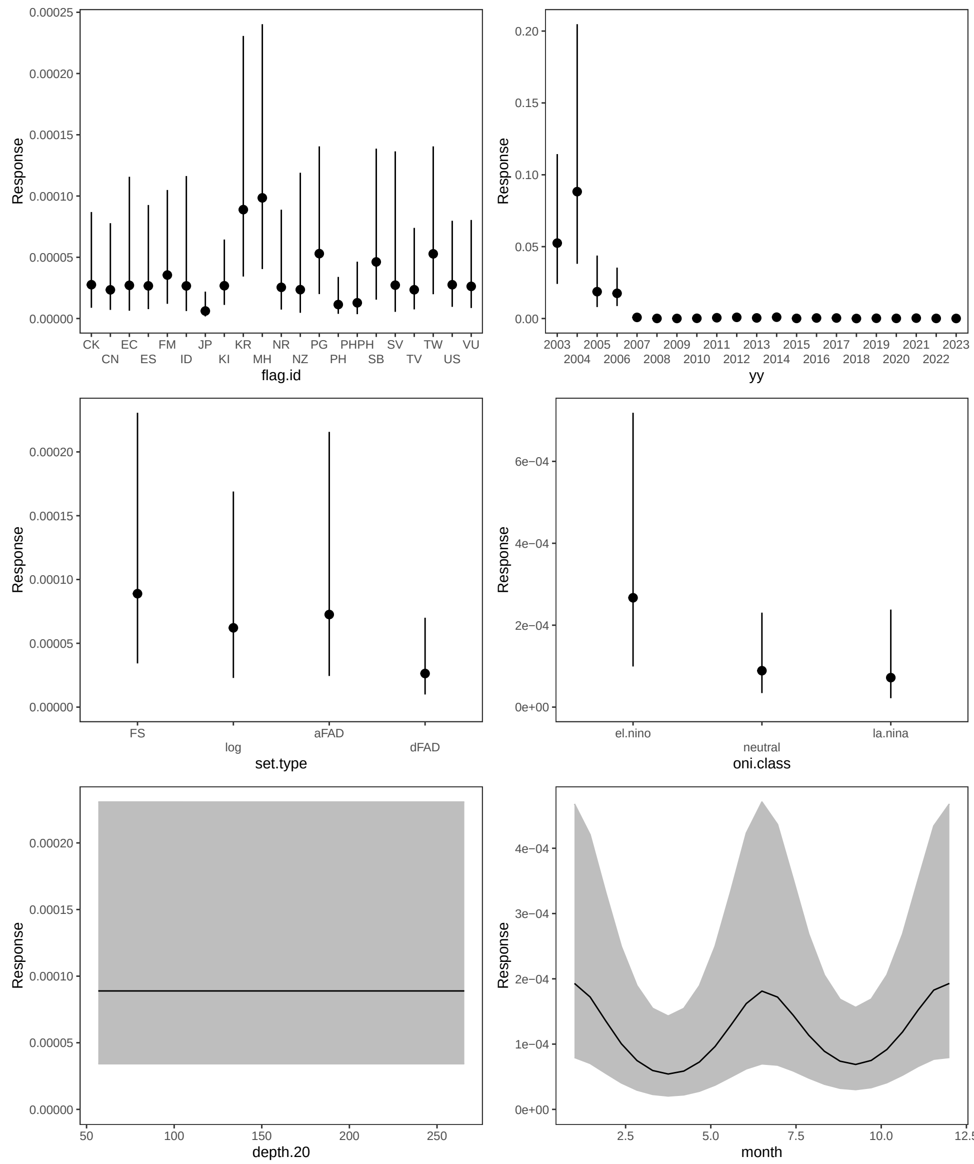


Figure B.110: Effects for the Marine mammals catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels' (year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the 20°C isotherm = 180m, latitude = 175°E, longitude = 2.5°S). See Figure B.111 for spatial effects.

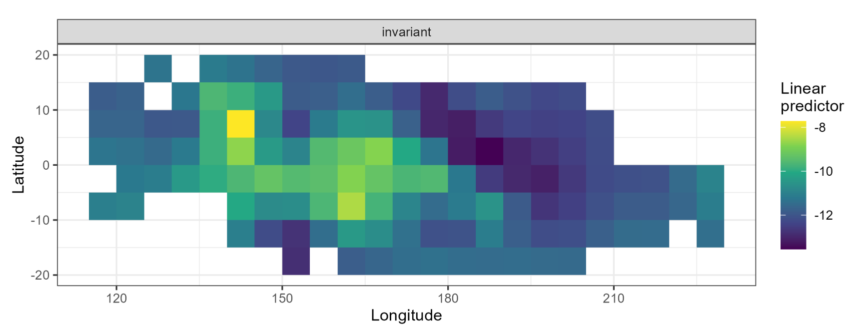


Figure B.111: Combined spatial effect for the Marine mammals catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.110).

Dolphins (Delphinidae)

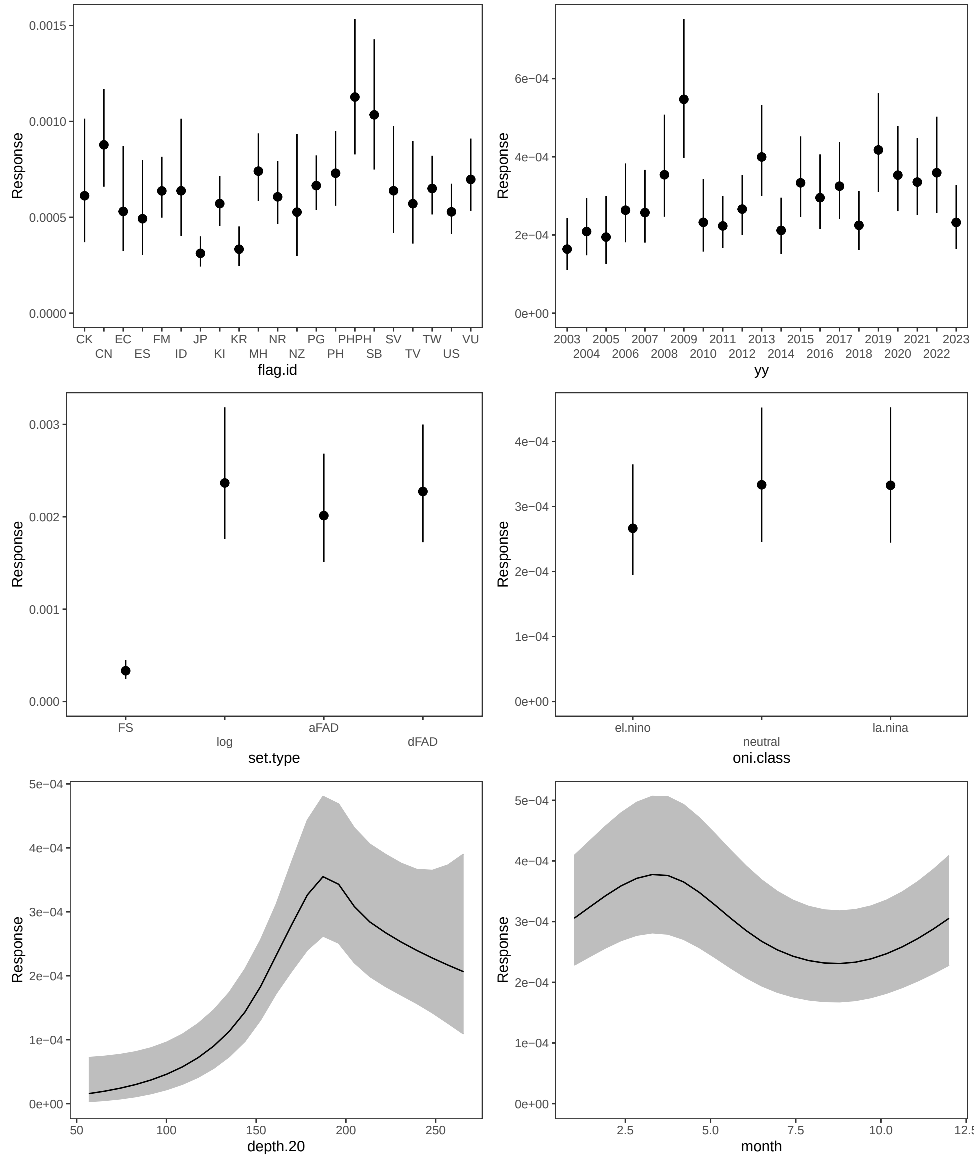


Figure B.112: Effects for the delta component of the Dolphins catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels': year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the $20°$C isotherm = 180m, latitude = $175°$E, longitude = $2.5°$S. See Figure B.114 for spatial effects.

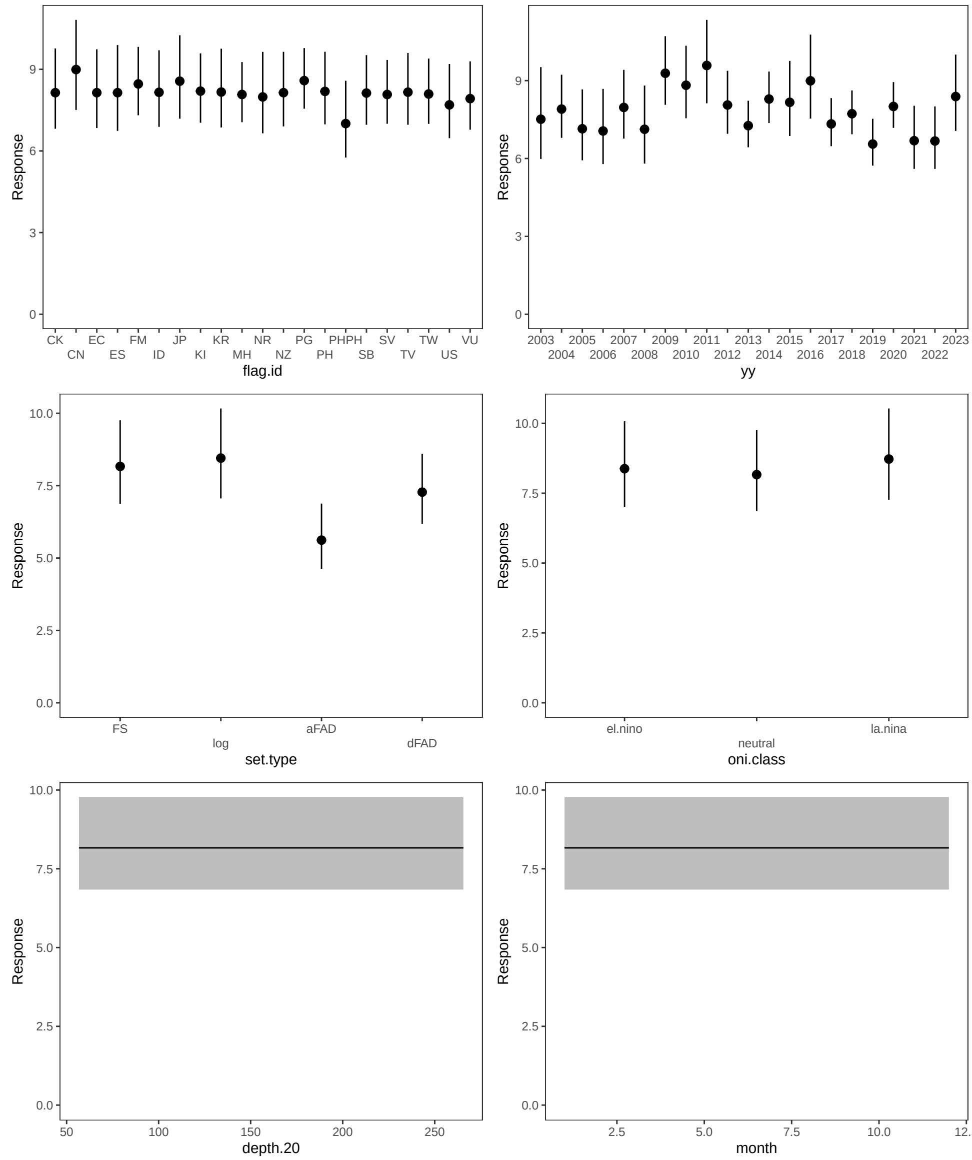


Figure B.113: Effects for the positives component of the Dolphins catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the remaining explanatory variables held constant at reference levels (see caption of Figure B.112). See Figure B.114 for spatial effects.

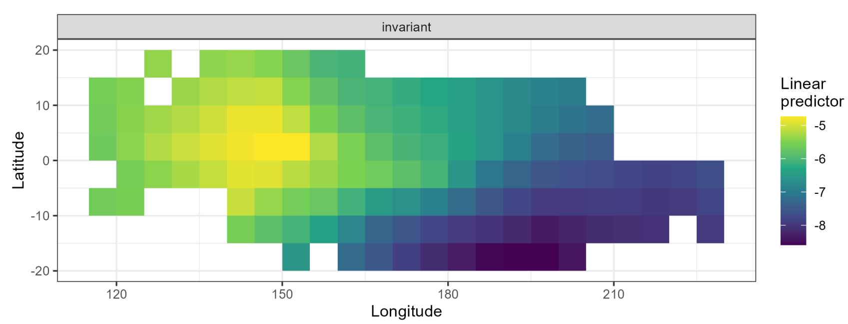


Figure B.114: Combined spatial effect for the delta and positives components of the Dolphins catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.112).

Short-finned pilot whale (*Globicephala macrorhynchus*)

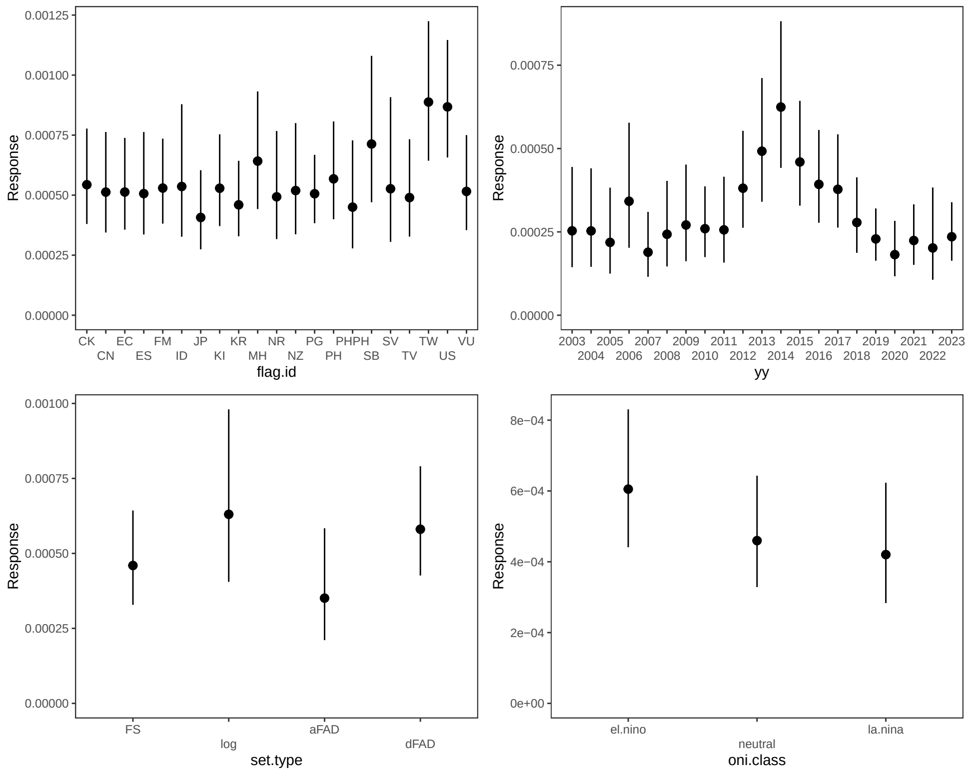


Figure B.115: Effects for the delta component of the Short-finned pilot whale catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels': year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the $20°$C isotherm = 180m, latitude = $175°$E, longitude = $2.5°$S. See Figure B.117 for spatial effects.

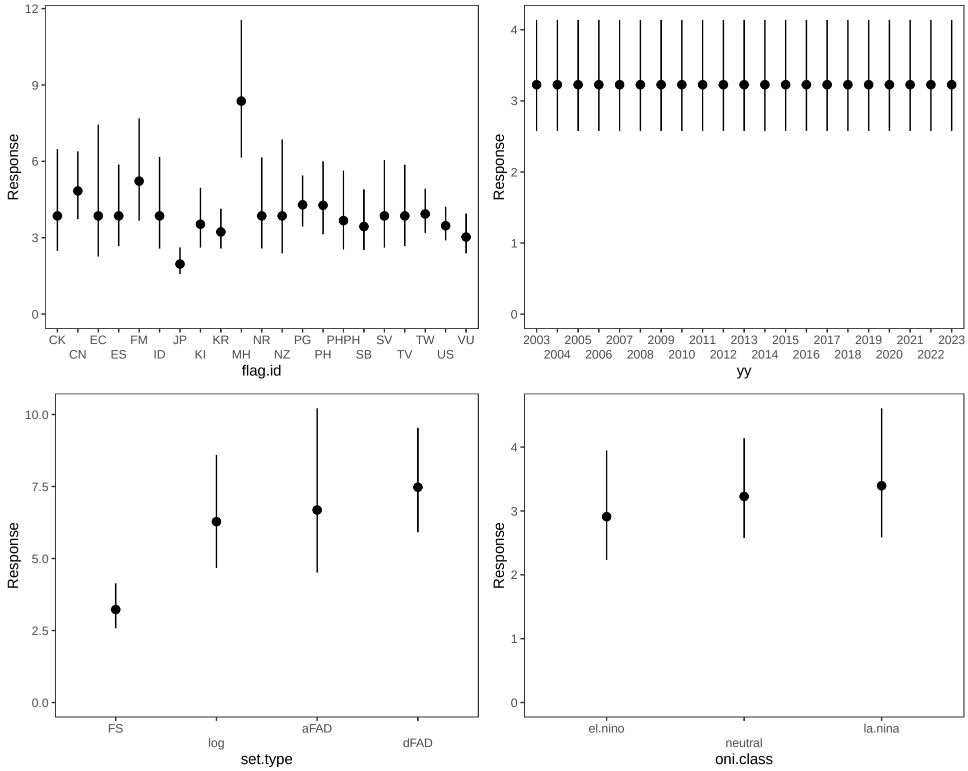


Figure B.116: Effects for the positives component of the Short-finned pilot whale catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the remaining explanatory variables held constant at reference levels (see caption of Figure B.115). See Figure B.117 for spatial effects.

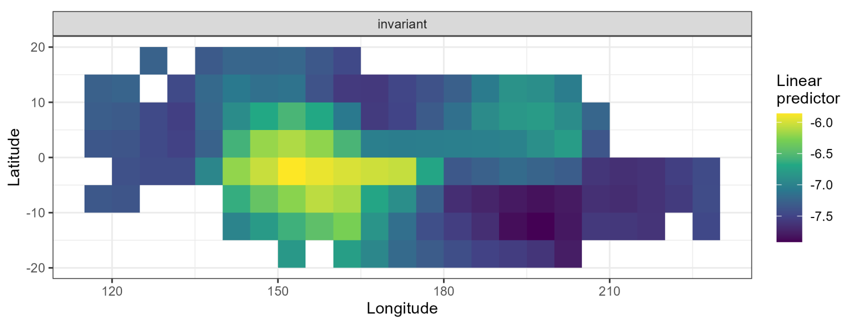


Figure B.117: Combined spatial effect for the delta and positives components of the Short-finned pilot whale catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.115).

Risso's dolphin (*Grampus griseus*)

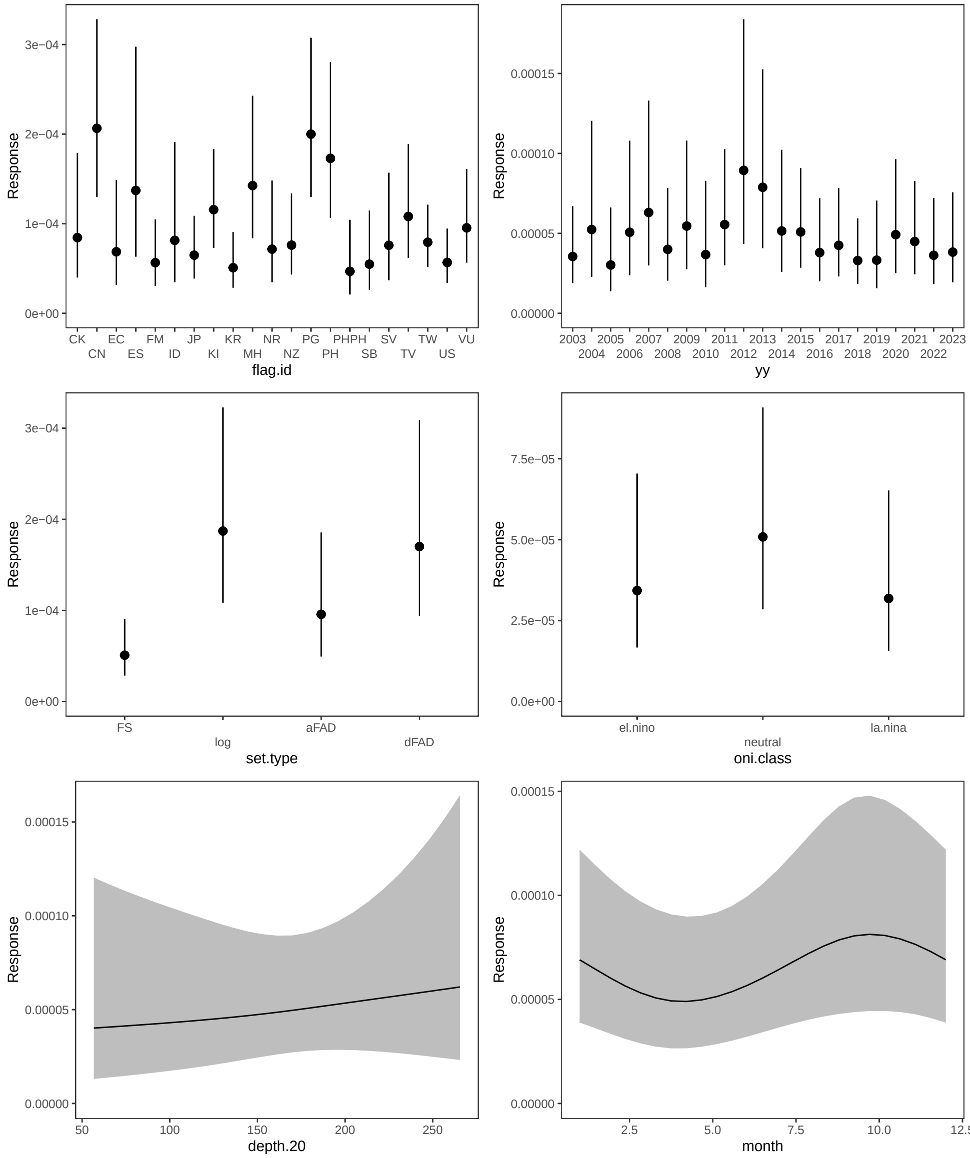


Figure B.118: Effects for the delta component of the Risso's dolphin catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels': year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the $20°$C isotherm = 180m, latitude = $175°$E, longitude = $2.5°$S. See Figure B.120 for spatial effects.

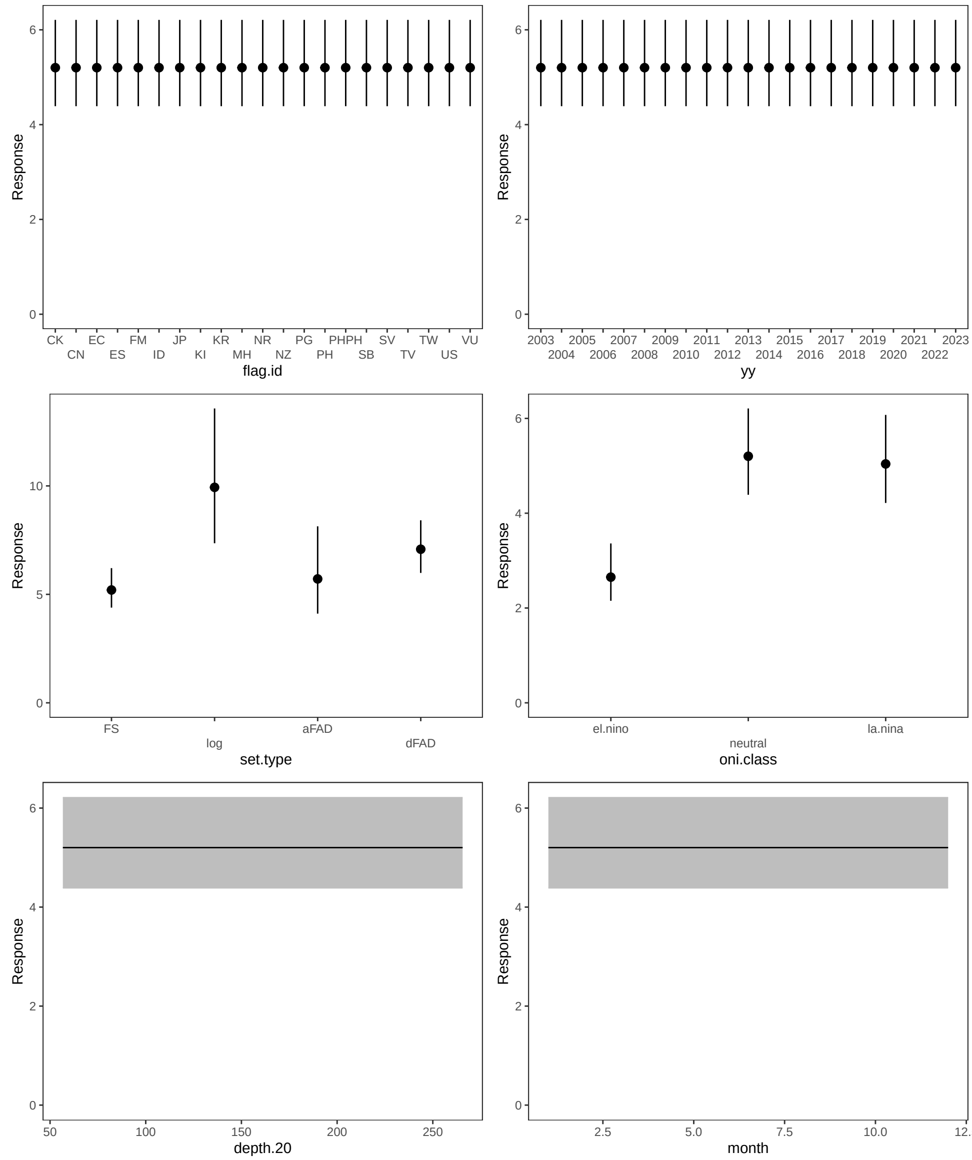


Figure B.119: Effects for the positives component of the Risso's dolphin catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the remaining explanatory variables held constant at reference levels (see caption of Figure B.118). See Figure B.120 for spatial effects.

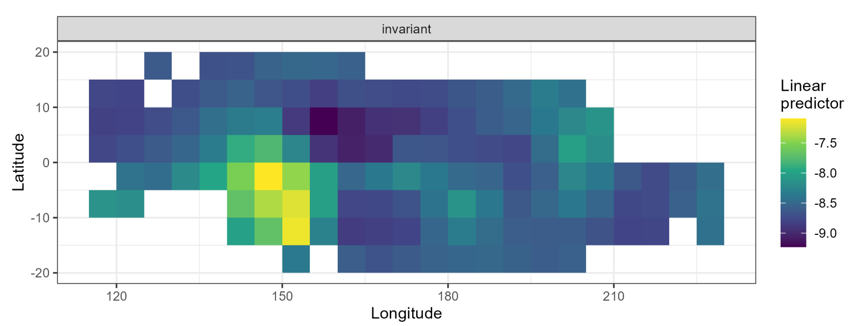


Figure B.120: Combined spatial effect for the delta and positives components of the Risso's dolphin catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.118).

Baleen whales (Mysticeti)

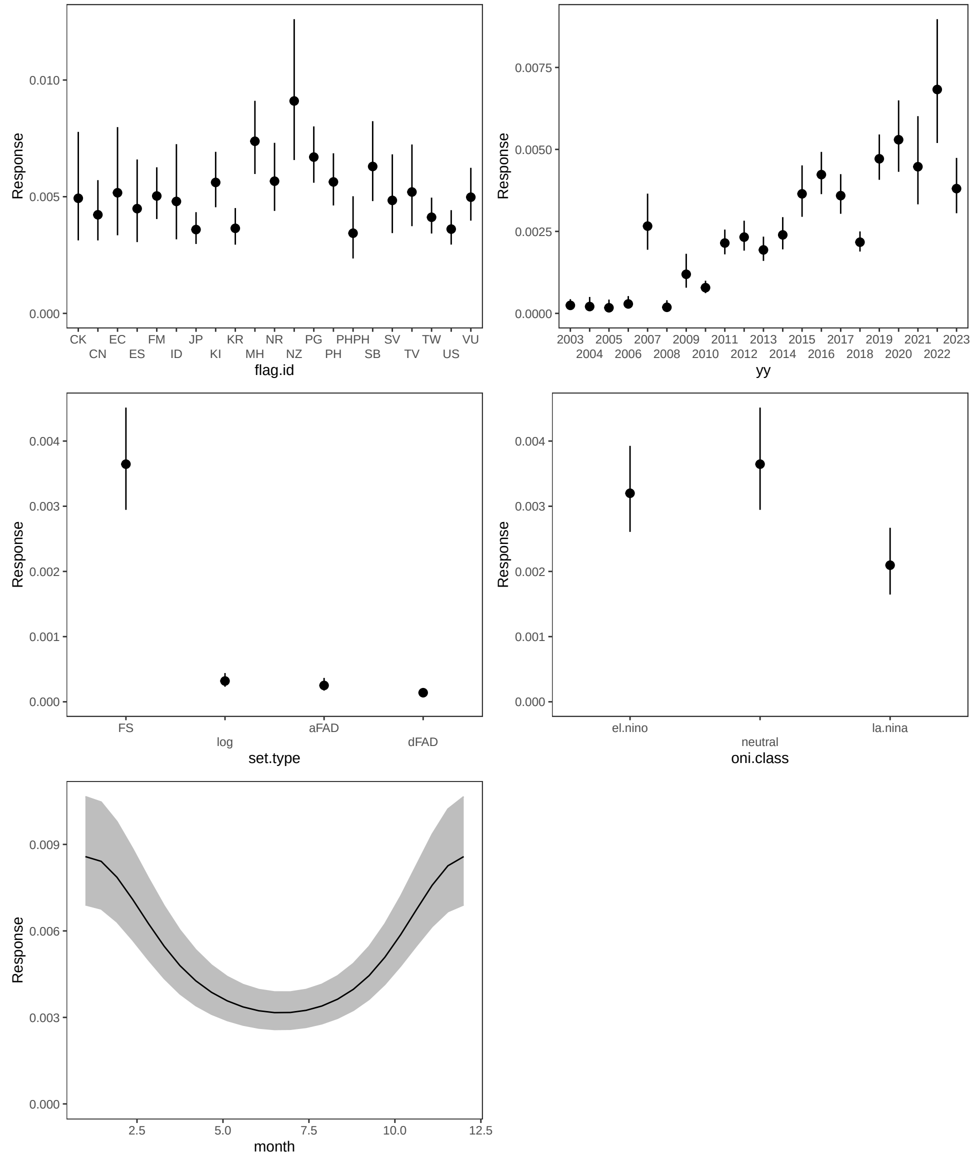


Figure B.121: Effects for the Baleen whales catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at ‘reference levels’ (year = 2015, month = 5, set-type = ‘FS’, flag = ‘KR’, ONI = ‘neutral’, depth of the $20°$C isotherm = 180m, latitude = $175°$E, longitude = $2.5°$S). See Figure B.122 for spatial effects.

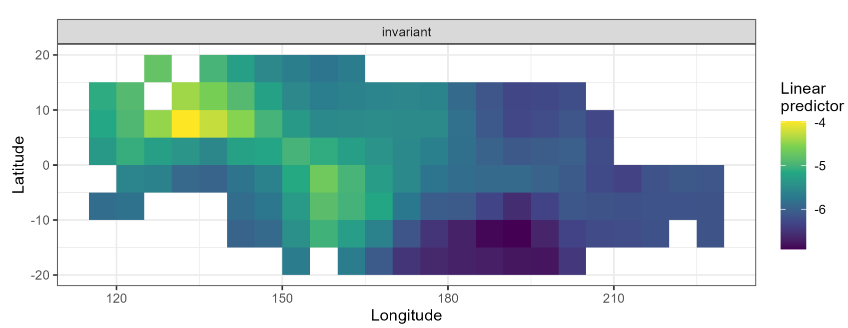


Figure B.122: Combined spatial effect for the Baleen whales catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.121).

Toothed whales (Odontoceti)

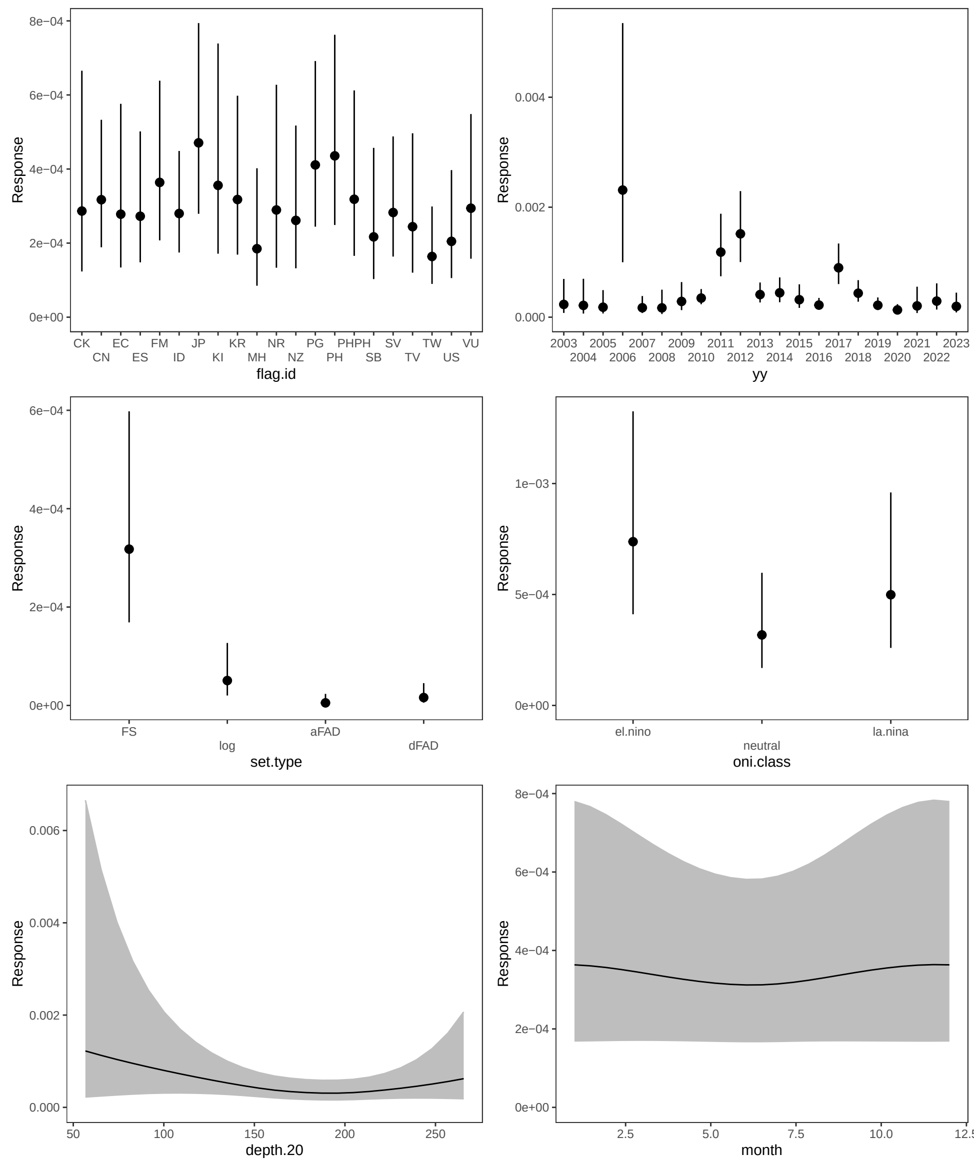


Figure B.123: Effects for the Toothed whales catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels' (year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the $20°$C isotherm = 180m, latitude = $175°$E, longitude = $2.5°$S). See Figure B.124 for spatial effects.

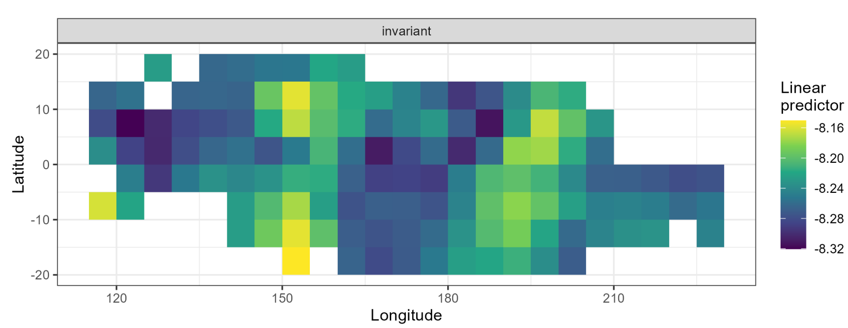


Figure B.124: Combined spatial effect for the Toothed whales catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.123).

False killer whale (*Pseudorca crassidens*)

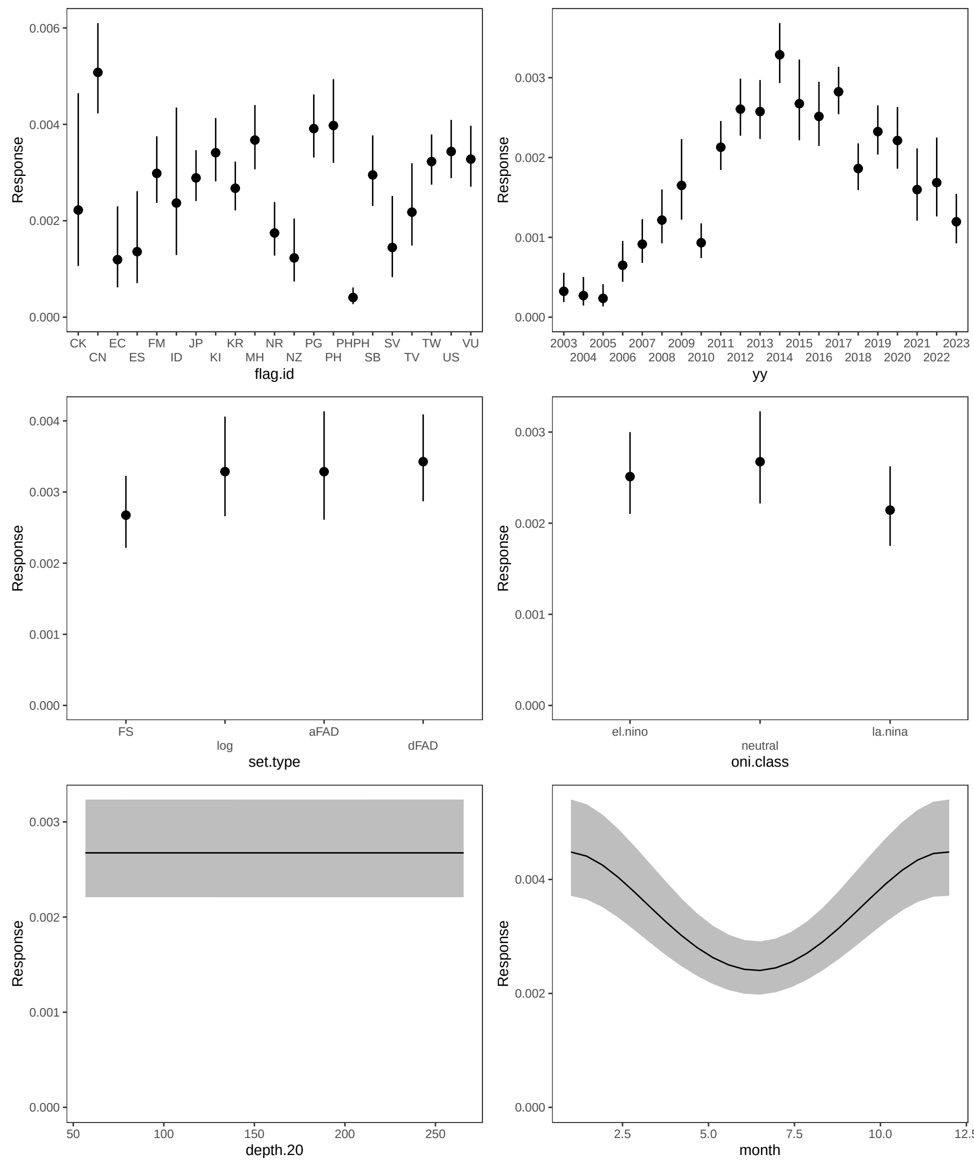


Figure B.125: Effects for the delta component of the False killer whale catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels': year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the $20°$C isotherm = 180m, latitude = $175°$E, longitude = $2.5°$S. See Figure B.127 for spatial effects.

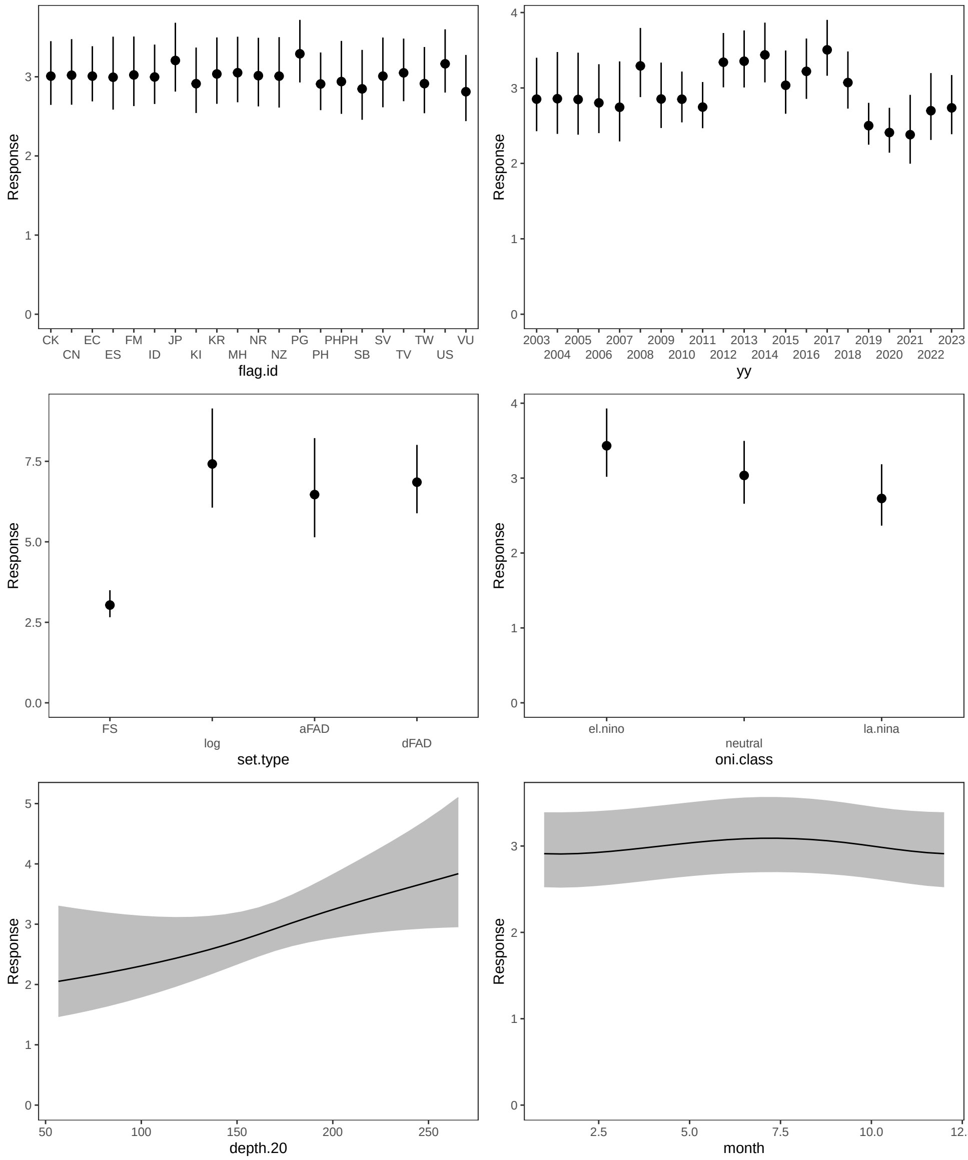


Figure B.126: Effects for the positives component of the False killer whale catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the remaining explanatory variables held constant at reference levels (see caption of Figure B.125). See Figure B.127 for spatial effects.

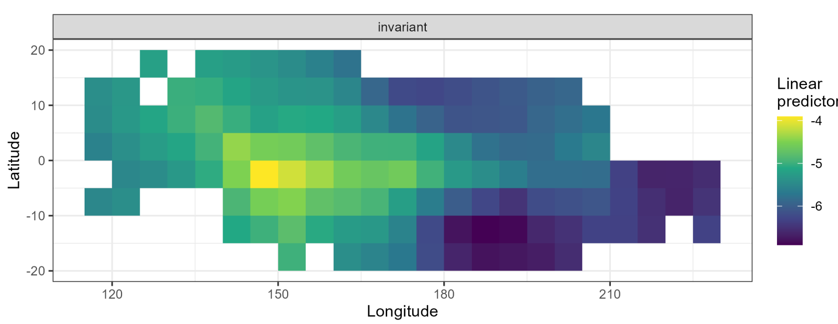


Figure B.127: Combined spatial effect for the delta and positives components of the False killer whale catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.125).

Beaked whales (*Ziphiidae*)

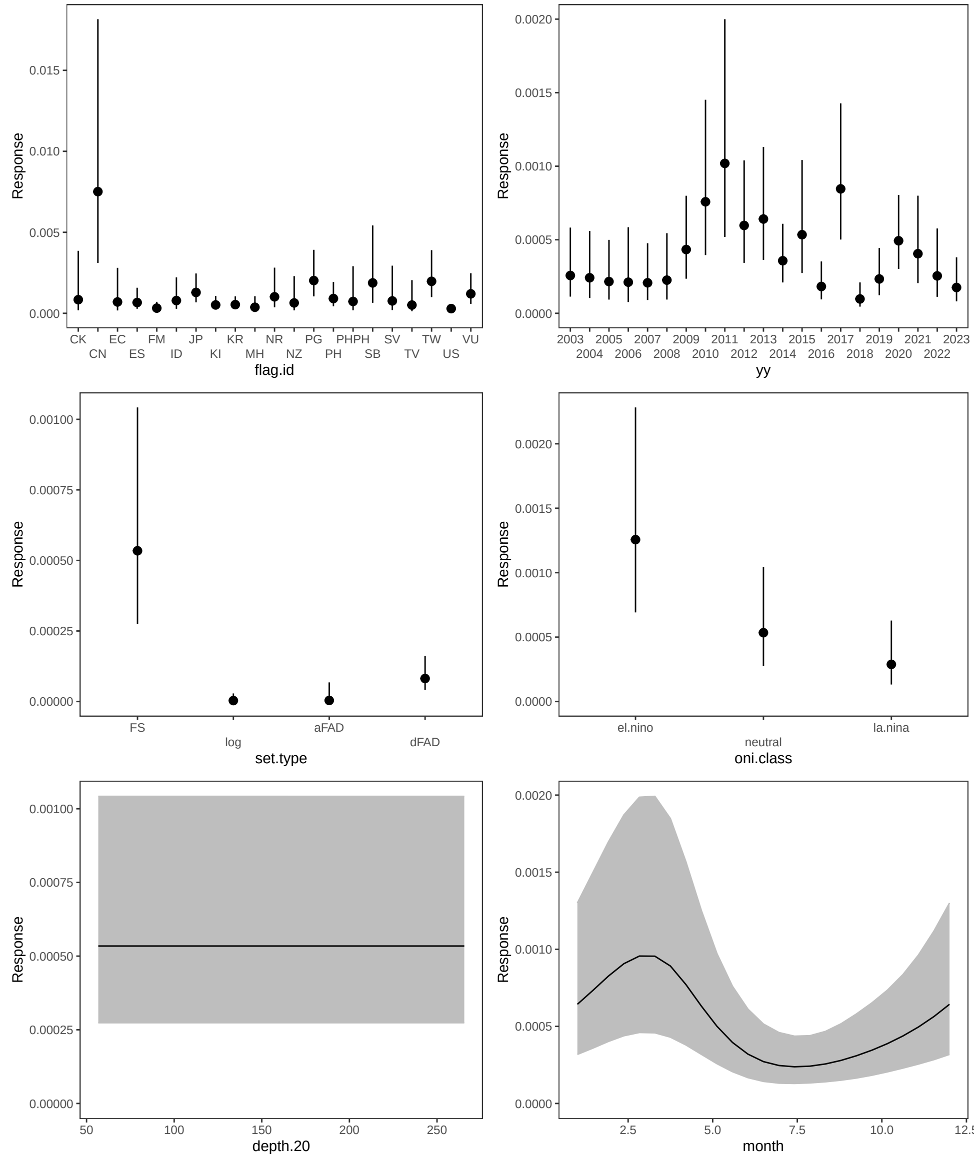


Figure B.128: Effects for the Beaked whales catch rate model. Each panel has the predicted response (± SE) for one explanatory variable, with the others held constant at 'reference levels' (year = 2015, month = 5, set-type = 'FS', flag = 'KR', ONI = 'neutral', depth of the 20°C isotherm = 180m, latitude = 175°E, longitude = 2.5°S). See Figure B.129 for spatial effects.

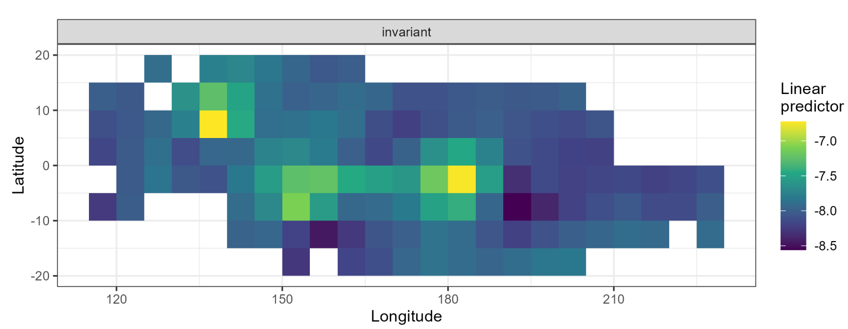


Figure B.129: Combined spatial effect for the Beaked whales catch rate model, at the linear predictor scale (i.e., log-transformed). Other explanatory variables were held constant at reference levels (see caption of Figure B.128).

C Tables of estimated catches

Table C.1: Estimated annual catch (95% confidence intervals in parentheses) for the large-scale equatorial purse seine fishery in the WCPFC Convention Area by species type. 'Other teleosts' excludes tropical tuna and and billfish species. Catch units are '000 for tropical tuna and other teleosts, and '000 individuals for billfish, elasmobranchs, marine mammals and sea turtles. Reported catches were used for tropical tuna and were assumed to be known without error.

Year	Tropical tunas	Other teleosts	Billfish	Elasmobranchs	Sea turtles	Marine mammals
2003	1,050	13.1 (12.6-13.8)	6.45 (6.05-6.86)	71.8 (66.9-77.7)	0.370 (0.278-0.507)	3.50 (1.70-8.25)
2004	1,120	18.0 (17.5-18.5)	6.78 (6.39-7.22)	69.0 (64.5-73.3)	0.231 (0.179-0.305)	5.94 (2.57-18.4)
2005	1,250	11.3 (10.9-11.6)	6.48 (6.10-6.84)	61.4 (58.7-64.5)	0.278 (0.228-0.363)	1.66 (1.20-2.58)
2006	1,280	9.45 (9.18-9.76)	6.12 (5.83-6.48)	62.3 (59.5-65.2)	0.230 (0.193-0.279)	2.34 (1.68-4.04)
2007	1,430	11.7 (11.4-12.1)	7.57 (7.20-7.93)	64.7 (61.5-67.3)	0.333 (0.276-0.407)	1.73 (1.39-2.16)
2008	1,480	7.95 (7.69-8.25)	6.67 (6.37-7.16)	60.4 (57.2-63.6)	0.325 (0.265-0.398)	2.18 (1.78-2.71)
2009	1,590	7.66 (7.44-7.90)	6.92 (6.63-7.30)	48.5 (46.1-51.4)	0.347 (0.290-0.407)	3.82 (3.27-4.65)
2010	1,530	6.66 (6.58-6.75)	6.07 (5.95-6.17)	43.6 (42.7-44.5)	0.266 (0.247-0.287)	1.49 (1.37-1.66)
2011	1,430	4.62 (4.57-4.67)	6.73 (6.61-6.85)	65.4 (64.5-66.4)	0.469 (0.448-0.492)	2.60 (2.44-2.77)
2012	1,650	4.55 (4.48-4.62)	8.86 (8.76-8.99)	47.2 (46.4-47.9)	0.429 (0.409-0.456)	3.60 (3.39-3.83)
2013	1,610	4.85 (4.81-4.90)	8.92 (8.84-9.00)	53.9 (53.4-54.6)	0.469 (0.454-0.488)	4.09 (3.93-4.29)
2014	1,800	6.47 (6.39-6.56)	8.26 (8.18-8.34)	70.3 (69.5-71.1)	0.340 (0.326-0.356)	3.28 (3.14-3.42)
2015	1,600	6.51 (6.45-6.59)	7.69 (7.63-7.76)	54.6 (54.0-55.3)	0.305 (0.291-0.320)	2.03 (1.94-2.14)
2016	1,610	7.79 (7.73-7.85)	6.10 (6.05-6.15)	84.6 (83.9-85.3)	0.243 (0.232-0.251)	2.09 (2.03-2.18)
2017	1,490	4.05 (4.00-4.09)	6.60 (6.56-6.65)	99.7 (99.1-100)	0.213 (0.206-0.222)	2.80 (2.71-2.88)
2018	1,690	3.67 (3.64-3.70)	5.97 (5.94-6.00)	84.6 (84.3-85.0)	0.294 (0.289-0.299)	1.74 (1.70-1.80)
2019	1,830	2.69 (2.67-2.72)	5.91 (5.88-5.94)	125 (124-125)	0.228 (0.223-0.234)	2.04 (2.00-2.09)
2020	1,680	3.39 (3.32-3.46)	4.23 (4.12-4.35)	116 (114-118)	0.180 (0.163-0.203)	2.08 (1.94-2.27)
2021	1,550	2.42 (2.36-2.51)	5.65 (5.29-6.04)	82.5 (78.9-85.8)	0.191 (0.161-0.234)	1.56 (1.35-1.91)
2022	1,640	2.62 (2.53-2.82)	5.55 (5.04-6.29)	98.9 (91.3-109)	0.265 (0.216-0.331)	2.23 (1.86-2.81)

Table C.2: Estimated annual catch by teleost estimation group (metric tonnes, 95% confidence intervals in parentheses) for the large-scale equatorial purse seine fishery in the WCPFC Convention Area. This table presents catch estimates for the top eight teleost estimation groups in terms of total estimated catch over the time series (see Tables C.3 & C.4 for the remaining teleost estimation groups), with estimation groups ranked in descending order of catch (left to right). Catches of billfish species are reported separately. Reported catches were used for tropical tuna and were assumed to be known without error.

Year	Skipjack	Yellowfin	Bigeye	Rainbow runner	Mackerel scad	Frigate & bullet tunas	Oceanic triggerfish	Mahi mahi
2003	691,000	304,000	51,900	4,100 (3,880-4,390)	3,850 (3,540-4,280)	2,540 (2,290-2,890)	922 (861-1,000)	618 (570-687)
2004	763,000	286,000	67,500	6,560 (6,310-6,830)	4,070 (3,790-4,390)	2,850 (2,560-3,150)	2,150 (2,060-2,260)	975 (912-1,050)
2005	870,000	312,000	63,900	4,040 (3,900-4,220)	2,940 (2,770-3,140)	1,710 (1,550-1,870)	1,120 (1,050-1,170)	584 (535-628)
2006	930,000	292,000	61,000	3,760 (3,620-3,920)	2,380 (2,260-2,510)	1,060 (935-1,160)	1,020 (984-1,080)	587 (552-632)
2007	1,070,000	299,000	62,200	4,230 (4,080-4,420)	3,110 (2,930-3,320)	2,070 (1,880-2,270)	1,180 (1,120-1,260)	409 (373-440)
2008	1,040,000	373,000	65,800	2,690 (2,570-2,800)	2,320 (2,120-2,540)	1,300 (1,190-1,450)	563 (526-600)	455 (417-493)
2009	1,220,000	299,000	66,000	2,850 (2,730-2,950)	1,820 (1,700-1,930)	1,060 (947-1,180)	622 (591-656)	526 (494-561)
2010	1,140,000	334,000	55,300	3,040 (2,990-3,090)	1,410 (1,360-1,470)	326 (295-367)	912 (892-930)	393 (382-406)
2011	1,060,000	294,000	76,100	2,240 (2,220-2,270)	508 (494-524)	289 (274-304)	514 (506-523)	312 (304-323)
2012	1,230,000	358,000	66,700	1,690 (1,680-1,720)	604 (584-628)	488 (461-517)	418 (410-426)	364 (357-372)
2013	1,220,000	316,000	72,700	1,690 (1,680-1,710)	975 (955-993)	538 (514-569)	517 (511-524)	498 (489-505)
2014	1,390,000	340,000	69,600	1,680 (1,670-1,700)	1,360 (1,330-1,380)	1,890 (1,830-1,970)	328 (324-332)	431 (425-438)
2015	1,260,000	291,000	52,400	2,470 (2,450-2,500)	1,550 (1,520-1,570)	1,250 (1,200-1,320)	374 (368-380)	431 (424-438)
2016	1,200,000	347,000	62,100	3,550 (3,530-3,580)	2,110 (2,080-2,150)	667 (645-693)	685 (677-692)	266 (262-269)
2017	1,050,000	387,000	57,700	1,580 (1,570-1,590)	1,260 (1,220-1,280)	228 (211-245)	273 (270-277)	236 (232-240)
2018	1,300,000	321,000	66,200	1,320 (1,310-1,330)	1,380 (1,360-1,400)	206 (197-215)	177 (176-179)	233 (231-235)
2019	1,480,000	303,000	44,500	1,220 (1,210-1,220)	715 (700-731)	240 (227-257)	183 (181-185)	144 (142-145)
2020	1,250,000	363,000	64,800	946 (926-967)	1,500 (1,470-1,520)	431 (405-466)	135 (129-141)	64.0 (60.8-67.1)
2021	1,140,000	348,000	63,200	859 (819-901)	863 (835-894)	126 (119-137)	224 (203-246)	42.4 (37.0-49.2)
2022	1,250,000	322,000	65,200	1,060 (984-1,180)	1,040 (1,010-1,100)	35.2 (22.6-60.4)	98.7 (87.3-116)	137 (113-170)

Table C.3: Estimated annual catch by teleost estimation group (metric tonnnes, 95% confidence intervals in parentheses) for the large-scale equatorial purse seine fishery in the WCPFC Convention Area. This table presents catch estimates for the teleost estimation groups ranked 9 to 16 in terms of total estimated catch over the time series (see Tables C.2 & C.4 for the remaining teleost estimation groups), with estimation groups ranked in descending order of catch (left to right). Catches of billfish species are reported separately.

Year	Kawakawa	Wahoo	Albacore	Barracudas	Amberjacks	Sea chubs	Marine fishes	Trevallies
2003	183 (124-293)	151 (133-167)	159 (75.2-372)	43.4 (38.9-48.1)	128 (71.3-231)	90.9 (68.0-124)	47.9 (25.4-100)	47.9 (39.1-60.5)
2004	256 (182-375)	247 (226-268)	64.4 (30.1-145)	49.9 (45.2-55.2)	94.8 (60.8-157)	79.7 (60.7-106)	87.6 (54.3-139)	60.8 (51.0-74.1)
2005	97.9 (64.9-154)	176 (161-193)	188 (112-373)	44.1 (41.0-48.1)	24.9 (13.0-49.2)	81.0 (68.3-97.6)	79.0 (53.1-136)	46.8 (39.1-55.6)
2006	60.9 (38.5-91.9)	127 (116-138)	99.7 (55.4-201)	54.2 (50.5-58.1)	14.1 (7.62-27.7)	58.1 (46.7-73.8)	29.5 (19.2-45.9)	43.7 (38.1-50.3)
2007	109 (75.7-156)	163 (149-177)	67.1 (32.7-143)	48.2 (44.4-52.8)	14.8 (7.45-29.0)	84.5 (66.7-105)	30.0 (24.3-44.4)	28.4 (23.1-35.8)
2008	143 (94.5-218)	194 (178-211)	69.5 (30.7-158)	56.6 (51.7-61.3)	10.3 (4.85-24.3)	17.3 (11.6-27.6)	33.5 (15.7-66.1)	14.2 (10.6-18.4)
2009	228 (171-297)	186 (172-203)	72.2 (40.8-134)	47.9 (44.1-52.9)	67.2 (43.7-108)	31.0 (23.2-41.6)	21.0 (11.7-38.3)	26.2 (21.5-31.8)
2010	73.5 (58.9-97.1)	118 (115-122)	51.7 (36.5-77.9)	40.4 (39.1-41.7)	118 (103-135)	40.5 (36.8-45.3)	28.0 (23.1-34.8)	20.3 (18.0-22.3)
2011	230 (205-267)	181 (178-185)	144 (122-177)	80.9 (79.2-82.7)	15.3 (11.5-20.8)	7.81 (6.66-9.24)	8.37 (6.82-11.0)	9.37 (8.62-10.2)
2012	244 (215-274)	193 (189-197)	292 (264-342)	43.2 (41.8-44.6)	75.1 (67.9-84.8)	13.8 (12.3-15.5)	10.6 (8.98-12.8)	9.31 (8.40-10.2)
2013	203 (184-227)	143 (141-145)	119 (108-144)	46.8 (45.8-47.9)	15.7 (12.9-20.2)	20.4 (19.2-22.1)	6.87 (5.84-8.75)	7.01 (6.34-7.70)
2014	401 (365-440)	191 (189-194)	51.9 (38.5-71.0)	28.5 (27.7-29.4)	11.6 (9.67-14.4)	23.4 (22.4-24.8)	8.30 (7.08-9.94)	6.56 (5.96-7.08)
2015	136 (119-156)	74.9 (73.4-76.5)	42.8 (34.9-57.5)	24.2 (23.4-25.1)	18.5 (16.0-21.5)	44.7 (42.4-47.0)	12.8 (10.8-14.8)	13.6 (12.7-14.7)
2016	149 (138-162)	86.8 (85.4-88.0)	76.0 (66.0-90.6)	24.1 (23.4-24.6)	24.2 (22.5-27.4)	67.3 (64.7-70.6)	6.94 (5.69-9.04)	11.2 (10.6-12.0)
2017	141 (133-151)	93.6 (92.6-94.8)	136 (119-158)	22.0 (21.7-22.4)	11.9 (10.6-14.0)	14.3 (13.8-14.9)	8.03 (7.36-8.92)	7.29 (7.09-7.57)
2018	116 (111-123)	122 (121-123)	43.1 (38.5-51.6)	18.9 (18.6-19.2)	3.86 (3.23-4.99)	5.60 (5.17-5.98)	3.60 (3.16-4.25)	2.43 (2.29-2.63)
2019	57.0 (54.6-60.5)	41.7 (41.3-42.1)	44.7 (39.9-55.7)	8.89 (8.70-9.08)	7.55 (7.11-8.18)	5.61 (5.31-5.92)	1.40 (1.17-1.73)	7.76 (7.47-8.11)
2020	71.4 (61.9-83.2)	36.4 (34.2-38.3)	89.3 (62.1-169)	19.5 (18.5-20.4)	28.2 (24.2-34.4)	8.96 (7.95-10.6)	1.47 (0.794-3.03)	3.51 (2.90-4.32)
2021	135 (126-150)	39.8 (33.3-47.7)	39.3 (17.9-85.7)	16.6 (14.9-18.3)	19.5 (8.73-48.5)	5.49 (3.22-8.97)	3.72 (1.45-9.94)	1.75 (0.765-2.96)
2022	25.0 (17.7-38.4)	51.6 (43.9-61.4)	37.9 (11.6-191)	35.1 (29.9-43.1)	4.57 (1.39-17.7)	7.04 (3.96-11.4)	2.36 (0.521-9.64)	2.42 (1.03-7.58)

Table C.4: Estimated annual catch by teleost estimation group (metric tonnnes, 95% confidence intervals in parentheses) for the large-scale equatorial purse seine fishery in the WCPFC Convention Area. This table presents catch estimates for the teleost estimation groups ranked 17 to 24 in terms of total estimated catch over the time series (see Tables C.2 & C.3 for the remaining teleost estimation groups), with estimation groups ranked in descending order of catch (left to right). Catches of billfish species are reported separately.

Year	Pomfrets	Scombrids	Filefishes	Sunfish	Golden trevally	Batfishes	Carangids	Triple-tail
2003	27.2 (18.2-41.8)	61.6 (42.0-102)	30.3 (22.1-40.5)	9.86 (4.32-22.0)	2.36 (0.942-5.45)	11.2 (7.25-19.4)	0.915 (0.247-2.64)	12.4 (6.38-21.1)
2004	37.2 (28.3-50.4)	151 (109-208)	105 (85.4-126)	20.3 (11.6-32.3)	18.5 (11.1-33.3)	25.9 (19.2-33.8)	11.5 (6.89-18.9)	14.5 (9.68-22.7)
2005	42.9 (30.0-59.2)	21.3 (12.1-35.0)	21.1 (16.4-27.9)	17.6 (10.5-28.4)	3.23 (1.52-6.70)	9.22 (6.34-13.1)	2.02 (0.899-4.82)	11.4 (7.20-16.5)
2006	37.4 (28.2-48.0)	12.9 (8.55-20.3)	43.9 (35.3-52.8)	15.7 (9.81-29.2)	1.86 (0.850-4.00)	15.9 (12.1-20.4)	2.49 (1.13-6.20)	10.2 (7.04-14.5)
2007	33.7 (24.2-48.4)	10.7 (5.07-26.2)	23.2 (17.3-31.0)	7.79 (3.94-13.9)	6.48 (3.40-10.8)	9.12 (5.97-13.3)	1.79 (0.812-3.95)	10.6 (7.06-19.6)
2008	18.0 (11.8-28.8)	1.84 (0.633-4.54)	13.8 (9.38-20.1)	7.59 (3.83-14.3)	20.8 (12.7-32.0)	5.55 (3.27-9.76)	1.24 (0.391-3.33)	4.62 (2.68-7.88)
2009	26.4 (19.2-37.1)	7.22 (4.56-12.4)	16.0 (12.3-21.6)	7.98 (4.34-13.6)	7.05 (4.37-11.6)	6.49 (4.13-10.1)	14.9 (9.23-23.9)	11.0 (6.86-16.9)
2010	32.8 (29.7-36.6)	3.33 (2.27-4.92)	12.0 (10.6-13.9)	9.17 (7.45-11.4)	4.87 (3.61-6.65)	6.98 (5.79-8.86)	6.16 (4.63-7.91)	11.1 (9.66-13.2)
2011	31.7 (30.3-33.5)	4.77 (4.13-5.58)	1.85 (1.36-2.45)	9.22 (7.70-11.6)	8.12 (7.74-8.66)	11.2 (9.13-14.2)	3.72 (2.76-5.18)	2.01 (1.61-2.63)
2012	12.8 (11.2-14.7)	7.99 (6.60-9.96)	8.61 (7.50-9.78)	37.5 (34.3-41.3)	3.23 (2.69-3.93)	8.61 (7.62-10.0)	8.01 (6.49-9.72)	5.95 (5.45-6.73)
2013	12.6 (11.5-14.1)	5.82 (4.92-7.19)	7.05 (6.70-7.50)	20.7 (18.9-23.2)	4.76 (4.08-5.58)	4.45 (4.00-4.97)	7.65 (6.60-9.52)	3.13 (2.83-3.65)
2014	5.22 (4.44-6.34)	5.50 (4.52-7.18)	1.66 (1.39-2.05)	24.5 (22.6-26.7)	9.69 (9.01-10.7)	2.12 (1.82-2.50)	6.03 (5.15-7.35)	1.21 (0.985-1.61)
2015	5.12 (4.43-6.39)	8.60 (7.40-10.4)	6.97 (6.38-7.65)	20.4 (19.0-22.6)	8.71 (7.97-9.54)	6.68 (5.89-7.71)	6.75 (6.18-7.44)	2.03 (1.75-2.43)
2016	12.6 (11.7-13.9)	3.48 (2.77-5.13)	6.40 (6.04-6.89)	9.69 (8.53-11.3)	4.12 (3.66-4.62)	5.67 (5.16-6.23)	9.30 (8.69-10.1)	1.87 (1.61-2.24)
2017	3.44 (3.11-3.90)	2.20 (1.92-2.66)	1.08 (0.960-1.28)	9.05 (8.49-9.95)	15.6 (14.7-16.8)	2.02 (1.84-2.28)	4.38 (3.95-4.93)	0.274 (0.231-0.346)
2018	2.23 (2.01-2.55)	0.758 (0.634-1.05)	1.86 (1.73-2.07)	6.62 (6.18-7.32)	17.9 (16.8-19.3)	1.94 (1.78-2.14)	4.21 (3.88-4.65)	0.445 (0.380-0.539)
2019	0.332 (0.262-0.477)	1.01 (0.842-1.41)	0.783 (0.707-0.877)	6.02 (5.69-6.62)	7.02 (6.62-7.59)	1.59 (1.49-1.78)	1.50 (1.32-1.78)	0.469 (0.420-0.544)
2020	1.24 (0.921-1.95)	5.91 (4.18-9.43)	0.865 (0.629-1.37)	3.89 (2.61-6.48)	20.2 (19.3-21.5)	1.42 (1.15-1.92)	7.56 (6.53-9.11)	0.414 (0.265-0.602)
2021	0.534 (0.138-1.68)	8.28 (4.13-23.7)	2.24 (1.36-4.02)	8.74 (4.43-19.4)	7.33 (6.49-8.20)	1.24 (0.656-2.56)	4.02 (2.65-6.13)	0.697 (0.346-1.45)
2022	2.99 (1.32-6.69)	2.44 (0.534-8.95)	0.480 (0.142-1.93)	15.3 (7.07-42.9)	23.3 (21.0-28.0)	0.712 (0.271-1.87)	24.8 (16.8-37.0)	1.24 (0.429-3.84)

Table C.5: Estimated annual catch by billfish estimation group (individuals, 95% confidence intervals in parentheses) for the large-scale equatorial purse seine fishery in the WCPFC Convention Area. Estimation groups are ranked in descending order of catch (left to right).

Year	Blue & black marlin	Striped marlin	Indo-Pacific sailfish	Swordfish	Short-billed spearfish
2003	5,090 (4,700-5,460)	740 (617-880)	471 (358-636)	72.8 (42.7-129)	74.2 (38.2-138)
2004	5,410 (5,090-5,820)	581 (482-695)	561 (430-733)	150 (106-218)	65.5 (36.2-130)
2005	5,130 (4,840-5,460)	632 (537-726)	541 (428-697)	110 (77.9-153)	53.8 (29.4-107)
2006	4,750 (4,520-5,100)	727 (622-850)	388 (308-489)	174 (120-234)	59.2 (32.1-105)
2007	6,230 (5,890-6,530)	652 (554-758)	370 (290-491)	202 (153-272)	115 (70.8-197)
2008	5,570 (5,250-5,950)	512 (442-617)	394 (307-532)	125 (80.5-180)	68.5 (40.5-128)
2009	5,180 (4,950-5,480)	881 (787-1,000)	571 (468-737)	154 (110-214)	115 (76.2-191)
2010	4,370 (4,300-4,460)	789 (756-823)	574 (527-619)	132 (118-153)	187 (162-227)
2011	5,040 (4,950-5,140)	887 (847-927)	555 (515-600)	160 (143-180)	89.4 (73.7-115)
2012	6,780 (6,700-6,890)	1,320 (1,280-1,360)	416 (388-447)	183 (164-203)	158 (136-193)
2013	6,960 (6,890-7,030)	1,310 (1,270-1,340)	384 (365-405)	108 (99.1-122)	157 (141-175)
2014	6,550 (6,480-6,620)	1,010 (980-1,040)	462 (439-487)	107 (95.0-122)	123 (108-140)
2015	6,210 (6,150-6,260)	1,010 (990-1,040)	296 (281-313)	60.5 (54.3-69.1)	113 (102-128)
2016	5,000 (4,950-5,040)	730 (712-750)	257 (246-270)	57.3 (50.4-65.2)	57.5 (50.7-66.3)
2017	5,530 (5,500-5,580)	675 (662-689)	253 (245-262)	70.9 (65.3-76.5)	69.1 (63.8-77.2)
2018	5,090 (5,070-5,120)	511 (505-518)	247 (242-253)	35.5 (33.1-38.8)	79.6 (75.4-85.8)
2019	5,010 (4,990-5,040)	489 (483-497)	289 (281-298)	37.2 (34.9-40.5)	77.7 (72.7-84.6)
2020	3,570 (3,460-3,670)	387 (353-415)	204 (174-241)	37.4 (27.8-49.9)	35.7 (23.0-59.9)
2021	4,750 (4,410-5,110)	396 (307-500)	364 (279-455)	46.0 (25.3-82.9)	72.2 (40.1-140)
2022	4,350 (3,900-5,050)	454 (347-584)	530 (401-710)	38.8 (19.2-83.8)	154 (91.6-266)

Table C.6: Estimated annual catch by elasmobranch estimation group (individuals, 95% confidence intervals in parentheses) for the large-scale equatorial purse seine fishery in the WCPFC Convention Area. Estimation groups are ranked in descending order of catch (left to right).

Year	Silky shark	Mobulid rays	Elasmobranchs	Oceanic whitetip shark	Whale shark	Pelagic stingray	Mako sharks	Thresher sharks	Hammerhead sharks	Blue shark
2003	51,500 (48,400-54,800)	2,050 (1,790-2,350)	14,600 (11,200-19,300)	1,760 (1,430-2,160)	299 (243-385)	50.7 (27.8-87.0)	843 (399-2,640)	672 (308-1,710)	24.5 (19.6-30.6)	21.1 (10.7-42.6)
2004	53,500 (50,700-56,200)	2,850 (2,560-3,170)	8,990 (6,330-13,600)	2,160 (1,840-2,440)	176 (146-213)	132 (97.1-172)	606 (251-1,960)	235 (122-520)	31.1 (25.7-38.4)	14.3 (9.14-28.8)
2005	54,400 (52,100-57,200)	2,450 (2,220-2,690)	2,310 (1,650-3,470)	1,560 (1,360-1,800)	267 (227-315)	198 (150-249)	64.0 (28.1-189)	26.8 (12.5-60.8)	24.9 (21.3-29.9)	19.2 (11.5-32.2)
2006	57,200 (54,500-59,800)	1,850 (1,680-2,040)	1,920 (1,190-3,550)	515 (424-617)	353 (310-405)	92.2 (67.6-125)	90.8 (35.1-287)	60.1 (29.0-142)	29.7 (24.4-37.4)	21.3 (14.0-34.4)
2007	58,800 (55,700-61,500)	2,570 (2,370-2,830)	1,320 (772-2,290)	953 (817-1,120)	465 (406-520)	293 (237-364)	81.7 (31.4-256)	21.8 (8.15-70.9)	30.4 (25.3-38.3)	12.4 (7.20-22.7)
2008	52,900 (50,000-56,000)	3,310 (3,020-3,660)	2,140 (1,410-3,420)	534 (444-651)	476 (417-550)	444 (362-552)	163 (63.8-395)	98.2 (48.7-211)	40.2 (32.3-48.9)	16.1 (9.43-30.1)
2009	43,900 (41,700-46,500)	2,360 (2,150-2,580)	964 (550-1,540)	204 (163-254)	371 (329-423)	521 (455-624)	32.8 (9.03-116)	29.7 (10.6-72.4)	47.0 (40.7-56.8)	16.7 (8.12-31.7)
2010	37,800 (36,900-38,600)	2,920 (2,830-3,030)	1,020 (802-1,300)	715 (686-744)	421 (402-441)	503 (481-529)	92.1 (68.2-134)	76.7 (55.1-108)	41.4 (36.4-48.1)	16.8 (12.0-24.0)
2011	59,000 (58,200-59,900)	3,160 (3,080-3,250)	1,780 (1,490-2,190)	591 (562-618)	345 (331-361)	302 (285-321)	62.9 (46.7-90.8)	56.1 (44.7-73.8)	40.9 (33.5-49.3)	34.5 (28.1-49.6)
2012	38,600 (37,900-39,300)	5,680 (5,560-5,780)	932 (762-1,190)	380 (361-401)	657 (638-682)	595 (571-626)	187 (162-222)	58.0 (44.4-81.5)	60.4 (55.7-66.8)	24.4 (18.3-32.9)
2013	47,400 (46,800-48,000)	4,000 (3,950-4,070)	957 (823-1,180)	408 (394-428)	580 (565-594)	522 (507-540)	26.6 (19.6-38.3)	27.7 (21.4-36.8)	44.4 (40.9-48.2)	11.5 (7.50-20.3)
2014	62,900 (62,100-63,700)	4,130 (4,060-4,210)	1,260 (1,070-1,530)	542 (526-564)	630 (615-647)	570 (552-588)	35.1 (27.2-47.0)	134 (116-158)	50.5 (46.4-55.0)	27.0 (21.5-38.0)
2015	47,100 (46,500-47,700)	3,340 (3,280-3,410)	2,600 (2,290-2,920)	444 (430-458)	574 (561-586)	401 (386-416)	76.4 (63.3-95.8)	28.8 (23.3-38.5)	64.2 (59.6-71.2)	16.2 (12.9-22.4)
2016	77,000 (76,400-77,700)	4,620 (4,560-4,690)	1,610 (1,440-1,860)	542 (529-558)	332 (324-342)	273 (262-285)	26.5 (20.7-37.8)	29.3 (24.8-37.0)	68.4 (64.8-73.2)	33.7 (29.8-40.6)
2017	92,000 (91,400-92,500)	3,770 (3,720-3,800)	2,550 (2,360-2,790)	563 (549-578)	495 (486-503)	196 (190-203)	49.1 (43.4-60.1)	34.5 (30.3-40.7)	45.0 (42.6-47.7)	11.3 (8.02-18.5)
2018	77,700 (77,400-78,100)	4,490 (4,460-4,520)	559 (512-621)	1,050 (1,040-1,070)	431 (427-435)	242 (237-246)	19.1 (16.6-23.2)	19.8 (18.0-22.8)	62.2 (60.0-65.6)	26.2 (24.6-29.1)
2019	117,000 (116,000-117,000)	4,370 (4,340-4,410)	1,070 (996-1,180)	1,110 (1,090-1,120)	772 (765-782)	143 (139-147)	22.6 (19.2-29.2)	14.6 (13.1-17.7)	64.7 (62.6-67.4)	67.4 (65.3-70.9)
2020	110,000 (108,000-112,000)	3,530 (3,390-3,700)	950 (765-1,290)	903 (839-974)	487 (456-517)	53.2 (44.6-63.3)	16.9 (8.88-41.0)	25.3 (18.1-37.6)	57.1 (51.2-65.6)	11.8 (5.93-25.4)
2021	74,800 (71,400-78,200)	4,920 (4,540-5,370)	1,610 (1,050-2,640)	456 (372-598)	331 (285-375)	105 (80.0-140)	18.2 (4.03-68.1)	25.3 (11.7-71.8)	55.4 (45.5-68.9)	13.7 (7.13-29.2)
2022	91,600 (83,600-101,000)	4,400 (3,920-5,230)	697 (315-1,460)	1,540 (1,300-1,890)	268 (221-344)	101 (72.6-157)	14.8 (2.28-97.9)	11.5 (2.42-49.5)	155 (66.0-617)	15.1 (5.88-42.1)

Table C.7: Estimated annual catch by sea turtle estimation group (individuals, 95% confidence intervals in parentheses) for the large-scale equatorial purse seine fishery in the WCPFC Convention Area. Estimation groups are ranked in descending order of catch (left to right).

Year	Olive ridley turtle	Green turtle	Loggerhead turtle	Hawksbill turtle	Sea turtles	Leatherback turtle
2003	49.0 (30.6-84.4)	33.1 (17.9-68.5)	28.4 (15.1-53.0)	39.1 (25.2-63.3)	204 (124-336)	7.13 (4.86-11.4)
2004	41.2 (25.2-67.0)	27.9 (15.1-60.0)	23.7 (12.4-45.2)	35.3 (21.1-62.8)	86.9 (48.5-154)	11.2 (8.01-17.5)
2005	32.9 (16.4-60.3)	53.4 (35.2-76.7)	43.8 (30.5-66.7)	35.5 (21.3-54.8)	98.6 (63.4-163)	8.61 (6.11-13.2)
2006	81.1 (60.6-108)	45.1 (28.7-71.5)	32.2 (19.6-55.9)	37.4 (23.2-56.2)	13.0 (5.45-33.6)	14.3 (11.6-19.0)
2007	95.0 (73.0-134)	91.4 (64.1-135)	73.9 (52.0-110)	40.7 (25.2-64.0)	13.3 (5.64-38.5)	9.05 (6.62-13.3)
2008	58.7 (39.5-88.2)	64.3 (44.2-99.4)	118 (87.9-170)	53.3 (35.4-81.0)	9.98 (2.65-36.8)	10.0 (7.71-13.9)
2009	85.4 (66.7-110)	55.4 (39.2-79.6)	129 (95.1-167)	54.4 (39.4-78.3)	8.56 (3.62-29.6)	10.5 (8.19-14.6)
2010	55.4 (48.8-65.9)	57.4 (49.7-67.7)	72.6 (63.6-83.8)	55.0 (47.7-65.8)	14.7 (10.7-23.3)	9.87 (8.36-12.2)
2011	152 (139-166)	102 (91.5-114)	105 (95.1-115)	81.7 (73.2-94.8)	13.7 (9.60-21.6)	12.9 (11.2-15.7)
2012	128 (116-143)	117 (106-130)	93.5 (84.1-104)	64.3 (56.3-73.8)	14.6 (10.4-22.2)	10.7 (9.16-12.7)
2013	101 (94.5-108)	135 (127-145)	102 (94.8-111)	102 (93.8-111)	18.5 (15.2-23.1)	10.4 (9.01-12.1)
2014	80.4 (74.7-89.7)	90.3 (81.5-99.3)	60.5 (55.2-68.3)	77.6 (69.0-87.5)	16.9 (13.3-23.3)	13.3 (11.9-15.2)
2015	75.6 (68.3-81.8)	96.5 (88.8-105)	71.4 (66.0-77.1)	39.5 (35.4-45.8)	12.0 (9.82-16.3)	9.31 (8.19-11.2)
2016	74.6 (69.5-80.1)	56.9 (52.8-61.9)	48.3 (45.3-53.1)	41.0 (37.7-46.8)	7.80 (6.22-10.8)	12.9 (12.1-14.0)
2017	80.5 (76.7-84.6)	51.6 (48.4-56.0)	33.1 (30.3-36.1)	29.9 (27.6-33.8)	8.85 (7.49-11.3)	8.54 (7.82-9.53)
2018	67.6 (65.3-70.2)	95.3 (92.7-98.9)	67.8 (65.6-70.5)	42.1 (40.4-44.4)	10.2 (9.30-12.3)	10.1 (9.59-10.8)
2019	54.0 (51.7-57.3)	65.6 (62.9-69.0)	52.5 (50.5-55.3)	42.6 (40.4-45.4)	7.94 (6.95-9.87)	5.12 (4.51-5.90)
2020	54.1 (46.1-68.3)	48.5 (40.0-61.8)	34.8 (27.1-47.1)	22.7 (17.0-32.4)	6.67 (3.86-16.1)	10.6 (8.72-12.7)
2021	52.7 (37.6-71.2)	41.4 (25.7-65.9)	30.2 (17.2-52.9)	45.6 (33.7-66.9)	7.91 (3.02-26.1)	8.77 (6.15-11.7)
2022	72.3 (49.7-103)	59.4 (37.9-104)	65.4 (41.4-105)	39.3 (21.8-70.5)	11.3 (3.51-33.1)	11.9 (7.61-18.2)

Table C.8: Estimated annual catch by marine mammal estimation group (individuals, 95% confidence intervals in parentheses) for the large-scale equatorial purse seine fishery in the WCPFC Convention Area. Estimation groups are ranked in descending order of catch (left to right).

Year	Dolphins	False killer whale	Marine mammals	Baleen whales	Short-finned pilot whale	Risso's dolphin	'Blackfish'	Beaked whales	Toothed whales
2003	425 (278-655)	108 (47.6-255)	2,710 (894-7,440)	16.7 (5.05-56.5)	88.8 (43.4-182)	57.1 (21.0-143)	55.5 (38.8-88.5)	14.5 (2.68-75.8)	8.81 (0.950-42.0)
2004	685 (480-993)	116 (51.6-256)	4,810 (1,540-17,200)	8.93 (3.13-28.5)	114 (63.5-248)	77.2 (32.6-196)	50.6 (25.1-106)	8.52 (1.62-50.3)	6.53 (0.774-42.3)
2005	594 (426-866)	88.2 (37.9-177)	711 (324-1,700)	8.69 (3.14-27.0)	91.9 (52.7-190)	52.5 (17.1-131)	40.7 (20.9-82.3)	9.97 (1.87-83.8)	6.16 (1.18-27.1)
2006	767 (572-1,050)	234 (153-391)	854 (329-2,570)	12.1 (5.36-32.7)	156 (91.3-269)	80.7 (39.8-175)	49.0 (30.9-93.6)	11.1 (2.08-67.2)	76.5 (24.0-300)
2007	990 (744-1,410)	319 (197-481)	27.3 (8.20-132)	115 (82.5-166)	78.8 (37.9-159)	103 (45.2-248)	35.0 (19.4-65.6)	10.1 (1.97-56.2)	6.43 (1.11-38.1)
2008	1,220 (916-1,760)	661 (485-924)	1.81 (0.0575-81.7)	9.92 (3.39-27.2)	108 (60.1-199)	72.6 (32.5-181)	33.7 (20.6-56.9)	8.42 (1.51-34.3)	7.00 (0.915-32.9)
2009	2,600 (2,070-3,390)	774 (577-1,030)	1.68 (0.0452-39.7)	60.9 (44.4-90.9)	136 (85.1-214)	107 (61.8-225)	48.8 (31.5-85.7)	38.1 (17.2-128)	15.2 (7.93-45.5)
2010	741 (637-926)	349 (305-405)	7.70 (4.08-17.3)	66.9 (59.8-77.3)	114 (90.2-148)	54.8 (39.3-89.9)	34.7 (25.4-50.7)	72.4 (46.3-160)	27.8 (21.0-41.1)
2011	1,070 (944-1,220)	913 (825-1,010)	13.3 (8.26-28.7)	140 (127-153)	145 (114-186)	101 (66.1-183)	35.9 (27.9-51.7)	68.9 (52.1-102)	88.9 (70.6-111)
2012	1,100 (985-1,230)	1,580 (1,460-1,710)	28.1 (21.0-39.3)	185 (172-201)	213 (183-264)	269 (214-361)	80.0 (61.8-106)	34.0 (24.1-54.3)	93.3 (77.1-117)
2013	1,470 (1,380-1,600)	1,700 (1,590-1,810)	20.2 (16.4-29.1)	194 (183-206)	286 (251-325)	255 (210-328)	74.7 (63.0-94.2)	66.4 (54.0-85.7)	20.1 (16.5-25.9)
2014	696 (617-786)	1,800 (1,680-1,930)	29.9 (23.9-43.1)	215 (203-230)	309 (276-359)	102 (73.8-145)	66.4 (55.0-86.4)	28.3 (21.7-46.0)	21.2 (17.1-31.5)
2015	527 (472-592)	843 (781-920)	4.67 (3.36-8.97)	241 (228-254)	164 (143-199)	45.8 (36.5-62.7)	101 (89.1-129)	57.6 (42.5-91.6)	32.4 (27.4-41.2)
2016	678 (625-741)	826 (773-881)	32.3 (29.0-41.2)	304 (291-315)	157 (141-180)	32.4 (25.2-50.0)	33.0 (26.9-46.7)	12.0 (8.04-21.8)	16.9 (13.7-22.4)
2017	798 (743-863)	1,270 (1,220-1,330)	12.1 (10.5-16.9)	321 (313-331)	152 (138-170)	75.0 (65.3-101)	48.5 (42.8-58.5)	68.4 (61.0-81.4)	45.8 (42.4-53.7)
2018	634 (599-679)	676 (654-705)	0.119 (0.00679-1.44)	170 (166-173)	174 (165-185)	26.8 (22.6-35.0)	31.6 (27.6-44.4)	3.96 (3.14-6.01)	24.8 (23.1-27.7)
2019	708 (674-747)	679 (654-710)	8.66 (7.51-11.6)	449 (440-460)	78.8 (70.9-87.1)	16.9 (11.4-26.6)	50.7 (46.0-59.7)	35.9 (32.9-41.0)	12.9 (11.3-16.2)
2020	842 (745-974)	572 (506-690)	3.33 (1.50-13.2)	426 (388-481)	72.1 (48.8-125)	72.3 (46.3-133)	38.6 (26.3-53.5)	31.3 (22.1-47.8)	5.44 (1.93-20.2)
2021	639 (504-824)	369 (273-529)	8.96 (2.22-81.7)	287 (231-360)	101 (54.7-216)	56.0 (29.6-115)	33.4 (19.3-60.7)	18.6 (8.08-51.8)	11.1 (3.53-41.6)
2022	946 (719-1,390)	555 (368-799)	1.74 (0.0778-102)	463 (357-620)	116 (56.3-215)	47.4 (16.3-133)	28.7 (14.8-55.9)	11.2 (3.67-60.1)	21.9 (6.80-79.5)