SCIENTIFIC COMMITTEE
SIXTEENTH REGULAR SESSION

ELECTRONIC MEETING
11 – 20 August 2020

PROJECT 60: PROGRESS TOWARDS ACHIEVING SC15 RECOMMENDATIONS

WCPFC-SC16-2020/ST-IP-04

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Introduction

Project Objective

The objective of Project 60 is to improve the accuracy and precision of species composition data for tuna (skipjack, yellowfin and bigeye) caught by purse-seine fisheries in the WCPO, in order to improve species-specific catch histories and size compositions that are used in the stock assessments of these key target species in the WCPO.

The project history is provided in Annex 1 of this report.

The Achievements to 30 June 2020 are provided in Table1 and the SC is invited to prioritise activities for 2021.

Progress towards addressing SC15 recommendations

Table 1. SC15 recommended that the following activities be considered under Project 60 over the coming year, with the outcomes reported to SC16:

Recommendation	Progress
Paired grab-spill trips (target: 4 to 6): • Targeting fleets with likely availability of comprehensive landings slips data (to be provided on a voluntary basis). • Additional data should allow for improved estimates of bias correction factors, and provide a more powerful dataset for testing for species and/or school association specific correction factors	Postponed to 2021 due to COVID-related travel restrictions
Continue to explore opportunities for collaboration with members, specifically undertaking comparisons of observer samples, and potentially model-based, species composition estimates, with accurate unloadings / landings / cannery data	**SC16-ST-IP-05** compared species compositions from cannery receipts data with grab-sample and model-based estimates for the USA purse seine fleet. Comparisons were undertaken at a range of resolutions, including by year, and a resolution as close as possible to that used in the MFCL assessments (i.e. year-quarter and region). Comprehensive cannery receipts data were available for the majority of vessel trips included in the study. Annual species compositions were broadly comparable between cannery receipts and grab-sample based estimates, though grab-sample estimates of skipjack proportions were generally lower than in cannery receipts, and vice versa for yellowfin and bigeye. Cannery data also had higher proportions of catch across all three species in the smallest size categories compared to grab-sample based estimates, and vice versa for the largest size categories. Comparisons suggest that grab-sample based species compositions are relatively imprecise at a resolution of year-quarter and a regional scale similar to that used in MFCL assessments, using cannery receipts as the point of comparison. This has implications on the precision of grab

	sample-based estimates of species compositions at an 'S_BEST' resolution. It would be beneficial to repeat these relatively fine-scale comparisons for other fleets, where possible, to explore this in more detail. Comparisons of grab-sample and model-based species composition estimates at a trip-level identified discrepancies in species proportions for USA purse seiners. The study demonstrates the utility of cannery receipts data as an independent dataset for validation of observer sample-based species composition estimates. Wider availability of comprehensive cannery receipts data would enable the benefits of cannery data to be realised for other purse seine fleets operating in the WCPO.
Investigation of video-based sampling for estimation of species and size compositions	Field trials initiated through support of TNC proposal for trials in Noro, however these are currently postponed to 2021 due to COVID-related travel restrictions SC16-ST-IP-09 included applications of video-based sampling for estimation of species and size compositions on purse-seine vessels. The paper notes that retained total catch of tunas by set was estimated by video-based sampling as reliable as that by both observer programs and logbook. When comparing the information by set, video-based sampling estimation of the main species, such as skipjack and bigeye and the combination of bigeye/yellowfin, was less accurate but statistically similar to the estimates made by observer programs. Video-based sampling tended to underestimate the retained catch of skipjack in comparison to both observers estimate and slightly overestimate bigeye and yellowfin, the overestimation being less pronounced for bigeye than for yellowfin. For bycatch species, the capability of video-based sampling to estimate the same number of bycatch items as observers

	varied by species group. For sharks, the overall congruence between video-based sampling and observers was high.
Simulation model • Exploration of potential bias from between-brail variability in size • Inform need for set and/or species-specific correction factors	Scheduled for 2020-21
Cost-benefit analysis of alternative sampling approaches for long-term estimation of species compositions (i.e. at-sea sampling vs port sampling vs cannery receipts)	Scheduled for 2020-21. Accurate cannery receipts data could be used, in combination with observer samples and other information, to generate species-specific catches with greater precision than based on grab samples alone. This warrants consideration as a possible approach to species-estimation in the long-term.
The following changes (as outcomes from Project 60) be incorporated into the process for generating the aggregated purse seine species catch estimates in the future: • Multinomial-model based correction factors be used to correct existing and future grab sample data, rather than the estimates of 'availability'; • The beta-response models be used to generate catch estimates; and, • Observer samples are stratified by flag when used to directly estimate species compositions.	The procedure used to estimate species catch estimates has been revised in line with recommendations from SC15 (see SC16-ST-IP-01). A description of this application is provided in Annex 2. Additionally, grab samples are now corrected for 'grab sample bias' using correction factors when generating purse seine size compositions for use in MFCL assessments (see SC16-SA-IP-18).

Issues arising

As noted above, species composition comparisons for USA purse seiners identified discrepancies between grab-sample and model-based species composition estimates at a trip-level (SC16-ST-IP-05). This may result from the use of random vessel intercepts in the species composition models. We recommend that equivalent comparisons should be undertaken across all fleets in 2020-21, to determine whether a similar pattern is observed for all fleets, and whether the pattern is caused by the use of random effects. If so, simplification of the species composition models should be considered.

The travel restriction associated with COVID-19 that prevented completion of paired grab-spill trips task so far in 2020 will likely result in an underspend of ~USD40,000 for Project 60 budget in 2020.

Recommendations

We invite SC to:

- note the progress towards the Project 60 workplan agreed at SC15.
- note the demonstrated utility of cannery receipts data to the objectives of Project 60.
- review the following proposed activities for Project 60 in the year ahead, with reporting to SC17:

Activity	Priority
Paired grab-spill trips (target: 4 to 6): • Targeting fleets with likely availability of comprehensive landings slips data (to be provided on a voluntary basis). • Additional data should allow for improved estimates of bias correction factors, and provide a more powerful dataset for testing for species and/or school association specific correction factors *Remaining 2020 Budget for this activity (~USD40,000)*	High
Continue to explore opportunities for collaboration with members, specifically undertaking comparisons of observer samples, and potentially model-based, species composition estimates, with accurate unloadings / landings / cannery data	High
Simulation model • Exploration of potential bias from between-brail variability in size • Inform need for set and/or species-specific correction factors	High
Comparisons of grab-sample and model-based estimates of species of compositions (i.e. observations vs model predictions) at a trip-level.	High
Investigation of video-based sampling for estimation of species and size compositions	Medium
Cost-benefit analysis of alternative sampling approaches for long-term estimation of species compositions (i.e. at-sea sampling vs port sampling)	Low

Annex 1

Project History

Project 60 and work on the collection and evaluation of purse seine species composition data through paired sampling and unloading data comparisons began in April 2009. The initial duration of the project was from April 2009 to the end of January 2010. The project was extended in April 2010 through January 2011, and then from February 2011 to 31 January 2012.

Following discussion of the "Plan for the improvement of the availability and use of purse-seine composition data" (SPC-OFP 2012), the Scientific Committee made the following recommendation (Anon., 2012a) at para 89, section d: *"Project 60 be continued through 2013. The study has a target of 50 trips to be sampled, of which 35 trips will be completed by the end of 2012".*

The Commission (Anon., 2012b) supported the SC8 recommendation and approved the project with funding to cover the cost of the remaining 15 trips for further analysis. In 2014 further research for project 60 was supported under the SC9 unobligated budget, with additional funding from PNG.

SC11 noted that future work should include finalisation of analyses of existing data, the collection of further paired sampling data where these results can be compared to accurate estimates of landed weights by species, and simulation modelling to assess alternative sampling protocols (Anon., 2015a). The Scientific Committee made the following recommendation (Anon., 2015a) at para 107:

a) The WCPFC science/data service provider produce an update to Table 1 in ST-WP-02 annually (until an agreement on methodology can be reached) as it provides a very useful summary of the purse-seine catch estimates derived using the four different methods to ascertain catch composition.

b) In regards to the implementation of observer spill sampling in the tropical purse seine fishery,

> *i. The WCPFC Secretariat and the WCPFC scientific services provider investigate operational aspects including alternatives for spill sampling on purse seine vessels where the current spill sampling protocol is difficult to implement and report back to SC12.*
>
> *ii. The WCPFC scientific services provider will undertake additional data collection and analyses to evaluate the benefits of spill sampling compared to corrected grab sampling.*

To implement the 2015 Scientific Committee recommendations, and after approval from the Commission (Anon., 2015b), the WCPFC Secretariat contracted the Scientific Services Provider to continue Project 60. In 2016, the Scientific Service Provider proposed a work plan for the continuation of Project 60 (Smith and Peatman, 2016) which was subsequently endorsed by the 2016 Scientific Committee (Anon., 2016). In 2017, the Scientific Service Provider presented work undertaken between SC12 and SC13, along with a proposed work plan moving forward (Peatman et al., 2017a). The 2017 Scientific Committee recommended that future work proposed by the Scientific Service provider continue over the coming year, with reporting to SC14, and agreed that the work should continue in the medium term subject to annual review (Anon., 2017). The Scientific Service Provider presented a two-year work plan to the 2018 Scientific Committee, reflecting the work undertaken between SC13 and SC14, which was subsequently endorsed (Anon., 2018).

Project 60 Scope

The scope of Project 60 as outlined in 2016 includes, but is not limited to, the following:

a) Continue to identify key sources of sampling bias in the manner in which species composition data are currently collected from WCPO purse seine fisheries and investigate how such biases can be reduced;

b) Review a broad range of sampling schemes at-sea as well as onshore; develop appropriate sampling designs to obtain unbiased species composition data by evaluating the selected sampling procedures; extend sampling to include fleets, areas and set types where no representative sampling has taken place; verify, where possible, the results of the paired sampling against cannery, unloading and port sampling data;

c) Review current stock assessment input data in relation to purse-seine species composition and investigate any other areas to be improved in species composition data, including the improvements of the accuracy of collected data;

d) Update standard spill sampling methodology if required; and,

e) Analyse additional data collected to evaluate the benefits of spill sampling compared to corrected grab-sampling.

Estimation of aggregated purse seine species catch estimates

Report prepared by

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Methods

As described in Peatman et al. (2019), observer samples are currently used to estimate species compositions of aggregate catch for the tropical purse seine fishery (20°S to 20°N) in the WCPFC Convention Area. These estimates do not cover: the Japanese fleet, which submits corrected catch data; the domestic fisheries of Indonesia and Vietnam; and, effort from the domestic Philippines fleet outside of the high seas pocket.

SC15 (Anon., 2019) recommended a number of changes to the estimation approach based on outcomes from WCPFC Project 60. The current approach depends on the levels of observer coverage:

- proportions of skipjack, yellowfin and bigeye are estimated directly from pooled observer data (with corrections for grab sample bias using multinomial-model based correction factors), stratified by year, quarter, 5° square, flag and school association (free school v associated), for strata with ≥ 20% observer coverage of catch;
- for strata with < 20% observer coverage of catch, zero and one inflated beta-response models are used to predict species proportions, with the models fitted to observer sample based species compositions (again with corrections for grab sample bias using 'availability'); and
- the estimates of species proportions are then applied to aggregate catch data at the S_BEST stratification, i.e. year, month, flag and fleet, 1° square and school association type (free school, anchored FAD, drifting FAD etc).

Observer-data based estimates of species proportions were estimated using the approach described in Peatman et al. (2019), provided in Appendix B. Observer data for 2019 had not been fully submitted to SPC and loaded into the master observer database at the time of writing, and so the catch estimates for 2019 should be considered preliminary.

Zero and one inflated beta-response models were fitted to observer-sample based estimates of species composition as described in Peatman et al. (2019), using the R package *gamlss* (Rigby and Stasinopoulos, 2005). A full description of the models is provided in Peatman et al. (2019). We provide a summary here, along with full specification of the models in Appendix A. Separate models were constructed for each species and school association (free school v associated) combination, and fitted to set-level observations. The contribution of each observation to the likelihood function was weighted by the square root of the number of samples from the set. Random vessel intercepts were used to account for between-vessel variation in catch compositions.

Results

The model fits of the catch proportion models are provided in Appendix A (Figure 3 to Figure 31). The effects are similar to those reported in Peatman et al. (2019) and are not summarised here. The overall estimates of species specific catch and catch proportions are provided in Figure 1 and Figure 2. The general trend of increasing skipjack proportions, and decreasing yellowfin and bigeye proportions, continued in 2019.

Notes

The author briefly looked at whether the models were improved by separating the PH high seas pocket fishery out from the PH fleet. This did not have any discernible effect on the catch estimates and proportions, so has not been on in the text. This may be considered further in the future.

References

Anon. (2019). Report of the 15th Regular Session of the Scientific Committee of the Western and Central Pacific Fisheries Commission. 12–20th August 2019, Pohnpei, Federates States of Micronesia.

Rigby R.A. and D.M. Stasinopoulos (2005). Generalized additive models for location, scale and shape,(with discussion). *Appl. Statist.*, **54**, 507-554.

Peatman T., N. Smith, S. Caillot, S. Fukofuka and T. Park (2018) Better purse seine catch composition estimates: progress on the Project 60 work plan. WCPFC-SC14-2018/ST-WP-02.

Peatman T., S. Fukofuka, T. Park, P. Williams, J. Hampton and N. Smith (2019) Better purse seine catch composition estimates: progress on the Project 60 work plan. WCPFC-SC15-2019/ST-WP-02.

Figures

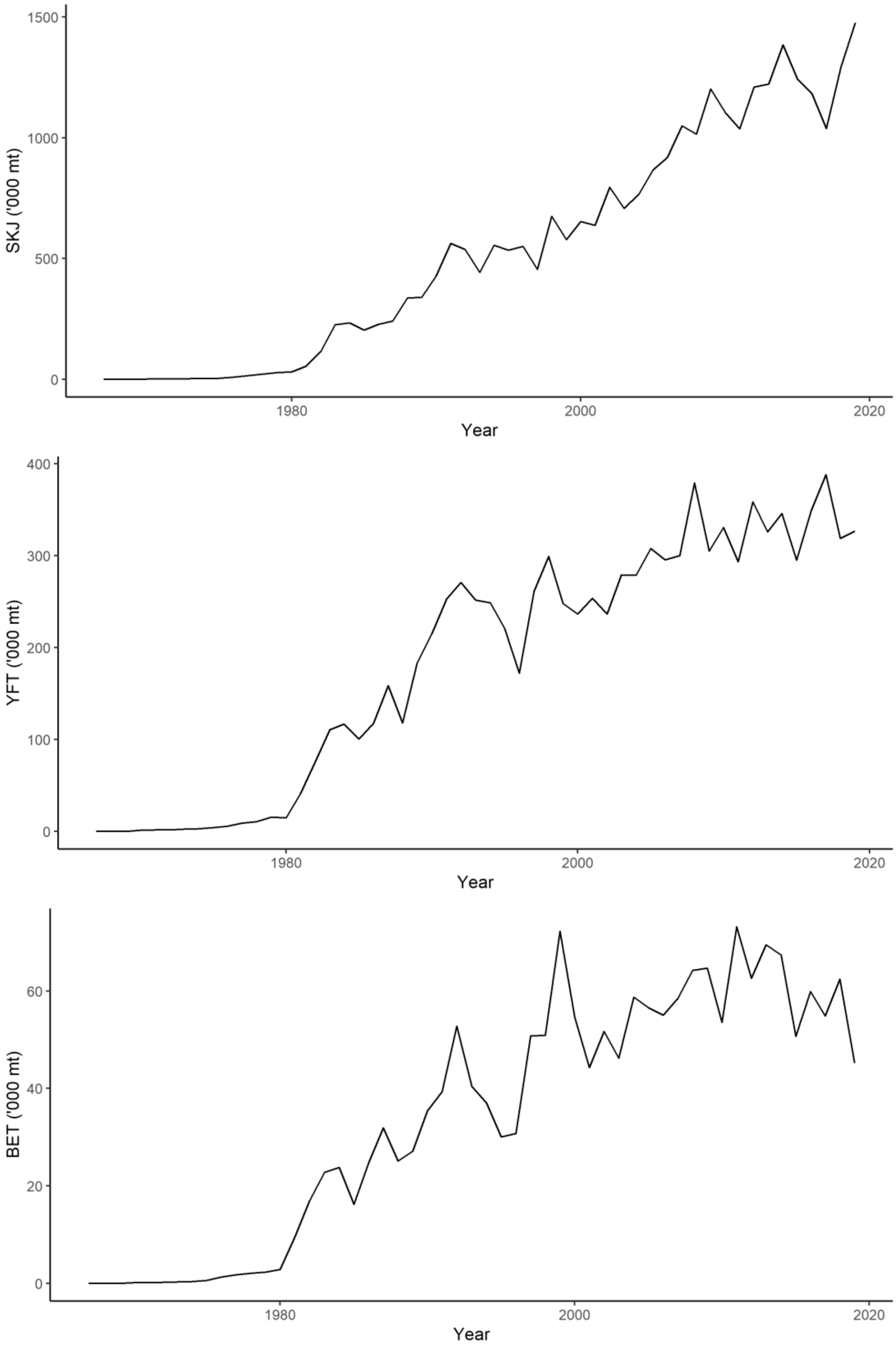

Figure 1 Annual purse seine catch estimates for skipjack (top), yellowfin (middle) and bigeye (bottom panel).

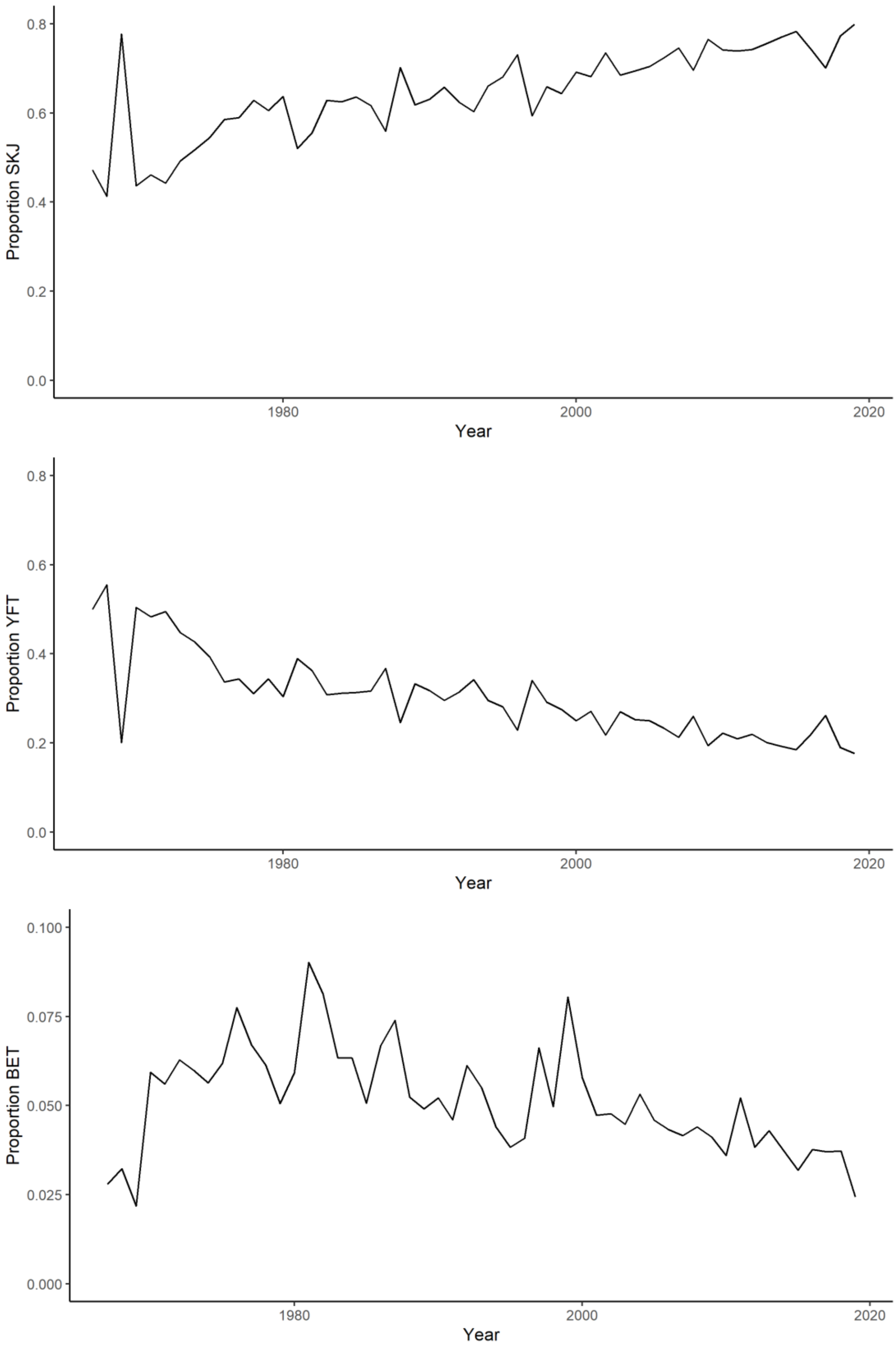

Figure 2 Annual purse seine catch proportion estimates for skipjack (top), yellowfin (middle) and bigeye (bottom panel).

Appendix A

Specification of inflated-beta response models of species compositions

The final model for skipjack proportions on associated sets was specified as:

$$E[SKJ_{ij}] = \frac{\tau_{ij} + \mu_{ij}}{1 + \upsilon_{ij} + \tau_{ij}}$$

where the mean of the beta distribution, μ_{ij}, the zero inflation component, υ_{ij}, the one inflation component, τ_{ij}, and the variance parameter, σ_{ij}, were parameterised:

$$\ln\left(\frac{\mu_{ij}}{1-\mu_{ij}}\right) = \beta_0 + flag_{ij} + assoc_{ij} + archipelagic_{ij} + qtr_{ij} + f(yy_{ij}) + f(isotherm_{ij}) + f(prop_{SKJ}) + ONI_{ij} * f(lon_{ij}) + b_j$$

$$\ln(\upsilon_{ij}) = \beta_0 + assoc_{ij} + f(prop_{SKJ}) + b_j$$

$$\ln(\tau_{ij}) = \beta_0 + flag_{ij} + assoc_{ij} + archipelagic_{ij} + qtr_{ij} + f(yy_{ij}) + f(isotherm_{ij}) + f(prop_{SKJ}) + ONI_{ij} * f(lon_{ij}) + b_j$$

$$\ln\left(\frac{\sigma_{ij}}{1-\sigma_{ij}}\right) = \beta_0$$

where subscripts i and j refer to set and vessel, $flag_{ij}$ is the flag of the vessel, $assoc_{ij}$ is the type of association (see below for more information), $archipelagic_{ij}$ is an identifier for sets in archipelagic waters, qtr_{ij} is (a categorical) quarter effect, yy_{ij} is year, $isotherm_{ij}$ is the depth of the 20°C isotherm, $prop_{SKJ}$ is the uncorrected proportion of skipjack from aggregate catch and effort data, ONI_{ij} is the Oceanic Nino Index (grouped to El Nino, neutral and La Nina), lon_{ij} is the longitude of the set, $f(\ )$ are cubic regression splines and b_j are random intercepts for vessel, $b_j \sim N(0, \sigma_b)$. The association types for unassociated sets were: unassociated schools, fs; and, unassociated schools feeding on baitfish, fs.bait. The association types for associated sets were: schools associated to anchored FADs (aFAD), drifting FADs (dFAD), logs (log), whales (whl) and whale sharks (whl.shk).

The zero-inflation parameter, υ_{ij}, does not directly reflect the probability of a zero response, this is given by $\upsilon_{ij}(1 + \upsilon_{ij} + \tau_{ij})^{-1}$. Similarly, the probability of a one response is $\tau_{ij}(1 + \upsilon_{ij} + \tau_{ij})^{-1}$.

The final model for yellowfin proportions on associated sets was specified as:

$$E[YFT_{ij}] = \frac{\tau_{ij} + \mu_{ij}}{1 + \upsilon_{ij} + \tau_{ij}}$$

where the mean of the beta distribution, μ_{ij}, the zero inflation component, υ_{ij}, the one inflation component, τ_{ij}, and the variance parameter, σ_{ij}, were parameterised:

$$\ln\left(\frac{\mu_{ij}}{1-\mu_{ij}}\right) = \beta_0 + flag_{ij} + assoc_{ij} + archipelagic_{ij} + qtr_{ij} + f(yy_{ij}) + f(isotherm_{ij}) + f(prop_{SKJ}) + ONI_{ij} * f(lon_{ij}) + b_j$$

$$\ln(\upsilon_{ij}) = \beta_0 + flag_{ij} + assoc_{ij} + archipelagic_{ij} + qtr_{ij} + f(yy_{ij}) + f(isotherm_{ij}) + f(prop_{SKJ}) + ONI_{ij} * f(lon_{ij}) + b_j$$

$$\ln(\tau_{ij}) = \beta_0 + assoc_{ij} + f(prop_{SKJ}) + b_j$$

$$\ln\left(\frac{\sigma_{ij}}{1-\sigma_{ij}}\right) = \beta_0$$

The final model for bigeye proportions on associated sets was specified as:

$$E[BET_{ij}] = \frac{\tau_{ij} + \mu_{ij}}{1 + \upsilon_{ij} + \tau_{ij}}$$

where the mean of the beta distribution, μ_{ij}, the zero inflation component, υ_{ij}, the one inflation component, τ_{ij}, and the variance parameter, σ_{ij}, were parameterised:

$$\ln\left(\frac{\mu_{ij}}{1-\mu_{ij}}\right) = \beta_0 + flag_{ij} + assoc_{ij} + archipelagic_{ij} + qtr_{ij} + f(yy_{ij}) + f(isotherm_{ij}) + f(prop_{SKJ}) + ONI_{ij} * f(lon_{ij}) + b_j$$

$$\ln(\upsilon_{ij}) = \beta_0 + flag_{ij} + assoc_{ij} + archipelagic_{ij} + qtr_{ij} + f(yy_{ij}) + f(isotherm_{ij}) + f(prop_{SKJ}) + ONI_{ij} * f(lon_{ij}) + b_j$$

$$\ln(\tau_{ij}) = \beta_0 + assoc_{ij}$$

$$\ln\left(\frac{\sigma_{ij}}{1-\sigma_{ij}}\right) = \beta_0$$

The final model for skipjack proportions on unassociated sets was specified as:

$$E[SKJ_{ij}] = \frac{\tau_{ij} + \mu_{ij}}{1 + \upsilon_{ij} + \tau_{ij}}$$

where the mean of the beta distribution, μ_{ij}, the zero inflation component, υ_{ij}, the one inflation component, τ_{ij}, and the variance parameter, σ_{ij}, were parameterised:

$$\ln\left(\frac{\mu_{ij}}{1-\mu_{ij}}\right) = \beta_0 + flag_{ij} + assoc_{ij} + archipelagic_{ij} + qtr_{ij} + f(yy_{ij}) + f(isotherm_{ij}) + f(prop_{SKJ}) + ONI_{ij} * f(lon_{ij}) + b_j$$

$$\ln(\upsilon_{ij}) = \beta_0 + f(prop_{SKJ}) + b_j$$

$$\ln(\tau_{ij}) = \beta_0 + flag_{ij} + assoc_{ij} + archipelagic_{ij} + qtr_{ij} + f(yy_{ij}) + f(isotherm_{ij}) + f(prop_{SKJ}) + ONI_{ij} * f(lon_{ij}) + b_j$$

$$\ln\left(\frac{\sigma_{ij}}{1-\sigma_{ij}}\right) = \beta_0$$

The final model for yellowfin proportions on unassociated sets was specified as:

$$E[YFT_{ij}] = \frac{\tau_{ij} + \mu_{ij}}{1 + \upsilon_{ij} + \tau_{ij}}$$

where the mean of the beta distribution, μ_{ij}, the zero inflation component, υ_{ij}, the one inflation component, τ_{ij}, and the variance parameter, σ_{ij}, were parameterised:

$$\ln\left(\frac{\mu_{ij}}{1-\mu_{ij}}\right) = \beta_0 + flag_{ij} + assoc_{ij} + archipelagic_{ij} + qtr_{ij} + f(yy_{ij}) + f(isotherm_{ij}) + f(prop_{SKJ}) + ONI_{ij} * f(lon_{ij}) + b_j$$

$$\ln(\upsilon_{ij}) = \beta_0 + flag_{ij} + assoc_{ij} + archipelagic_{ij} + qtr_{ij} + f(yy_{ij}) + f(isotherm_{ij}) + f(prop_{SKJ}) + ONI_{ij} * f(lon_{ij}) + b_j$$

$$\ln(\tau_{ij}) = \beta_0 + f(prop_{SKJ}) + b_j$$

$$\ln\left(\frac{\sigma_{ij}}{1-\sigma_{ij}}\right) = \beta_0$$

The final model for bigeye proportions on unassociated sets was specified as:

$$E\left[BET_{ij}\right] = \frac{\tau_{ij} + \mu_{ij}}{1 + \upsilon_{ij} + \tau_{ij}}$$

where the mean of the beta distribution, μ_{ij}, the zero inflation component, υ_{ij}, the one inflation component, τ_{ij}, and the variance parameter, σ_{ij}, were parameterised:

$$\ln\left(\frac{\mu_{ij}}{1-\mu_{ij}}\right) = \beta_0 + flag_{ij} + assoc_{ij} + archipelagic_{ij} + qtr_{ij} + \ f\left(isotherm_{ij}\right) + f\left(prop_{SKJ}\right) + ONI_{ij} * f\left(lon_{ij}\right)$$

$$\ln\left(\upsilon_{ij}\right) = \beta_0 + flag_{ij} + assoc_{ij} + archipelagic_{ij} + qtr_{ij} + \ f\left(yy_{ij}\right) + \ f\left(isotherm_{ij}\right) + f\left(prop_{SKJ}\right) + ONI_{ij} * f\left(lon_{ij}\right) + b_j$$

$$\ln\left(\tau_{ij}\right) = \beta_0 + assoc_{ij}$$

$$\ln\left(\frac{\sigma_{ij}}{1-\sigma_{ij}}\right) = \beta_0$$

Effect plots for inflated-beta response models of species compositions

Skipjack – free school

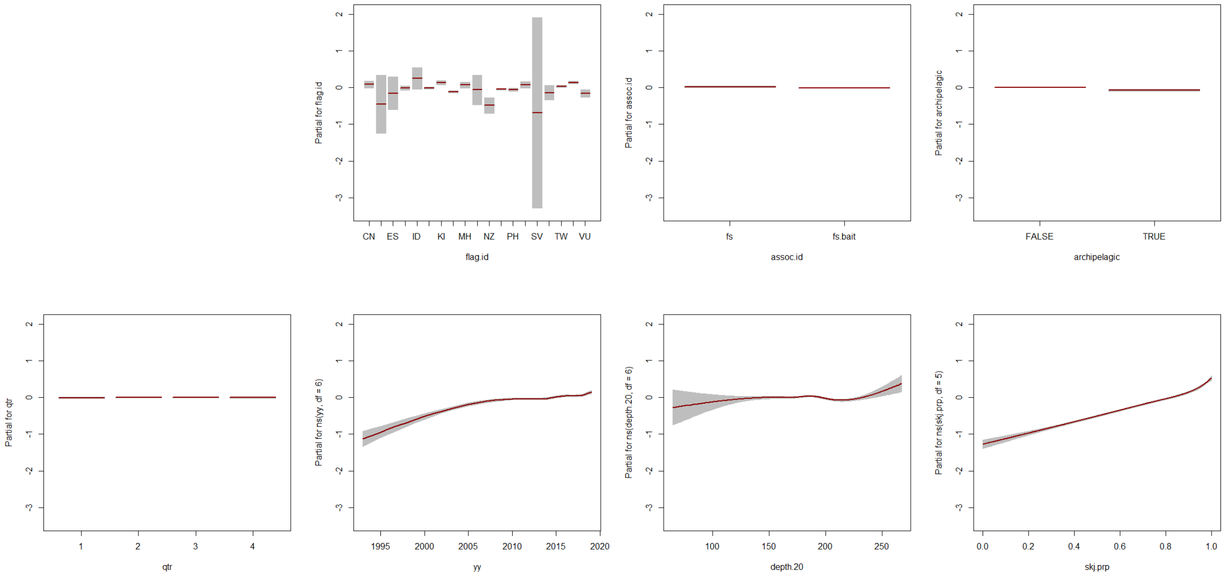

Figure 3 Fixed effects on the mean of the beta-component of the skipjack free-school model. Top row, left to right: flag; association type (free school – fs, and free school feeding on baitfish – fs.bait); archipelagic waters. Bottom row, left to right: quarter; year; isotherm depth; and, uncorrected skipjack proportion from vessel logbooks.

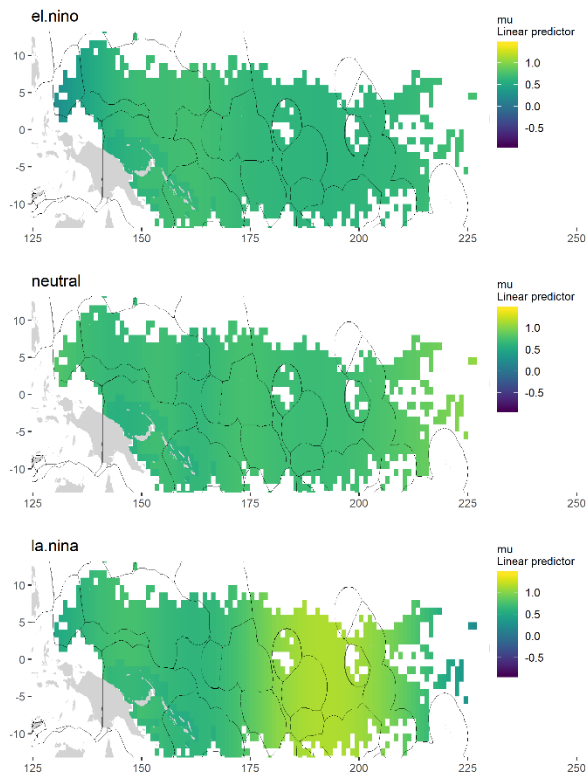

Figure 4 The combined effect of the archipelagic term and the longitude:ONI interaction on the mean of the beta component of the skipjack free-school model.

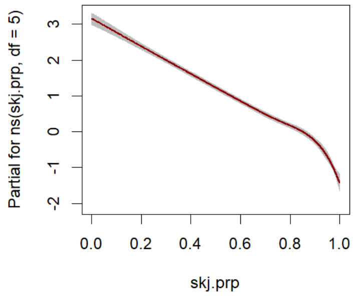

Figure 5 Effects on the zero-inflation component of the skipjack free-school model: uncorrected skipjack proportion from vessel logbooks.

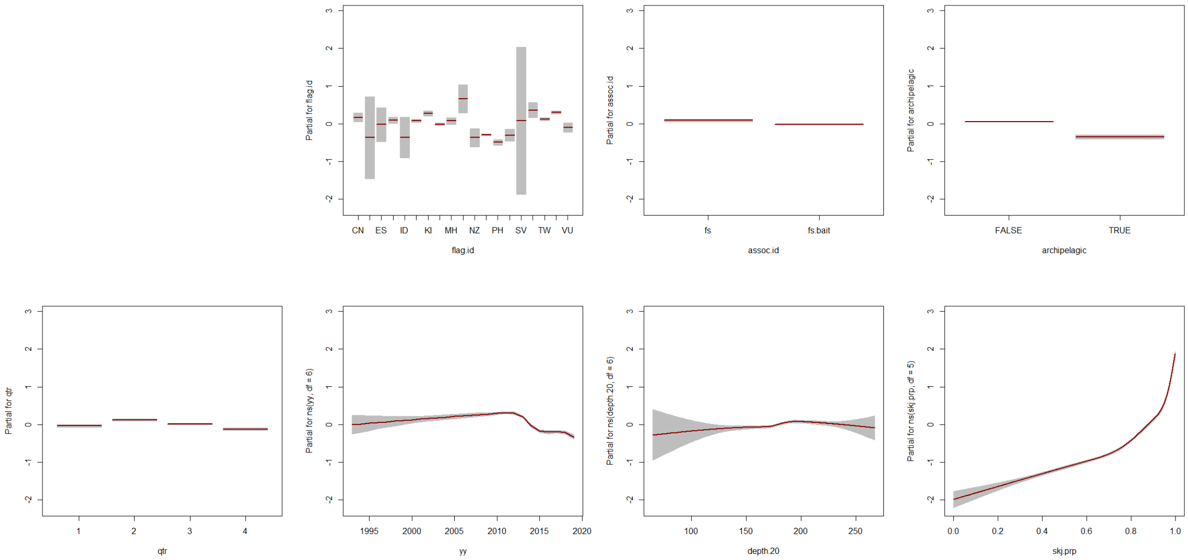

Figure 6 Fixed effects on the one-inflation component of the skipjack free-school model. Top row, left to right: flag; association type (free school – fs, and free school feeding on baitfish – fs.bait); archipelagic waters. Bottom row, left to right: quarter; year; isotherm depth; and, uncorrected skipjack proportion from vessel logbooks.

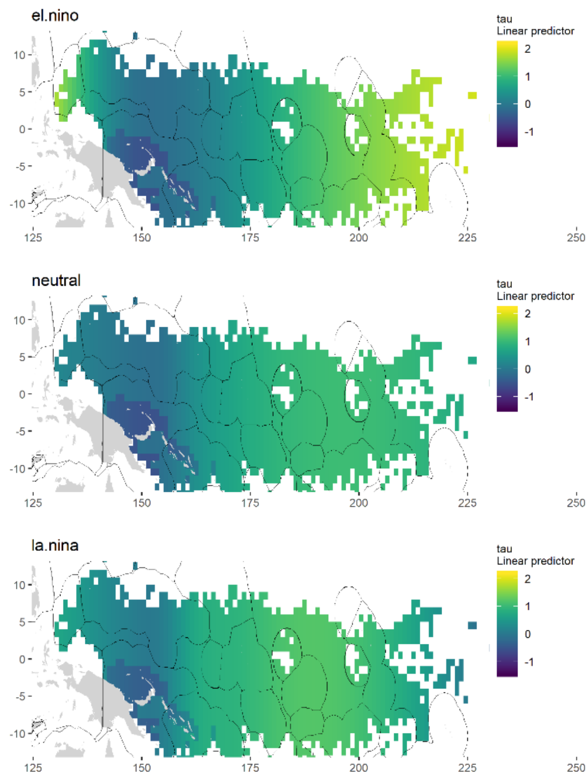

Figure 7 The combined effect of the archipelagic term and the longitude:ONI interaction on the one-inflation component of the skipjack free-school model.

Yellowfin – free school

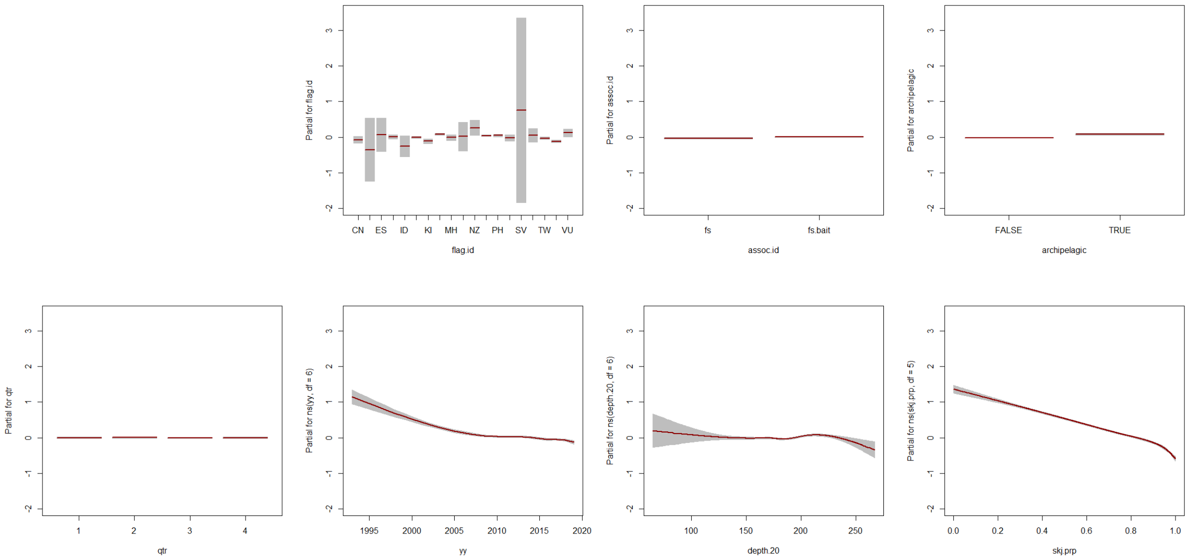

Figure 8 Fixed effects on the mean of the beta-component of the yellowfin free-school model. Top row, left to right: flag; association type (free school – fs, and free school feeding on baitfish – fs.bait); archipelagic waters. Bottom row, left to right: quarter; year; isotherm depth; and, uncorrected skipjack proportion from vessel logbooks.

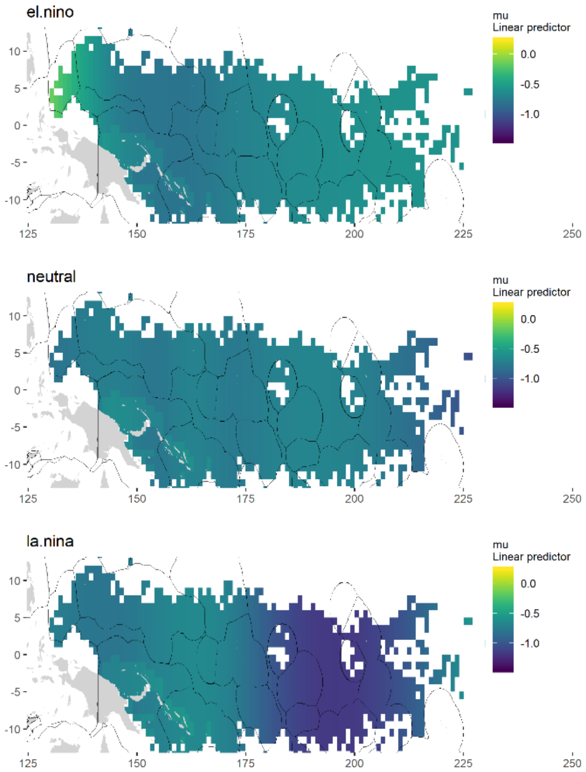

Figure 9 The combined effect of the archipelagic term and the longitude:ONI interaction on the mean of the beta component of the yellowfin free-school model.

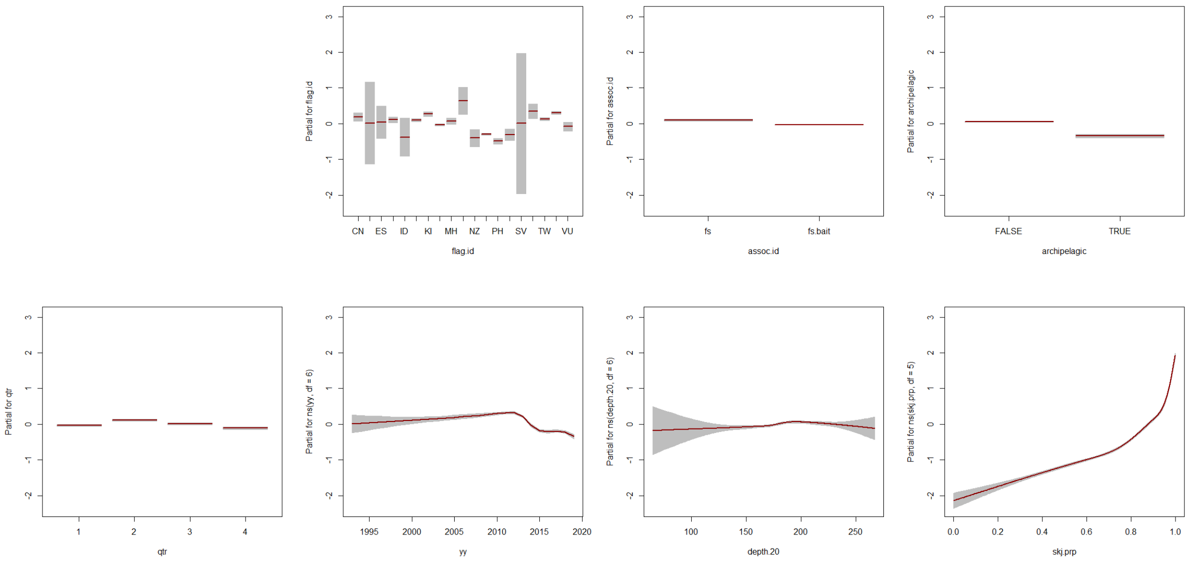

Figure 10 Fixed effects on the zero-inflation component of the yellowfin free-school model. Top row, left to right: flag; association type (free school – fs, and free school feeding on baitfish – fs.bait); archipelagic waters. Bottom row, left to right: quarter; year; isotherm depth; and, uncorrected skipjack proportion from vessel logbooks.

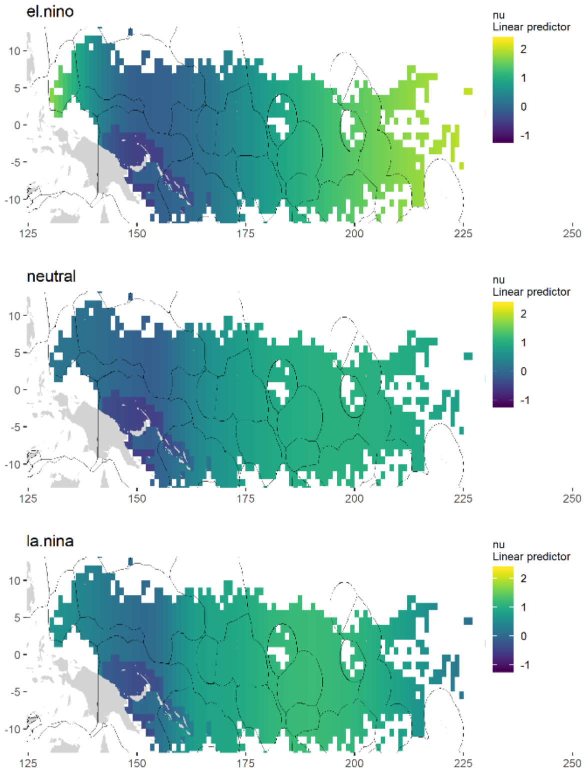

Figure 11 The combined effect of the archipelagic term and the longitude:ONI interaction on the zero-inflation component of the yellowfin free-school model.

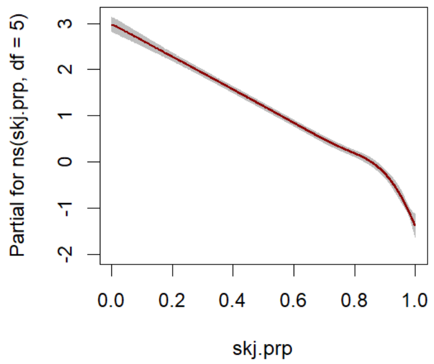

Figure 12 Fixed effects on the one-inflation component of the yellowfin free-school model: uncorrected skipjack proportion from vessel logbooks (right).

Bigeye – free school

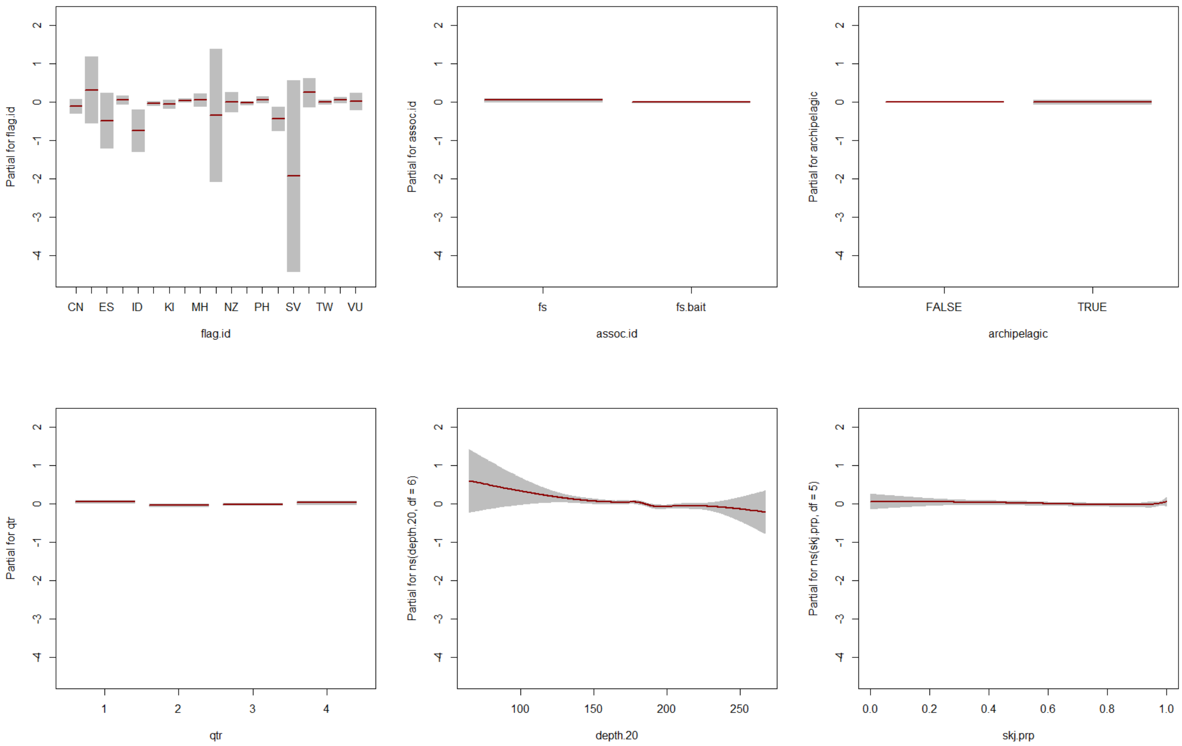

Figure 13 Fixed effects on the mean of the beta-component of the bigeye free-school model. Top row, left to right: flag; association type (free school – fs, and free school feeding on baitfish – fs.bait); archipelagic waters. Bottom row, left to right: quarter; isotherm depth; and, uncorrected skipjack proportion from vessel logbooks.

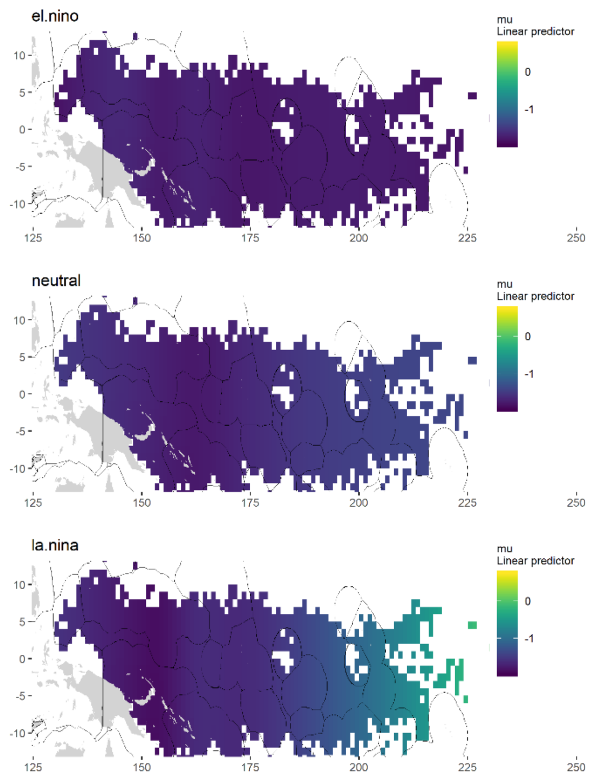

Figure 14 The combined effect of the archipelagic term and the longitude:ONI interaction on the mean of the beta component of the bigeye free-school model.

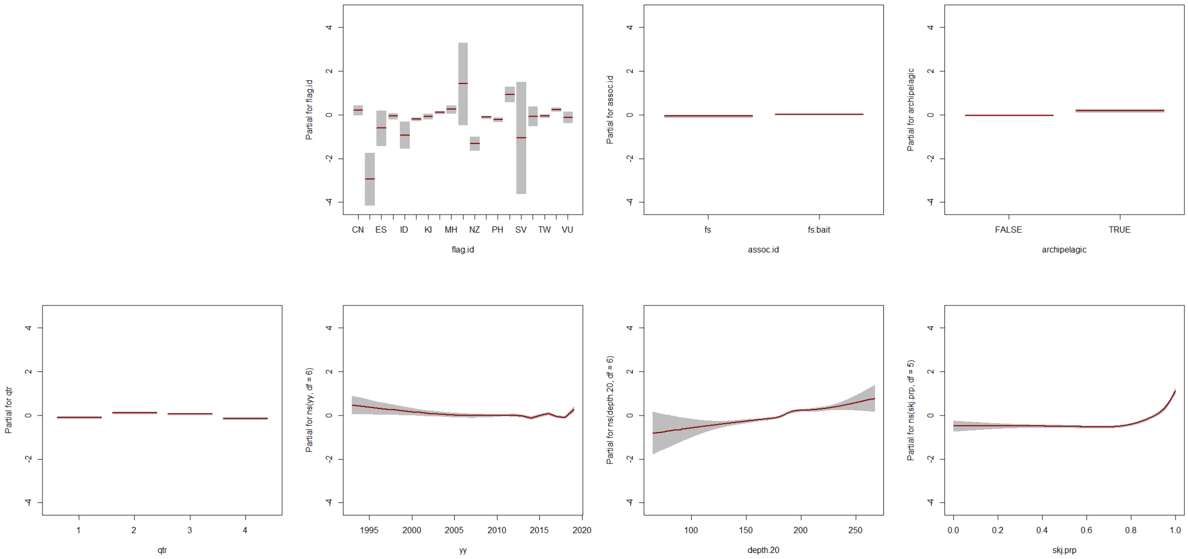

Figure 15 Fixed effects on the zero-inflation component of the bigeye free-school model. Top row, left to right: flag; association type (free school – fs, and free school feeding on baitfish – fs.bait); archipelagic waters. Bottom row, left to right: quarter; year; isotherm depth; and, uncorrected skipjack proportion from vessel logbooks.

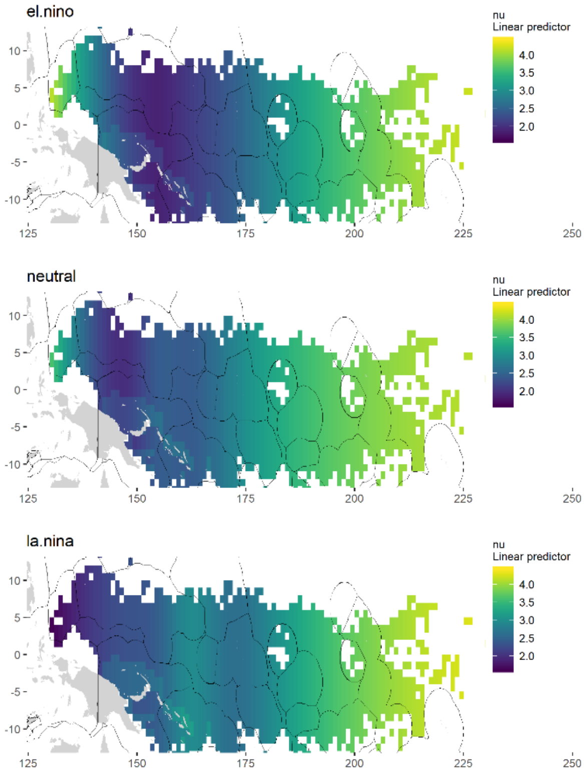

Figure 16 The combined effect of the archipelagic term and the longitude:ONI interaction on the zero-inflation component of the bigeye free-school model.

Skipjack – associated

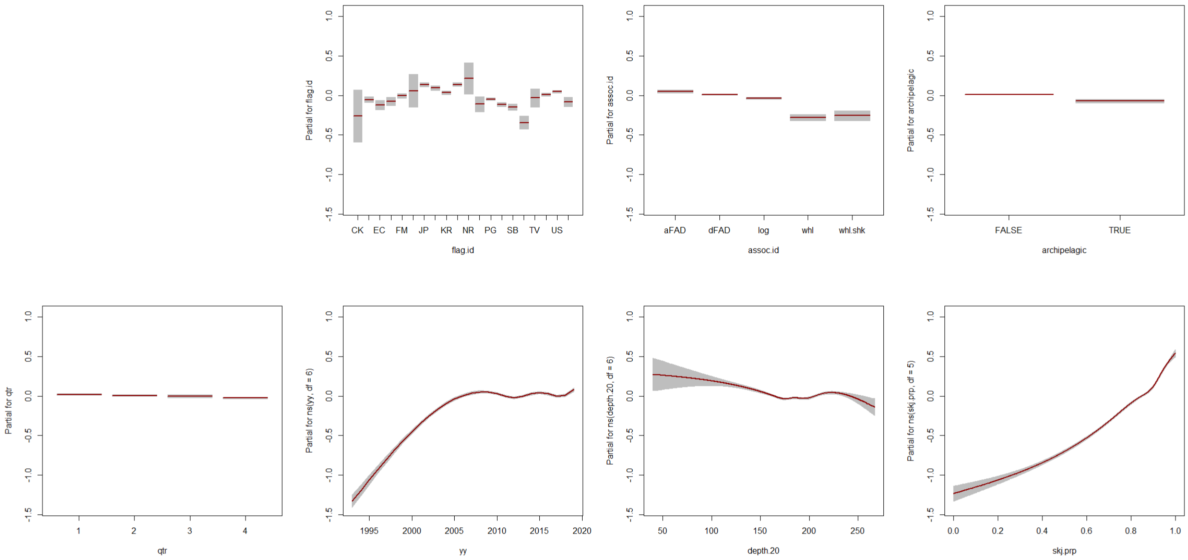

Figure 17 Fixed effects on the mean of the beta-component of the skipjack associated model. Top row, left to right: flag; association type (anchored FAD – aFAD, drifting FAD – dFAD, log sets, whale associated – whl, and whale shark associated – whl.shk); archipelagic waters. Bottom row, left to right: quarter; year; isotherm depth; and, uncorrected skipjack proportion from vessel logbooks.

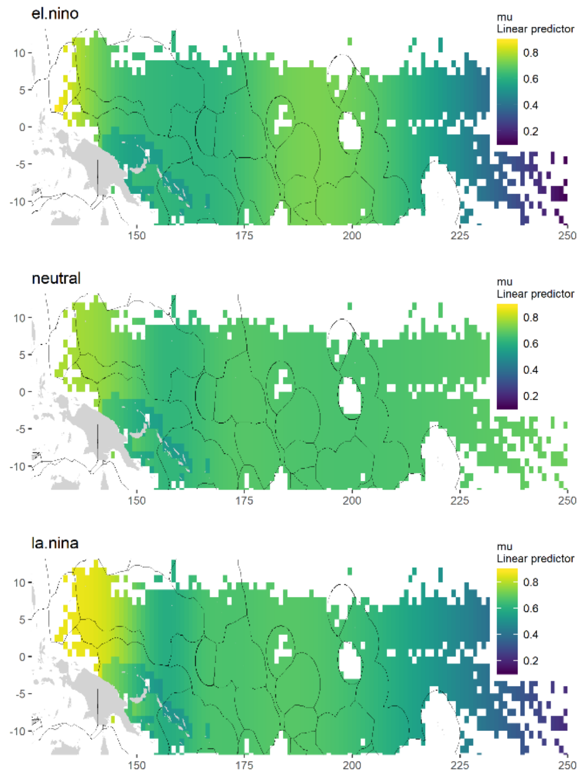

Figure 18 The combined effect of the archipelagic term and the longitude:ONI interaction on the mean of the beta component of the skipjack associated model.

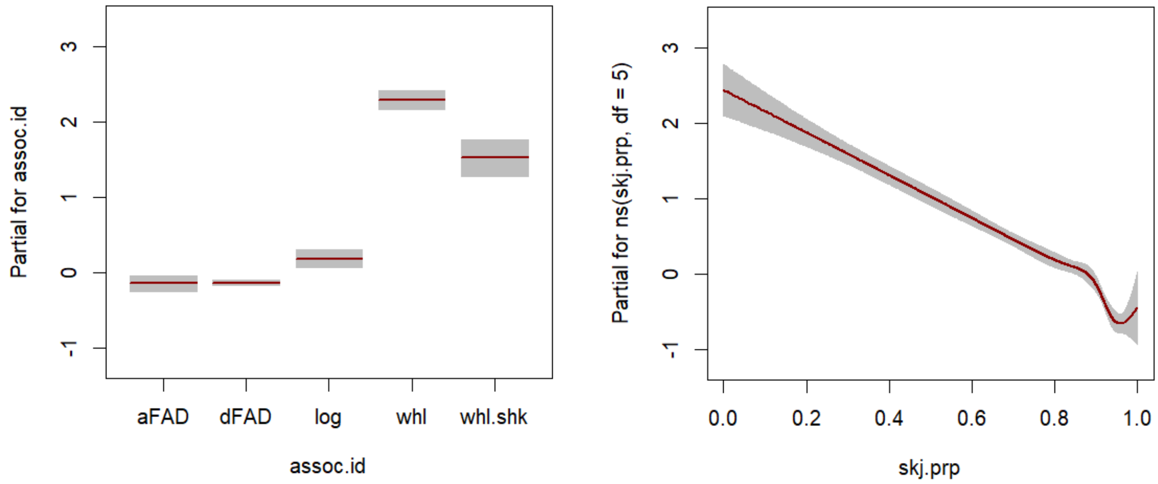

Figure 19 Fixed effects on the zero-inflation component of the skipjack associated model: association type (left panel, anchored FAD – aFAD, drifting FAD – dFAD, log sets, whale associated – whl, and whale shark associated – whl.shk) and, uncorrected skipjack proportion from vessel logbooks (right).

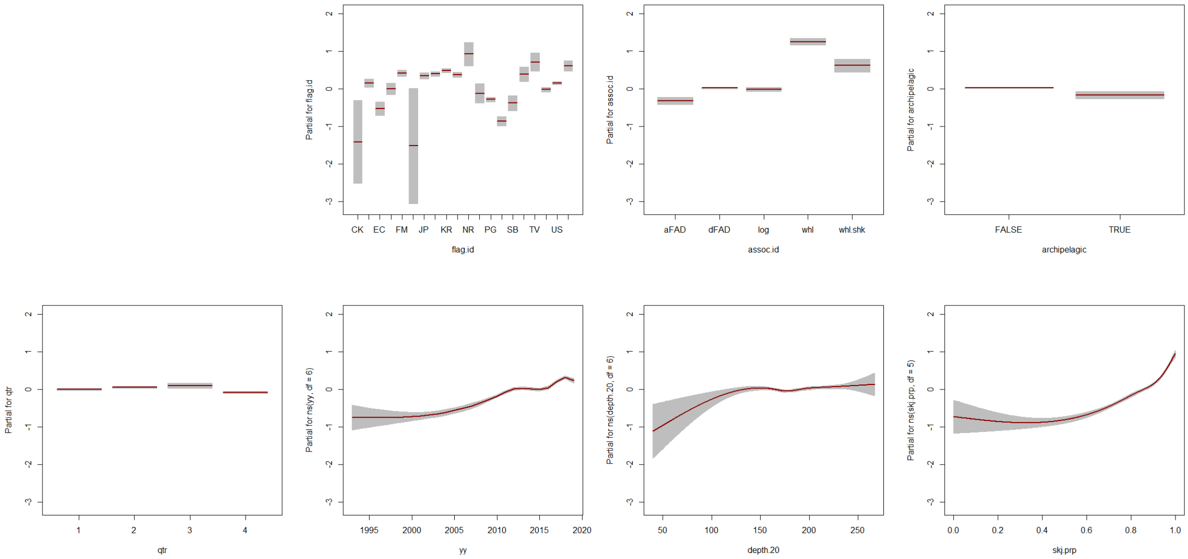

Figure 20 Fixed effects on the one-inflation component of the skipjack associated model. Top row, left to right: flag; association type (anchored FAD – aFAD, drifting FAD – dFAD, log sets, whale associated – whl, and whale shark associated – whl.shk); archipelagic waters. Bottom row, left to right: quarter; year; isotherm depth; and, uncorrected skipjack proportion from vessel logbooks.

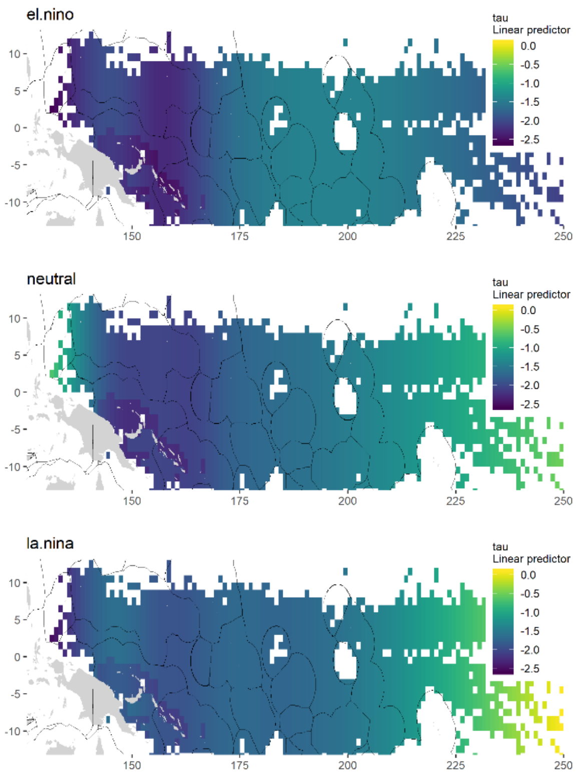

Figure 21 The combined effect of the archipelagic term and the longitude:ONI interaction on the one-inflation component of the skipjack associated model.

Yellowfin – associated

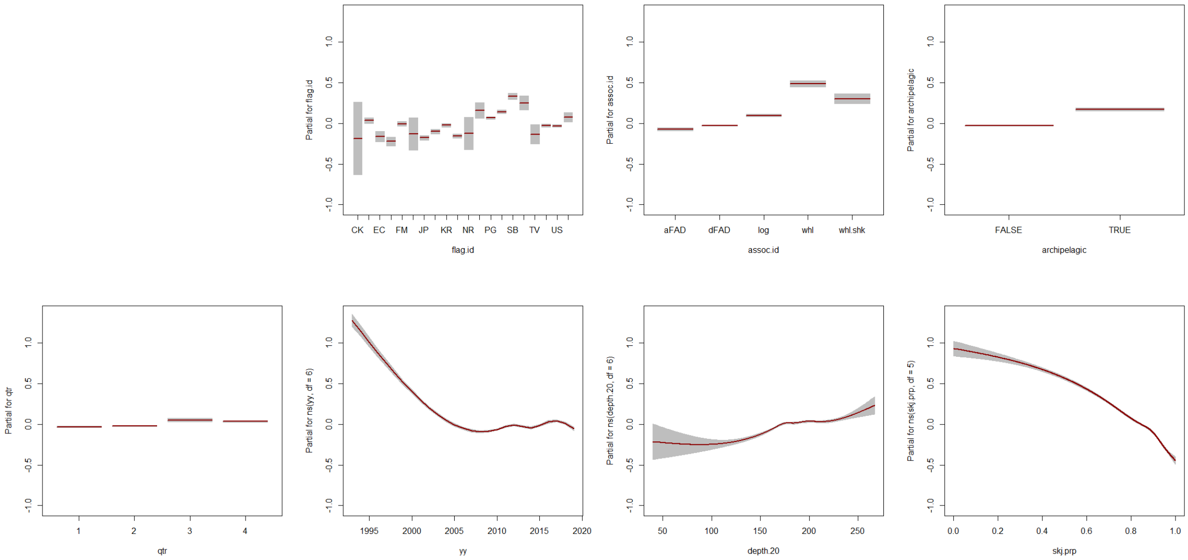

Figure 22 Fixed effects on the mean of the beta-component of the yellowfin associated model. Top row, left to right: flag; association type (anchored FAD – aFAD, drifting FAD – dFAD, log sets, whale associated – whl, and whale shark associated – whl.shk); archipelagic waters. Bottom row, left to right: quarter; year; isotherm depth; and, uncorrected skipjack proportion from vessel logbooks.

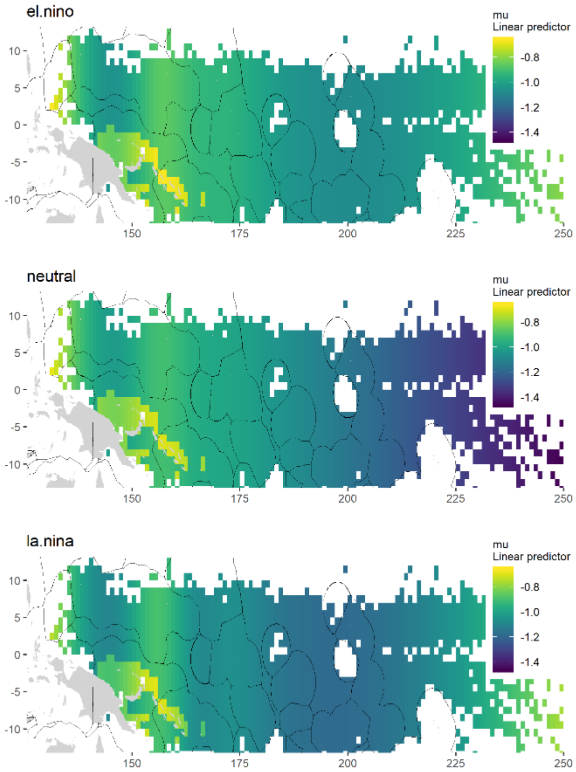

Figure 23 The combined effect of the archipelagic term and the longitude:ONI interaction on the mean of the beta component of the yellowfin associated model.

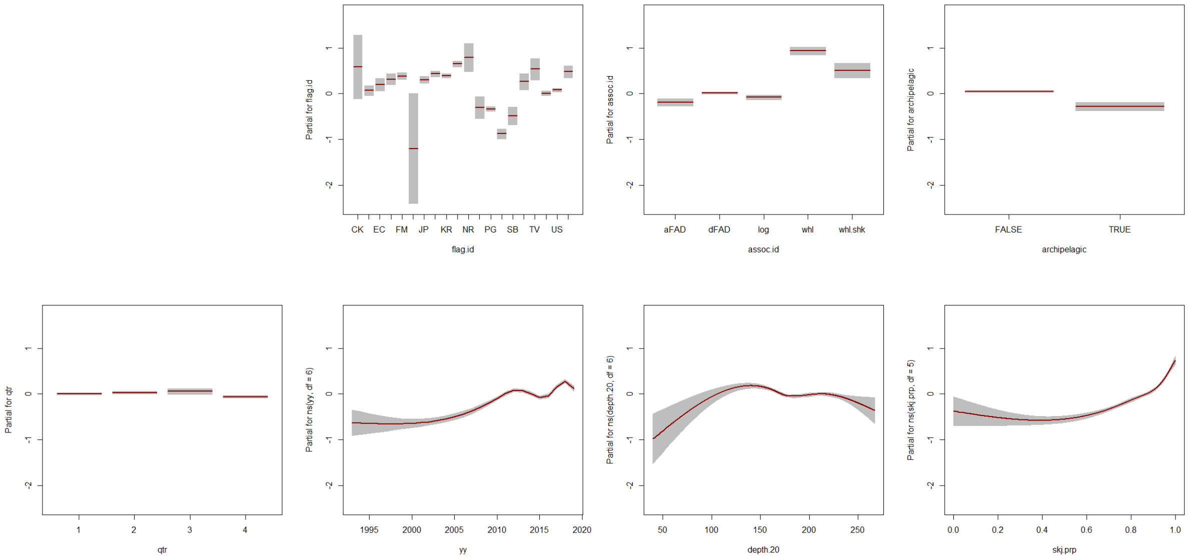

Figure 24 Fixed effects on the zero-inflation component of the yellowfin associated model. Top row, left to right: flag; association type (anchored FAD – aFAD, drifting FAD – dFAD, log sets, whale associated – whl, and whale shark associated – whl.shk); archipelagic waters. Bottom row, left to right: quarter; year; isotherm depth; and, uncorrected skipjack proportion from vessel logbooks.

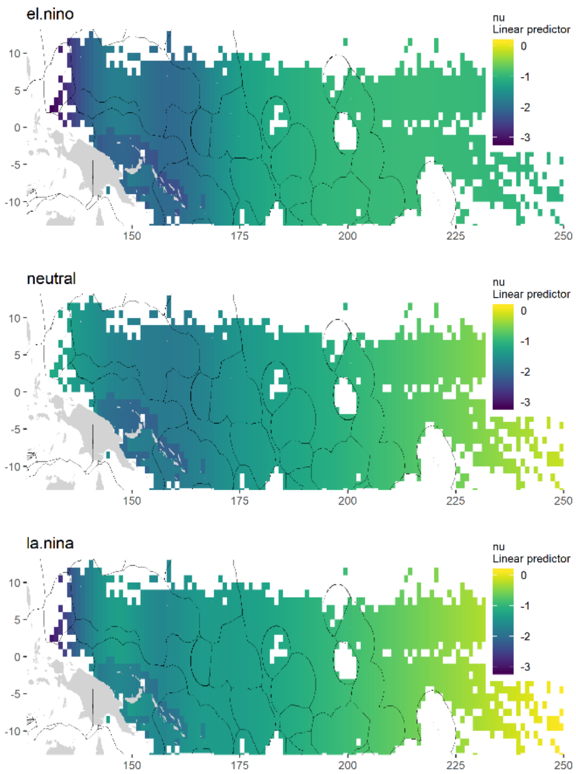

Figure 25 The combined effect of the archipelagic term and the longitude:ONI interaction on the zero-inflation component of the yellowfin associated model.

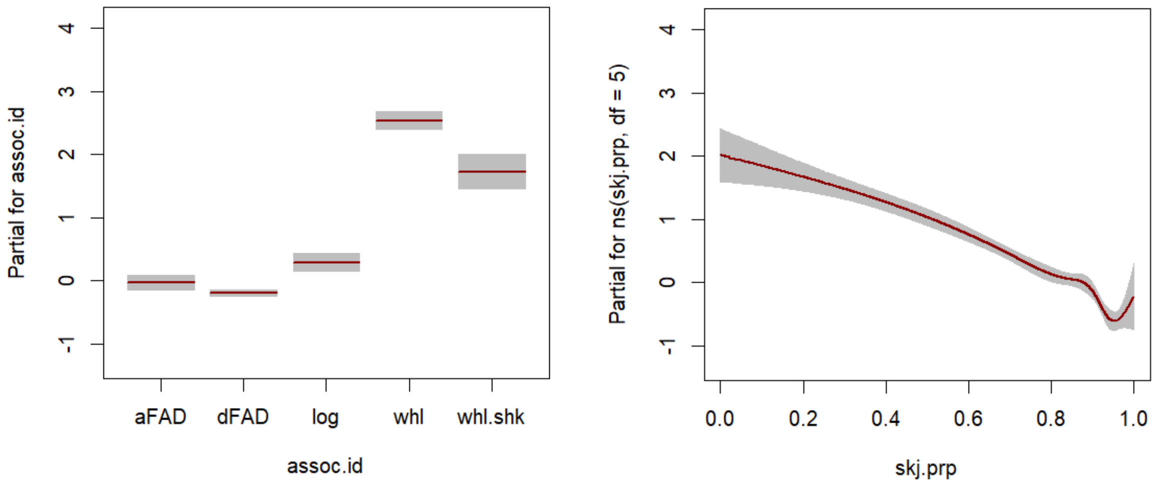

Figure 26 Fixed effects on the one-inflation component of the yellowfin associated model: association type (left - anchored FAD – aFAD, drifting FAD – dFAD, log sets, whale associated – whl, and whale shark associated – whl.shk) and, uncorrected skipjack proportion from vessel logbooks (right).

Bigeye – associated

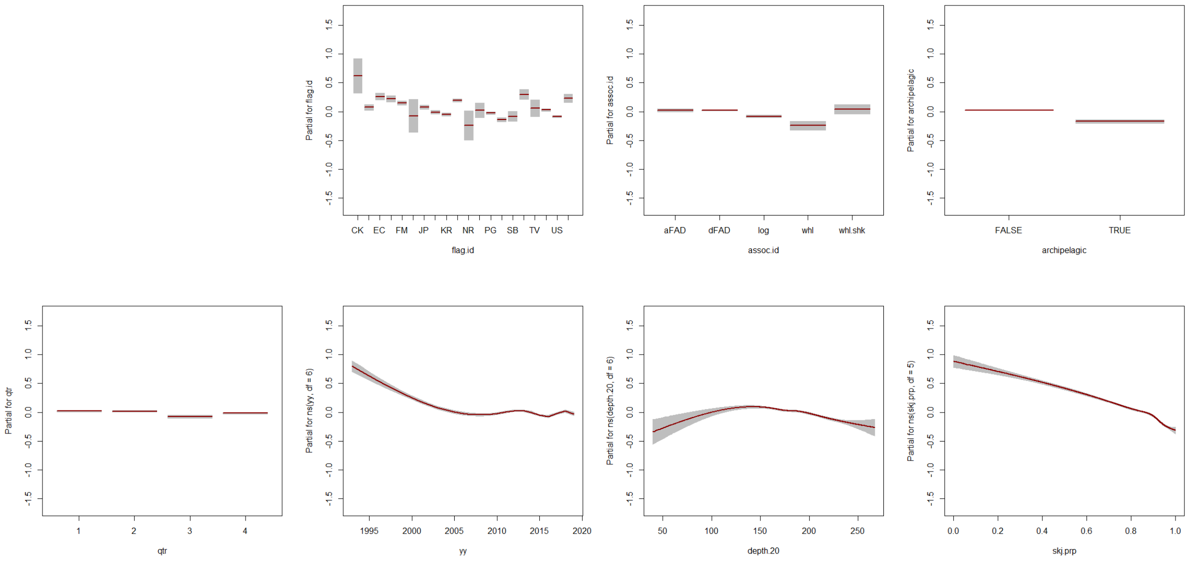

Figure 27 Fixed effects on the mean of the beta-component of the bigeye associated model. Top row, left to right: flag; association type (anchored FAD – aFAD, drifting FAD – dFAD, log sets, whale associated – whl, and whale shark associated – whl.shk); archipelagic waters. Bottom row, left to right: quarter; isotherm depth; and, uncorrected skipjack proportion from vessel logbooks.

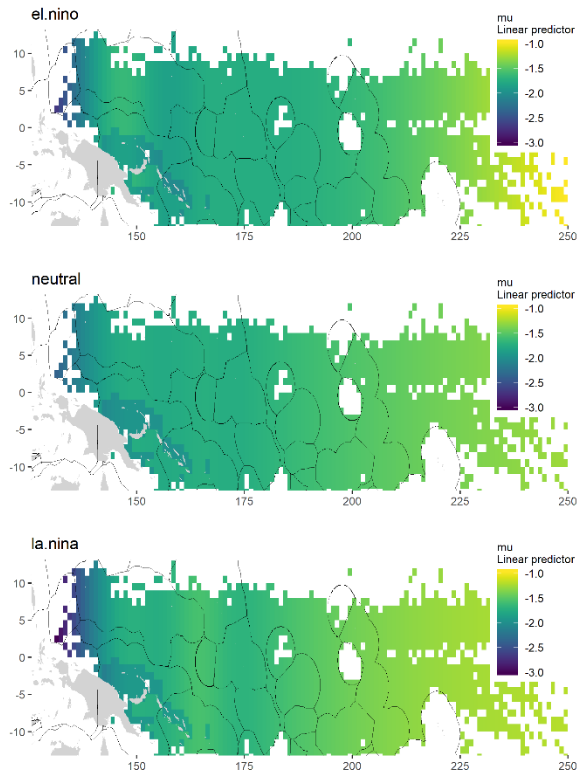

Figure 28 The combined effect of the archipelagic term and the longitude:ONI interaction on the mean of the beta component of the bigeye associated model.

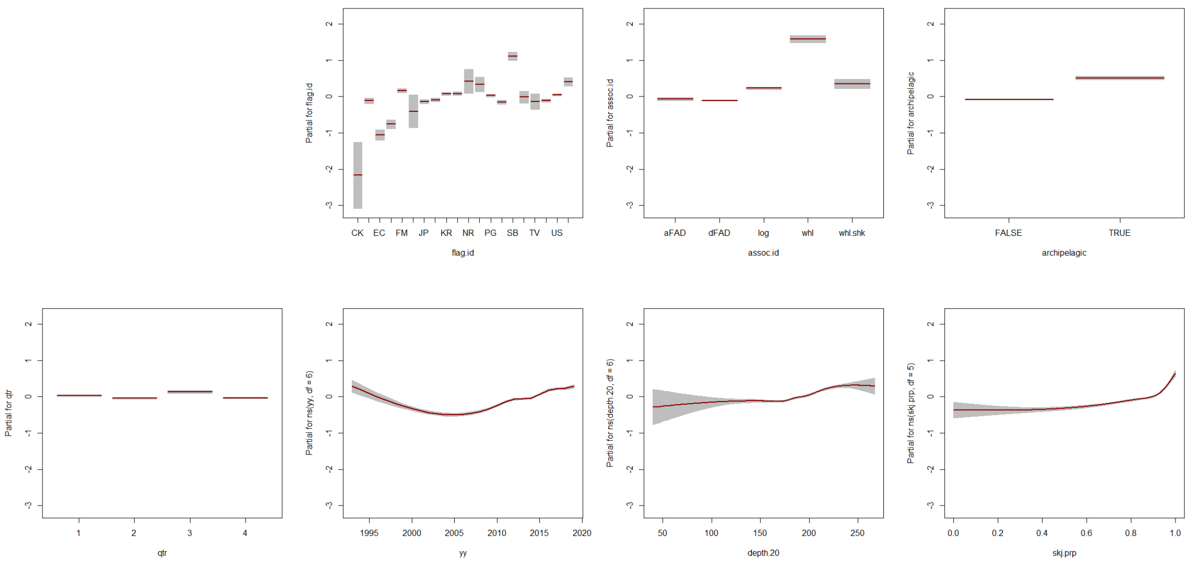

Figure 29 Fixed effects on the zero-inflation component of the bigeye associated model. Top row, left to right: flag; association type (anchored FAD – aFAD, drifting FAD – dFAD, log sets, whale associated – whl, and whale shark associated – whl.shk); archipelagic waters. Bottom row, left to right: quarter; year; isotherm depth; and, uncorrected skipjack proportion from vessel logbooks.

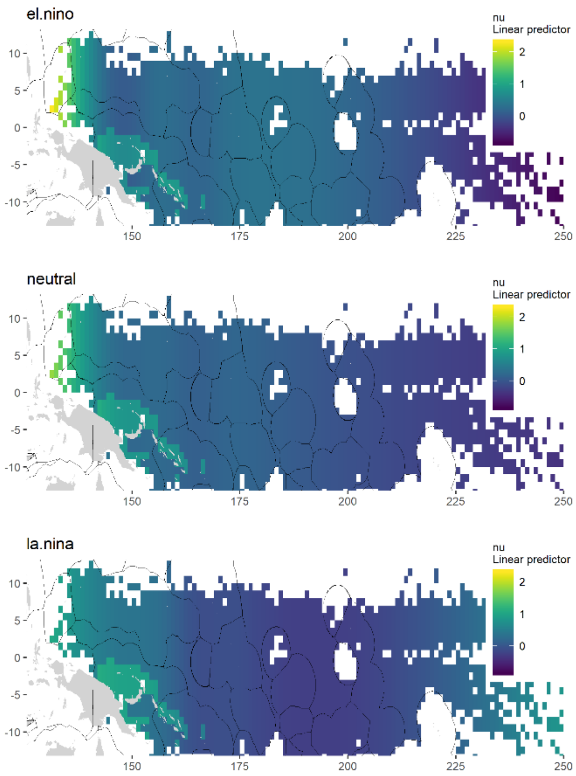

Figure 30 The combined effect of the archipelagic term and the longitude:ONI interaction on the zero-inflation component of the bigeye associated model.

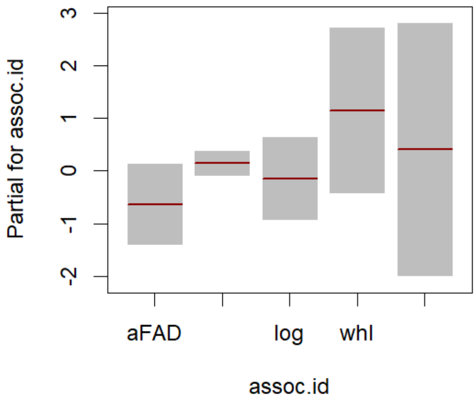

Figure 31 Fixed effects on the one-inflation component of the bigeye associated model for association type (anchored FAD – aFAD, drifting FAD – dFAD, log sets, whale associated – whl, and whale shark associated – whl.shk).

Appendix B

Obtaining species compositions from observer samples

Here we describe the approach used to estimate species compositions from grab samples, using correction factors to account for grab sample bias. Throughout we use i, j and k to refer to species, 1cm length bin and set respectively. First we describe the process used to obtain (uncorrected) grab sample based species compositions. We then explain how the grab sample based species compositions were corrected for bias using correction factors.

As described in Peatman et al. (2017a), uncorrected grab sample based species compositions were estimated as follows. Grab samples were used to estimate the proportion of fish in set k that were species i and length bin j, denoted α_{ijk}

$$\alpha_{ijk} = \frac{n_{ijk}}{n_k}$$

where n_{ijk} is the number of sampled fish from set k that were species i and length bin j, and n_k is the total number of grab sampled fish from set k. The proportion of catch weight in set k from species i, denoted p_{ik}, was then calculated as

$$p_{ik} = \frac{\sum_j \alpha_{ijk}\, a_i j^{b_i}}{\sum_{ij} \alpha_{ijk}\, a_i j^{b_i}}$$

where a_i and b_i are species-specific length weight parameters. Species and set specific catch weight proportions were then applied to the observer's visual estimates of the set-specific catch w_k, to obtain catch weights of species i in set k, denoted w_{ik}

$$w_{ik} = w_k\, p_{ik}$$

We corrected for grab sample bias using correction factors pooled across species and association types Set-specific corrected proportions by species, length, β_{ijk}, were calculated as

$$\beta_{ijk} = \frac{\alpha_{ijk}/r_j}{\sum_{ij} \alpha_{ijk}/r_j}$$

where r_j is the correction factor that applies to a fish of length j and the denominator ensures that set-specific proportions sum to one. The proportion of catch weight in set k from species i, denoted p_{ik}, was then calculated as

$$p_{ik} = \frac{\sum_j \beta_{ijk}\, a_i j^{b_i}}{\sum_{ij} \beta_{ijk}\, a_i j^{b_i}}$$

and the catch weights of species i in set k, (w_{ik}) recalculated as above.

Spill sample based species compositions were estimated using the same approach as for grab samples, but with two differences. First, there is no correction for grab sample bias. Second, for sets with more than one sampled brail, the estimates of α_{ijk} (the proportion of sampled fish in set k that were species i and length bin j) and p_{ik} (the proportions of catch weight by species) were estimated separately for each sampled brail. We then took the mean species-specific catch proportion across the sampled brails, and used this to estimate the species-specific catch weights for the set in question.