SCIENTIFIC COMMITTEE

NINETEENTH REGULAR SESSION

Koror, Palau
16-24 August 2023

ANALYSIS OF TAG SEEDING DATA AND REPORTING RATES FOR PURSE SEINE FLEETS

WCPFC-SC19-2023/SA-IP-07

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Executive summary

Reporting rate models were constructed based on the approach of Peatman et al. (2020), 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 2023 bigeye and yellowfin assessments. 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 from 2015 onwards. However there remains considerable uncertainty around the structure, strength and timing of any change in reporting rates due to the limited number of tag seeding experiments conducted from 2015 onwards. 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 2023 bigeye and yellowfin assessments, given the additional flexibility that this would give the assessment model. 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.

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

- The Scientific Committee note that the continuing low levels of tag seeding experiments have compromised the ability to explore in detail what might be driving apparent recent reductions in tag reporting, and to robustly estimate the timing and strength of these apparent reductions. 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.

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 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 2023 bigeye and yellowfin stock assessments, based on the approach of Peatman (2020). Throughout the report, region numbers refer to the 9 region structure considered for the 2023 assessments (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 2021 inclusive (Table 1, Table 2). Tag seeding experiments from 2022 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). The analysed dataset for the reporting rate models was filtered to remove tag seeding experiments where observers did not provide the required information to determine whether a tag seeding experiment was likely to have been compromised. This left data from 262 seeding experiments, representing 5,583 seeded tags from which 3,292 recaptures were reported to SPC.

Beta-binomial models of reporting rates were fitted in R version 4.3.0 (R Core Team, 2023) using the 'gamlss' package (Rigby and Stasinopoulos, 2005). We used the reporting rate model specification from Peatman (2020) as a starting point. 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, and step-changes in reporting (see Results for more information). We also tested the inclusion of total PTTP tag releases within a specified time period before each tag seeding experiment, referred to as a 'pre-experiment releases' effect. All reporting models included categorical variables for vessel flag and whether available information suggested a tag seeding experiment was compromised. 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

$$\mathrm{E}(rec_t) = rel_t \mu_t$$

$$\mathrm{Var}(rec_t) = rel_t \mu_t (1 - \mu_t) \left[1 + \frac{\sigma}{1 + \sigma}(rel_t - 1)\right]$$

$$\log\left(\frac{\mu_t}{1 - \mu_t}\right) = \beta_0 + flag_t + compromised_t + period_t$$

with: μ_t the reporting rate for seeding experiment t; rel_t and rec_t, the total number of seeded tags and reported recoveries, respectively; β_0, the global intercept; $flag_t$, a categorical variable for vessel flag; $compromised_t$, a categorical variable for whether available information suggested that the seeding experiment was likely compromised (*TRUE* - the observer was aware that he was seen seeding tags by crew, the crew asked the observer questions about the seeding experiment, or the observer was uncertain as to whether or not they had been seen seeding tags), or that the observer considered it likely that they had seeded tags without the knowledge of the crew (*FALSE*); $period_t$, a categorical variable for the time period of the seeding experiment (i.e. whether the seeding experiment started before 2015, or from 2015 onwards); and, σ an overdispersion parameter.

Flag-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 time-period to generate 10,000 reporting rate estimates for each combination. The $compromised$ variable was set to '*FALSE*' in predictions, to give reporting rate estimates for uncompromised seeding experiments.

Region-specific reporting rate distributions for the time periods 2006 to 2014 and 2015 onwards were obtained by taking species-specific catch-weighted means of the flag-specific reporting rates across the relevant time period. Region-specific reporting rate distributions for the duration of the PTTP were obtained by calculating the weighted mean of the flag and time period-specific reporting rates, weighted by the product of flag and time-period species-specific catch and period-specific proportion of total PTTP species-specific tag releases. The region-specific reporting rate distributions were then mapped to fisheries in the 2023 bigeye and yellowfin assessments (Day et al., 2023; Magnusson et al., 2023). The time-period specific proportions of bigeye releases were 0.840 (pre-2015) and 0.160 (2015 onwards). The time-period specific proportions of yellowfin releases were 0.940 (pre-2015) and 0.060 (2015 onwards). This approach ensures that flags with higher catches contribute more to region-specific reporting rates, and the same for time periods 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 7.

Results and discussion

Previous analyses of tag seeding data have suggested an apparent reduction in reporting rates from 2015 onwards (e.g. Peatman, 2020). Model runs with year as a categorical variable continue to suggest an apparent step change in reporting rates, with lower levels of reporting from 2015 onwards (Figure 2). Including year as a categorical variable increased the AIC slightly relative to a model with no temporal effects (Table 3, ΔAIC = 0.7). Introducing a step-change in reporting rates in 2015, i.e. defining a time period effect as pre-2015 and 2015 onwards, gave the strongest reduction in AIC (Table 3, ΔAIC = -14.5). Models with a linear and non-linear temporal effect were equivalent, giving a more modest reduction in AIC (Table 3, ΔAIC = -7.1) with a significant linear reduction in tag reporting rates over time (coefficient = -0.255, p = 0.0024). The relatively low numbers of tag seeding experiments from 2015 onwards resulted in lower precision in temporal effects in the latter part of the time series (e.g. see Figure 2).

Tested time-windows for the 'pre-experiment releases' effect of 12 months or longer all led to a decrease in AIC, with the most support for a time-window length of 42 months (Table 4, ΔAIC = -12.5).

Introduction of step-change in reporting rates in 2015 led to a stronger reduction in AIC than including a 'pre-experiment releases' effect (ΔAIC = -14.5), and so the term was added to the model specification. After the inclusion of the step-change in reporting rate, there was no support for inclusion of the 'pre-experiment releases' effect (ΔAIC = 0.1). This resulted in the selected reporting rate model provided in the Methods Section.

The selected reporting rate model estimated significantly lower tag reporting rates from 2015 onwards relative to pre-2015 levels (Figure 3; coefficient = -0.833, p < 0.001). Tag seeding experiments considered likely to be compromised were associated with slightly lower reporting rates, though the effect was not significant (Figure 3; coefficient = -0.031, p = 0.86). The models detected strong between-flag variation in reporting rates (Figure 3). 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 (Figure 3).

We also tested reporting rate models with a $compromised_t$ effect in the specification of the overdispersion parameter, i.e. allowing a differing level of overdispersion for seeding experiments considered likely to be compromised. Inclusion of the additional overdispersion parameter was not supported by AIC (ΔAIC = 0.7).

The Japanese flag effect (Figure 3) was considered unlikely given the numbers of reported 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. see 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.

Flag-specific reporting rate distributions are provided in Figure 4. The resulting region-specific reporting rate distributions for the nine-region structure are provided in Figure 5, with reporting rate prior parameters provided in Table 5. The reduction in reporting rates in region 8 from 2015 onwards was weaker than for regions 3 and 4 for both bigeye and yellowfin, due to increases in catch proportions in region 8 from flags with high reporting rates in recent years.

Reporting rates for fisheries in region 7 were generated using the approach from the 2019 skipjack assessment (Vincent et al., 2019), i.e. by estimating a reporting rate distribution for regions 3 and 4 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 region 7 (fishery IDs 30.PS.ASS.7 and 31.PS.UNA.7) are relatively high, which is reflected in the reduction applied to the penalty parameter. However, as noted in the Methods section, available tag seeding data may not be representative of reporting rates for the domestic Indonesia and Philippines fishery in region 7 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 'distant water' fisheries in region 7 (fishery IDs 30.PS.ASS.7 and 31.PS.UNA.7).

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 ($p = 0.14$). We note that the numbers of bigeye seeded with tags are relatively low (5% of the total), compared with 76 and 19% for skipjack and yellowfin respectively.

The analyses presented here continue to suggest a change in tag reporting during the PTTP. However, the relatively low numbers of tag seeding experiments undertaken in recent years, 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 2023 bigeye and yellowfin 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 reduced reporting rates from 2015 onwards. We also provide reporting rates for the period pre-2015, which could be used to assess the sensitivity of the assessment models to the exclusion of PTTP tagging data from 2015 onwards due to the uncertainty in reporting rates. 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 fewer reporting rates for tag seeding experiments with fewer tag releases up to 42 months prior to the experiment. This may explain 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. We note that the SSP has recently implemented new schemes for tag finders to encourage the return of found tags (see SC18-RP-PTTP-01 for details).

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. In addition to incentives for observers these include incentives for officers involved in observer placement and debriefing. At this stage it is too early to assess the whether the incentive schemes have led to increased numbers of tag seeding experiments.

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

- The Scientific Committee note that the continuing low levels of tag seeding experiments have compromised the ability to explore in detail what might be driving apparent recent reductions in tag reporting, and to robustly estimate the timing and strength of these apparent reductions. 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.

Acknowledgements

T. Peatman’s contribution was supported by the WCPFC and the European Union’s “Pacific-European Union Marine Partnership Programme”.

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-SA-IP-06.

Day, J. et al. (2023). Stock assessment of bigeye tuna in the Western and Central Pacific Ocean. WCPFC-SC19-2023/SA-WP-05.

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

Magnusson, A. et al. (2023). Stock assessment of yellowfin tuna in the Western and Central Pacific Ocean. WCPFC-SC19-2023/SA-WP-04.

Peatman, T. (2020). Analysis of tag seeding data and reporting rates for purse seine fleets. WCPFC-SC16-2020/SA-IP-04.

Peatman, T., S. Caillot, B. Leroy, S. McKechnie F. Roupsard, C. Sanchez, S. Nicol and N. Smith (2016). Analysis of tag seeding data and reporting rates. WCPFC-SC12-2016/SA-IP-13.

Peatman, T., J. Scutt Phillips, F. Roupsard, C. Sanchez, B. Leroy and N. Smith (2019). Analysis of tag seeding data and reporting rates. WCPFC-SC15-2019/SA-IP-06.

R Core Team (2023). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

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

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.

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	0
2008	15	0
2009	22	2
2010	17	0
2011	45	31
2012	78	74
2013	80	74
2014	30	29
2015	19	18
2016	15	8
2017	9	5
2018	7	7
2019	7	7
2020	6	5
2021	2	2

Table 2 Tag seeding experiments in the modelled dataset by year and flag, having excluded seeding experiments missing information for the 'compromised' variable.

Year	CN	EC	FM	JP	KI	KR	MH	MX	NZ	PG	PH	SB	SV	TW	US	VU	Total
2009	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	**2**
2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
2011	0	0	0	1	0	12	2	0	0	3	4	3	0	1	5	0	**31**
2012	1	1	2	3	6	21	2	1	0	9	2	1	3	6	14	2	**74**
2013	0	0	0	3	9	11	4	0	2	23	7	0	0	0	13	2	**74**
2014	0	2	0	0	0	5	3	0	1	7	2	1	0	3	5	0	**29**
2015	0	0	0	3	4	0	0	0	0	0	1	1	1	2	6	0	**18**
2016	0	0	0	0	2	0	1	0	0	0	0	0	0	1	4	0	**8**
2017	0	0	0	0	3	0	0	0	0	0	0	0	0	0	2	0	**5**
2018	0	0	1	0	0	0	0	0	0	1	0	0	0	0	5	0	**7**
2019	0	0	1	1	0	0	0	0	0	3	0	1	0	0	1	0	**7**
2020	0	0	0	1	0	0	0	0	0	3	1	0	0	0	0	0	**5**
2021	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	**2**
Total	**1**	**3**	**4**	**12**	**24**	**49**	**12**	**1**	**3**	**53**	**17**	**7**	**4**	**13**	**55**	**4**	**262**

Table 3 AIC comparisons used to select the specification of temporal effects in the reporting rate model with most support from the observations. The change in AIC (ΔAIC) is provided relative to the model with no temporal effects.

Formula	df	AIC	ΔAIC
~ *flag* + *compromised*	18	1413.9	0.0
~ *flag* + *compromised* + *year*	19	1406.9	-7.1
~ *flag* + *compromised* + pb(*year*)	19	1406.9	-7.1
~ *flag* + *compromised* + factor(*year*)	29	1414.6	0.7
~ *flag* + *compromised* + factor(*year* >= 2010)	19	1415.9	1.9
~ *flag* + *compromised* + factor(*year* >= 2011)	19	1415.9	1.9
~ *flag* + *compromised* + factor(*year* >= 2012)	19	1415.9	2.0
~ *flag* + *compromised* + factor(*year* >= 2013)	19	1414.8	0.9
~ *flag* + *compromised* + factor(*year* >= 2014)	19	1406.8	-7.2
~ *flag* + *compromised* + factor(*year* >= 2015)	**19**	**1399.4**	**-14.5**
~ *flag* + *compromised* + factor(*year* >= 2016)	19	1410.0	-4.0
~ *flag* + *compromised* + factor(*year* >= 2017)	19	1415.9	1.9

Table 4 AIC comparisons used to select the time-window length (months) of the 'pre-experiment releases' effect with most support from the observations. The change in AIC (ΔAIC) is provided relative to the model with no 'pre-experiment releases' effect.

Formula	df	AIC	ΔAIC
~ *flag* + *compromised*	18	1413.9	0.0
~ *flag* + *compromised* + $pre\text{-}exp_{6}$	19	1415.5	1.6
~ *flag* + *compromised* + $pre\text{-}exp_{9}$	19	1414.8	0.8
~ *flag* + *compromised* + $pre\text{-}exp_{12}$	19	1411.9	-2.1
~ *flag* + *compromised* + $pre\text{-}exp_{18}$	19	1408.0	-5.9
~ *flag* + *compromised* + $pre\text{-}exp_{24}$	19	1406.8	-7.2
~ *flag* + *compromised* + $pre\text{-}exp_{30}$	19	1407.7	-6.2
~ *flag* + *compromised* + $pre\text{-}exp_{36}$	20	1404.7	-9.3
~ *flag* + *compromised* + $pre\text{-}exp_{42}$	**20**	**1401.5**	**-12.5**
~ *flag* + *compromised* + $pre\text{-}exp_{48}$	19	1408.7	-5.2

Table 5 PTTP reporting rate prior distribution parameters for purse seine fisheries, for the 9 region structure. Reporting rate priors are provided for the time period 2006-2014 ('pre-2015'), 2015-2021 ('post-2015'), and the period 2006-2021 ('PTTP overall'). Reporting rate priors for 2006-2020 ('PTTP overall') are recommended for use in the 2023 bigeye and yellowfin assessments. Purse seine fisheries in the 2023 yellowfin and bigeye assessments are defined in Magnusson et al. (2023) and Day et al. (2023) respectively.

		PTTP pre-2015		PTTP 2015-onwards		PTTP overall	
Species	**Fishery**	**Mean**	**Penalty**	**Mean**	**Penalty**	**Mean**	**Penalty**
Yellowfin	13.PS.ASS.3 & 14.PS.UNA.3	0.610	458	0.446	228	0.600	476
	15.PS.ASS.4 & 16.PS.UNA.4	0.583	945	0.383	339	0.571	1022
	30.PS.ASS.7 & 31.PS.UNA.7	0.604	321	0.417	138	0.593	339
	25.PS.ASS.8 & 26.PS.UNA.8	0.753	1043	0.640	294	0.747	1081
Bigeye	13.PS.ASS.3 & 14.PS.UNA.3	0.600	427	0.426	217	0.572	463
	15.PS.ASS.4 & 16.PS.UNA.4	0.656	449	0.430	311	0.620	510
	30.PS.ASS.7 & 31.PS.UNA.7	0.629	308	0.426	150	0.596	346
	25.PS.ASS.8 & 26.PS.UNA.8	0.728	727	0.612	292	0.709	798

Figures

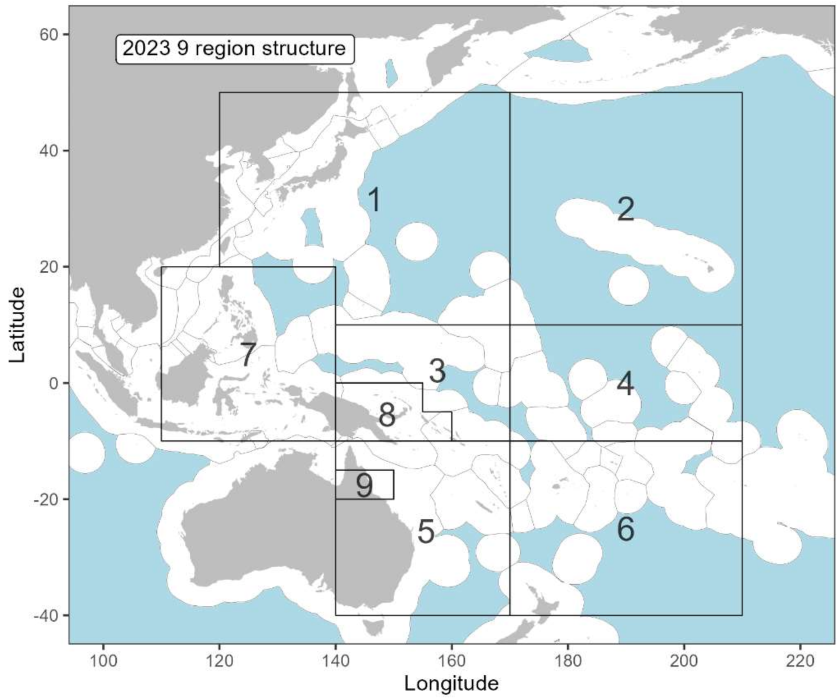


Figure 1 The nine region structure used to generate reporting rate priors.

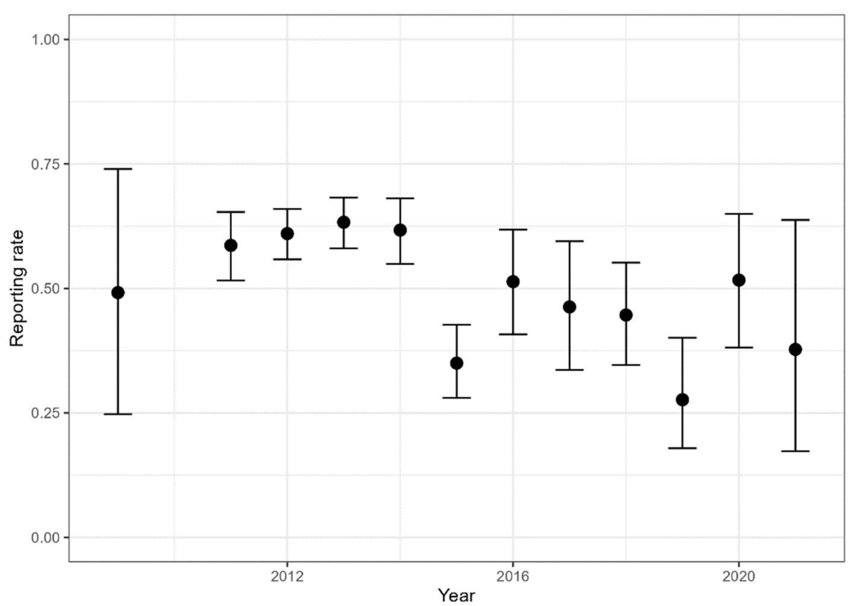
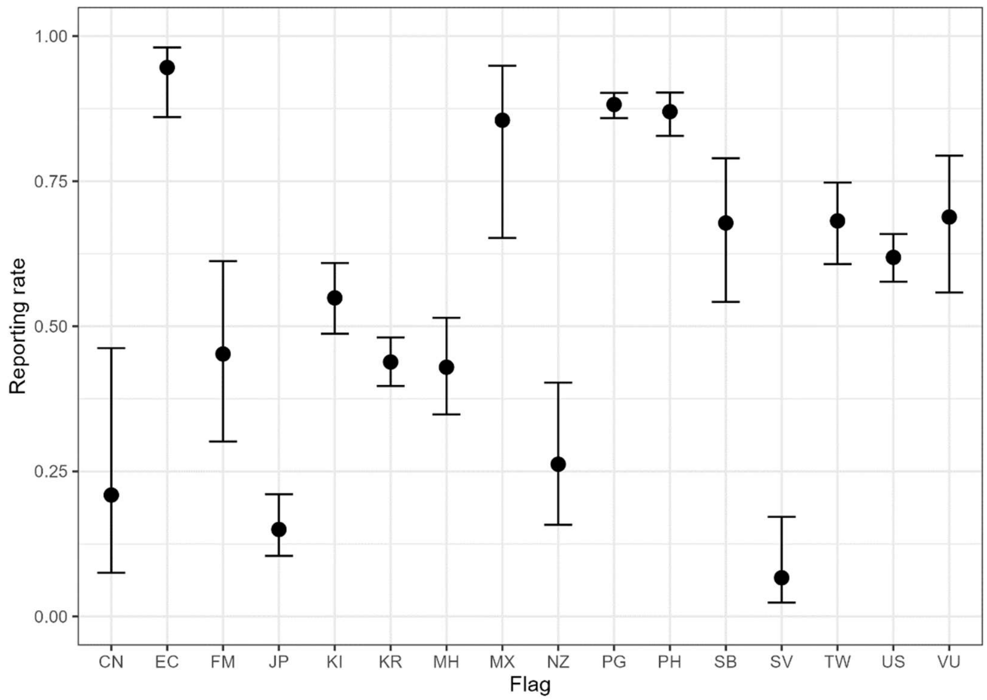
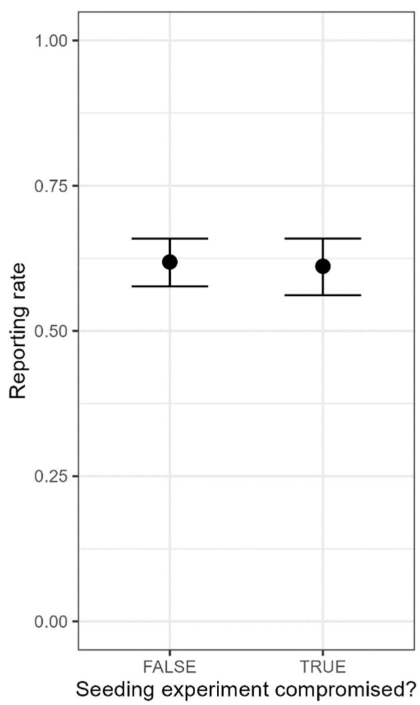


Figure 2 The effect of year (mean ± SE) on reporting rates when included as a categorical variable, for the reporting rate model with categorical variables for year, 'compromised' and flag. 'Compromised' was set to FALSE, with flag set to 'US'.

a) Flag effects



b) 'Compromised' effect



c) Time period

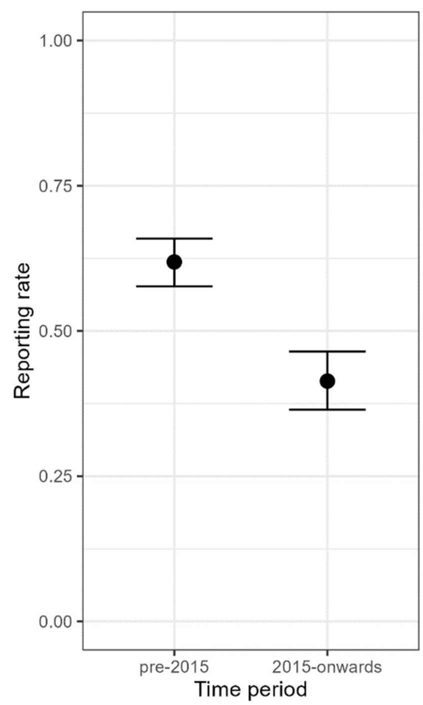
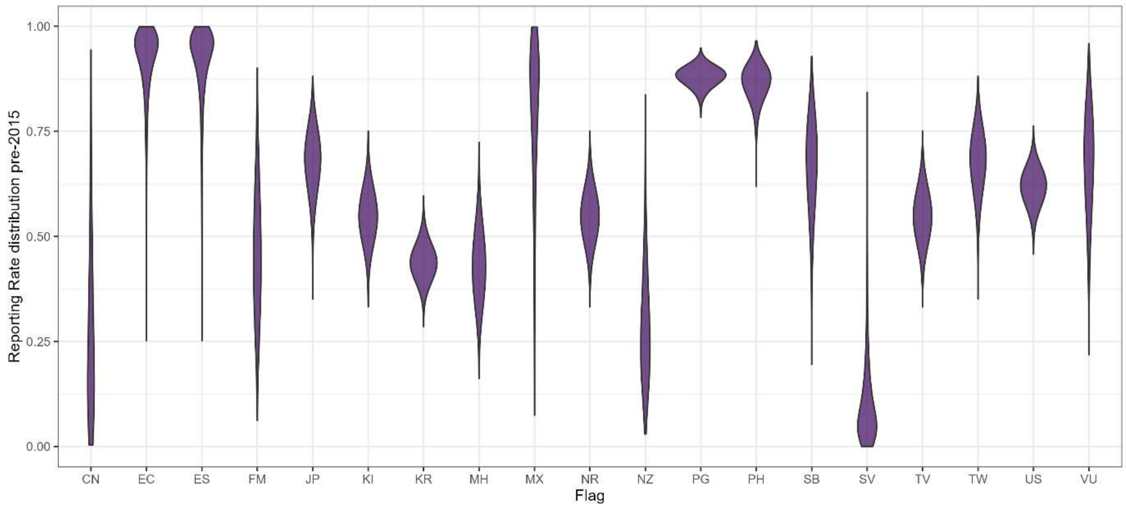


Figure 3 The effect of covariates on reporting rates (mean ± SE) for the selected reporting rate model with effects for flag (top panel), whether available information suggested the seeding experiment was compromised (bottom left), and the time period of the seeding experiment (bottom right). The effect of each covariate was estimated in turn by holding the remaining covariates constant at reference levels (flag = 'US', compromised = 'FALSE', and time period = 'pre-2015').

a) 2006-2014



a) 2015 onwards

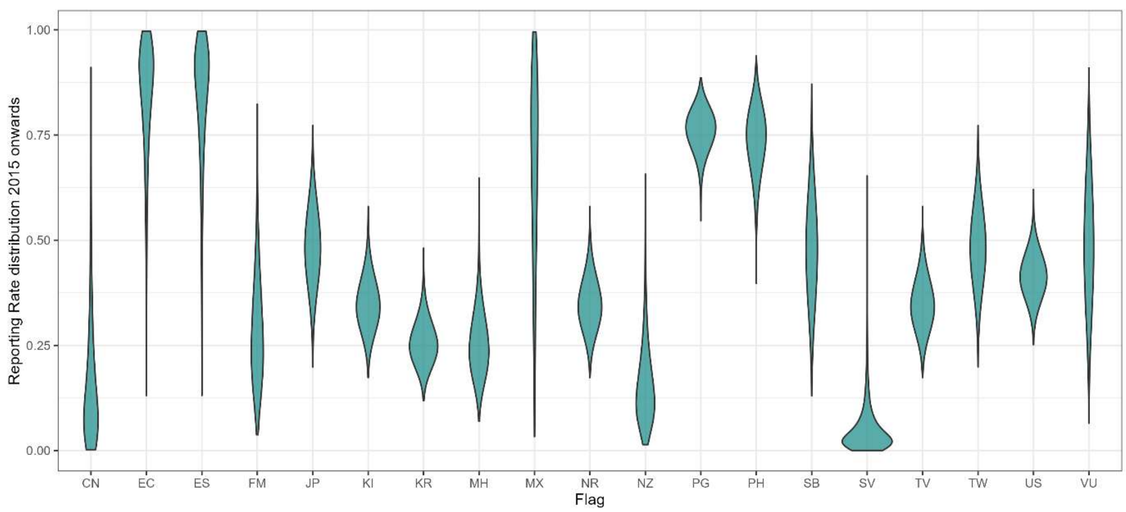
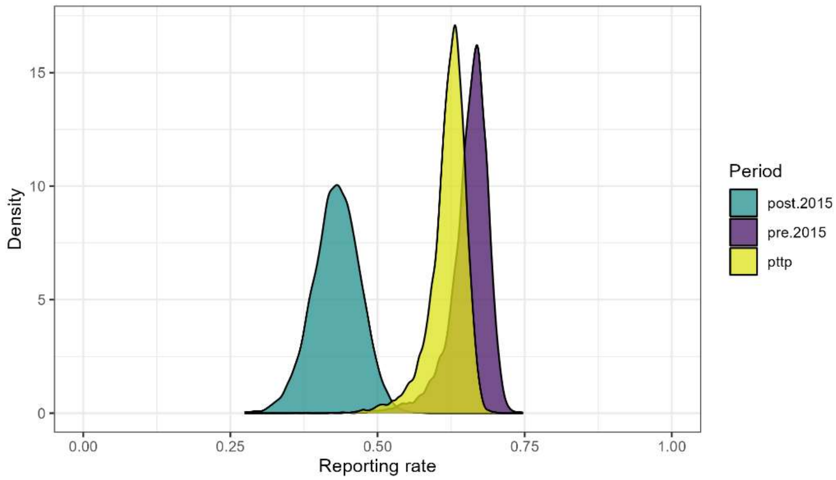
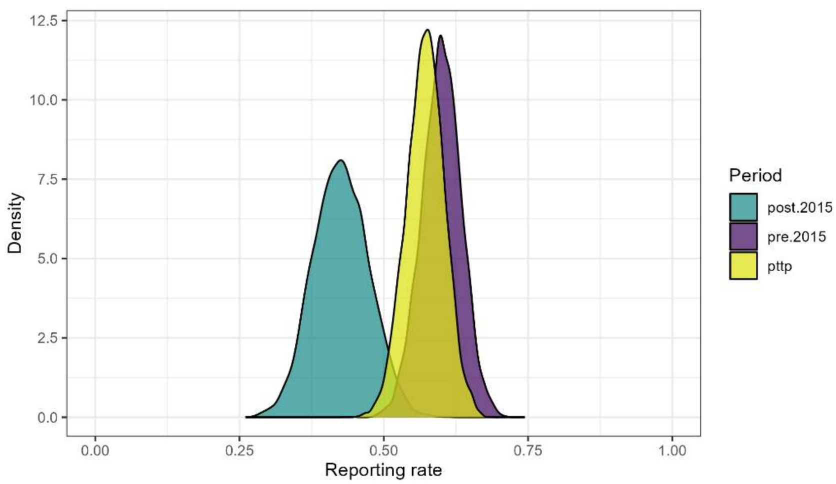


Figure 4 Flag specific reporting rate distributions used to calculate reporting rate prior parameters for a) 2006-2014 and b) 2015 onwards.

a) Bigeye - region 3



b) Bigeye - region 4



c) Bigeye - region 8

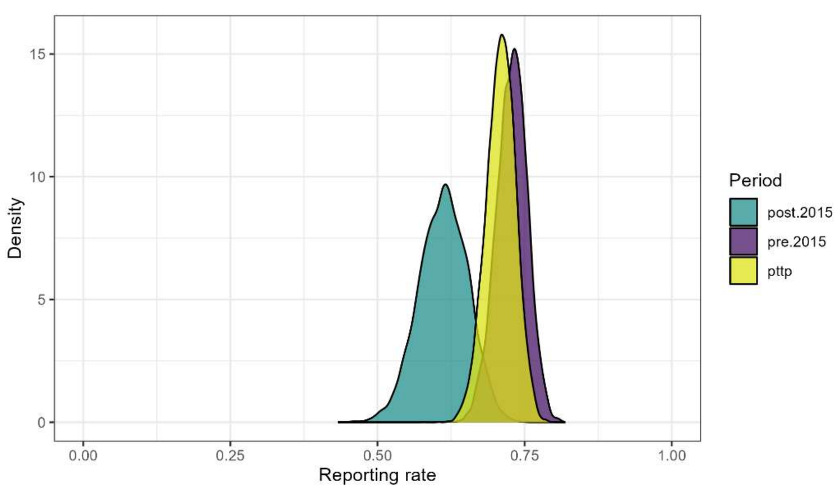


Figure 5 Region-specific reporting rate distributions for bigeye with the nine region structure for a) region 3, b) region 4 and c) region 8.

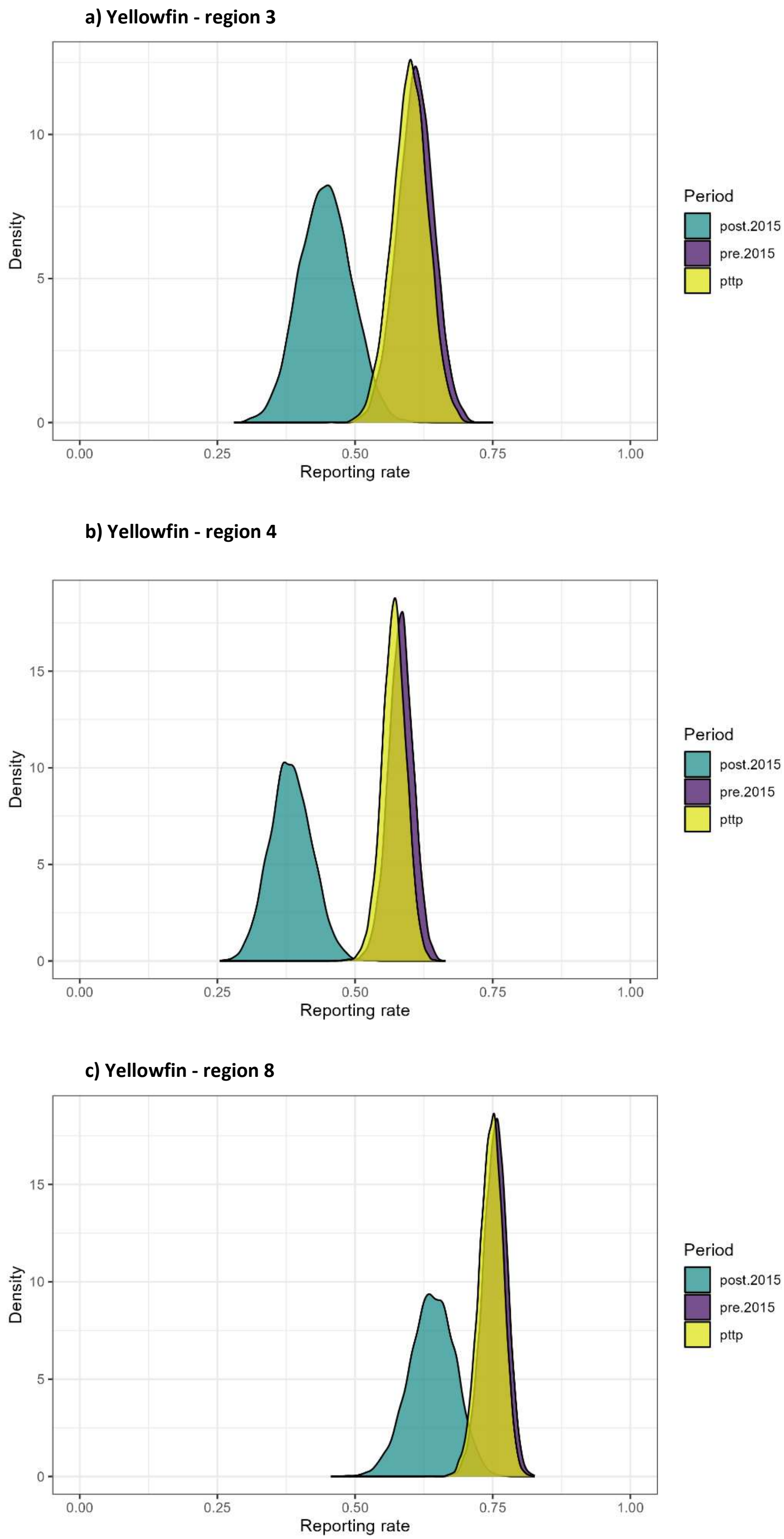


Figure 6 Region-specific reporting rate distributions for yellowfin with the nine region structure for a) region 3, b) region 4 and c) region 8.

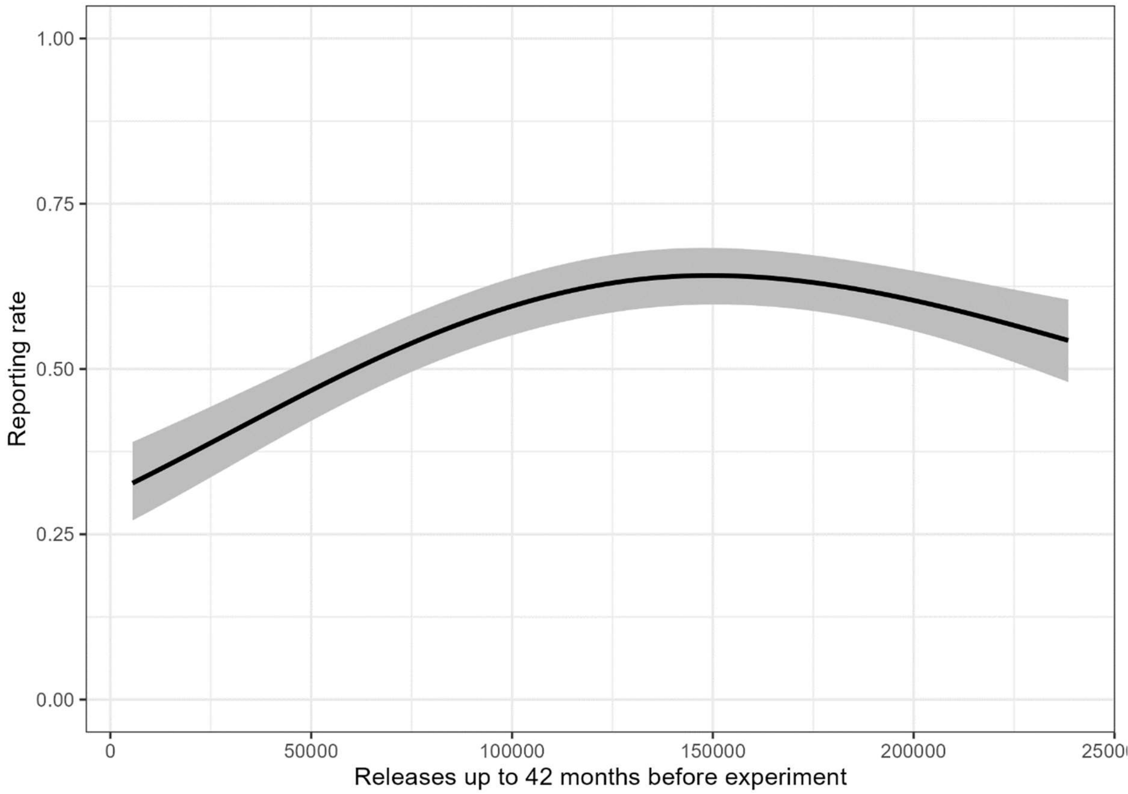


Figure 7 The effect of total PTTP releases up to 42 months before a tag seeding experiment (mean ± SE) on reporting rates, for the reporting rate model with categorical variables for flag and whether the experiment was likely to be compromised. Flag was set to 'US', and 'compromised' was set to FALSE.