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Analysis Of Tag Seeding Data For The 2025 Skipjack Assessment: Reporting Rates For Purse Seine Fleets

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WCPFC-SC21-2025/SA-IP-07

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Executive summary

Reporting rate models were constructed based on the approach of Peatman et al. (2023), fitted to data from tag seeding experiments on purse seine vessels undertaken during the PTTP. The reporting rate models were used to estimate flag-specific reporting rate distributions. Flag-specific reporting rates were combined to generate reporting rate distributions for purse seine fisheries in the 2025 skipjack assessment. Parameters for reporting rate prior distributions were then extracted for use in the assessment models.

The analyses presented here provide the strongest evidence yet of a change in tag reporting during the PTTP, with an apparent reduction in reporting rates in 2015, as well as a suggestion of increasing reporting rates through time from 2015 onwards. However there remains considerable uncertainty around the structure, strength and timing of any changes in reporting rates due to the limited number of tag seeding experiments conducted from 2015 through to 2022. The evidence for a temporal change in reporting rates during the PTTP does not appear sufficiently strong to support the inclusion of time-varying reporting rates in the 2025 skipjack assessments, given the additional flexibility that this would give the assessment model.

There has been a rapid increase in tag seeding experiments in 2024 and 2025, including an increase in coverage of the different fleets comprising the large-scale purse seine fishery operating in the Western and Central Pacific Ocean. This dataset should enable more robust monitoring for temporal changes in reporting rates. Preliminary analyses of the recent tag seeding experiments are also reported here, including exploration of additional variables that are not included in the current models of tag reporting rates, and that are influential on tag reporting rates. Preliminary results show that including recovery port as a covariate significantly improves the fit of reporting rate models. However, further investigation is needed to assess the influence of additional factors on the reporting rate, including the context in which tags are recovered (e.g., during processing, fishing, or transhipment), the location of recovery (such as canneries or carrier vessels), to better reflect the complexity of tag reporting. Additionally, methods to incorporate such results into reporting rate priors for stock assessment models would need to be developed.

We invite the Scientific Committee to consider the following recommendations for the tag seeding experiments and analysis:

- The Scientific Committee note that the low levels of tag seeding experiments from 2015 to 2022 have compromised our ability robustly monitor for temporal changes in tag reporting. The low level of seeding experiments is exacerbated by the imbalanced nature of the tag seeding data with respect to fleet-specific coverage through time;
- Tag seeding should be continued as long as regular tag recoveries are being received, targeted to fleets and regions where these regular recoveries are most likely;
- A minimum target of 32 seeding experiments per year is recommended (see Peatman et al., 2019);
- More consistent coverage of tag seeding experiments through time is recommended, with a particular emphasis on fleets that are likely to be recovering tags based on their areas of operation relative to PTTP tag releases;

- With enough tag seeding data, more detailed analyses of variables influencing tag reporting rates have potential benefits for informing reporting rate parameters for stock assessments of tropical tuna in the WCPO, as well as other analyses of conventional tagging data which are conditional on assumed tag reporting rates.

Introduction

SPC have tagged and released tunas 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), since 2006. Tag seeding experiments have been undertaken as a component of both the RTTP and PTTP, in which observers on purse seiners surreptitiously mark caught tuna with conventional plastic tags, thereby 'seeding' the catch with tagged fish. Throughout this report, 'tag seeding experiment' refers to an observer trip on a specific fishing vessel during which tags were seeded.

The MULTIFAN-CL stock assessments of WCPO tropical tuna stocks account for recovered tags that are not detected and/or reported to SPC using fishery and tag programme specific reporting rates, i.e. the proportion of recovered tags that are detected and reported. Incorporation of reporting rates in the assessment models addresses systematic under-estimation of fishing mortality rates and over-estimation of stock biomass due to under-reporting of tag recoveries. Reporting rates are estimated within the assessment model and are constrained by reporting rate prior distributions which are provided as an input, based on either analyses of data external to the assessment model or more subjective determinations of plausible reporting rates. The priors penalise estimated reporting rates that are further away from the mean of the prior distribution, with the strength of the penalisation controlled by a penalty term. Historically, purse seine tag reporting rate prior distributions for MULTIFAN-CL assessments have been estimated using tag seeding experiments, using the proportion of seeded tags that are subsequently detected and reported to SPC (e.g. Hampton 1997; Berger et al., 2014).

This information paper estimates reporting rate priors based on tag seeding experiments for application in the 2025 skipjack stock assessment, based on the approach of Peatman (2023). Throughout the report, region numbers refer to the eight-region structure considered for the 2025 assessment (Figure 1).

Methods

Tag release and recovery information were extracted from SPC's master tuna tagging database for all tag seeding experiments undertaken from 2007 to 2022 inclusive (Table 1, Table 2). Tag seeding experiments from 2023 onwards were excluded to ensure sufficient time for seeded tags to be detected and reported to SPC and thus minimise downwards bias in estimated reporting rates in recent years.

Since 2009, observers have recorded whether they believed that fishing vessel crew had seen the seeding of tags, or whether crew had asked questions that suggested that they were aware that tag seeding had taken place, i.e. whether the tag seeding experiment was likely to have been compromised. The rates of detection and reporting of tags on fishing vessels are higher from compromised seeding experiments (Peatman et al., 2016). However, recent analyses have not detected a significant effect on reporting rates based on whether a tag seeding experiment was considered likely to have been compromised (e.g., Peatman 2022; Peatman & Nicol, 2023), which was also consistent with exploratory model runs in the current analysis. As such, all tag seeding experiments were retained in the analysed dataset, regardless of tag seeding experiment was considered likely to have been compromised. This analysed dataset included 375 seeding experiments, representing 7,850 individuals marked with tags from which 4,723 recaptures were reported to SPC. The majority of individuals had a single tag (n = 6,321), with the remainder double tagged (n = 1533). Plastic anchor tags were used for all single-tagged fish. Double tagged fish were either marked with two plastic anchor tags (n = 1,281), or one plastic and one steel anchor tag (n = 252).

Beta-binomial models of reporting rates were fitted in R version 4.4.1 (R Core Team, 2024) using the 'gamlss' package (Rigby and Stasinopoulos, 2005). Following Peatman & Nicol (2023), we tested alternative approaches to modelling temporal variation in reporting rates, including: no temporal effects, inclusion of the year of seeding as a categorical variable, inclusion of year as a continuous variable as a linear effect (with year standardised by its mean and standard deviation) or as a penalised spline smoother to test for non-linear effects, step-changes in reporting in a given year (tested years were 2010 to 2020 inclusive); and, the number of total PTTP tag releases within a specified time-period before each tag seeding experiment (tested time-periods were 6, 9, 12, 18, 24, 30, 36, 42 and 48 months), referred to as a 'pre-experiment releases' effect, and included as penalised smoother.

All reporting models included categorical variables for vessel flag, and whether the fish was seeded with a single tag or double tagged. We first identified the approach to modelling temporal variation that had most support from the observations, and the time-window for pre-experiment releases with most support. We then used a forward selection procedure, informed by AIC (described in the Results section). Reporting rate models were fitted to tag seeding data aggregated across all species.

The selected model specification was

$$\mathrm{E}(rec_{nt}) = rel_{nt}\mu_{nt}$$

$$\mathrm{Var}(rec_{nt}) = rel_{nt}\mu_{nt}(1 - \mu_{nt})\left[1 + \frac{\sigma}{1+\sigma}(rel_{nt} - 1)\right]$$

$$\log\left(\frac{\mu_{nt}}{1-\mu_{nt}}\right) = \beta_0 + flag_t + double_{nt} + year_t$$

with: μ_{nt} is the reporting rate for fish from seeding experiment t seeded with n tags; rel_{nt} and rec_{nt}, the total number of seeded tags and reported recoveries, respectively; β_0, the global intercept; $flag_t$, a categorical variable for vessel flag; $double_{nt}$, a categorical variable for whether the fish were double (TRUE) or single (FALSE) tagged; $year_t$, a categorical variable for the year of the mean date of seeding; and, σ an overdispersion parameter.

Flag and year-specific reporting rate distributions were generated from the fitted model by drawing 10,000 sets of parameters from the multivariate normal distribution $N_k(\boldsymbol{\beta}, \boldsymbol{\Sigma})$, defined by the vector of estimated parameter means $\boldsymbol{\beta}$ and their covariance matrix $\boldsymbol{\Sigma}$, where k is the number of estimated parameters. These parameter sets were then applied to each combination of flag and year to generate 10,000 reporting rate estimates for each combination. The double-tag effect was set to FALSE when estimating reporting rates, as PTTP tag releases typically had a single tag (> 99.7%).

MFCL region-specific reporting rate distributions for the duration of the PTTP were obtained by calculating the weighted mean of the flag and year-specific reporting rates, weighted by the product of flag and year-specific reported catch of skipjack (in the region) and the number of PTTP skipjack releases (in all regions). The region-specific reporting rate distributions were then mapped to purse seine fisheries in the 2025 skipjack assessments. This approach ensures that flags with higher catches contribute more to region-specific reporting rates, and the same for years with more PTTP tag releases.

The mean and variance of the region-specific reporting rate distributions were then extracted, with the penalty parameter given by $penalty = (2 * variance)^{-1}$. Flags that did not contribute a minimum of 1% to the total catch for any assessment region were excluded. Catches of the domestic Indonesian and Philippines purse seine fisheries were also excluded, on the assumption that available tag seeding data are only representative of reporting rates for the distant water fishery in region 5.

Results and discussion

In the current analysis, a variety of approaches were tested for representing temporal variation in reporting rates, relative to a model with only flag and double-tag effects (Table 3). The inclusion of the year of tag seeding experiment as a categorical variable had the most support, and so was included in the selected model used to estimate reporting rates (ΔAIC = -25.0). This resulted in the selected reporting rate model provided in the Methods section. The tested time-window for the pre-experiment releases effect with most support was 42 months (ΔAIC = -20.5), though with support for all time window lengths of 18 months or greater. A step-change in reporting in 2015 received more support than a step change in any other year (ΔAIC = -17.5). Models with a linear and non-linear temporal effect were equivalent, with both receiving less support than a model with no representation of temporal effects (ΔAIC = 1.8; Table 3).

Year effects from the selected reporting rate model displayed an apparent decrease in tag reporting rates in 2015, along with a suggested increasing temporal trend in reporting rates for 2007 to 2011, and from 2015 onwards (Figure 2). Fish seeded with double tags were associated with significantly higher reporting rates compared to those seeded with a single tag (Figure 2; coefficient = 0.495, p = < 1E-5). The models detected strong between-flag variation in reporting rates (Figure 2), though there were relatively few seeding experiments in the modelled dataset for a number of flags (Table 2), resulting in lower precision in some flag effects.

Previous analyses of tag seeding data have suggested an apparent reduction in reporting rates from 2015 onwards, with most support for a step-change in reporting rates in 2015 (e.g. Peatman & Nicol, 2023). The increase in support for inclusion of seeding experiment year as a categorical variable in this analysis is likely driven by the apparent increasing trends in reporting rates from 2007 to 2010 and 2015 onwards, noting that there are more seeding experiments in this analysed dataset in both periods relative to earlier studies. The increase from 2007 to 2011 may reflect increases in awareness of the PTTP of fishers and other potential tag finders in the supply chain in the early years of the tagging programme. Potential causes of the estimated decrease in reporting rates in 2015 could include the reduction in the numbers of tag releases at this time.

The significant double-tag effect may reflect the increased visibility of a tag when multiple tags are used. It may also reflect tag-shedding, i.e., a greater probability of a tag being retained when multiple tags are used (all else being equal). It is important to note that the double tagged effect is likely to partially account for the (unmodelled) effect of tag-type, as all steel-headed tags were used on double tagged fish. However, exploratory model runs supported inclusion of a double tagged effect (ΔAIC = -19.4), rather than a tag-type effect in isolation (ΔAIC = -2.3), or both a tag-type and double-tagged effect (ΔAIC = -17.5).

The Japanese flag effect (Figure 2) was considered unlikely given the numbers of reported PTTP recoveries relative to other flags. The Taiwanese flag effect was applied to Japan when estimating flag-specific reporting rate distributions, as assumed in previous analyses (e.g., Berger et al. 2014). We note that Japanese vessels unload catches in Japanese ports, in contrast to other purse seine fleets operating in the WCPO. As such reporting rate estimates for Taiwanese purse seiners, or indeed those of other purse seine fleets, may not reflect those for Japanese vessels due to differences in the supply chains of product between the fleets. In the absence of empirical data, reporting rates for EU Spanish vessels were assumed to be the same as those for Ecuadorean flagged vessels (e.g. see Berger et al., 2014), and reporting rates for purse seiners flagged to Nauru and Tuvalu were assumed to be the same as those for vessels flagged to Kiribati.

An example of the flag-specific reporting rate distributions are provided in Figure 3 (for 2014). The resulting region-specific reporting rate distributions for the eight-region structure are provided in Figure 4, with reporting rate prior parameters provided in Table 4. The means of the reporting rate prior distributions are 9 to 15% lower than those used in the 2022 skipjack assessment (Peatman, 2022), reflecting the lower estimated reporting rates for single tagged fish. The penalty terms are c. 20% higher for fisheries in regions 6 and 7, and 17% lower for region 8, relative to their 2022 equivalents.

Reporting rates for the ‘large scale’ purse fisheries in regions 3 and 5 were generated using the approach from the 2019 skipjack assessment (Vincent et al., 2019), i.e. by estimating a reporting rate distribution for regions 7 and 8 combined and applying a 50% reduction to the penalty parameter. The percentage of purse seine catches from Japanese vessels in the ‘distant water’ fisheries in regions 3 and 5 are relatively high, which is reflected in the reduction applied to the penalty parameter. As noted in the Methods section, available tag seeding data may not be representative of reporting rates for the domestic fisheries of Indonesia and the Philippines in region 5 due to differences in fishing vessel characteristics, product flows of catches through the supply chain etc. As such, we recommend that the reporting rate prior is only used for the ‘large scale’ fisheries in region 5, and not the domestic fisheries of Indonesia and the Philippines.

Reporting rate models were fitted to tag seeding data from all three tropical tuna species combined, reflecting the assumption that reporting rates were species invariant. We fitted reporting rate models including a species effect and a random intercept for tag seeding experiment ID, to explore whether this assumption was likely to be violated. This model did not detect significant variation in reporting rates between species, though there was a suggestion of higher reporting rates for bigeye. We note that the numbers of bigeye seeded with tags are relatively low (6% of the total), compared with 74 and 20% for skipjack and yellowfin respectively.

The analyses presented here continue to suggest a temporal change in tag reporting during the PTTP, and suggest that the temporal trend is more nuanced than simply a reduction reporting rates from 2015 onwards. However, the relatively low numbers of tag seeding experiments undertaken in recent years and the imbalanced coverage of fleets, coupled with the high levels of variation in tag reporting rates between seeding experiments, has compromised our ability to explore these temporal changes in detail, or be confident that a change in reporting rates has actually occurred. As such, there remains considerable uncertainty around the structure, strength and timing of any change in reporting rates. The evidence for a temporal change in reporting rates during the PTTP does not appear sufficiently strong to support the inclusion of time-varying reporting rates in the 2025 skipjack assessments, given the additional flexibility that this would give the assessment model. Instead, we recommend using reporting rate prior parameters calculated for the duration of the PTTP, which take account of the apparent temporal trends in reporting rates throughout the PTTP.

Higher levels of tag seeding experiments are required to enable more robust monitoring of temporal changes in reporting rates in the future, and to provide more confidence that reporting rates are appropriately represented in stock assessment models.

The model selection procedure suggested lower reporting rates for tag seeding experiments with fewer tag releases up to 42 months prior to the experiment. This may explain the tendency for lower reporting rates from 2015 onwards, when the numbers of tag releases per year were low relative to the early years of the PTTP. The apparent relationship between reporting rates and the numbers of pre-seeding experiment tag releases may reflect reduced incentives for potential tag finders to search for tagged fish when there are likely to be fewer tagged fish in catches. Noting the decision to return to 100% purse seine observer coverage at the beginning of 2023 the SSP has implemented new incentives schemes within the national and regional observer programmes to encourage tag seeding experiments (see SC18-RP-PTTP-01 for details). In addition to incentives for observers these include incentives for officers involved in observer placement and debriefing.

Exploring the Integration of Covariates to Improve Reporting Rate Models

The strong evidence for changes in reporting rate over time, alongside the recent increase in tag seeding experiments (SC21-RP-PTTP-01), supports the potential for a more detailed examination of reporting rates and the covariates that may to influence them. While MULTIFAN-CL reporting rate parameters must be structured at the flag-region-tagging programme level, the reality of the modern tuna product network is likely to exhibit levels of reporting that vary by many other factors. For example, particular canneries where tag awareness campaigns have been recently carried out may report higher numbers of tags found during processing but receive fish from many different subsets of vessels with varying flags. Similarly, the tags reported from vessels that regularly change their port of unloading/transhipping may be driven more by awareness and operations during unloading at these different ports, rather than the flag of the vessel itself. Including such factors may enhance the accuracy and explanatory power of reporting rate models.

To explore such effects further, we here examine data from tag seeding experiments, including those most recent events which were not included in the above reporting rate estimation. The analysis focuses exclusively on seeded tags released between 2007 and 2024.

The aim of the analysis was to test whether inclusion of an individual return port term into statistical models of reporting probability improves the fit to data for tag seeding experiments relative to the typical estimation of reporting rates for informing stock assessment. The return port refers to the port visited by the vessel after the seeding experiment. As described above, it is unlikely that vessel flag fully captures variation in reporting rates within the supply chain of tuna from the WCPO purse seine fishery. Information on port for purse seine trips explicitly captures at least a component of the supply chain experienced by individual seeded fish and is readily available. Tags were considered as reported only if found during unloading, in order to best estimate the effect of return port on reporting rates. Seeded tags found at other stages of the fisheries process (e.g., transhipment, processing, or fishing) were not considered as reported. The dataset included 7 155 conventional tags released on 217 vessels among which 2 247 were recovered in 34 different ports. Figure 6 summarises temporal coverage for the 10 most frequent return ports in the extended tag seeding dataset, as well as the overall mean observed reporting rate by year-quarter.

To compare the performance of alternative model formulations, AIC comparisons between the reporting rate model presented in the Methods section and an extended model including the port of recovery were estimated using the extended tag seeding dataset. The specification of mean reporting rate in the extended model was:

$$\log\left(\frac{\mu_{nt}}{1-\mu_{nt}}\right) = \beta_0 + flag_t + double_{nt} + \ year_t + recovery\ port_t$$

The inclusion of recovery port covariate significantly improved the model fit as shown both by a likelihood ratio test ($\chi^2 = 80.05$, df = 33, $p = < 1E\text{-}5$) and a reduction in AIC value compared to the model without port effects (ΔAIC = -18.1; Table 5). There was substantial variation in estimated port effects (Figure 7) with three apparent groups: high-reporting ports (mean probability > 0.7), intermediate-reporting ports (0.15–0.6), and low-reporting ports (near zero).

While such analyses may be useful in identifying weak areas of the tag recovery network, using them to inform reporting rate penalty prior distributions for stock assessment fleets is non-trivial, as it requires comprehensive information on the flow of tuna products through the supply chain for each fleet. However, the potential for more accurately capturing highly influential reporting rate parameters is appealing. Combining the results of more complex statistical models of tag seeding data, with a more holistic characterization of the fishery and tuna production distribution network (Gislard et al., 2025), may be one way of providing more informative priors for stock assessment.

Recommendations

We invite the Scientific Committee to consider the following recommendations for the tag seeding experiments and analysis:

- The Scientific Committee note that the low levels of tag seeding experiments from 2015 to 2022 have compromised our ability robustly monitor for temporal changes in tag reporting. The low level of seeding experiments is exacerbated by the imbalanced nature of the tag seeding data with respect to fleet-specific coverage through time;
- Tag seeding should be continued as long as regular tag recoveries are being received, targeted to fleets and regions where these regular recoveries are most likely;
- A minimum target of 32 seeding experiments per year is recommended (see Peatman et al., 2019);
- More consistent coverage of tag seeding experiments through time is recommended, with a particular emphasis on fleets that are likely to be recovering tags based on their areas of operation relative to PTTP tag releases;

- With enough tag seeding data, more detailed analyses of variables influencing tag reporting rates have potential benefits for informing reporting rate parameters for stock assessments of tropical tuna in the WCPO, as well as other analyses of conventional tagging data which are conditional on assumed tag reporting rates.

Acknowledgements

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Tables

Table 1 Total tag seeding experiments per year, and tag seeding experiments per year in the modelled dataset used to estimate reporting rate priors.

Year	Total experiments	Experiments in modelled dataset
2007	11	11
2008	15	15
2009	22	22
2010	16	16
2011	47	47
2012	79	79
2013	80	80
2014	30	30
2015	19	19
2016	15	15
2017	9	9
2018	7	7
2019	7	7
2020	5	5
2021	3	3
2022	10	10
Total	**375**	**375**

Table 2 Tag seeding experiments in the modelled dataset by year and flag.

Year	CN	EC	FM	JP	KI	KR	MH	MX	NZ	PG	PH	SB	SV	TV	TW	US	VU	Total
2007	0	0	0	0	0	0	1	0	0	5	1	0	0	0	2	1	1	**11**
2008	1	0	0	0	0	0	3	0	0	5	3	0	0	0	0	3	0	**15**
2009	0	0	0	0	0	0	0	0	3	8	1	0	0	0	0	10	0	**22**
2010	0	0	0	0	0	4	1	0	0	2	0	0	0	0	0	8	1	**16**
2011	0	0	1	1	0	12	2	0	0	3	5	3	0	0	1	19	0	**47**
2012	1	1	2	4	6	21	2	1	0	12	3	1	3	0	5	17	0	**79**
2013	0	0	0	3	10	12	4	0	2	26	8	0	0	0	0	14	1	**80**
2014	0	2	0	0	0	5	3	0	1	7	3	1	0	0	3	5	0	**30**
2015	0	0	0	4	4	0	0	0	0	0	1	1	1	0	2	6	0	**19**
2016	0	0	0	0	4	0	1	0	0	0	0	0	1	0	1	8	0	**15**
2017	0	0	1	1	3	0	0	0	0	1	0	0	0	0	0	3	0	**9**
2018	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	5	0	**7**
2019	0	0	1	1	0	0	0	0	0	3	0	1	0	0	0	1	0	**7**
2020	0	0	0	1	0	0	0	0	0	3	1	0	0	0	0	0	0	**5**
2021	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	**3**
2022	0	0	0	0	0	0	0	0	0	9	0	0	0	1	0	0	0	**10**
Total	**2**	**3**	**6**	**15**	**27**	**54**	**17**	**1**	**6**	**88**	**26**	**7**	**5**	**1**	**14**	**100**	**3**	**375**

Table 3 AIC comparisons used to select the approach to representing temporal variation in reporting rates with the most support from observations. The change in AIC (ΔAIC) is provided relative to the base model with no temporal effects (i.e., only flag and double-tagged effects). 'pb' refers to P-splines implemented within gamlss (Rigby and Stasinopoulos, 2005). pre-rel_{42} refers to total PTTP tags released up to 42 months before the seeding experiment.

Formula	df	AIC	ΔAIC
~ flag + double	19.0	2788.4	0.0
~ flag + double + year	20.0	2790.2	1.8
~ flag + double + pb(year)	20.0	2790.2	1.8
~ flag + double + factor(year)	34.0	2763.4	-25.0
~ flag + double + factor(year >= 2015)	20.0	2770.9	-17.5
~ flag + double +pb(pre-rel_{42})	21.5	2767.9	-20.5

Table 4 PTTP reporting rate prior distribution parameters for purse seine fisheries in the 2025 skipjack assessment, with the eight region structure.

Region	Fishery	Mean	Penalty
3	PS.ALL.3	0.505	331
5	PS.ASSOC.DW.5 & PS.UNASSOC.DW.5	0.505	331
6	PS.ASSOC.ALL.6 & PS.UNASSOC.ALL.6	0.619	857
7	PS.ASSOC.ALL.7 & PS.UNASSOC.ALL.7	0.512	523
8	PS.ASSOC.ALL.8 & PS.UNASSOC.ALL.8	0.491	870

Table 5 AIC comparisons used to assess support for inclusion of the recovery port term in an extended version of the reporting rate model.

Formula	Df	AIC	ΔAIC
~ flag + double + factor(year)	38	1903.9	0
~ flag + double + factor(year) + return port	69	1885.8	-18.1

Figures

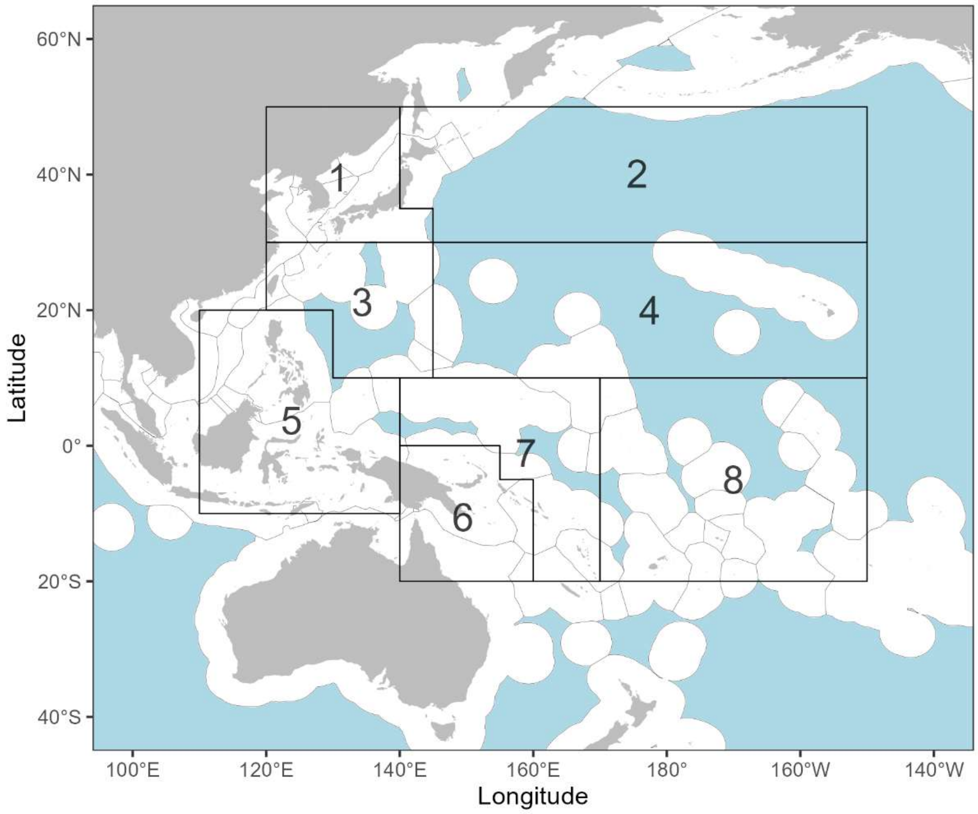
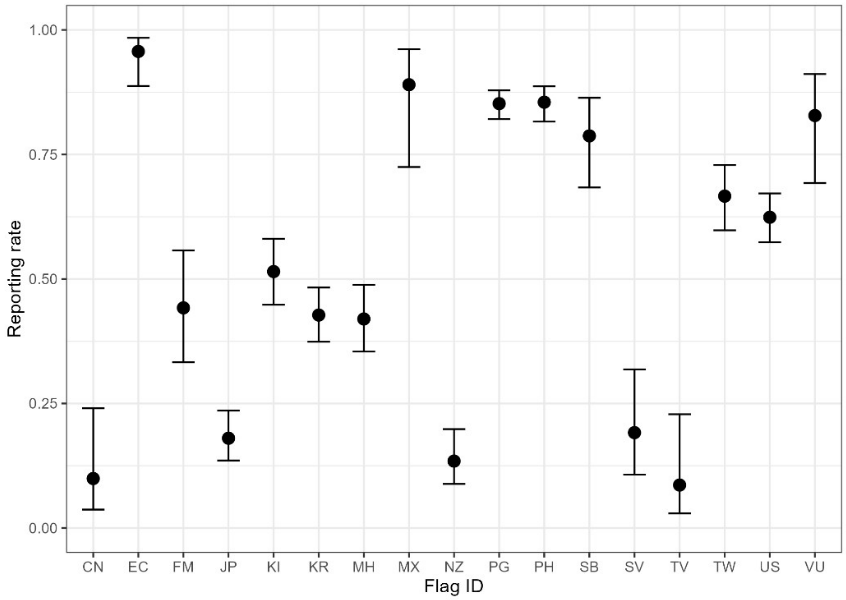


Figure 1 The eight region structure used to generate reporting rate priors.

a) Flag



b) Year

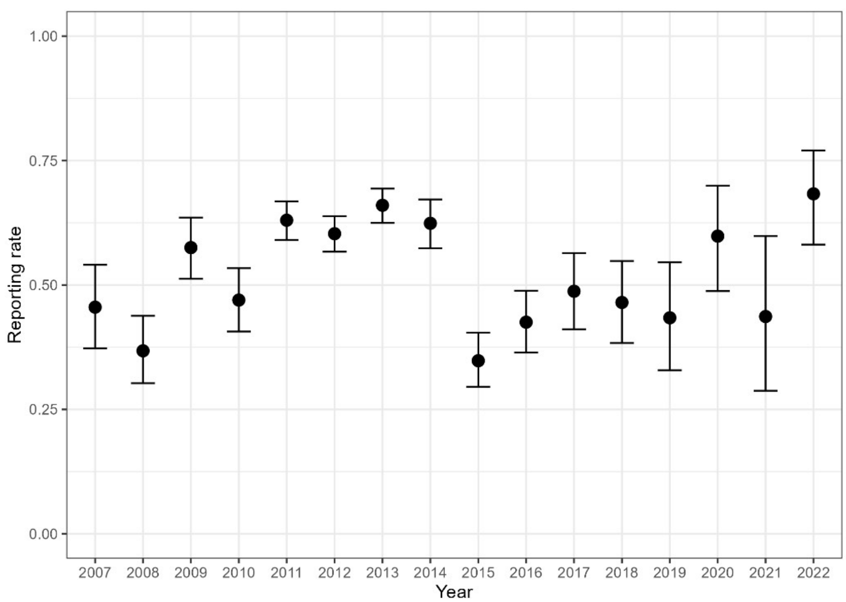


Figure 2 The effect of covariates on reporting rates (mean ± SE) for the selected reporting rate model: a) flag, b) the year of the seeding experiment, and c) (next page) double tag. The effect of each covariate was estimated in turn by holding the remaining covariates constant at reference levels (flag = 'US', year = 2014, double tag = FALSE).

c) Double tagged

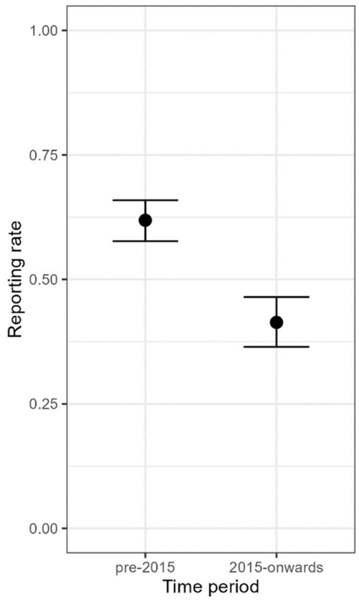


Figure 2 continued.

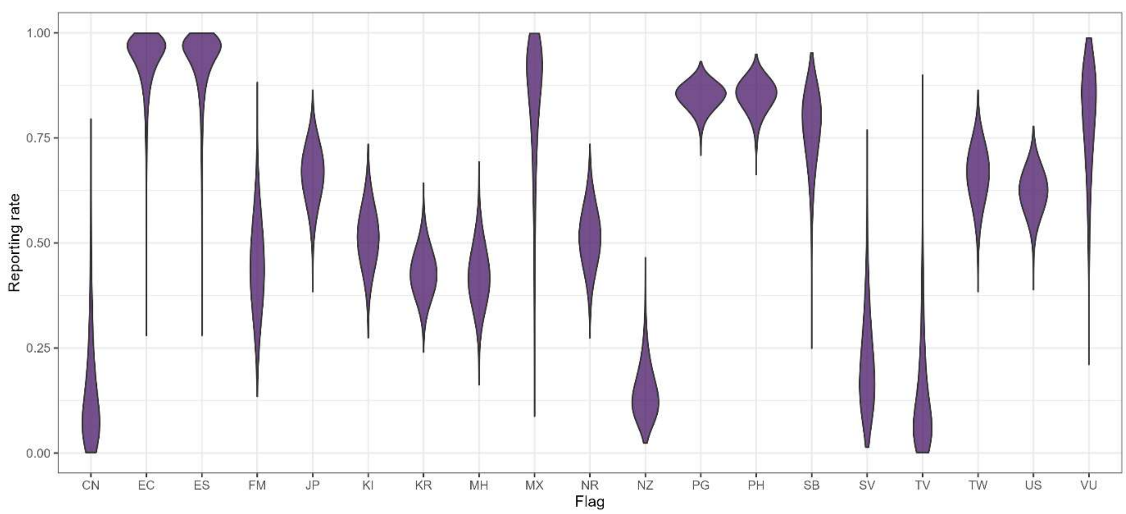


Figure 3 Flag specific reporting rate distributions for 2014, as an example of the distributions used to calculate reporting rate prior parameters.

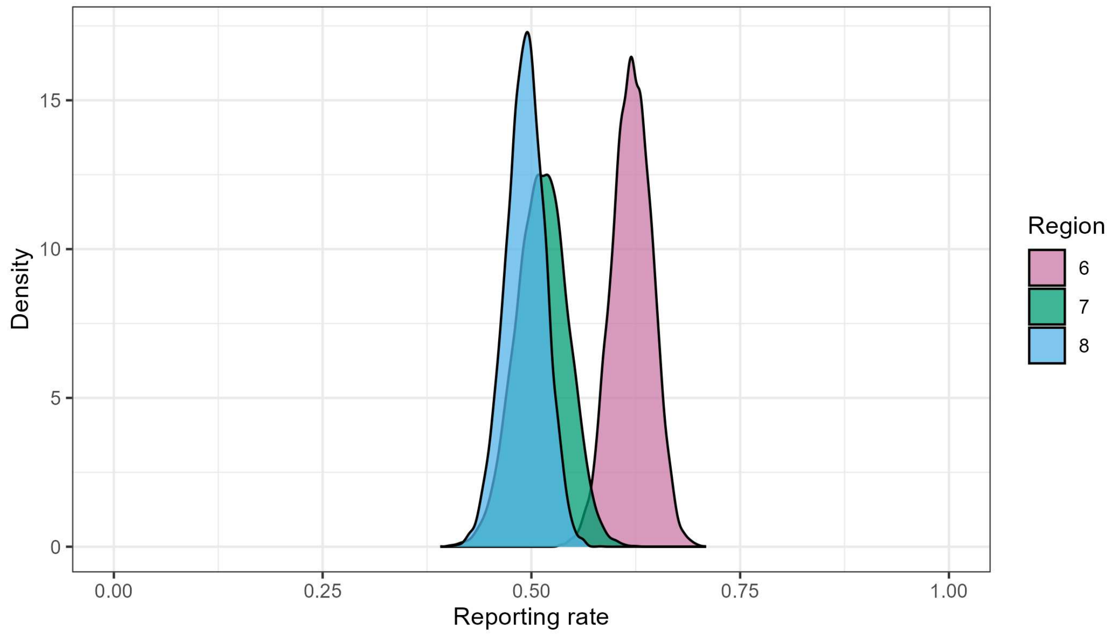


Figure 4 Region-specific reporting rate distributions for skipjack, with the eight region structure (see Figure 1).

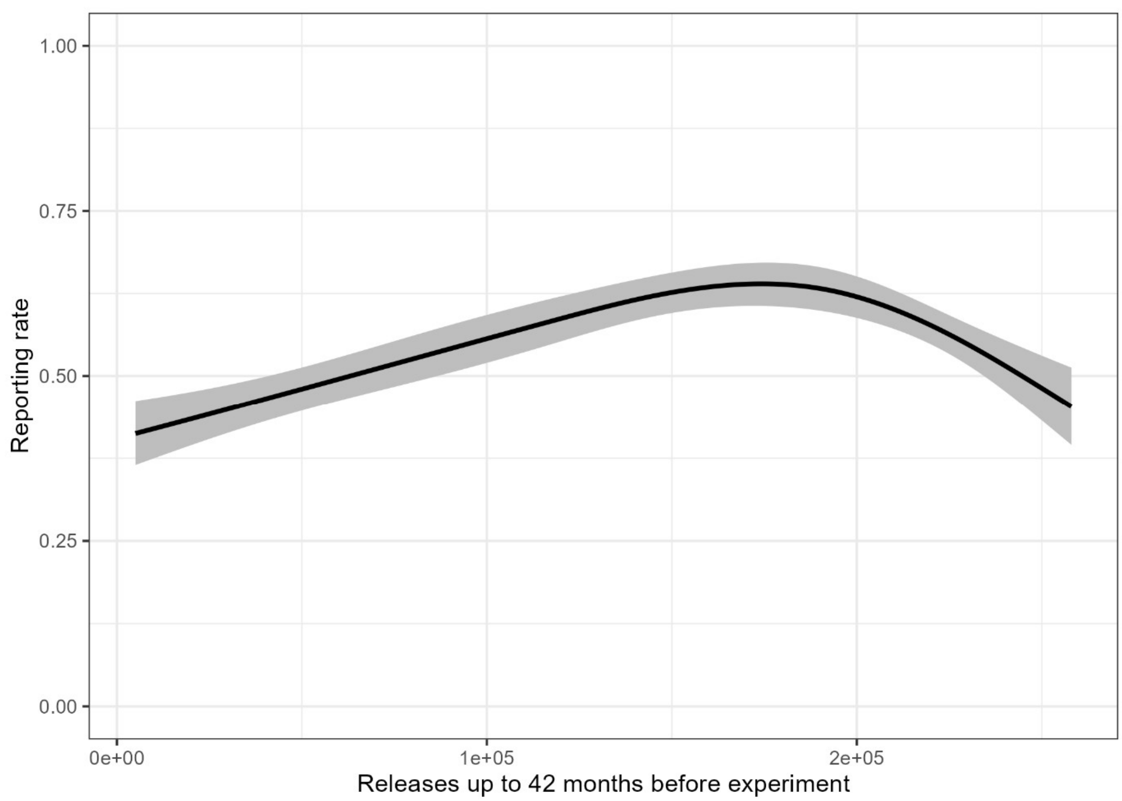


Figure 5 The effect of total PTTP releases up to 42 months before a tag seeding experiment (mean ± SE) on reporting rates, for the reporting rate model with additional categorical variables for flag and whether the fish was double-tagged. Flag was set to 'US', and double-tag set to FALSE.

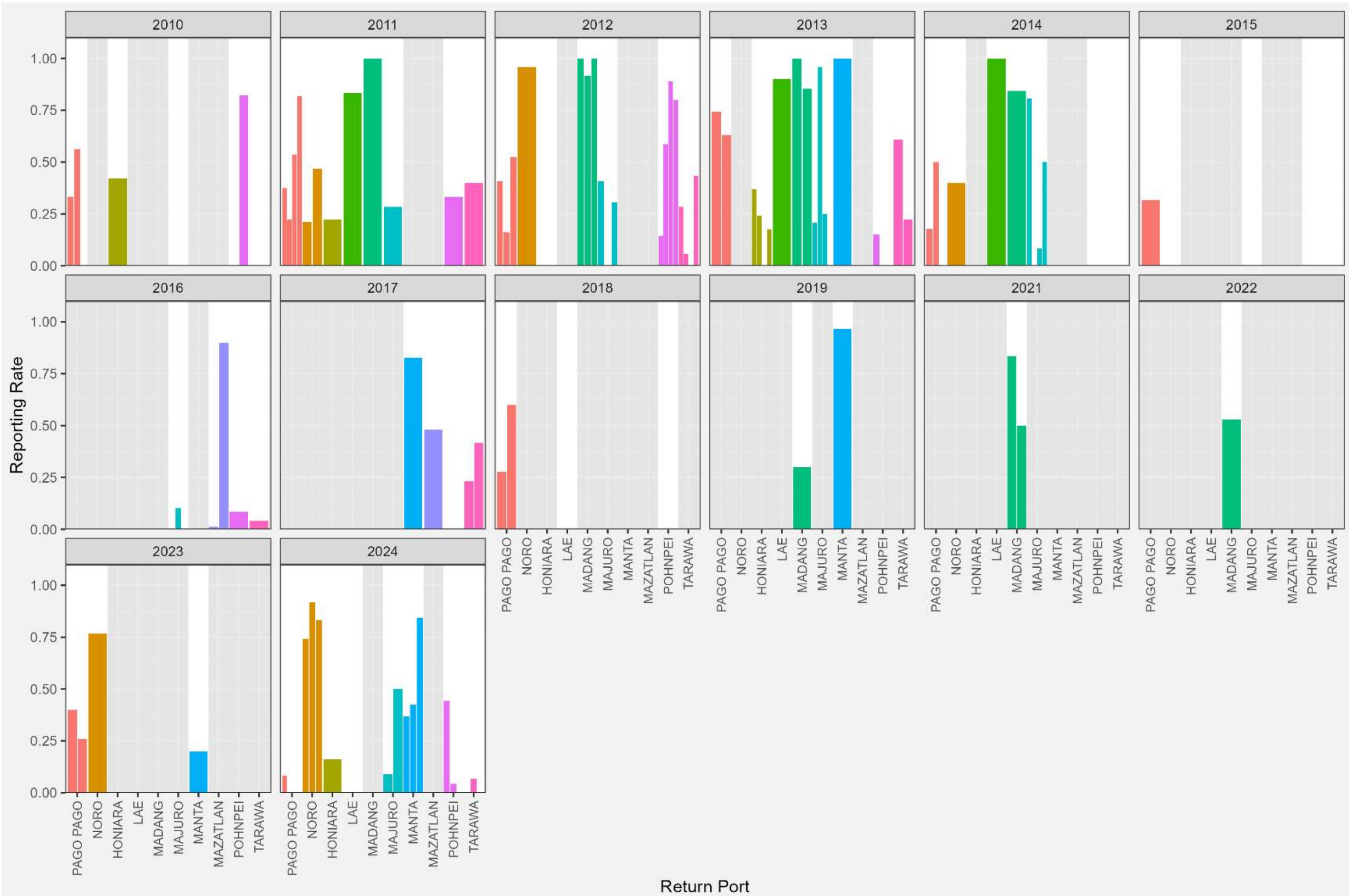


Figure 6 Quarterly reporting rates by return port and year. The reporting rates are grouped by quarter (indicated by the dodged bars) within a given year and port. Ports shown represent the top 10 recovery ports with tag seeding transiting through at landing. Grey shading highlights missing data combinations, while zero values are shown by zero-height bars.

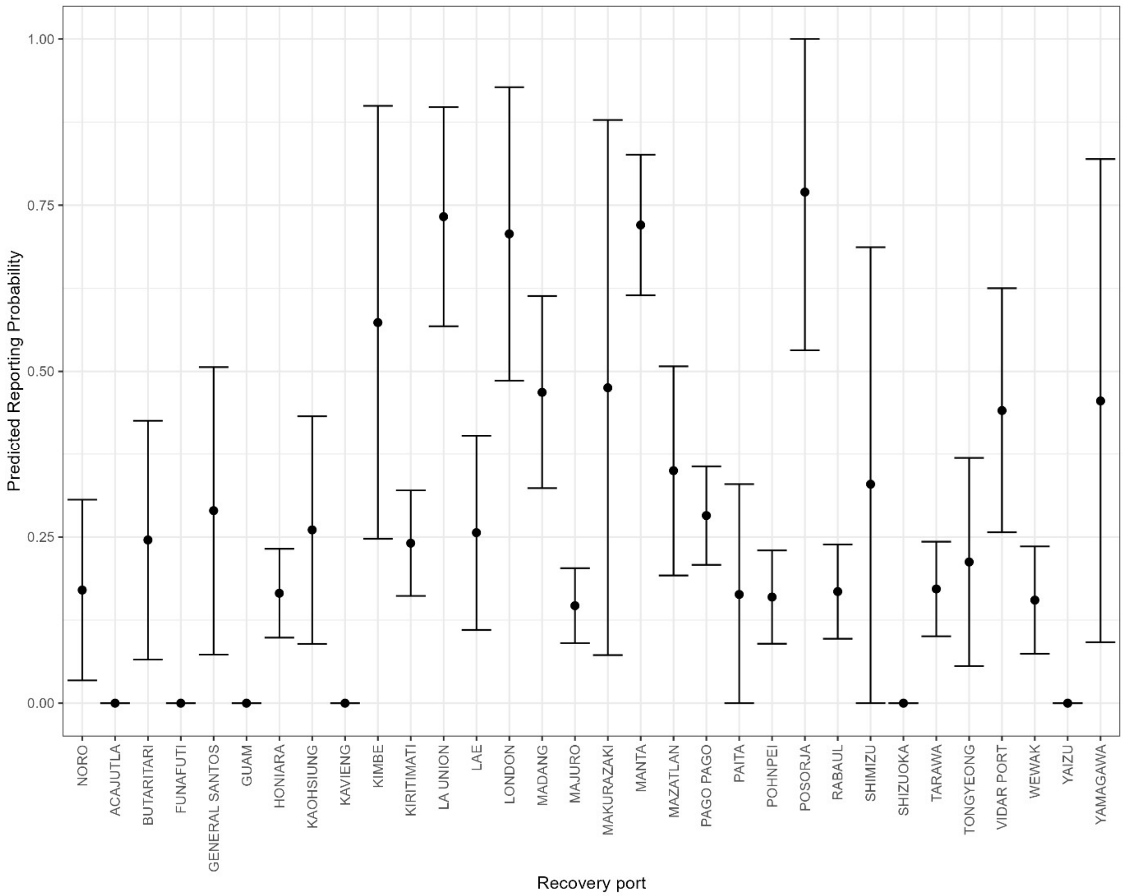


Figure 7 The effect of recovery port on reporting rates (mean ± SE) for the extended reporting rate model. The effect of recovery port covariate was estimated by holding the remaining covariates constant at reference levels (flag = 'US', year = 2014, double tag = FALSE).