SCIENTIFIC COMMITTEE

NINETEENTH REGULAR SESSION

Koror, Palau
16-24 August 2023

ANALYSIS OF TAGGING DATA FOR THE 2023 BIGEYE AND YELLOWFIN TUNA ASSESSMENTS: CORRECTIONS TO TAG RELEASES FOR TAGGING CONDITIONS

WCPFC-SC19-2023/SA-IP-08

T. Peatman[1], J. Scutt Phillips[2], S. Nicol[2]

[1] Independent fisheries consultant for the Oceanic Fisheries Programme, Pacific Community (SPC)
[2] Oceanic Fisheries Programme (OFP), Pacific Community (SPC), Nouméa, New Caledonia

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 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, over and above base rates.

The estimated correction factors result in substantial reductions (c. 25%) in the number of both RTTP and PTTP releases of yellowfin, and more modest reductions (c. 8%) of RTTP and PTTP releases of bigeye.

We invite the Scientific Committee to:

- Note the use of combined modelling of bigeye and yellowfin releases that enabled separate estimation of correction factors for Central Pacific PTTP tagging cruises.
- Note that combined modelling of bigeye and yellowfin releases also enabled estimates of correction factors for RTTP bigeye releases.

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 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 raised 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 use a 'tagging effects' modelling framework similar to Hoyle et al. (2015) and Berger et al. (2014) to estimate correction factors for the 2023 bigeye and yellowfin assessments, but with a focus on developing an approach to enable Central Pacific tagging cruises to be treated separately to other PTTP tagging cruises.

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 2021 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 yellowfin and bigeye releases from the RTTP (8,565 bigeye and 41,569 yellowfin) and PTTP (58,979 bigeye and 113,806 yellowfin).

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. For models fitted to bigeye only: individual taggers with fewer than 100 bigeye releases were removed; tagging events with fewer than 15 bigeye releases were removed; and, any levels of covariate levels with fewer than 100 bigeye releases were removed. For models fitted to yellowfin only: individual taggers with fewer than 200 yellowfin releases were removed; tagging events with fewer than 20 yellowfin releases were removed; and, any levels of covariate levels with fewer than 100 yellowfin releases were removed. For models fitted to both bigeye and yellowfin releases, the thresholds for the 'bigeye-only' models were applied to releases of bigeye and yellowfin combined, e.g., a minimum of 100 releases of bigeye and yellowfin combined for inclusion of a tagger.

All data analysis was undertaken in R v4.3.0 (R Core Team, 2023), 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 modelled 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 100 times.

First, we selected models for: RTTP releases of yellowfin; 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 RTTP yellowfin and WP PTTP yellowfin was:

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

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

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

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 cruise leg, *cruise*; the individual that tagged the fish, *tagger*; the station where the fish was tagged, *station*, the condition of the fish on release, *condition* (i.e. good, eye damage, mouth damage, bleeding, dropped on deck, shark bite); and, the quality of tag placement, *quality* (i.e. 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 random intercept. We note that tagging cruise was included to improve the distribution of the tagging event intercepts.

Exploratory model runs for CP PTTP bigeye releases with both tagging cruise effects and tagger effects did not converge. Replacing the tagging cruise effects with *gear* and school association (*assoc*) effects allowed model convergence. Additionally, we did not include station effects for CP models, as there are no *a priori* reasons to expect differences in recapture probabilities between tagging stations for tag releases on CP tagging platforms (noting the differences in tagging platforms between WP and CP cruises). Additionally, there was no need for *quality* effect as all tag releases were of 'good' quality.

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

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

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

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

First, we tested for removal of tagger and station effects. We did not test for removal for condition and quality effects, as we *a priori* considered that these should influence tag-induced mortality and tag shedding rates, and so recapture probabilities. 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 the bigeye and yellowfin combined models, with the addition of a categorical variable for species. For the bigeye and yellowfin combined models, we first tested for inclusion of species-specific tagger and station effects (if these effects were in the starting model), included as a random intercept. We then tested for the addition of species-specific tagging cruise and tagging event effects, included as random intercepts, and release length effects, included as species-specific natural splines. We did not test for species-specific condition and quality effects, as there were generally limited releases outside of the 'good' level for RTTP and WP PTTP bigeye releases, and CP PTTP yellowfin releases.

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.

Exploratory model runs including experience splines detected significant experience effects. However the shapes of the effects were counter-intuitive and considered to be implausible, e.g. U-shaped relationships with the highest recapture probabilities for the lowest and highest levels of experience. As such, we did not include experience effects 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 of RTTP yellowfin was used to estimate correction factors for RTTP yellowfin releases, and the model of RTTP yellowfin and bigeye releases was used for RTTP bigeye.

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, 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 when 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}.

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 programme.

3 Results

3.1 Model selection process

3.1.1 Models of RTTP releases

The model selection process for RTTP yellowfin releases selected the starting model, with no support for dropping tagger or station effects, or adding tagger:station interactions (see Section 2.1). The model selection process for RTTP yellowfin and bigeye releases supported inclusion of (in order of selection) species-specific station effects (AUROC = 0.7420 compared with 0.7416 for the initial model), species-specific tagger effects (AUROC = 0.7429), and species-specific tagging event effects (AUROC = 0.7436).

3.1.2 Models of WP PTTP releases

The model selection process for WP PTTP yellowfin releases selected the starting model (see Section 2.1). The model selection process for WP PTTP yellowfin and bigeye supported inclusion of (in order of selection) species-specific station effects (AUROC = 0.7132 compared with 0.7117 for the starting model), species-specific tagger effects (AUROC = 0.7134), species-specific tagging event effects (AUROC = 0.7136), and species-specific tagging cruise effects (AUROC = 0.7146).

3.1.3 Models of CP PTTP releases

The model selection process for CP PTTP bigeye releases selected the starting model (see Section 2.1). The model selection process for bigeye and yellowfin releases did not provide support for inclusion of species-specific tagger effects. However, there was support for inclusion of (in order of selection) species-specific release length (AUROC = 0.6732 compared with 0.6730), and then tagging event effects (AUROC = 0.6755).

3.2 Summaries of selected tagging effects models

3.2.1 Tagging effects models of RTTP releases

The effects from the selected model of RTTP yellowfin releases are provided in Figure 1. There was substantial variation in recapture probability between cruise legs. Recapture probabilities increased with increasing release lengths up to 40cm. There was also evidence for increasing recapture probabilities for the releases larger than 100cm. Recapture probabilities varied between taggers, with a tendency for the most experienced taggers to have higher recapture probabilities. Releases from the starboard bow had the highest recapture probabilities, and tags released midships the lowest. Individuals dropped on deck had the lowest recapture probabilities, with fish in good condition or with cookie-cutter shark bites having the highest recapture probabilities. Slow tagging reduced recapture probabilities, whereas badly placed tags did not impact the probability of recapture.

The effects from the selected model of RTTP yellowfin and bigeye are provided in Figure 2. The relationships between tagging effects and probability of recapture were generally similar to those for the selected RTTP yellowfin model. However, tagging station had a more limited effect on recapture probability for bigeye. Additionally, there was support for species-specific tagger effects.

3.2.2 Tagging effects models of PTTP releases from western Pacific cruises

The effects from the selected model of WP PTTP yellowfin releases are provided in Figure 3. There was substantial variation in recapture probability between cruise legs. Recapture probabilities were highest for release lengths of approximately 50cm, with a sharp decline in recapture probabilities for smaller releases. Recapture probabilities varied between taggers, with a tendency for more experienced taggers to have higher recapture probabilities, though with appreciable levels of variability. Releases from the port bow had the highest recapture probabilities, with releases midships associated with the lowest recapture probabilities. Individuals that were dropped on deck, had eye or tail damage, or were bleeding, had reduced recapture probabilities. Mouth damage and cookie cutter shark bites were not associated with reduced recapture probabilities. Individuals that were tagged too slow were associated with reduced recapture probabilities, as were individuals with badly placed tags.

The effects from the selected model of WP PTTP yellowfin and bigeye are provided in Figure 4. The fitted effects were generally similar to those for the WP PTTP yellowfin model. However, there was between-species variation in cruise effects. Additionally, the effects of station on recapture probability were more limited for bigeye relative to yellowfin, with exception of releases midships that were associated with lower recapture probabilities for both species.

3.2.3 Tagging effects models of PTTP releases from central Pacific cruises

The effects from the selected model of CP PTTP bigeye releases are provided in Figure 5. Hook-and-line releases were associated with slightly higher recapture probabilities, though with some uncertainty given the relatively low levels of releases. 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 55cm, with relatively strong declines in recapture probability for smaller and larger fish. There was relatively limited variability in recapture probabilities between taggers, compared to the WP PTTP models. Releases with eye damage, and to a lesser extent individuals that were bleeding, were associated with lower recapture probabilities.

The effects from the selected model of CP PTTP bigeye and yellowfin releases are provided in Figure 6. The relationships between effects and probability of recapture were similar to those for the CP PTTP bigeye model. However, release length was less influential on recapture probability than for yellowfin, with a broad peak of relatively high recapture probabilities spanning release lengths from 45 to 80cm.

3.3 Estimated corrections to tag releases

Optimal levels used to estimate correction factors for yellowfin were:

- RTTP yellowfin: tagger ='ETP', station = 'starboard bow', condition = 'good', quality = 'good'.
- WP PTTP yellowfin: tagger ='BRL', station = 'port bow', condition = 'good', quality = 'good'.
- CP PTTP yellowfin: tagger ='BRL', condition = 'good'.

Optimal levels used to estimate correction factors for bigeye were:

- RTTP bigeye: tagger = 'LJO', station = 'port bow', condition = 'good', quality = 'good'.
- WP PTTP bigeye: tagger ='DVP', station = 'port bow', condition = 'good', quality = 'good'.

- CP PTTP bigeye: tagger ='BRL', condition = 'good'.

Estimated correction factors for yellowfin were stronger than for bigeye for both the RTTP and PTTP (Figure 7 and Figure 8). For RTTP yellowfin releases, the 90% interval of correction factors at an assessment model release group resolution spanned 0.5 to 0.84, compared with an interval of 0.6 to 1 for PTTP yellowfin releases. Overall, the estimated correction factors resulted in a 26.6% reduction RTTP yellowfin releases, and a 26.0% reduction in PTTP yellowfin releases. For RTTP bigeye releases, the 90% interval of correction factors at an MFCL release group resolution spanned 0.84 to 1.0, compared with an interval of 0.64 to 1.0 for PTTP bigeye releases. Overall, the estimated correction factors resulted in an 8.4% reduction RTTP bigeye releases, and a 7.6% reduction in PTTP bigeye releases.

4 Discussion

The estimated correction factors resulted in a c. 25% reduction in yellowfin releases across the RTTP and PTTP tagging programmes, and a more modest c. 8% reduction in bigeye releases across these programmes. 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), particularly for yellowfin. The reductions in release numbers were approximately 3 times stronger for yellowfin than for bigeye. This partially reflects the relatively weak station effects for bigeye in the selected RTTP and WP PTTP models (fitted to bigeye and yellowfin releases). Additionally, c. 85% of PTTP releases of bigeye were released on CP cruises, which have weaker overall corrections to tag releases compared with WP cruises for both species.

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 (e.g. Hoyle et al., 2015). The weak station effects for bigeye in RTTP and WP PTTP models suggest that the species may be more resilient than yellowfin to these processes driving the station effects. However, the differences between the species could also be explained by more rigorous selection of bigeye for tagging, or more careful handling, given their relative rarity during these tagging cruises. The inconsistency in station effects for RTTP and WP PTTP yellowfin releases is difficult to explain, noting that similar differences were also observed in tagging effect models for skipjack for the same programmes (Peatman et al., 2022).

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. As described in Section 2, experience effects were not included in the model selection process as fitted relationships in exploratory model runs were considered implausible. However, we note that there were suggestions of increasing recapture probabilities for taggers with the highest number of releases. 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. Future analyses should consider increasing the number of draws used in the cross-validation process, to mitigate the risk of random noise influencing the model selection procedure.

In this analysis, we estimated correction factors for CP PTTP tagging cruises separately to WP PTTP tagging cruises. This required separately modelling CP and WP cruises, but fitting the models to releases of both yellowfin and bigeye, given the relatively limited releases of yellowfin from CP cruises (3,115 individuals) and bigeye releases from WP cruises (9,327 individuals) in the modelled datasets. The modelling approach allowed species-specific differences in tagging effects to be accounted for, where supported by the data. However, the low numbers of releases in the modelled datasets suggest that the estimated correction factors for these species are uncertain.

Earlier analyses used bigeye-specific models for the RTTP (e.g. Berger et al., 2014). This did not allow estimation of correction factors, as no significant tagging effects were detected. Here, we also fitted models to RTTP models of both yellowfin and bigeye, which allowed for estimation of correction factors for bigeye releases. However, the limited number of releases of bigeye during the RTTP suggest that the estimated correction factors are also uncertain.

We invite the Scientific Committee to:

- Note the use of combined modelling of bigeye and yellowfin releases that enabled separate estimation of correction factors for Central Pacific PTTP tagging cruises.
- Note that combined modelling of bigeye and yellowfin releases also enabled estimates of correction factors for RTTP bigeye releases.

Acknowledgements

T. Peatman's contribution was supported by the WCPFC and the European Union's "Pacific-European Union Marine Partnership Programme". We thank participants at the tagging condition effects workshop and the pre-assessment workshop for their insightful comments and discussions, which contributed to the analyses presented here.

References

Berger A.M., S. McKechnie, F. Abascal, B. Kumasi, T. Usu and S.J. Nicol (2014). Analysis of tagging data for the 2014 tropical tuna assessments: data quality rules, tagger effects, and reporting rates. WCPFC-SC10-2014/SA-IP-06.

Brooks, M.E., Kristensen, K., Van Benthem, K.J., Magnusson, A., Berg, C.W., Nielsen, A., Skaug, H.J., Machler, M. and Bolker, B.M. (2017). glmmTMB balances speed and flexibility among packages for zero-inflated generalized linear mixed modeling. *The R journal*, **9(2)**, 378-400.

Hampton, J. (1997) Estimates of tag-reporting and tag-shedding rates in a large-scale tuna tagging experiment in the western tropical Pacific Ocean. *Fishery Bulletin*, **95**, 68-79

Hoyle, S.D., B.M. Leroy, S.J. Nicol and J. Hampton (2015). Covariates of release mortality and tag loss in large-scale tuna tagging experiments. *Fisheries Research*, **163**, 106-118.

Peatman, T., J. Scutt Phillips, J. Potts, S. Nicol (2022). Analysis of tagging data for the 2022 skipjack tuna assessment: corrections for tagging conditions. WCPFC-SC18-2022/SA-IP-20.

R Core Team (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Scutt Phillips, J., T. Peatman, M. Vincent, S. Nicol (2020). Analysis of tagging data for the 2020 tropical tuna assessments: tagger and condition effects. WCPFC-SC16-2020/SA-IP-05.

Vincent, M. T., Y. Aoki, H. Kiyofuji, J. Hampton and G. M. Pilling (2019). Background analyses for the 2019 stock assessment of skipjack tuna. WCPFC-SC15-2019/SA-IP-04.

Figures

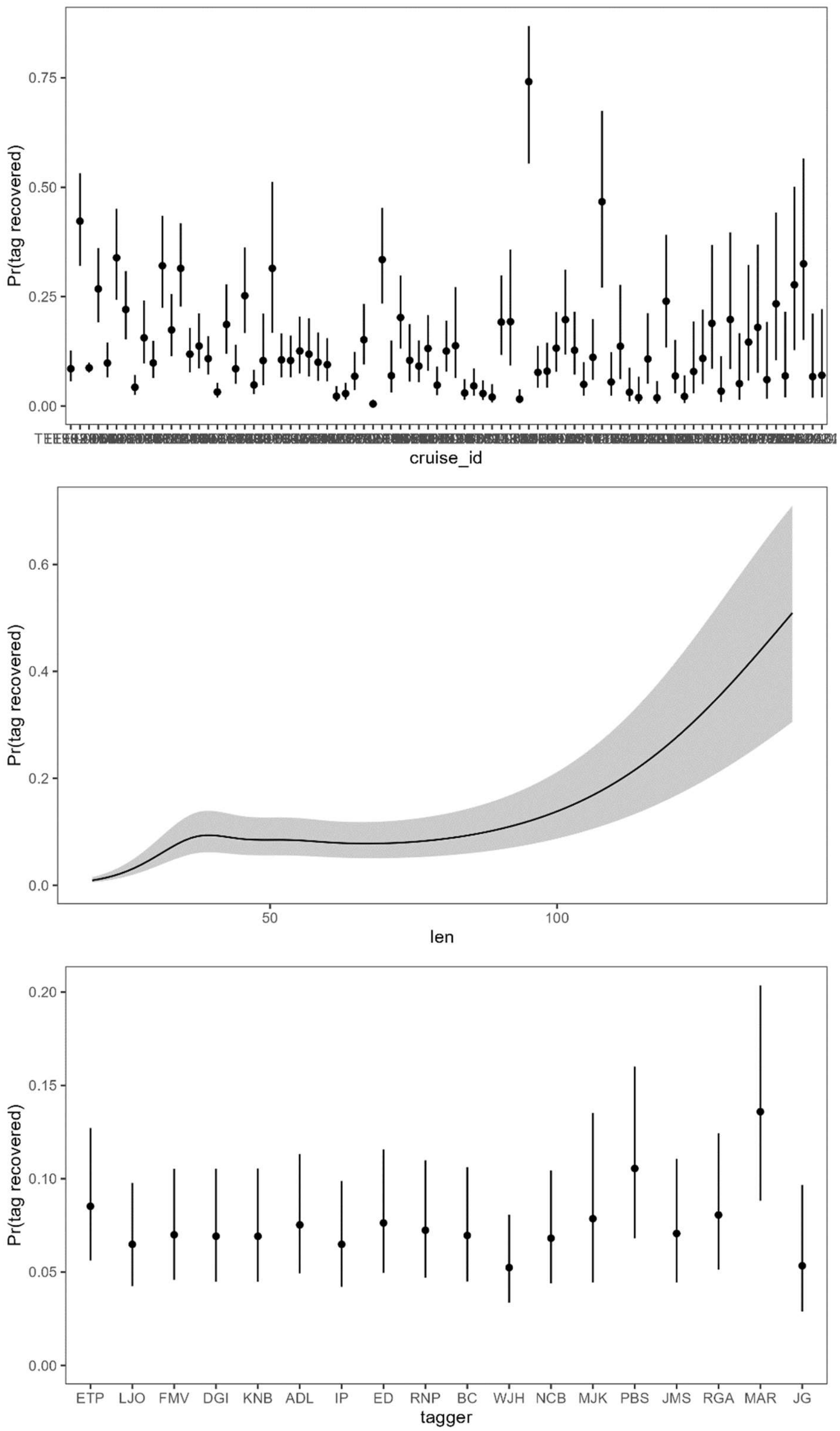


Figure 1 (continued on following page) Effect plots for the selected RTTP model of tagging effects for yellowfin (mean ± 1 SE). The effects are (from top panel to bottom): tagging event, length, tagger, station, condition and quality. Levels of categorical variables are ranked in descending order of 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.

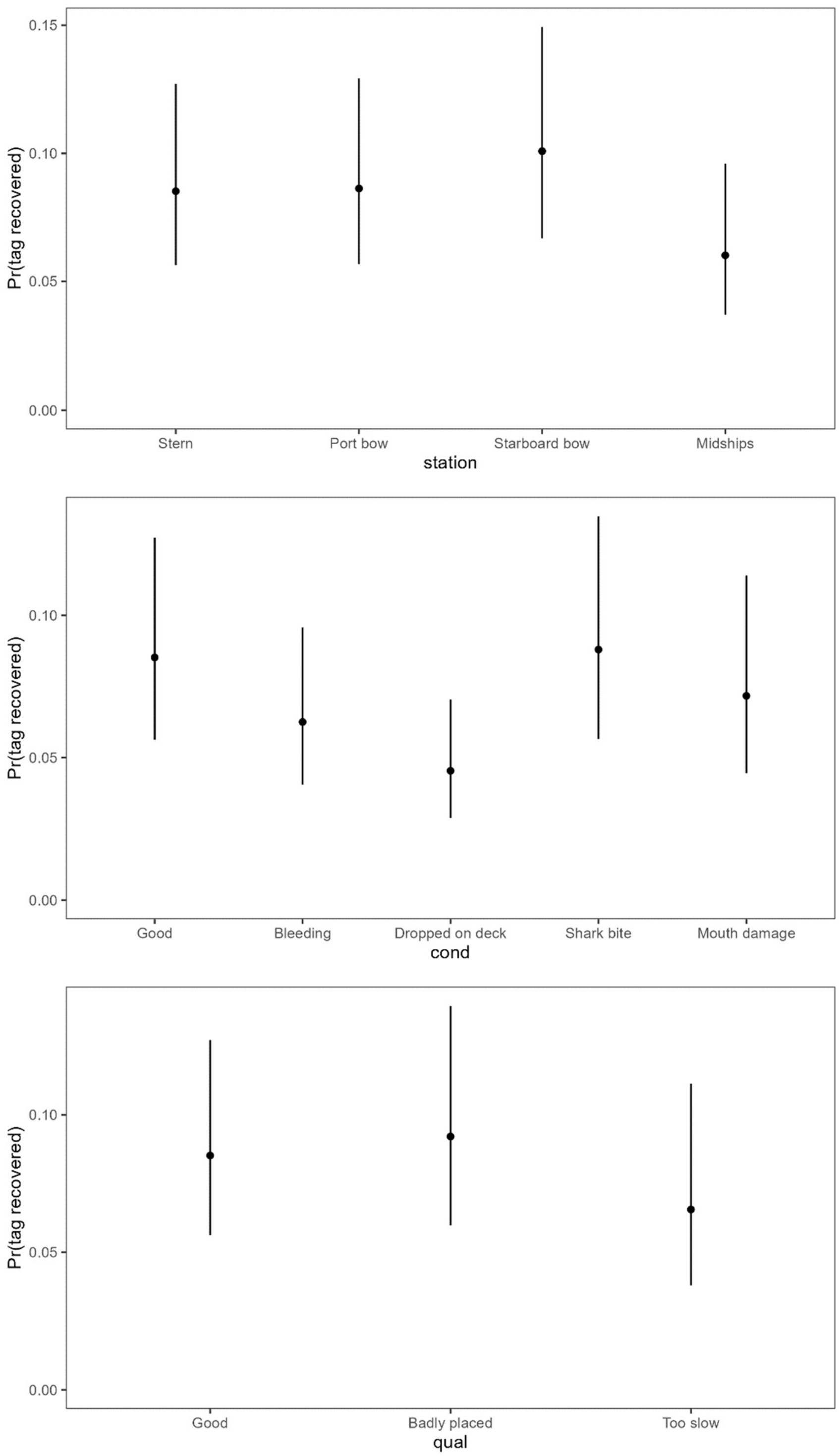


Figure 1 continued.

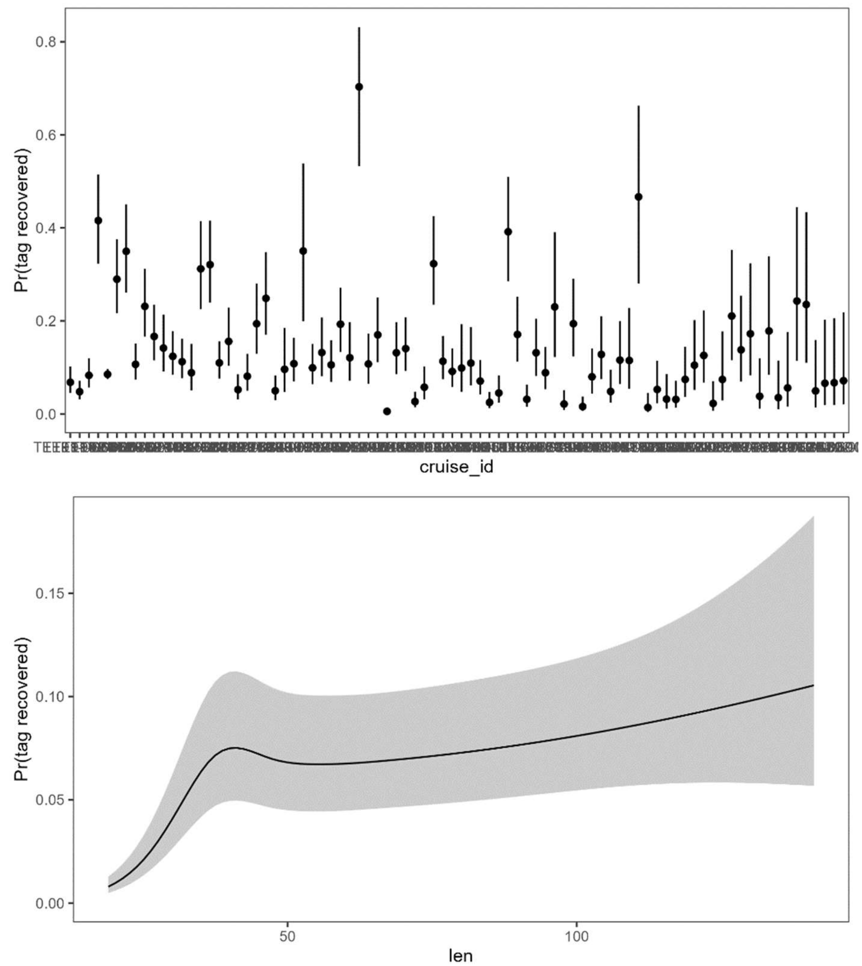
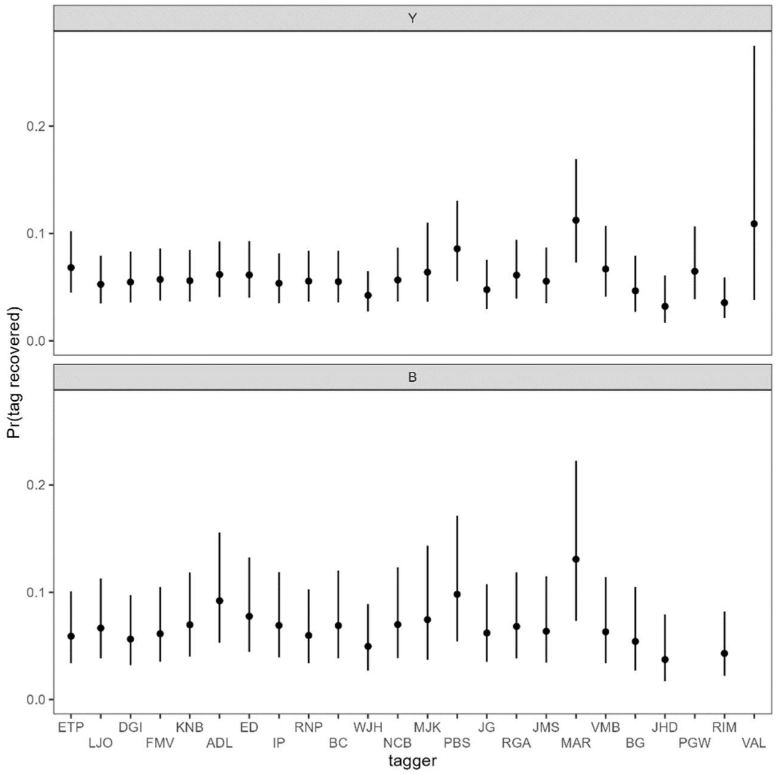


Figure 2 (continued on following pages) Effect plots for the selected RTTP model of tagging effects for yellowfin and bigeye (mean ± 1 SE). The effects are (from top panel to bottom): tagging event, length, tagger (species specific), station (species specific), condition and quality. Levels of categorical 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.



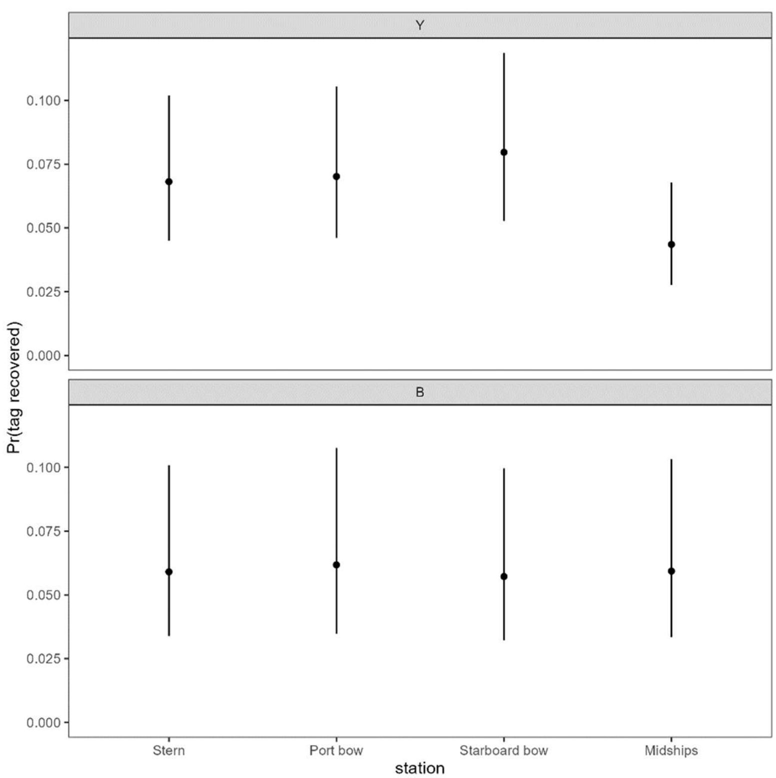


Figure 2 continued.

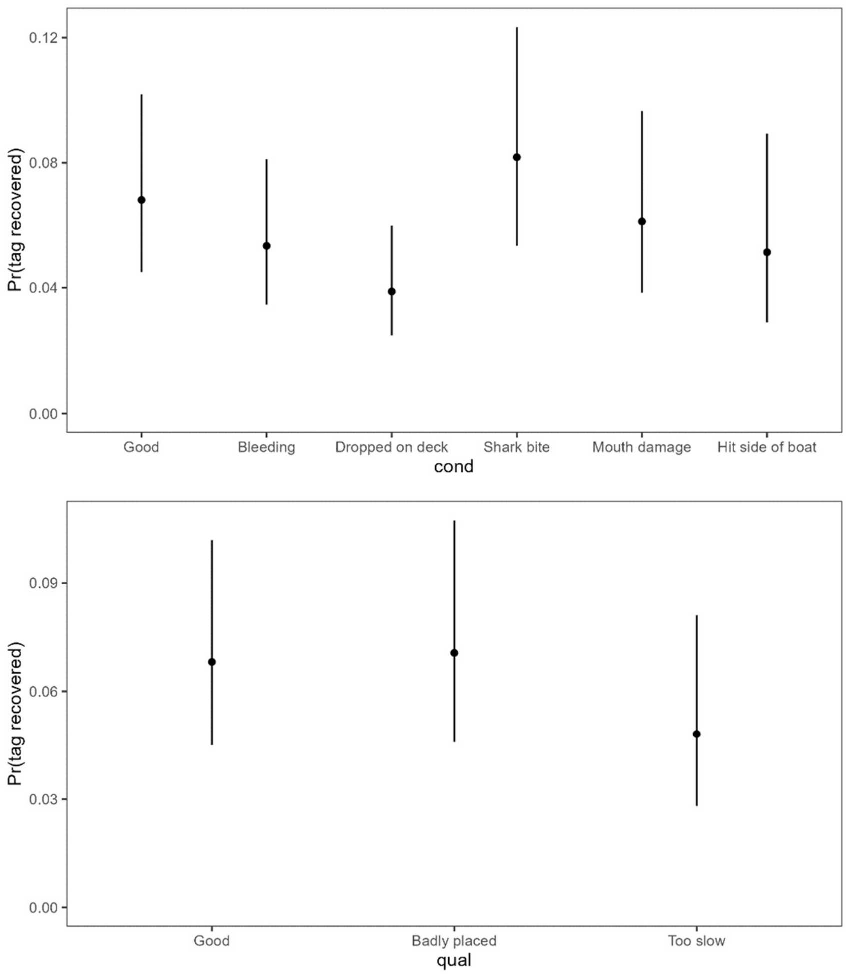


Figure 2 continued.

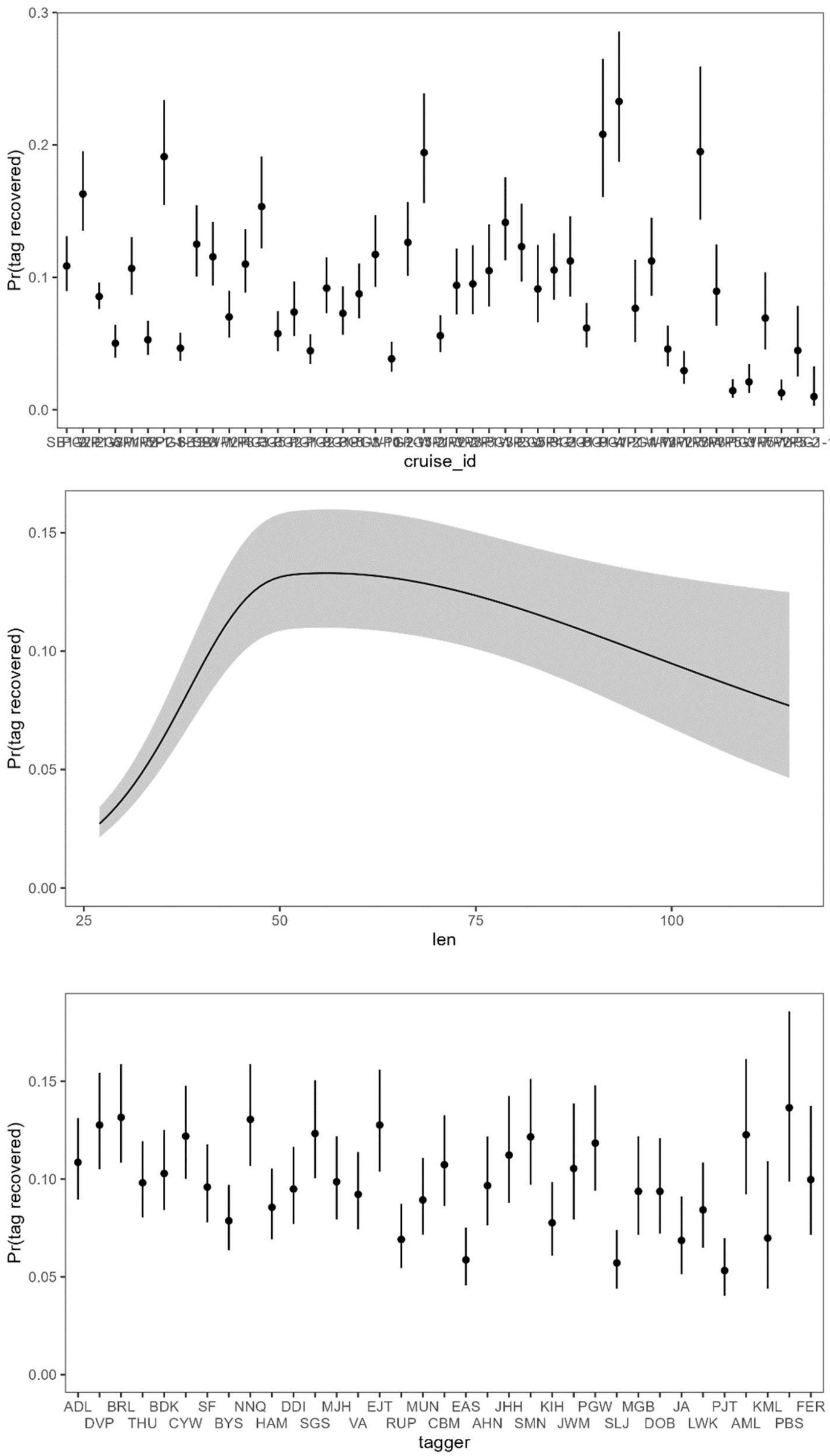


Figure 3 (continued on following page) Effect plots for the selected Western Pacific PTTP model of tagging effects for yellowfin (mean ± 1 SE). The effects are (from top panel to bottom): tagging event, length, tagger, station, condition and quality. Levels of categorical variables are ranked in descending 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.

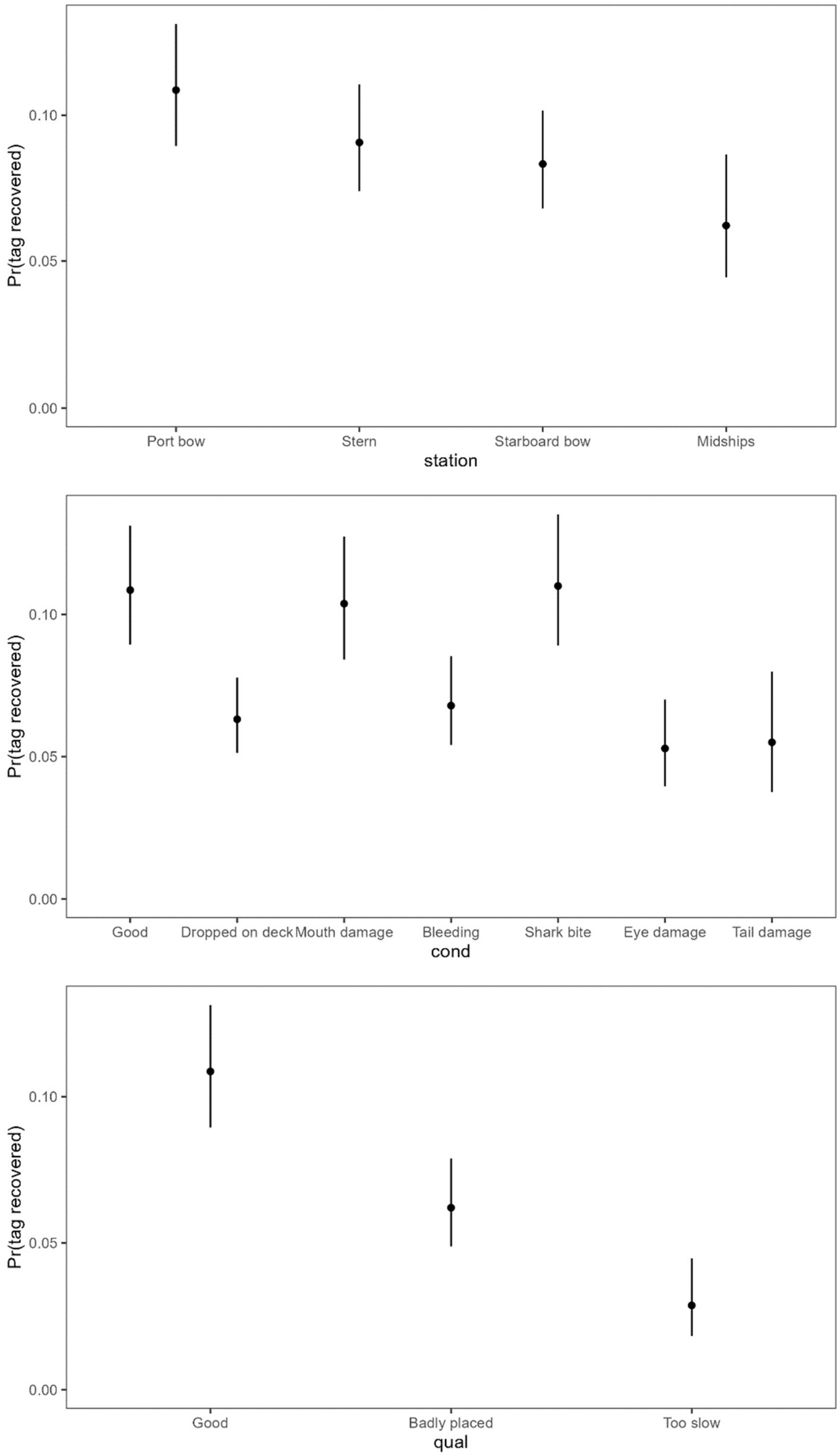


Figure 3 continued.

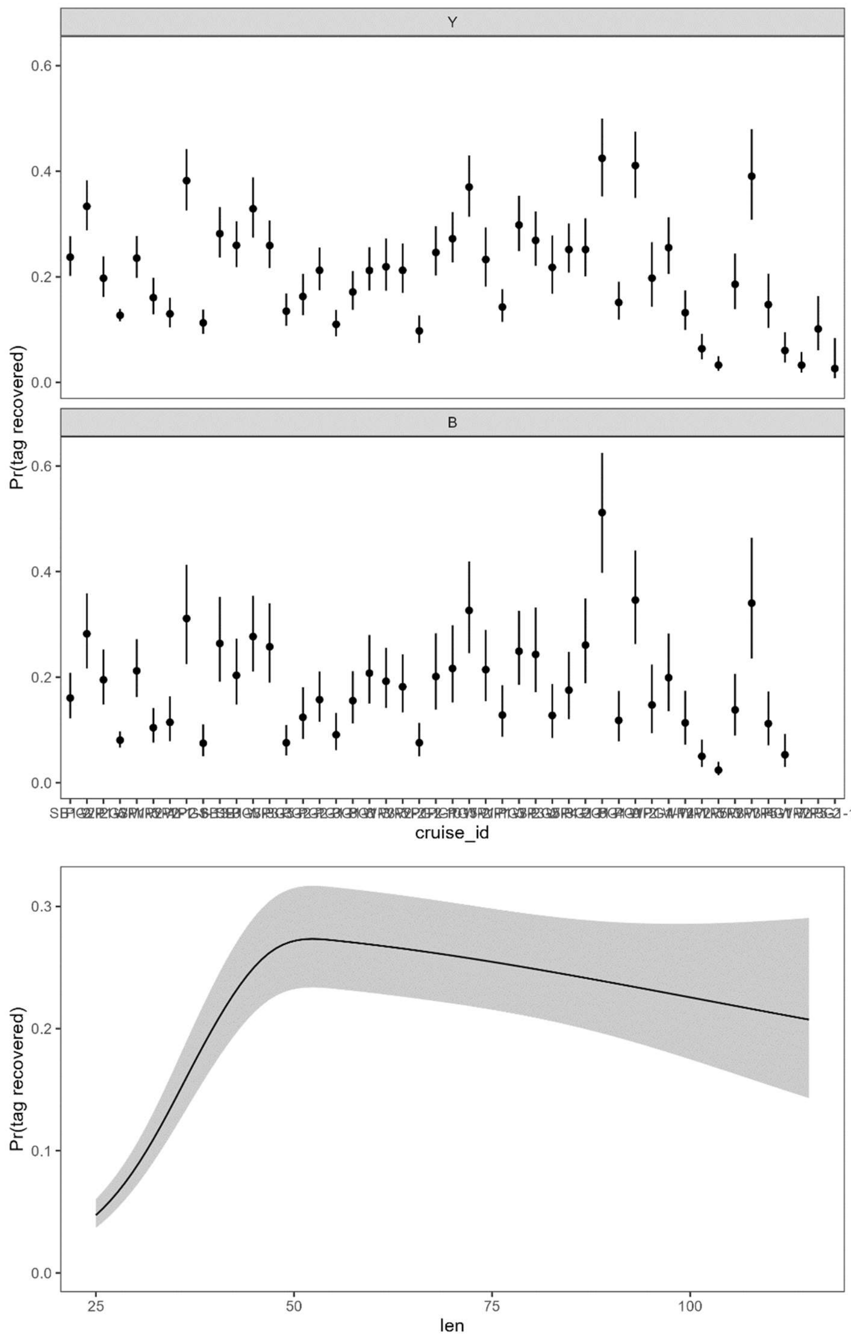


Figure 4 (continued on following pages) Effect plots for the selected Western Pacific PTTP model of tagging effects for yellowfin and bigeye (mean ± 1 SE). The effects are (from top panel to bottom): tagging event (species specific), length, tagger (species specific), station (species specific), condition 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.

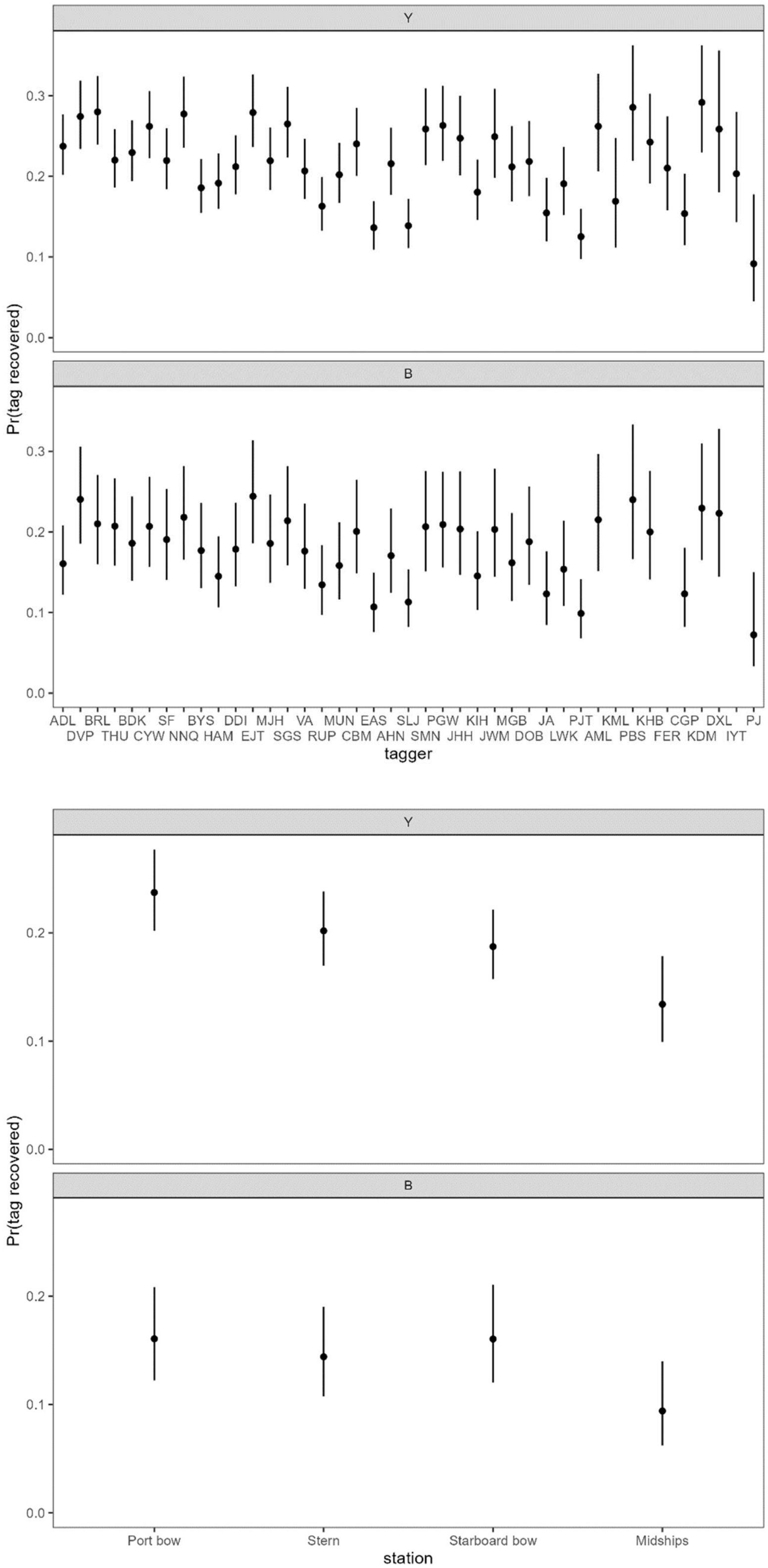


Figure 4 continued.

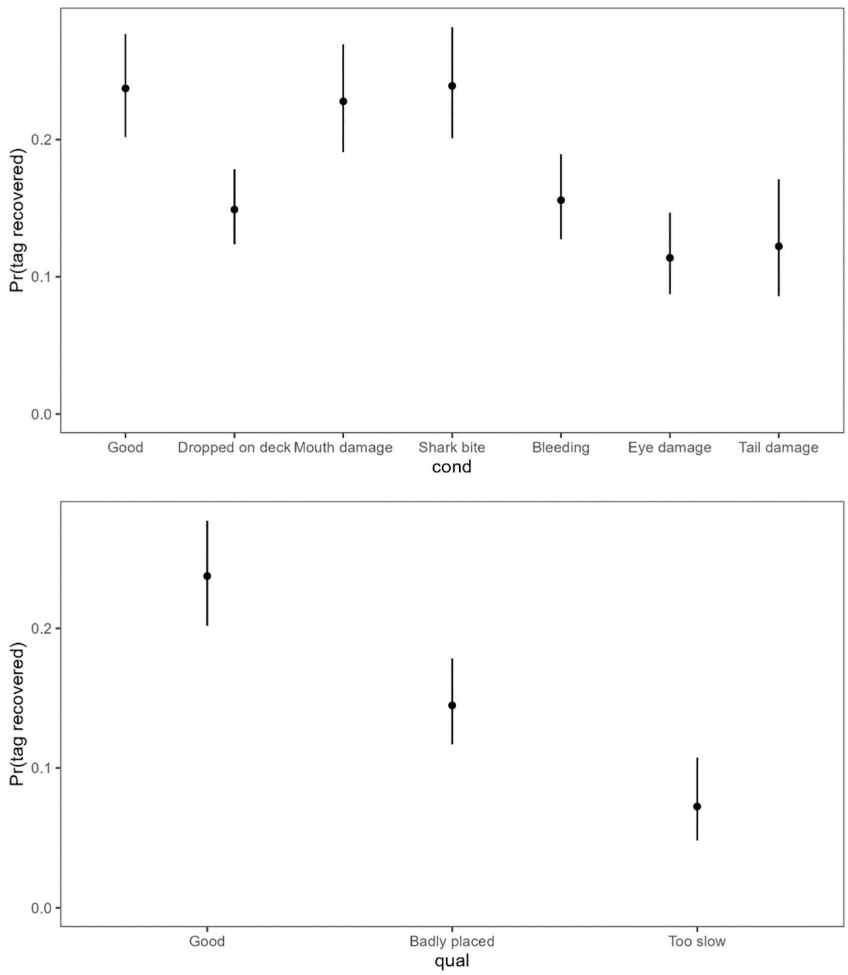


Figure 4 continued.

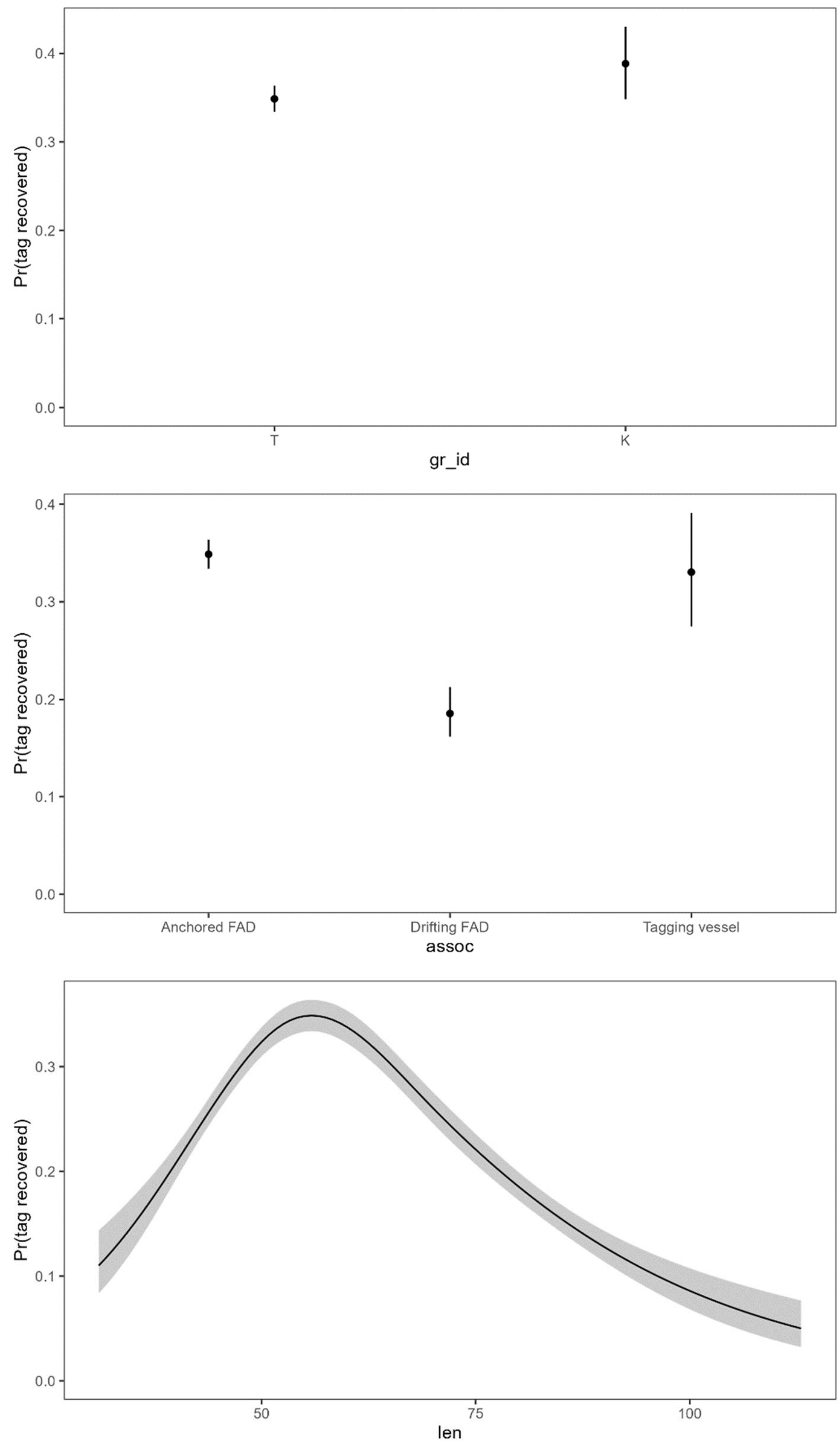


Figure 5 (continued on following page) Effect plots for the selected Central Pacific PTTP model of tagging effects for bigeye (mean ± 1 SE). The effects are (from top panel to bottom): gear, school association, length, tagger, and condition. Levels of categorical variables are ranked in descending order 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.

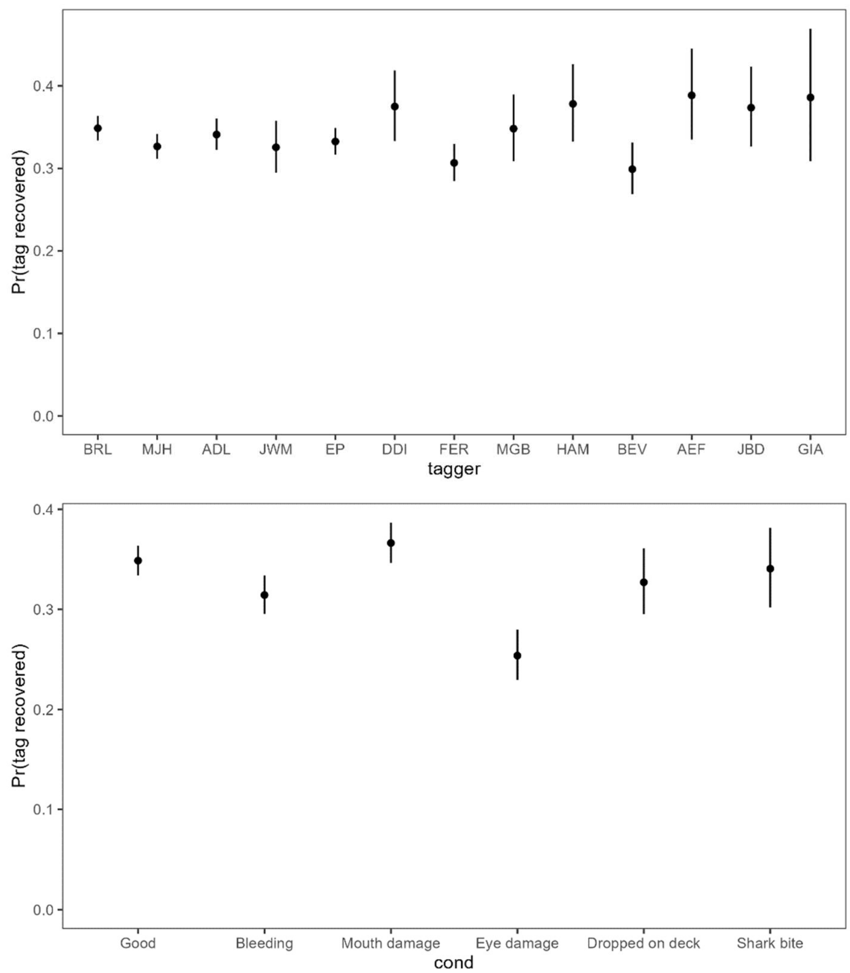
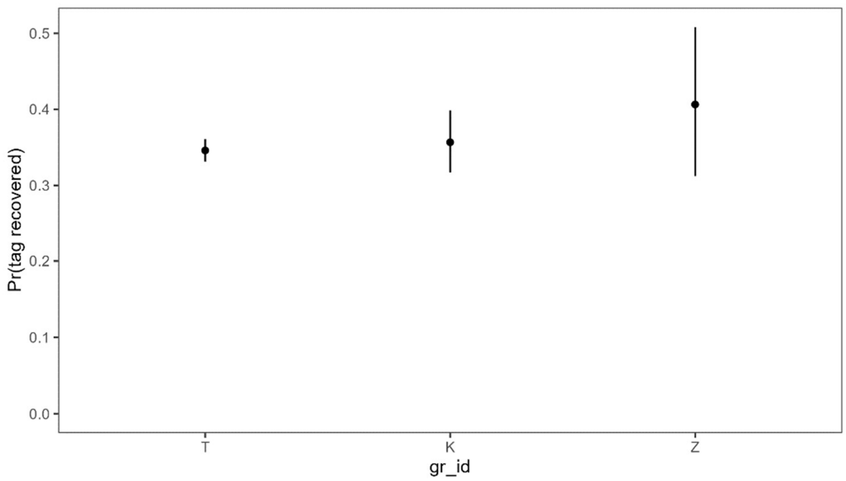


Figure 5 continued.



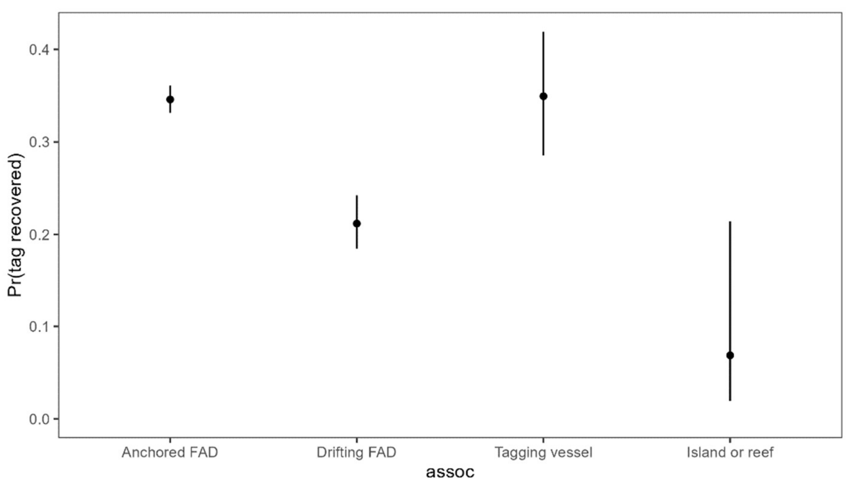
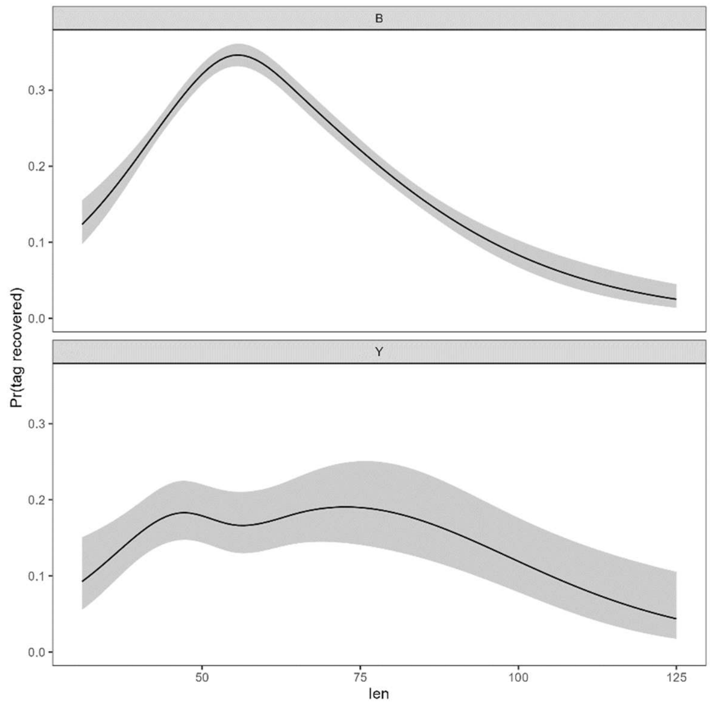


Figure 6 (continued on following pages) Effect plots for the selected Central Pacific PTTP model of tagging effects for bigeye and yellowfin (mean ± 1 SE). The effects are (from top panel to bottom): gear, school association, length (species specific), tagger and condition. Levels of categorical variables 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.



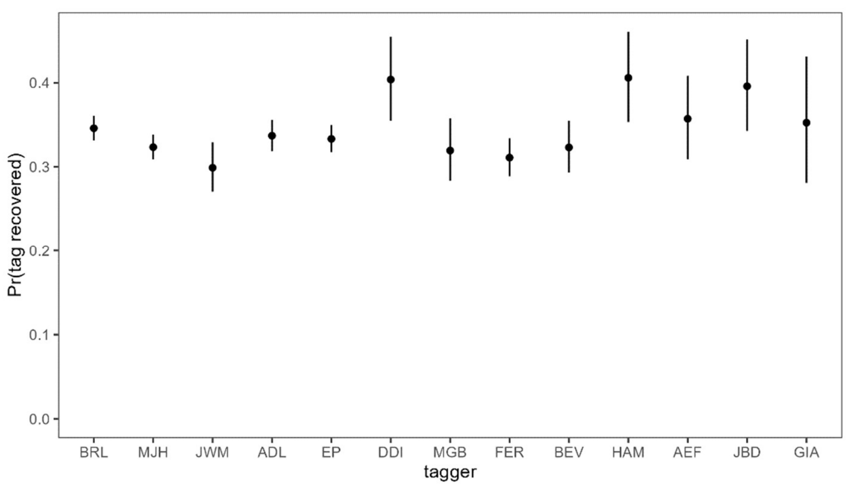


Figure 6 continued.

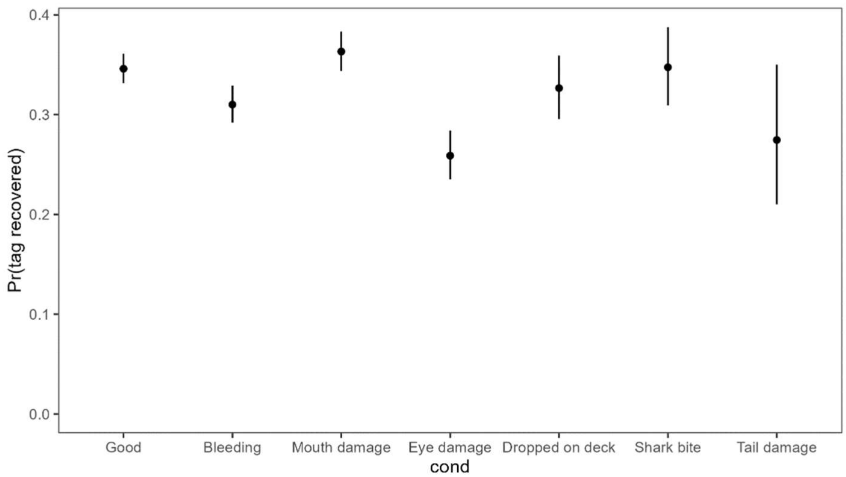
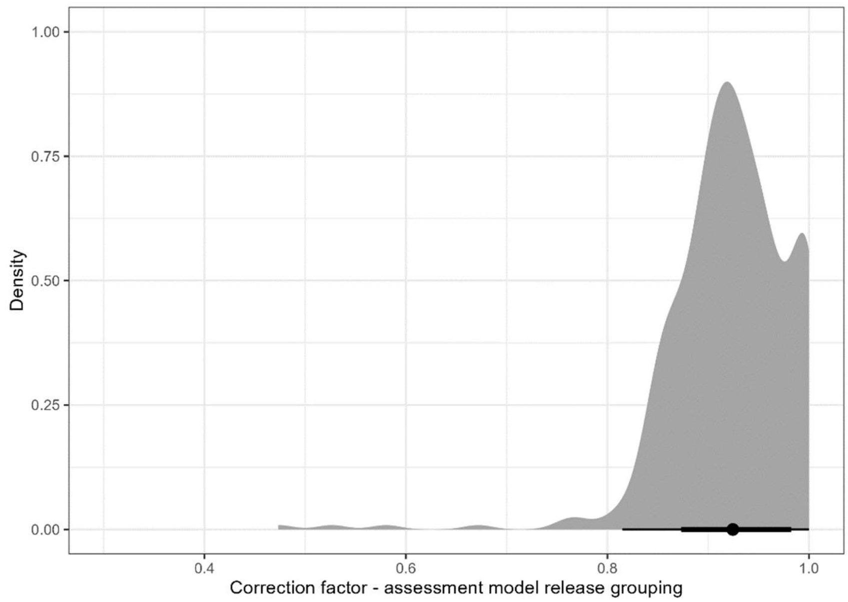


Figure 6 continued.

a) BET RTTP



a) BET PTTP

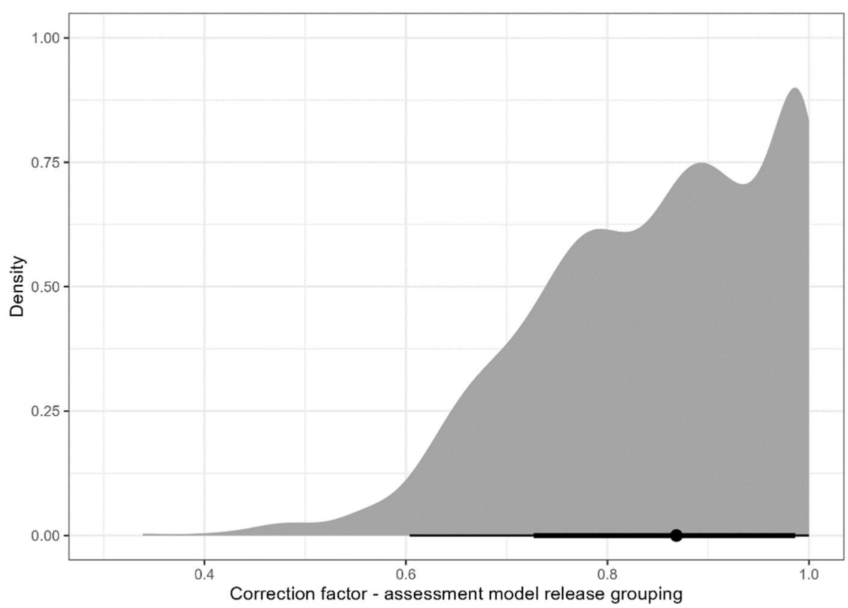
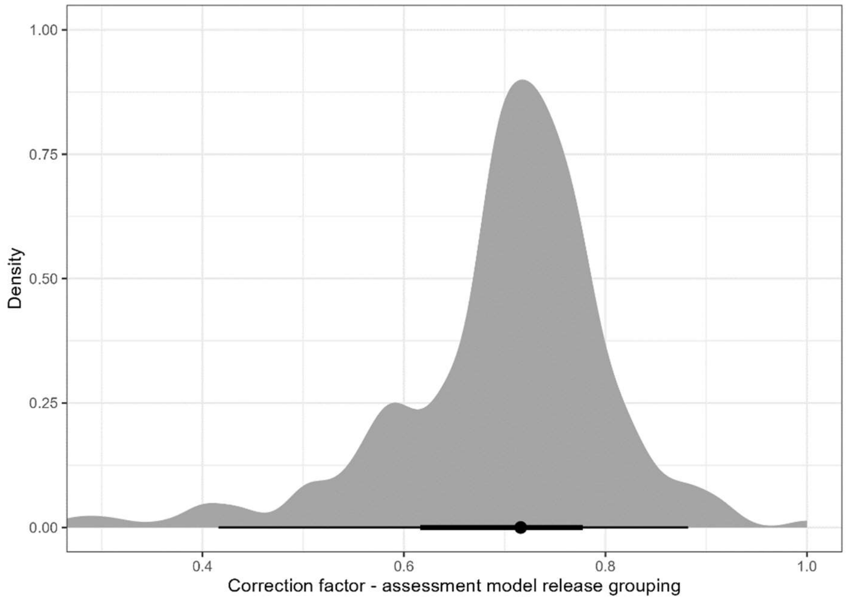


Figure 7 Estimated bigeye correction factors for the a) RTTP and b) PTTP by assessment model release grouping (i.e. combinations of region, year, quarter and release length class). The mean (point), 66% interval (thick line) and 95% interval (thin line) are provided for reference.

a) YFT RTTP



a) YFT PTTP

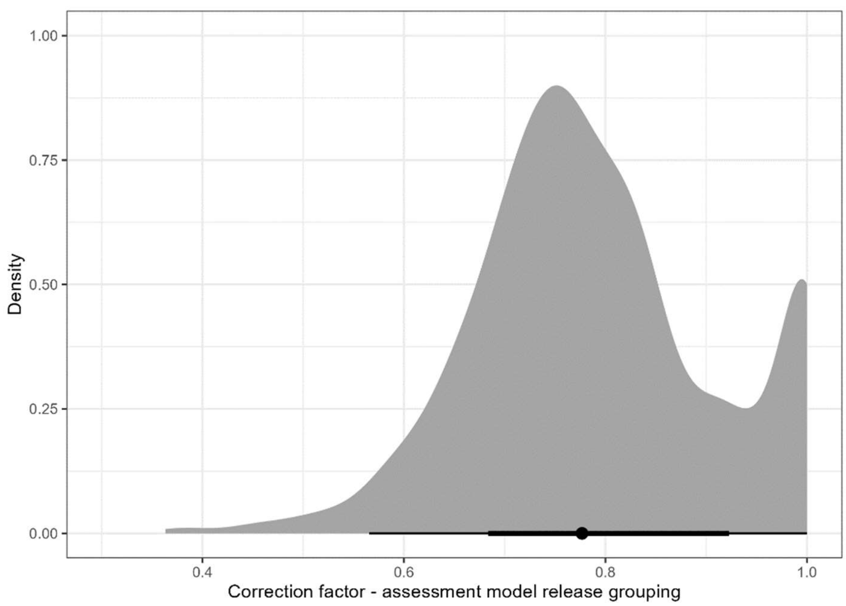


Figure 8 Estimated bigeye correction factors for the a) RTTP and b) PTTP by assessment model release grouping (i.e. combinations of region, year, quarter and release length class). The mean (point), 66% interval (thick line) and 95% interval (thin line) are provided for reference.