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ANALYSIS OF TAGGING DATA FOR THE 2026 BIGEYE AND YELLOWFIN ASSESSMENTS: CORRECTIONS TO TAG RELEASES FOR TAGGING CONDITIONS

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Executive summary

Mark-recapture tagging data are adjusted prior to use in assessments of WCPO tropical tuna to account for tagging-induced mortality and tag shedding, which mitigates against downwards bias in fishing mortality estimates. A range of variables have been shown to impact the probability of recapturing tagged fish, including tagger experience and identity, the quality of tag placement and the condition of a tagged fish at release. The reduction in recapture probability caused by these tagging effects is assumed to reflect the combination of tag shedding and tagging-induced mortality.

Here, we fit statistical models to estimate the effects of these variables on the probability of tag recovery. The statistical models were then used to generate 'correction factors' which were used to reduce PTTP tag release numbers to account for the apparent additional tag shedding and tagging-induced mortality resulting from the specific conditions of each tag release, over and above base rates.

The estimated correction factors result in substantial reductions in the number of PTTP releases of yellowfin (ca. 25%) and bigeye (ca. 8%) used in the 2026 assessments. Reductions in tag releases were stronger for tagging cruises on pole-and-line platforms, leading to stronger reductions for yellowfin compared to bigeye, and stronger reductions for cruises in the western Pacific vs the central Pacific.

We invite the Scientific Committee to:

- Note the substantial reductions in effective tag releases used in the assessment, and the subsequent impact on apparent fishing mortality rates.

1 Introduction

SPC have tagged and released tropical tuna in the Western Central Pacific Ocean (WCPO) since 1977 across three tagging programmes: the Skipjack Survey and Assessment Programme (SSAP), 1977 to 1981; the Regional Tuna Tagging Programme (RTTP), 1989 to 1992; and, the current Pacific Tuna Tagging Programme (PTTP), from 2006 onwards. Mark-recapture tagging data are adjusted prior to use in assessments of WCPO tropical tuna to account for tagging-induced mortality and tag failure. This includes base-rates of tagging-induced mortality and tag shedding (e.g. Hampton, 1997; Vincent et al., 2019), as well as additional tagging-induced mortality and tag-shedding over and above base rates as a result of the specific conditions at release for each tagged fish. This mitigates against downwards bias in fishing mortality estimates (e.g. see Vincent et al., 2019). A range of variables have an apparent effect on the probability of recapturing tagged fish, including tagger experience and identity, the quality of tag placement and the condition of a tagged fish at release (Hoyle et al., 2015). We refer to these variables as 'tagging effects'. In combination, these variables act to reduce the probability of recapturing tagged fish, which is assumed to reflect a combination of tag shedding and tagging-induced mortality. Statistical models are used to estimate the effects of these variables on the probability of tag recovery, and generate 'correction factors' which are used to reduce tag release numbers to account for the apparent additional tag shedding and tagging-induced mortality resulting from the specific conditions of each tag release.

In the context of the estimation of corrections for tagging conditions, the mark-recapture dataset is relatively imbalanced (Scutt Phillips et al., 2020). There is limited overlap between taggers and tagging stations, with experienced taggers tending to tag from different stations than those with less experience. Additionally, there is a relatively large pool of taggers within a tagging programme but limited overlap between taggers and tagging events or tagging cruises, as well as differences in tagging platforms between tagging cruises with implications on the equivalence of tagging stations. This led to concerns that the imbalanced nature of the dataset may lead to difficulties in separating the effects of the different variables, and so lead to bias in correction factors.

SPC convened a tagging effects workshop in December 2021 to review the mark recapture dataset and modelling approach that has been used generate correction factors, and identify potential improvements and changes to the methodology in the context of the characteristics of the dataset. The workshop recommended that Central Pacific tagging cruises be treated separately to other PTTP tagging cruises, as the Central Pacific tagging cruises have used different tagging platforms, such that tagging stations are not directly comparable. Additionally, the Central Pacific tagging cruises have used a different pool of taggers and have different overall objectives.

Recent simulations using PTTP skipjack releases have suggested that the tagging effects modelling framework from Hoyle et al. (2015) and Berger et al. (2014) can separate the effects of key variables, giving unbiased estimates of correction factors, despite the correlation between covariates, assuming the model structure is appropriate (Peatman et al., 2022).

In this information paper we apply a similar modelling framework to Hoyle et al. (2015) and Berger et al. (2014), based on that used for the 2023 bigeye and yellowfin assessments (Peatman et al., 2023), to estimate correction factors for PTTP tagging data for use in the 2026 bigeye and yellowfin stock assessments.

2 Methods

Tag release and recovery information for tropical tuna were extracted from SPC's master tuna tagging database for the SSAP, RTTP and PTTP. The dataset consisted of mark-recapture data from conventional tag releases; fish instrumented with archival or sonic tags were not included. PTTP releases from 2024 onwards were removed, to mitigate against bias due to delays in the reporting and processing of tag recovery data. RTTP and PTTP tag releases from purse seine vessels were excluded, as were releases from Japanese research tagging cruises. The cumulative total number of tropical tuna released by each tagger (across all three programmes) at the end of each tagging event was calculated. This was then used to define the 'experience' of each tagger for a tagging event, set at the mean of their cumulative releases at the beginning and the end of the tagging event in question. The tagging dataset was then filtered for PTTP releases of yellowfin and bigeye tuna, with 118,225 yellowfin releases (of which 19,414 recoveries were reported to the Pacific Community), and 64,975 bigeye releases (15,906 recoveries).

As per Berger et al. (2014), data filtering rules were applied to exclude levels of candidate categorical variables with insufficient releases to inform robust estimation of model parameters. Single-species models were used to estimate tagging effects for western Pacific yellowfin tag releases and central Pacific bigeye releases. Multi-species models were used to estimate tagging effects for western Pacific bigeye, given the more limited number of tag releases, using both bigeye and yellowfin releases. Similarly, both bigeye and yellowfin data were used to estimate tagging effects for central Pacific yellowfin releases. For models fitted to a single species only: individual taggers with fewer than 200 yellowfin or 100 bigeye releases were removed; tagging events with fewer than 20 yellowfin or 10 bigeye releases were removed; and, any levels of covariate with fewer than 100 yellowfin or bigeye releases were removed. For models fitted to both yellowfin and bigeye releases: individual taggers with fewer than 100 total releases were removed; tagging events with fewer than 15 total releases were removed; and, any levels of covariate with fewer than 100 total releases were removed.

All data analysis was undertaken in R v4.5.1 (R Core Team, 2025), with tagging effects models fitted using the R package 'glmmTMB' (Brooks et al., 2017).

2.1 Selection of tagging effects models

Model selection was informed by a stratified repeated random sub-sampling procedure. For each draw the analysed dataset was split at random into 10 folds, stratified by tagging event. The first fold was then held back as a testing dataset to validate the model, with the remaining 9 folds used as the training dataset to fit the model. Predictions were then generated from the fitted model for the testing dataset, and the Area Under the Receiver Operating Characteristic curve (AUROC) extracted. This process was repeated 256 times, with the training and testing datasets used for each model specification under consideration at a given stage in the model selection procedure. The proportion of testing datasets with an improved AUROC was used to assess support for alternative model specifications relative to a reference specification.

First, we selected models for: PTTP releases of bigeye from Central Pacific (CP) tagging cruises; and, PTTP releases of yellowfin from Western Pacific (WP) tagging cruises (i.e. not Central Pacific tagging cruises).

The starting point for the model selection procedure for CP PTTP bigeye was:

$$y_{ij} \sim \text{Binomial}(n_{ij}, p_{ij})$$

$$\alpha_{event[j]} \sim \text{Normal}(0, \sigma_e)$$

$$\log\left(\frac{p_{ij}}{1-p_{ij}}\right) = \beta_0 + \beta_{gear[i]} + \beta_{association[i]} + \beta_{tagger[i]} + \beta_{condition[i]} + \beta_{quality[i]} + f(length[i]) + \alpha_{event[j]}$$

where i refers to a group of tag releases with a shared set of covariate values from tagging event j, p_{ij} is the probability of tag recovery and n_{ij} and y_{ij} are the number of releases and recaptures respectively. Categorical covariates were included for: the tagging *gear* used to catch the released individuals (troll or handline); the school *association* type for the tagging event (associated with an anchored FAD, drifting FAD or the tagging vessel); the individual that tagged the fish, *tagger*; the station where the fish was tagged, *station*; the condition of the fish on release, *condition* (good, eye damage, mouth damage, bleeding, dropped on deck, shark bite); and, the quality of tag placement, *quality* (good, badly placed). The *length* of the tagged fish was included as a continuous variable, modelled with a natural cubic spline denoted $f(\,)$. Tagging *event* was included as a normally distributed random intercept (standard deviation σ_e). Tagging gear and school association were included to attempt to improve the distribution of the tagging event intercepts, noting the convergence issues experienced for Central Pacific models with tagging cruise effects (see Peatman et al., 2023).

The starting point for the model selection procedure for WP PTTP yellowfin was:

$$y_{ij} \sim \text{Binomial}(n_{ij}, p_{ij})$$

$$\alpha_{event[j]} \sim \text{Normal}(0, \sigma_e)$$

$$\log\left(\frac{p_{ij}}{1-p_{ij}}\right) = \beta_0 + \beta_{cruise[i]} + \beta_{tagger[i]} + \beta_{station[i]} + \beta_{condition[i]} + \beta_{quality[i]} + f(length[i]) + \alpha_{event[j]}$$

with categorical covariates included for: the tagging cruise leg, *cruise*; the *station* where the fish was tagged. Tagging cruise was included to improve the distribution of the tagging event intercepts.

For selection of the single-species models, we first tested for removal of tagger, station, condition and quality effects. We then tested for inclusion of tagger:station interactions (if both effects were in the model), included as a random intercept.

The selected single-species models were then used as the starting point for bigeye and yellowfin combined models for Western Pacific releases and Central Pacific releases, with the addition of a categorical variable for species. The starting point for WP bigeye and yellowfin releases was:

$$\log\left(\frac{p_{ij}}{1-p_{ij}}\right) = \beta_0 + \beta_{cruise[i]} + \beta_{species[i]} + \beta_{tagger[i]} + \beta_{station[i]} + \beta_{condition[i]} + \beta_{quality[i]} + f(length[i]) + \alpha_{event[j]}$$

and the starting point for CP bigeye and yellowfin releases was:

$$\log\left(\frac{p_{ij}}{1-p_{ij}}\right) = \beta_0 + \beta_{gear[i]} + \beta_{association[i]} + \beta_{species[i]} + \beta_{tagger[i]} + \beta_{condition[i]} + \beta_{quality[i]} + f(length[i]) + \alpha_{event[j]}$$

For selection of the bigeye and yellowfin combined models, we first tested for inclusion of species-specific tagger, station, condition and quality effects (if these effects were in the starting model), included as random intercepts. We then tested for the addition of species-specific tagging event, cruise and tagging event effects, included as random intercepts, and release length effects, included as species-specific natural splines.

Tagging event, tagging cruise and release length were included in models to control for variation in recapture probability caused by temporal-spatial variation in fishing effort relative to release locations and selectivity of fishing gear. These effects are not considered to reflect rates of tagging induced mortality or tag shedding. These effects were included in all models in the model selection process. Gear and association effects were included as the nearest proxy to tagging cruise for the CP PTTP models, and so were also kept in all CP models in the model selection process.

For all models, we rounded release lengths to the nearest 2cm, to reduce the number of records in the modelled datasets. Quantile residual diagnostics were used to assess model fits, with residuals conditional on fitted random effects.

2.2 Estimation of corrections to releases

Species-specific tagging effects models were used where available to estimate correction factors, otherwise the combined-species tagging effects models were used. For example, the model fitted to Central Pacific (PTTP) bigeye data was used to estimate correction factors for CP bigeye, whereas the model fitted to Central Pacific bigeye and yellowfin data was used to estimate correction factors for CP yellowfin releases.

Correction factors for each modelled tag release group, r_{ij}, were generated from the selected tagger effects models by first estimating the probability of recovery with the actual conditions at release (μ_{ij}^{actual}). Then, the probability of recovery was estimated with tagging effects set to their optimal levels ($\mu_{ij}^{optimal}$), i.e. the levels of tagger, station, condition and quality effects with the highest recovery probability. The correction factor was then:

$$r_{ij} = \frac{\mu_{ij}^{actual}}{\mu_{ij}^{optimal}}$$

Optimal conditions were defined based on estimated effect size, along with consideration of the number of releases for different levels as well as the precision of the estimated parameters as a proxy for their reliability. For example, there were taggers with high mean effect sizes but high standard errors due to limited release numbers. These taggers were not considered when setting optimal conditions. Tagging cruise, tagging event and length were not adjusted when calculating $\mu_{ij}^{optimal}$, as these effects are assumed to reflect the spatial and temporal distribution of tag releases relative to fishing effort, and the selectivity of the fisheries recapturing tags in the case of release length. Similarly for models of CP PTTP data, gear and association were not adjusted, as these were included as a proxy for cruise.

For tagging events that were not in the modelled dataset due to the data filtering, we used a similar approach to estimate correction factors. We first excluded all tags with station, condition and quality covariate levels not included in the modelled dataset due to the sample size filters. For the remaining tags we set the tagging event effect to zero (the mean of the assumed distribution for the random intercept) when calculating μ_{ij}^{actual} and $\mu_{ij}^{optimal}$. In cases where the tagger had been excluded from the modelled dataset, we used the median tagger effect when calculating μ_{ij}^{actual} and $\mu_{ij}^{optimal}$.

The correction factors were then aggregated to assessment model tag release groups, i.e. combinations of model region, year, quarter and 2cm length class, by taking the weighted mean correction factor across tag groups, weighted by the number of releases n_{ij}. The regional structures for the 2026 assessment models are provided in Figure 1.

There were a limited number of assessment model tag release groups with no corresponding estimated correction factors, reflecting tagging event and length combinations that were filtered from the modelled dataset when excluding other covariate levels with low sample sizes. In these cases, we used the (weighted) mean correction factor for the tagging event in question where available, and otherwise the (weighted) mean correction factor for the tagging cruise.

3 Results

3.1 Model selection process

The model selection process for WP PTTP yellowfin and CP PTTP bigeye releases both selected the starting models, with no support for dropping tagger, station, condition or quality effects, and no support for adding tagger:station interactions for the WP PTTP yellowfin model.

The model selection process for CP PTTP yellowfin and bigeye releases supported inclusion of species-specific tagger effects (mean AUROC 0.7175, relative to the starting model's mean AUROC of 0.7172), but not the inclusion of species-specific condition or quality effects. There was also support for the addition of species-specific length effects (mean AUROC 0.7200), but not addition of species-specific event effects.

The model selection process for WP PTTP yellowfin and bigeye releases supported inclusion of species-specific tagger effects (mean AUROC 0.7127, relative to the starting model's mean AUROC of 0.7121), and station effects (mean AUROC 0.7123). There was also support for the addition of species-specific event effects (mean AUROC 0.7126).

3.2 Summaries of selected tagging effects models

3.2.1 Tagging effects models of PTTP releases from central Pacific cruises

The effects from the selected model of central Pacific PTTP bigeye releases are provided in Figure 2. Hook-and-line releases (rod & reel) were associated with slightly reduced recapture probabilities. Releases from schools associated with drifting FADs had lower recapture probabilities than those associated with anchored FADs (or TAO buoys) or the tagging vessel. Recapture probabilities were highest for release lengths of 58 cm, with relatively strong declines in recapture probability for smaller and larger fish. There was relatively limited variability in recapture probabilities between taggers, with no clear evidence of decreasing tagger effects with increasing experience. Releases that had eye or tail damage, and to a lesser extent those that were bleeding, were associated with lower recapture probabilities. Mouth damage, cookie cutter shark bites or releases dropped on deck were not associated with reduced recapture probabilities. Releases with badly placed tags had lower recapture probabilities relative to where quality was judged to have been good.

The effects from the selected model of central Pacific PTTP bigeye and yellowfin were similar to that from the model fitted only to bigeye data (Figure 3). Yellowfin recapture probabilities demonstrated a different relationship against release lengths, with highest recapture probabilities at c. 75 cm. Tagger effects also demonstrated variation between species, though taggers with high effects for one species generally had high effects for the other species, and vice versa.

3.2.2 Tagging effects models of PTTP releases from western Pacific cruises

The effects from the selected model of western Pacific PTTP yellowfin releases are provided in Figure 4. There was substantial variation in recapture probability between cruise legs. Recapture probabilities increased with increasing release lengths up to 50cm, then demonstrated a relatively weak decreasing trend with increasing lengths. Recapture probabilities varied between taggers, with evidence of lower recapture probabilities for the least experienced taggers, though with appreciable levels of variability. Releases from the port bow had the highest recapture probabilities, followed by releases from the stern and starboard bow. Releases midships were associated with the lowest recapture probabilities. Individuals that were dropped on deck, bleeding, or had eye or tail damage, had reduced recapture probabilities. Mouth damage and cookie cutter shark bites were not associated with substantially reduced recapture probabilities. Individuals that were tagged too slow were associated with reduced recapture probabilities, as were individuals with badly placed tags though to a lesser extent.

The effects from the selected model of western Pacific PTTP yellowfin and bigeye releases were similar to those from the model fitted only to yellowfin data (Figure 5). Tagger effects demonstrated variation between species, though taggers with high effects for one species generally had high effects for the other species, and vice versa. Station effects also demonstrated some variation between species. The relative rankings of station effects were broadly equivalent for both species, though for bigeye releases recapture probabilities for port bow, stern and starboard bow releases were more similar. Releases of yellowfin from the stern mattress had the highest recapture probabilities, though the effect was uncertain due to the limited number of releases.

3.3 Estimated corrections to tag releases

Optimal levels used to estimate correction factors were:

- Central Pacific yellowfin releases:
  tagger ='MAB', condition = 'good', quality = 'good'
- Central Pacific bigeye releases:
  PTTP: tagger ='BML', condition = 'good', quality = 'good'
- Western Pacific yellowfin releases:
  tagger ='BML', station = 'port bow', condition = 'good', quality = 'good'
- Western Pacific bigeye releases:
  PTTP: tagger ='DVP', station = 'port bow', condition = 'good', quality = 'good'

We note that 'DGI' provided an alternative optimal tagger level for CP PTTP releases, with a higher estimated tagger coefficient. However, BML was retained on the basis of the greater number of releases, and the consequent increase in precision for estimated probability of recovery.

Estimated corrections were on average stronger for yellowfin releases than for bigeye (Figure 6). For yellowfin releases, the 90% interval of correction factors at an assessment model release group resolution spanned 0.61 to 1.00, compared with an interval of 0.65 to 1.00 for PTTP bigeye releases. Overall, the estimated correction factors resulted in a 25.3% reduction in PTTP yellowfin releases, and an 8.4% reduction in PTTP bigeye releases. For both species, correction factors for region 4 (and to a lesser extent region 1) were weaker than those for the other regions (Figure 7 and Figure 8), driven by relatively weak corrections to releases from Central Pacific tagging cruises.

4 Discussion

The estimated correction factors resulted in a c. 25% and 8.4% reduction in yellowfin and bigeye PTTP releases, respectively. This represents a significant level of apparent additional tag shedding and/or tagging induced mortality over and above base rates (c. 14% combined – see Vincent et al., 2019). The reductions in release numbers were relatively weak for central Pacific PTTP releases compared to western Pacific PTTP releases, which may reflect the relatively strong down-weighting of western Pacific releases from 'suboptimal' tagging stations, as well as the stronger variability in tagger effects relative to central Pacific releases. The reductions in releases are broadly similar to those applied to tag releases used in the 2023 yellowfin (26%) and bigeye assessments (7.6%) assessments.

Estimates of correction factors have not been generated for the JP tagging programme (JPTP) or the SSAP. However, additional levels of tag shedding and/or tagging induced mortality over and above base rates appear likely for these tagging programmes. Following Vincent et al. (2019), we recommend applying the overall RTTP correction factor to SSAP releases (see Peatman et al., 2023). For the JPTP releases, we recommend that the overall correction factor for western Pacific PTTP tag releases be applied, given that the western Pacific tag cruises are undertaken on similar tagging platforms to those used in the Japanese tagging programme. This would correspond to a 26.5% reduction in yellowfin JPTP releases, and a 21.7% reduction in bigeye JPTP releases.

In this analysis, following Peatman et al. (2023), we estimated correction factors for central Pacific (CP) PTTP tagging cruises separately to western Pacific tagging cruises, by fitting models to the combined releases of yellowfin and bigeye, with inclusion of species-specific effects where supported by the data. Additionally, we estimated corrections for western Pacific releases of bigeye from a model fitted to both bigeye and yellowfin releases. This approach allows direct estimation of corrections for both central Pacific PTTP yellowfin releases and western Pacific PTTP bigeye releases. However, we note that the low numbers of Central Pacific yellowfin releases and western Pacific bigeye releases suggests high uncertainty in their estimated correction factors.

Releases from trolls (danglers) were associated with higher recapture probabilities than those from on hook-and-line (rod and reel). This may reflect tagged individuals experiencing greater stress when caught on hook-and-line, e.g., spending longer times on the hook, or being caught at greater depths. If this is the case, then it would be appropriate to control for the effect of release gear when estimating correction factors for Central Pacific tagging cruises. This should be considered when estimating correction factors for use in the next bigeye and yellowfin assessments. Investigation of available tag release data from Central Pacific tagging cruises would be helpful to ensure that releases from trolls (during daylight) and hook-and-line (predominantly at night) that likely came from the same school have the same tagging event ID, in order to best estimate the effect of release gear.

There are a number of hypotheses for causes of station effects on recapture probability, which often relate to the station directly or indirectly influencing the condition of fish arriving at the tagging cradle, e.g. differing chains of handling teams or assistants, or delays to fish being delivered to the station (e.g. Hoyle et al., 2015). However, as noted in earlier analyses (e.g., Peatman et al., 2022), the inconsistency in station effects for RTTP and western Pacific PTTP releases is difficult to explain. Implementing a policy of taggers rotating amongst stations during tagging events would be beneficial in reducing the correlation between taggers and stations; at present the most experienced taggers tend to operate exclusively from the port-bow station.

It appears likely that tag shedding and tagging induced mortality varies between taggers, and is also a function of a tagger's experience (e.g. Hoyle et al., 2015). We explored the inclusion of experience effects, defined as their cumulative releases across all tropical tuna species and tagging programmes. However, experience effects were not included in the model selection process as fitted relationships in exploratory model runs were considered unlikely. However, we note that there were suggestions of increasing recapture probabilities for taggers with the highest number of releases on western Pacific tagging cruises. As discussed in Peatman et al. (2022), alternative metrics of tagger experience may allow better representation in tagging effects models, e.g. species-specific experience metrics.

Predictive accuracy was used to support the model selection process. The difference in predictive accuracy between different model specifications was often relatively small, which may be explained by the control variables explaining a substantial amount of observed variation in recapture probabilities. Here we increased the number of draws used in the cross validation process, and fitted each candidate model specification to the same training dataset draws, to mitigate the risk of random noise influencing the model selection procedure.

We invite the Scientific Committee to:

- Note the substantial reductions in effective tag releases used in the assessment, and the subsequent impact on apparent fishing mortality rates.

Acknowledgements

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Declaration of generative AI and AI-assisted technologies in the SC paper preparation process.

No AI technologies were used in the preparation of this paper.

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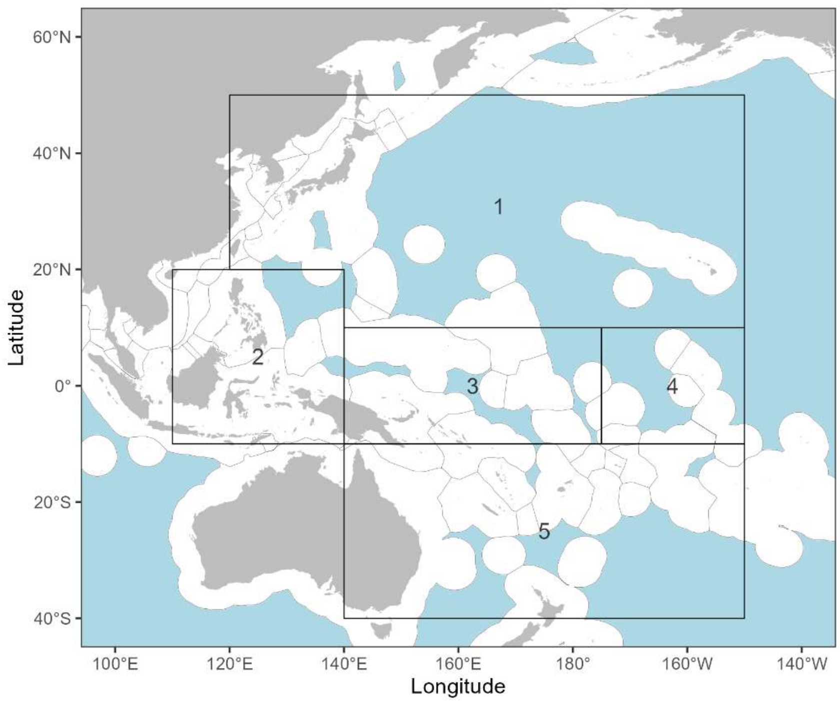
Figures

a) Bigeye



b) Yellowfin

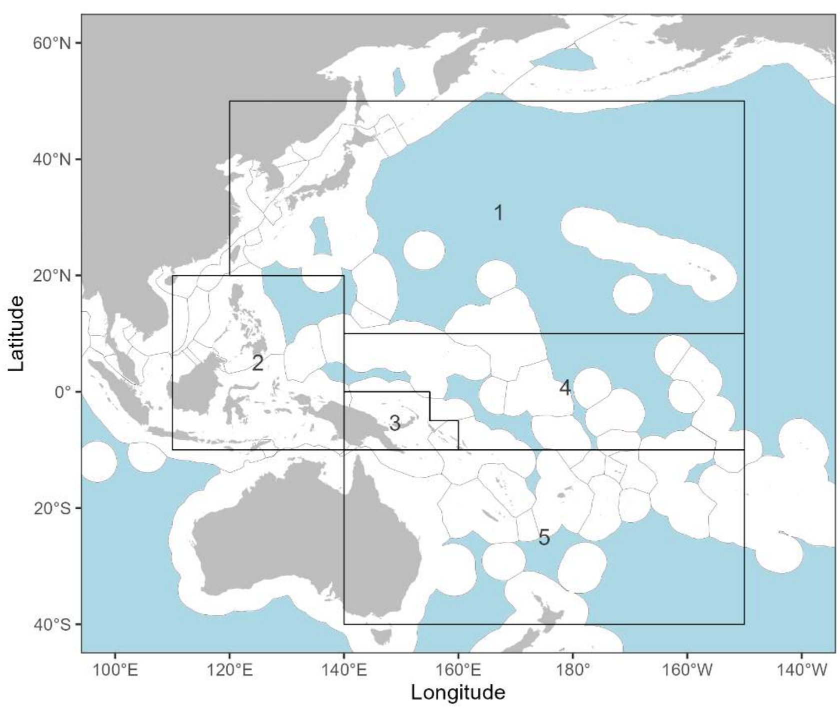


Figure 1 Region structures for the 2026 a) bigeye and b) yellowfin assessments.

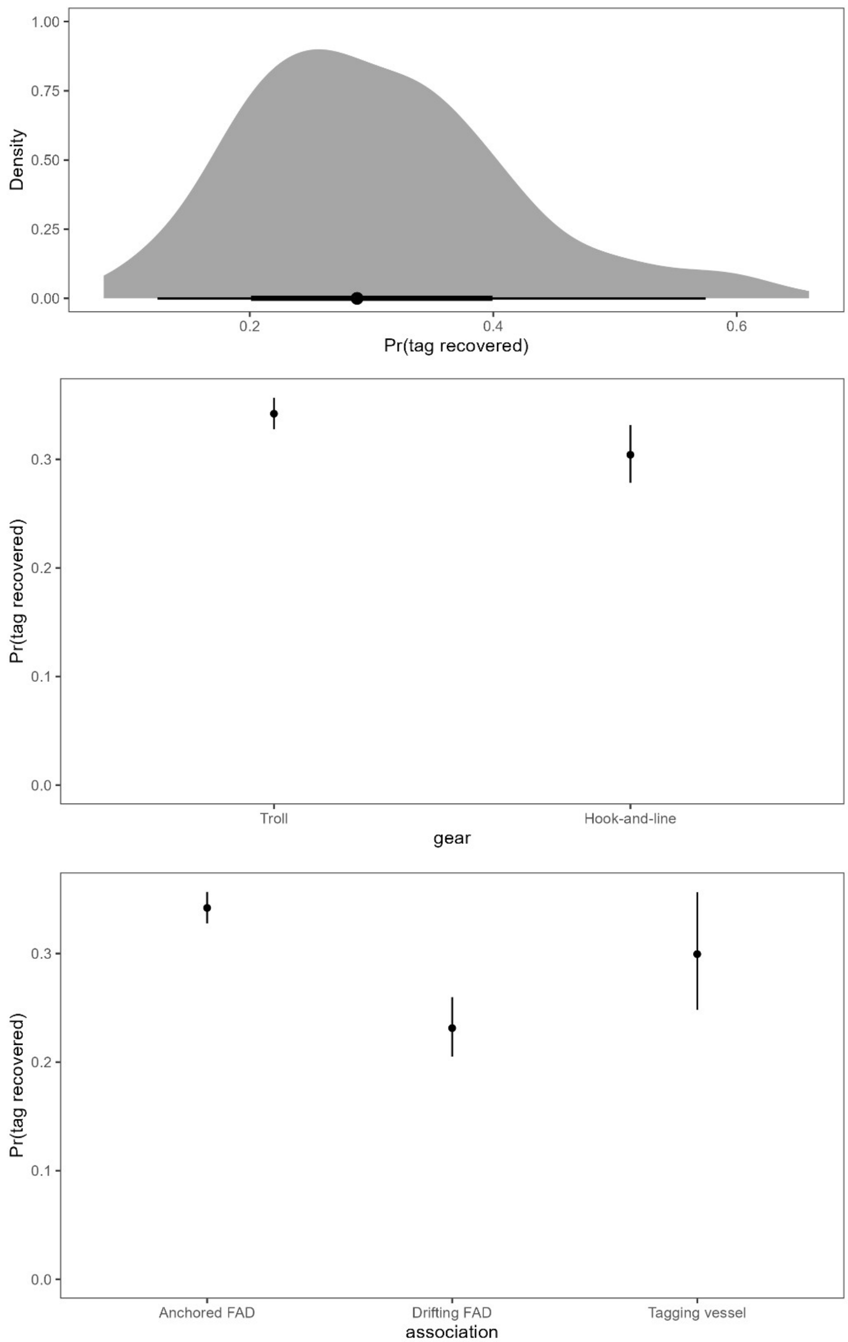


Figure 2 (continued on following page) Effect plots for the selected Central Pacific PTTP model of tagging effects for bigeye (mean ± 1 SE). The effects are (from top panel to bottom): event (species specific), gear, association, length, tagger, condition and quality. Levels of categorical variables are ranked in descending order of releases (left to right). For a given term, the predictions were generated with other categorical variables set at the level with the highest releases, and continuous variables were set at their mean.

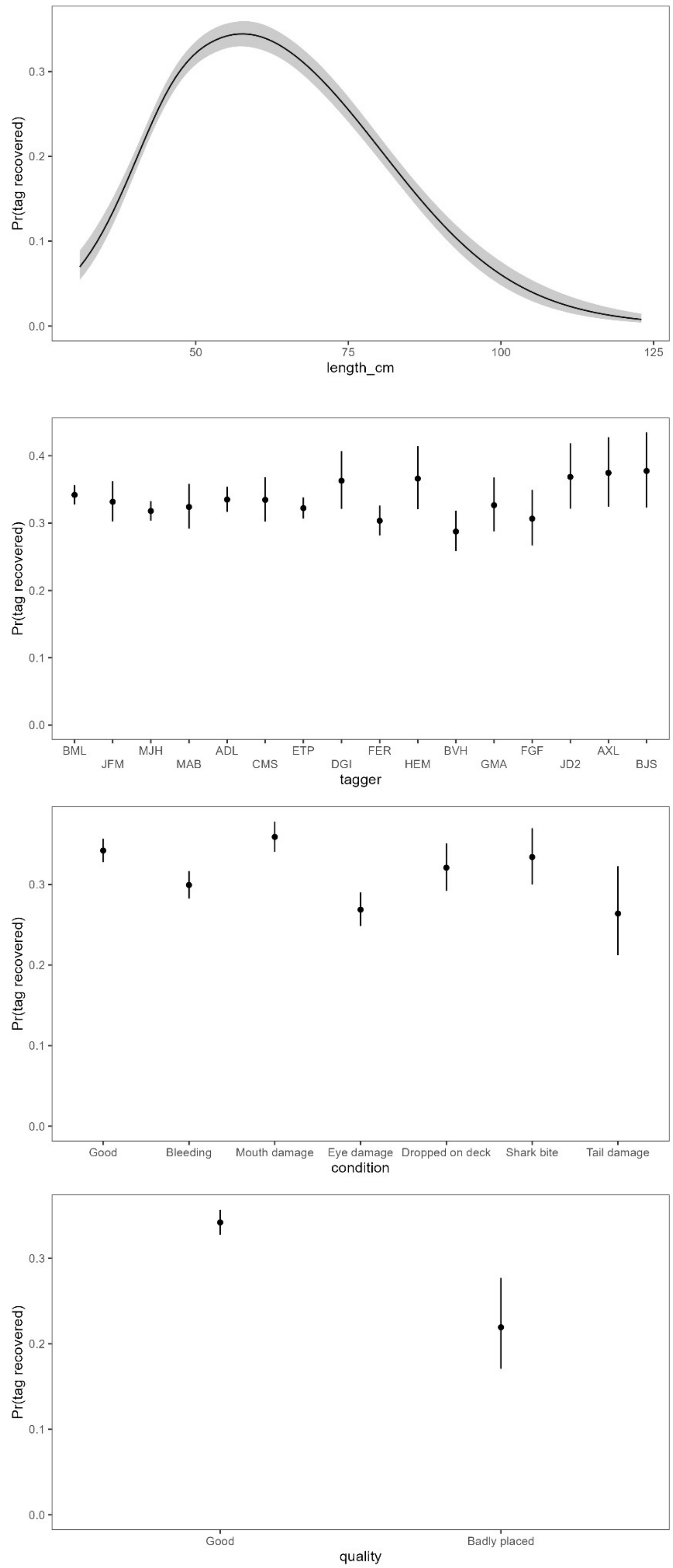
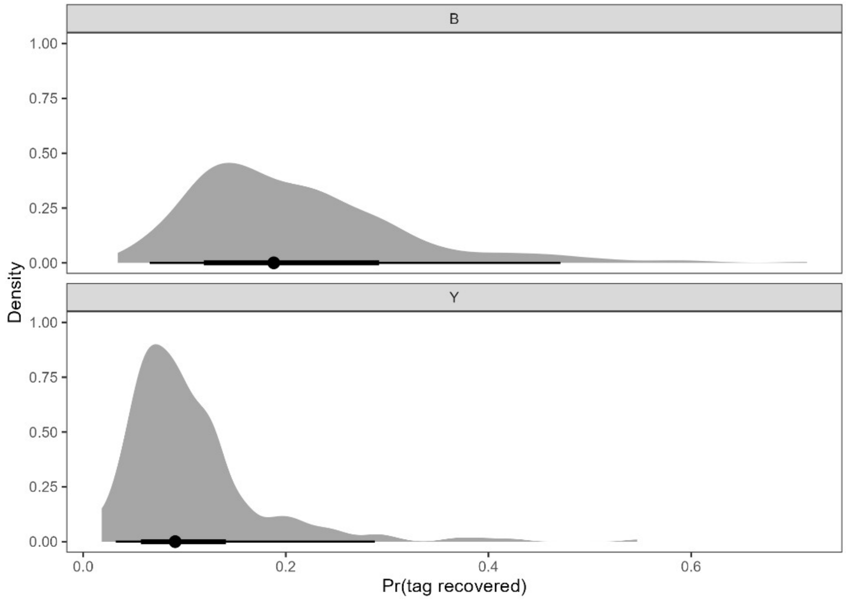


Figure 2 continued.



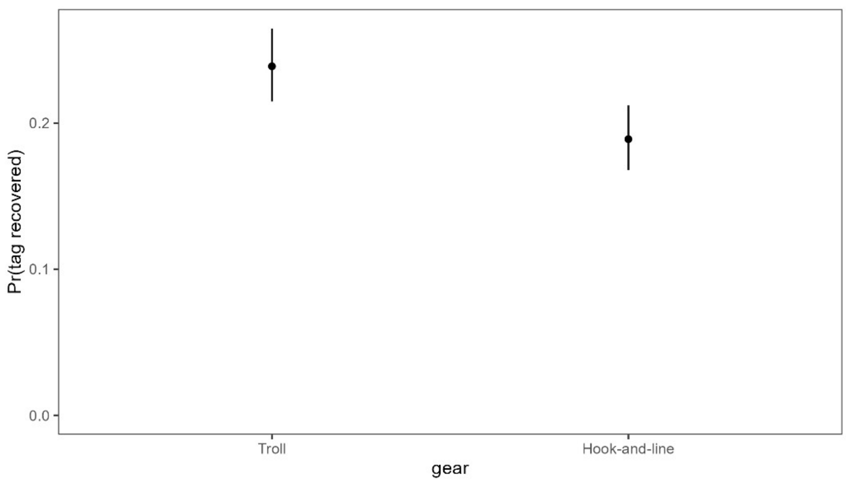


Figure 3 (continued on following pages) Effect plots for the selected Central Pacific PTTP model of tagging effects for yellowfin and bigeye (mean ± 1 SE). The effects are (from top panel to bottom): event (species specific), gear, association, length (species-specific), tagger (species-specific), condition and quality. Levels of categorical variables are ranked in descending order of releases (left to right). For a given term, the predictions were generated with other categorical variables set at the level with the highest releases, and continuous variables were set at their mean.

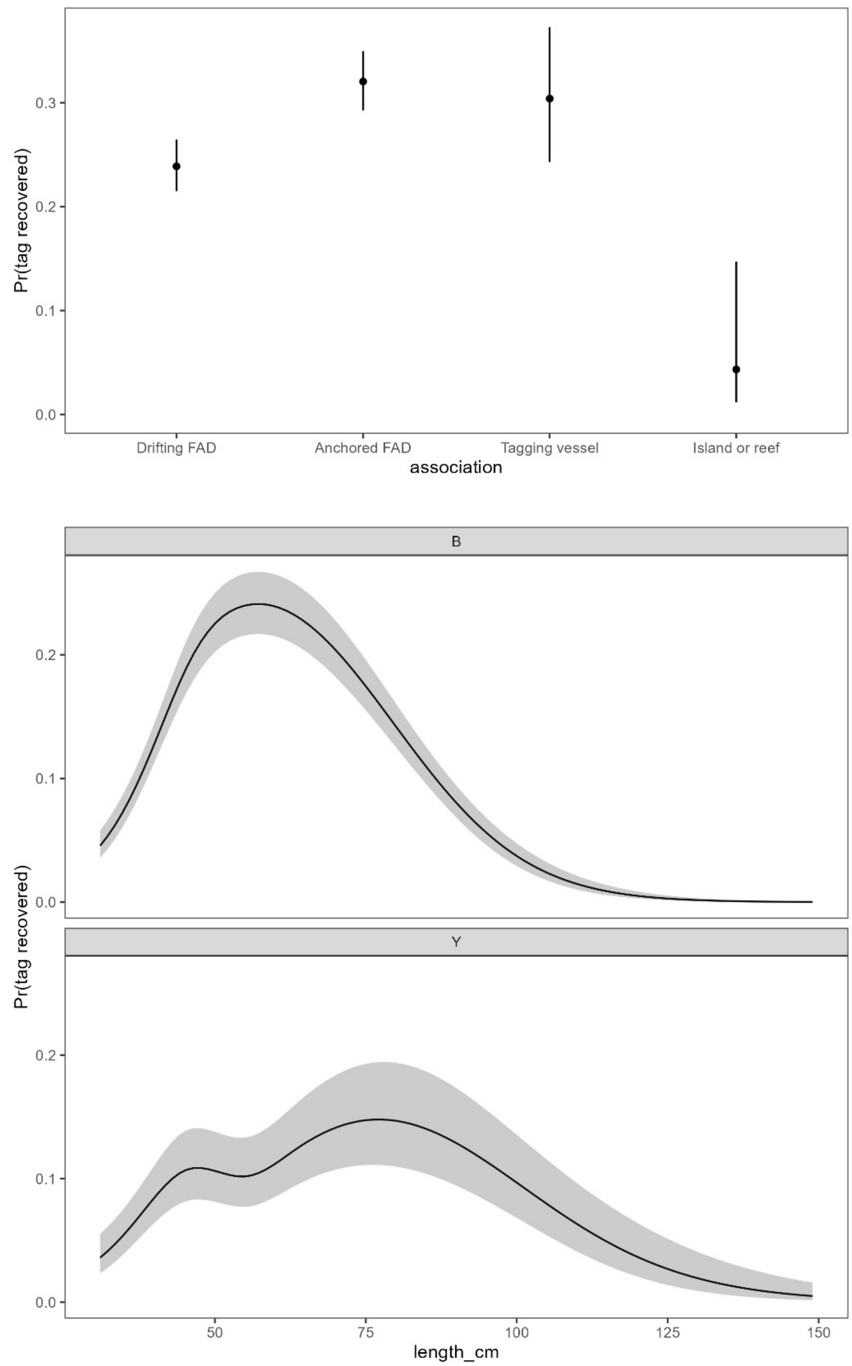


Figure 3 continued.

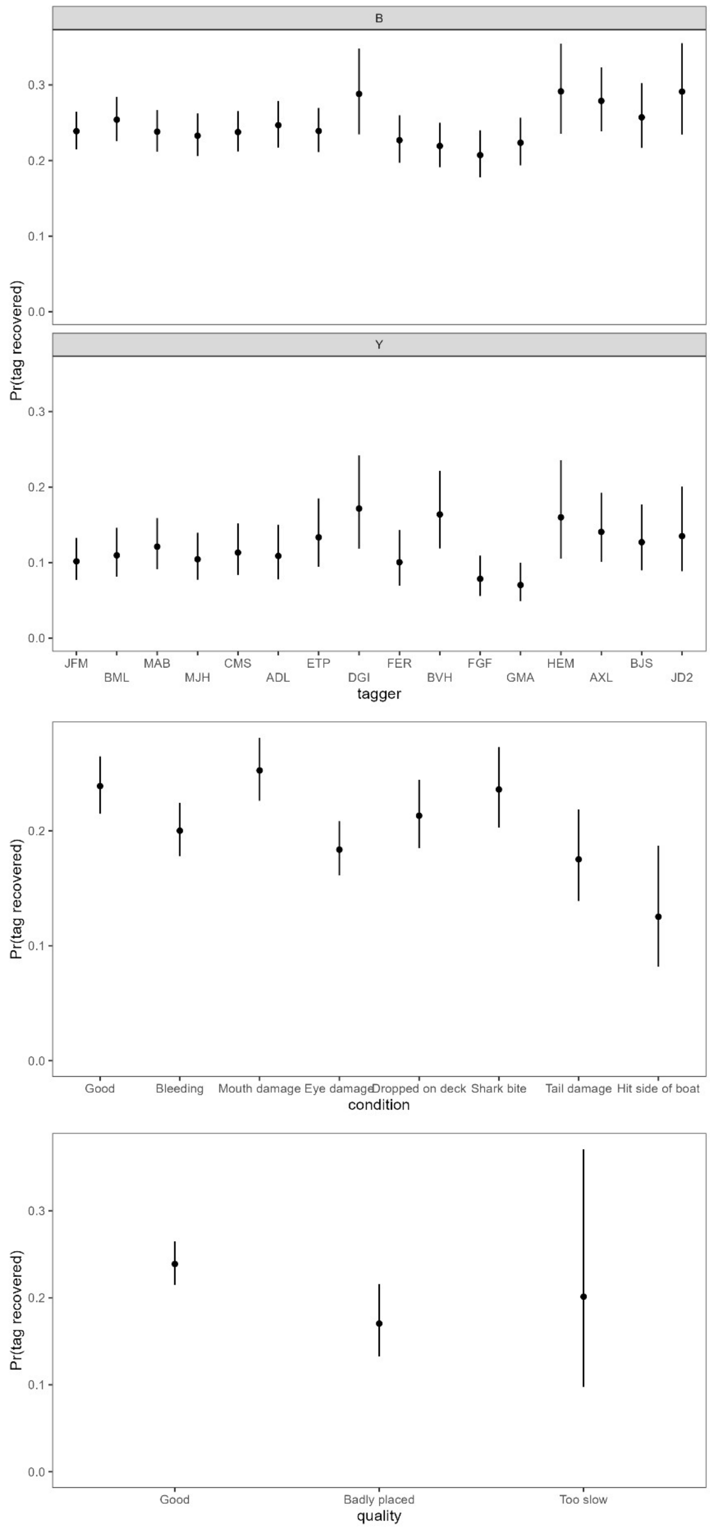


Figure 3 continued.

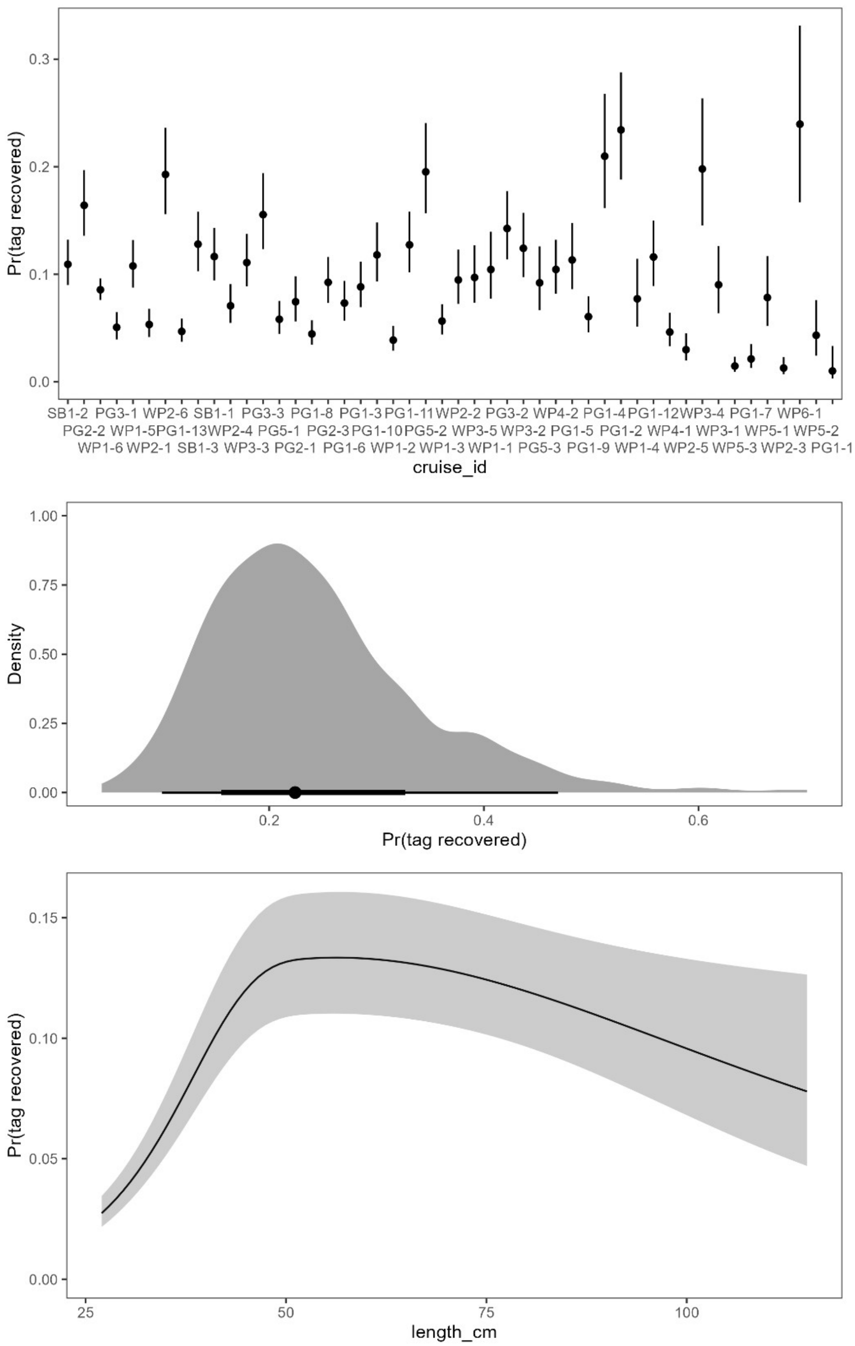


Figure 4 (continued on following page) Effect plots for the selected Western Pacific yellowfin model of tagging effects for yellowfin (mean ± 1 SE). The effects are (from top panel to bottom): cruise, tagging event, length, tagger, station, condition and quality. Levels of categorical variables are ranked in descending order of releases (left to right). For a given term, the predictions were generated with other categorical variables set at the level with the highest releases, and continuous variables were set at their mean.

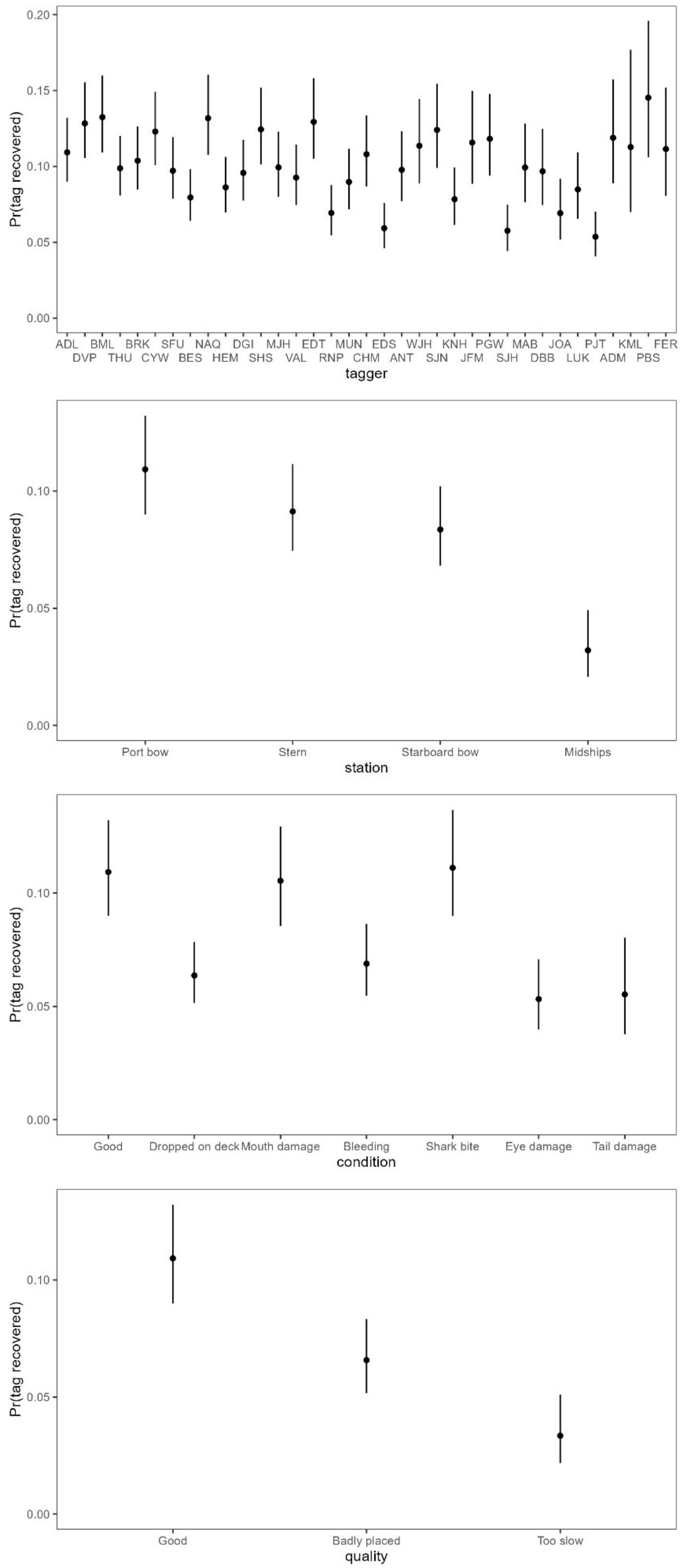


Figure 4 continued.

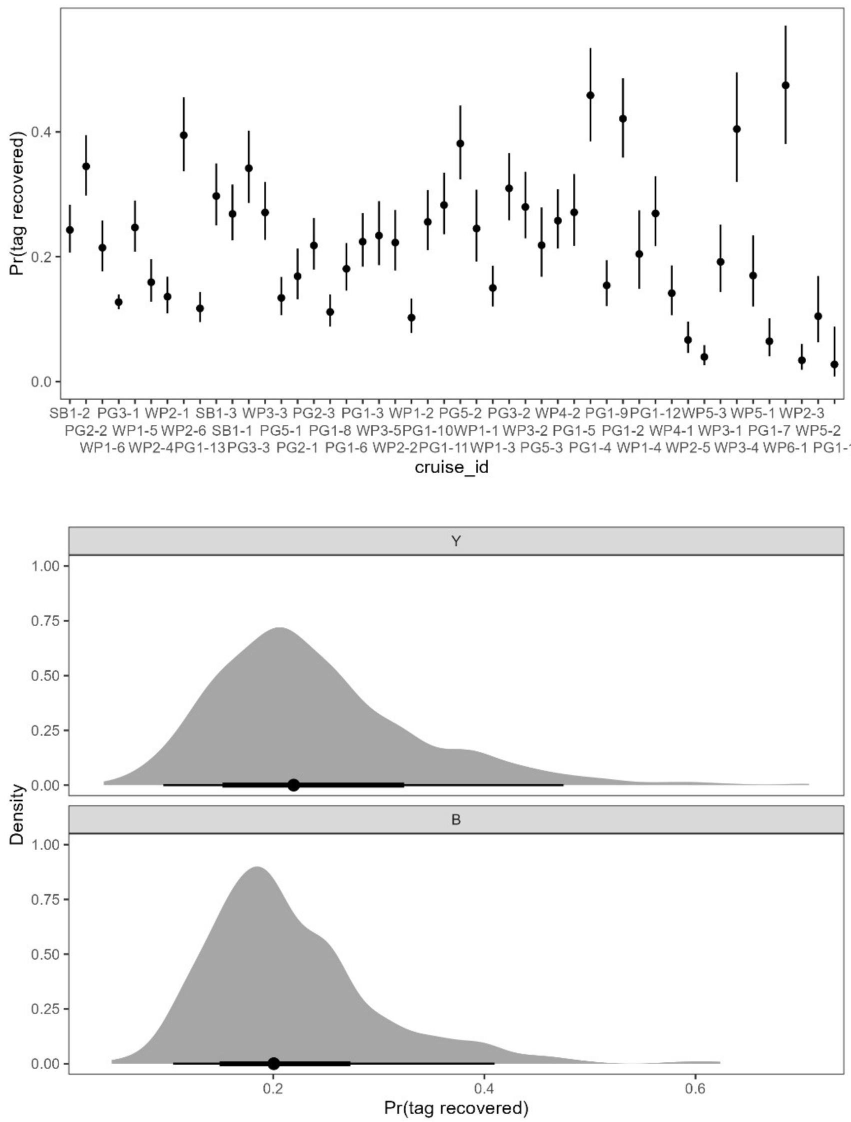


Figure 5 (continued on following pages) Effect plots for the selected Western Pacific model of tagging effects for bigeye and yellowfin (mean ± 1 SE). The effects are (from top panel to bottom): cruise, tagging event (species-specific), length, tagger (species-specific), station (tagger-specific), condition and quality. Levels of categorical variables are ranked in descending order of releases (left to right). For a given term, the predictions were generated with other categorical variables set at the level with the highest releases, and continuous variables were set at their mean.

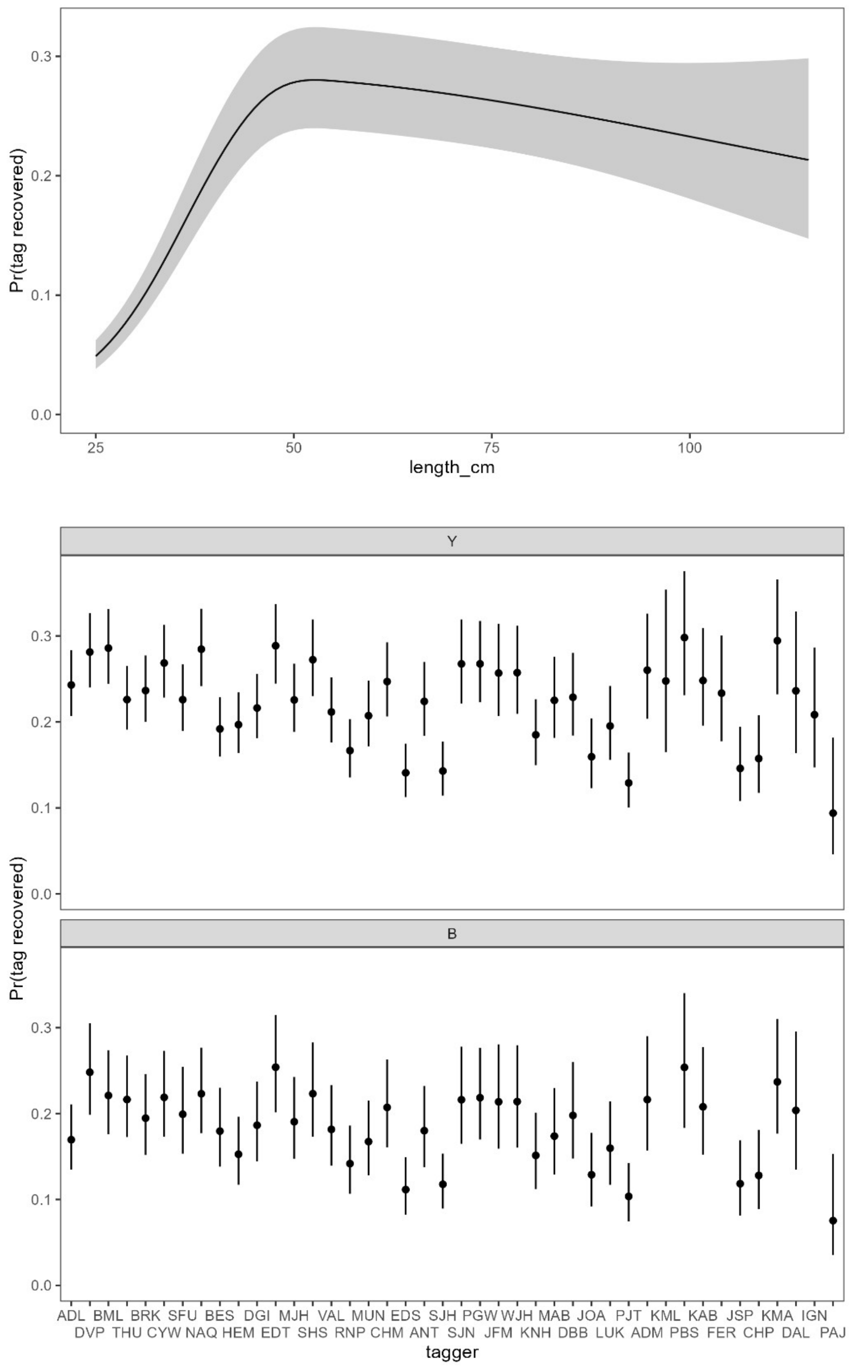


Figure 5 continued.

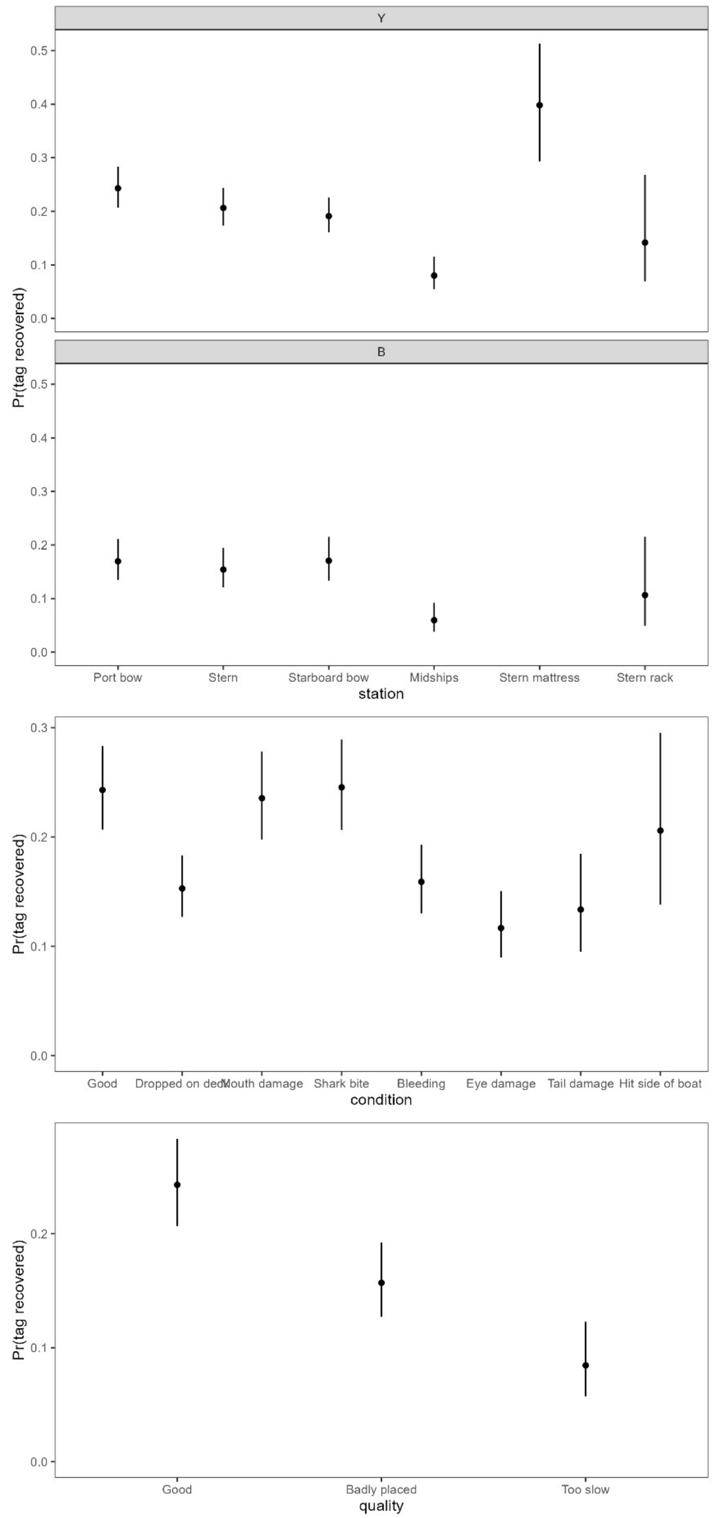
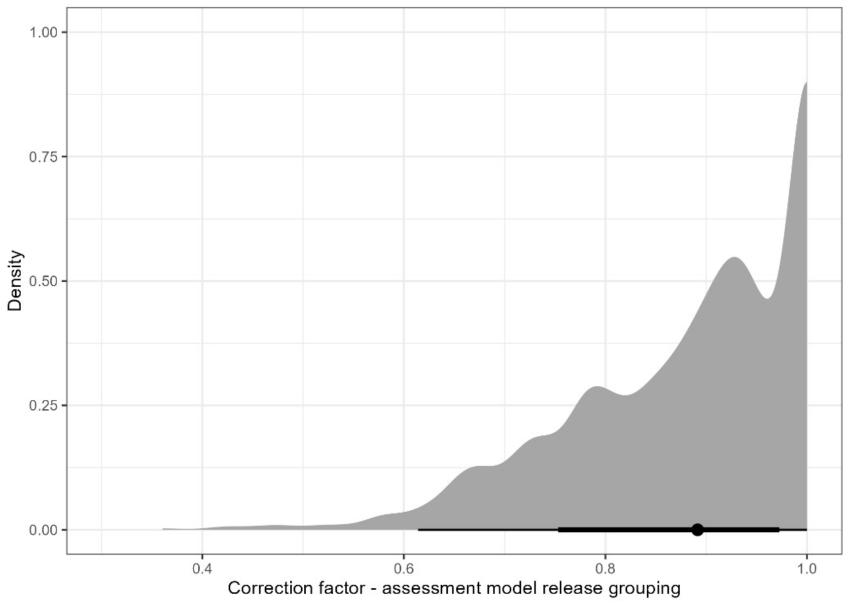


Figure 5 continued.

a) Bigeye



b) Yellowfin

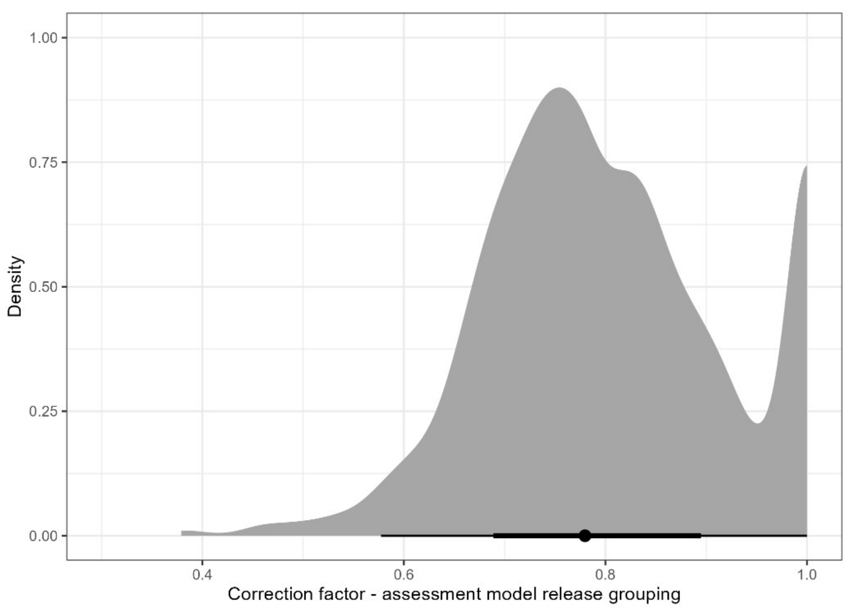


Figure 6 Estimated PTTP correction factors for a) bigeye and b) yellowfin releases by assessment model release grouping (i.e. combinations of region, year, quarter and release length class). The mean (point), 66% interval (thick line) and 95% interval (thin line) are provided for reference.

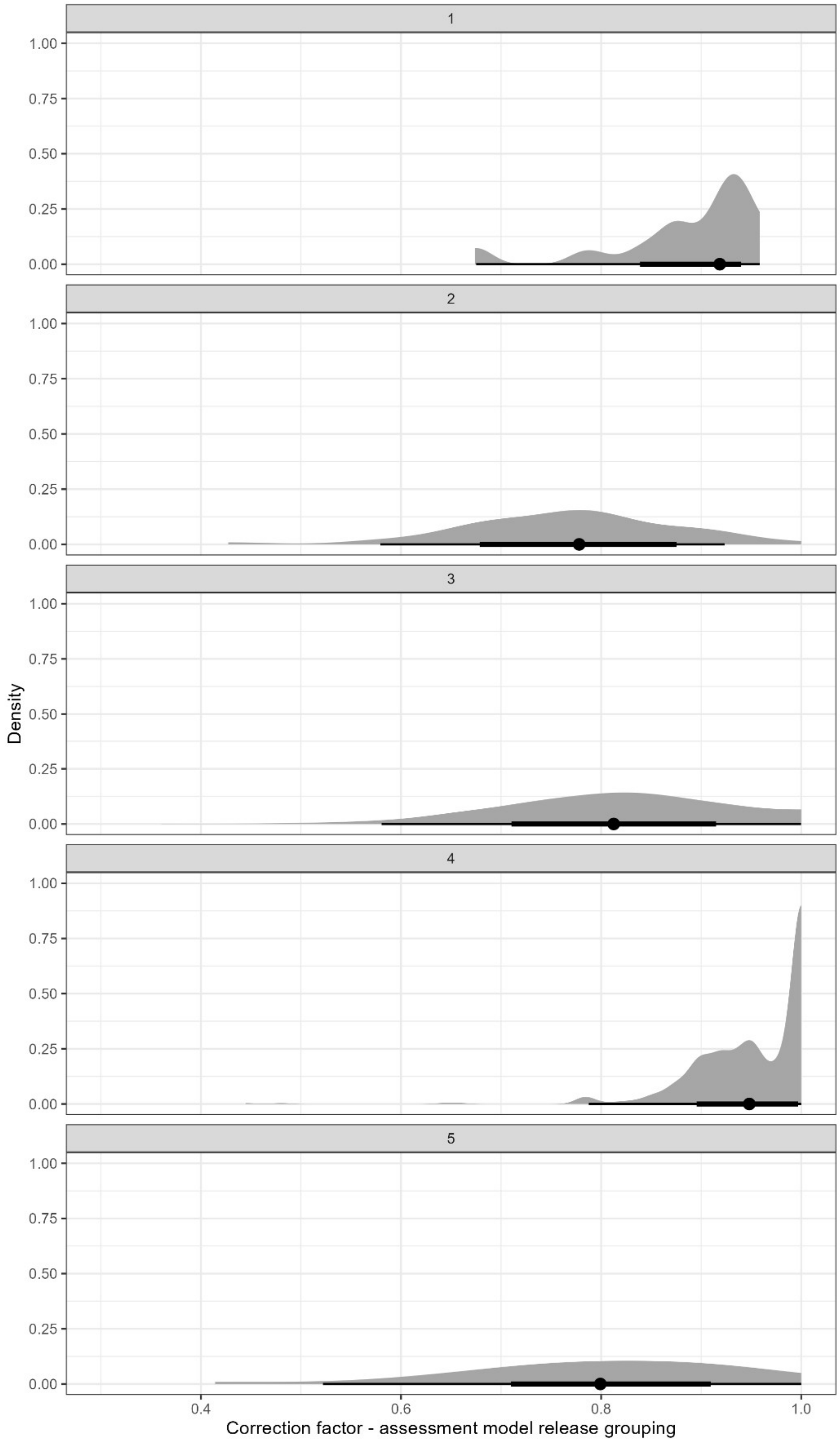


Figure 7 Estimated correction factors for PTTP bigeye releases by assessment model release grouping (i.e. combinations of region, year, quarter and release length class) per region. The mean (point), 66% interval (thick line) and 95% interval (thin line) are provided for reference.

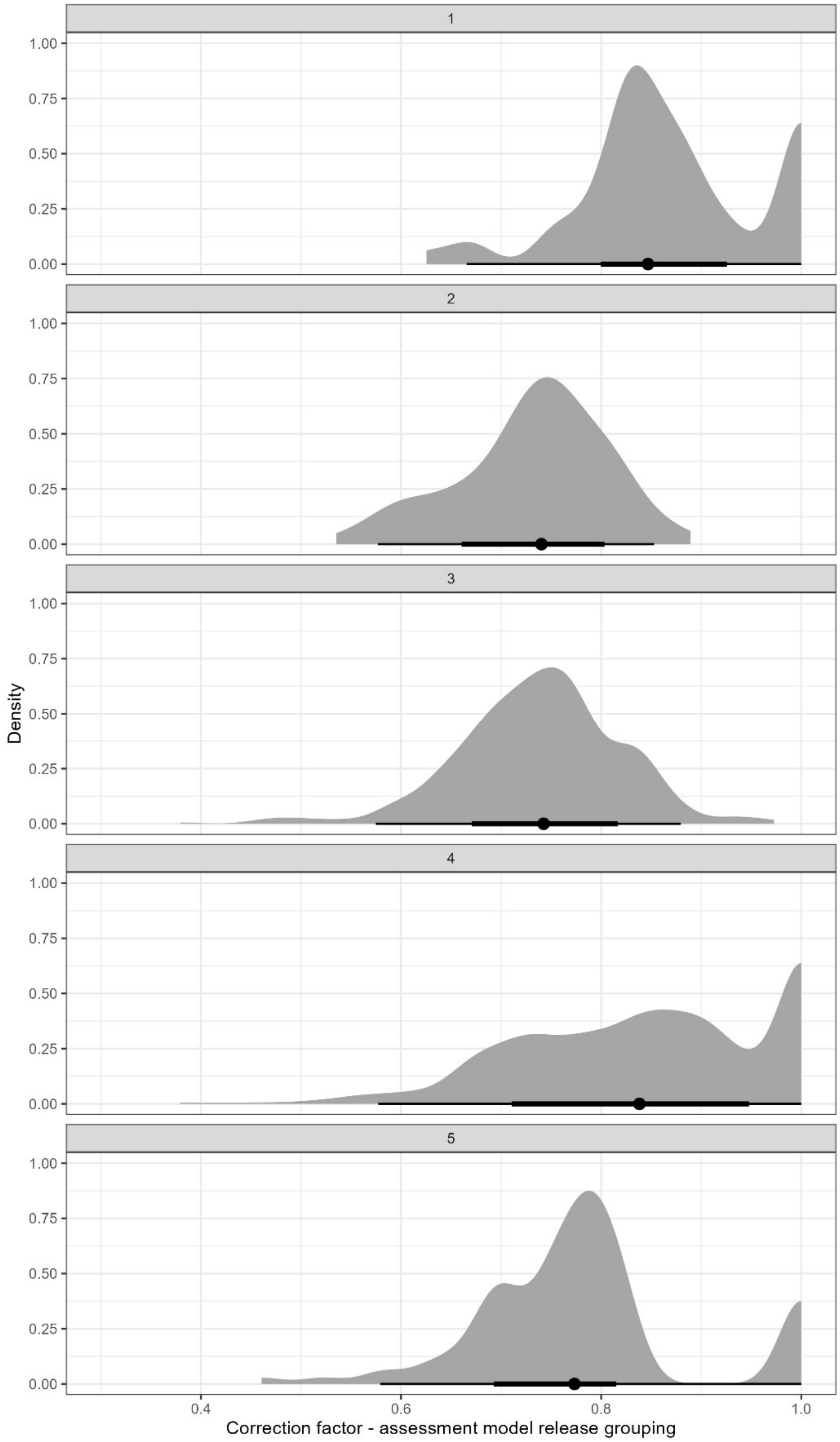


Figure 8 Estimated correction factors for PTTP yellowfin releases by assessment model release grouping (i.e. combinations of region, year, quarter and release length class) per region. The mean (point), 66% interval (thick line) and 95% interval (thin line) are provided for reference.