SCIENTIFIC COMMITTEE

SEVENTH REGULAR SESSION

9-17 August 2011

Pohnpei, Federated States of Micronesia

TAG REPORTING RATE PRIOR DISTRIBUTIONS FOR THE 2011 BIGEYE, YELLOWFIN, AND SKIPJACK STOCK ASSESSMENTS

WCPFC-SC7-2011/SA- IP-10

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Introduction

A tag reporting rate is a critical parameter required for modelling tag recapture data and defines the probability that a tag is returned, given that a tagged fish was recaptured. The tag reporting rate directly scales the number of returned tags, and therefore directly affects the estimate of fishing mortality. In the absence of other information, knowing only total catch and the proportion of released tags that were returned, the biomass estimate is directly proportional to the tag reporting rate (RR), and the fishing mortality estimate is proportional to 1/RR.

The tag reporting rates used in MFCL are affected by the following factors.

1. Tagging-related mortality and tag shedding before capture
2. Non-reporting of tags that have been captured

This purpose of this paper is to provide estimates for input to the MULTIFAN-CL stock assessments for bigeye, yellowfin, and skipjack tuna.

Methods

Tagging data were analyzed for bigeye, yellowfin, and skipjack to estimate two major components of tag reporting rates: tag-related mortality and tag shedding before capture (i.e. at sea), and non-reporting of captured tags (i.e. on board or at the cannery).

The first component was investigated in two stages. First, average return rates were estimated relative to a tag that was well-placed in a well-treated fish by the most experienced tagger, by comparing the effects on return rate of tagging characteristics such as the tagger identity, fish condition, and tag placement quality. Second, 'base' rates of tag mortality and tag shedding for this 'ideal' condition were assigned. Tag shedding was estimated from double tagging experiments, in which tags were well placed by the most experienced taggers, and assumptions were made about tag-related mortality rates.

Captured-tag reporting rates for the PTTP were estimated via an analysis of data from tag seeding experiments, while for the RTTP they were available from previous work (Hampton 1997).

Finally, the components were combined using a Monte-Carlo process to give an overall reporting rate prior distribution.

Tag related mortality and loss

Relative return rates

The effects on tag return rate of tagger, release condition and tag placement were estimated for tags placed during the Regional Tuna Tagging Programme (RTTP, 1989-1992) and the Pacific Tuna Tagging Programme (PTTP, 2006-ongoing).

Relative return rates were modelled by tagging event using a binomial GLM and analyzed in the statistical package R (Ihaka and Gentleman 1996). Releases with the following characteristics were removed: fish length <=15cm, tag quality of 'tag lost', tag rejected', or 'unknown'.

The following variables were included in the analysis: fish length, tagging vessel, tagging station, fish condition, tag placement quality, tag type, tag release group, tagger id, and fish species.

The analysis with carried out with a generalized linear model in R, as follows:

$$\log\left(\frac{\pi}{1-\pi}\right) = \beta_0 + \beta_1 tag\ release\ group + \beta_2 tagger + \beta_3 tag\_type + \beta_4 spline(length) \cdot \beta_5 species + \beta_6 condition + \beta_7 quality$$

The model was then used to predict the expected number of tags recovered given the observed variable states, and then to predict the expected recoveries if all fish had been released in optimal condition, by the best tagger. Length was not included in predictions but held constant because the ratio of the expected recoveries under these two sets of conditions was estimated. This ratio was the expected tag-related mortality and tag shedding for all fish released, relative to fish released in optimal condition by the most experienced tagger.

Base rates of tag shedding and mortality

Next, the additional contribution to a) tag shedding and b) tag mortality was estimated for fish released by the best taggers, in good condition, and with tags that were considered well-placed.

Tag shedding for skipjack tuna in the RTTP was estimated from double tagging experiments (Hampton 1997), with a short term (immediately post-release) shedding rate of 5.86%. Limited repeat experiments during the PTTP gave results that were not significantly different (John Hampton personal communication).

Tag-related mortality rates were not available for any tuna species. Values were inferred and assigned probability distributions based on an understanding of tuna biology. Tuna tagged by pole-and-line methods are caught at the surface so do not suffer barotrauma. However, they are highly active (particularly skipjack) and may suffer damage during the time they are kept out of the water. Return rates differed substantially among taggers, suggesting that tagger-related differences in the tagging and release processes can translate into substantial variability in survival rates. The tagging process is a significant event for even the best-treated fish. A tagging-related mortality rate for expert taggers was assumed to be 7%, with 95% CI from 3% to 16%.

Reporting rates of captured tags

Reporting rates for the RTTP were available from previous work (Hampton 1997). Reporting rates of tags captured during the PTTP were estimated via an analysis of data from tag seeding experiments. Tag-seeding experiments involve the surreptitious tagging of dead fish on board fishing vessels, before the great majority of tag detection processes begin (WCPFC Regional Tagging Project Steering Committee 2007).

Reporting rates for purse seine fisheries in the two equatorial regions during the PTTP were estimated from tag seeding data. Data from 59 tag seeding kits was available for analysis (Table 1). Two types of tag (steelhead and conventional) were seeded onto vessels flagged to various nations across the WCPO fleet. Seeded steelhead tags attach much more firmly to fish than conventional tags. Seeded conventional tags may be lost at a much higher rate on board the vessel than livetagged conventional tags, which is why the use of steelhead tags was started. Seeding of conventional tags began in February 2007, and steelhead tag seeding began in June 2009.

The influence of factors affecting reporting rates (RR) were analyzed in the statistical package R (Ihaka and Gentleman 1996) using a GLM with quasibinomial error distribution. Explanatory variables included vessel flag, tag type, and trip start date. The quasibinomial distribution allowed the model to estimate over-dispersion in the data, reflecting the fact that tags within a trip were not returned independently of one another (Venables and Ripley 2002). Models were compared using F tests (via 'anova.glm' in the R 'stats' package, with dispersion based on the fully parameterized model).

Independently of the optimal model, return rates were estimated by vessel flag in order to provide input reporting rates for MULTIFAN-CL.

Individual flag-level reporting rates were accumulated to a reporting rate for each region's purse seine fishery reporting rate by species, based on the catch by flag and region of each flag. Flags for which no tags were seeded were allocated a reporting rate from another country, based on the canneries used by each flag. Catches were summed across the equatorial area by flag for 2007-2010, and the proportions taken by each flag calculated. Catch proportions were multiplied by country-level reporting rates, and summed to give overall on-vessel reporting rates per species and region.

Reporting rate prior distributions for MFCL

Uncertainties in reporting rate were estimated through Monte Carlo simulation, as the product of on-vessel reporting rate, relative return rate, base tag shedding, and base tag mortality.

For the PTTP, each flag, a reporting rate was generated from the probability distribution of the estimated reporting rate. Conventional seeded tags are thought to have a lower reporting rate than actual conventional tags (i.e. those deployed in the tagging programme itself) due to poor retention in already frozen fish, so the reporting rate for steelhead tags were used in all cases. Uncertainty in steelhead tag reporting rate was included by sampling from the probability distribution of the tag term, and including each sample in the RR for all countries. For flags without estimates, RR distribution was sampled from the distribution of the logit of the assumed reporting rate with assumed SE of 2.

Base tag mortality was sampled from its assumed distribution. Base tag shedding was sampled from the estimated distribution.

For each parameter required by the stock assessment, ((RTTP + PTTP) x (western region + eastern region) x (SKJ + BET + YFT)), 1 000 000 samples were generated. The distributions were used to estimate prior distributions and the target reporting rate and penalty inputs used in MULTIFAN-CL.

Results

Data were analyzed for 266 882 tagged tuna in the PTTP, for which 42 792 tags were returned. The ratio of predicted returns to predicted returns under ideal conditions was 87.3 %. For the RTTP, 74 265 releases and 9087 recoveries were analyzed, and the return ratio was 89.2%.

The short term tag shedding rate for tags placed by expert taggers estimated during the RTTP (5.86%) (Hampton 1997) was applied. Longer term tag shedding was not included, and no uncertainty was included.

A tagging-related mortality rate for expert taggers was assumed to be 7%, with 95% CI from 3% to 16%.

For analyses of seeded tag reporting rates in the PTTP, the best fitting models included flag and tag type (Table 2, Table 3). A model that also included time, modelled as a spline with 5 degrees of freedom, improved the fit significantly (Table 4). Reporting rates varied strongly between tag seeding events.

Because steelhead tags were not seeded on the same trips as conventional tags, or indeed at the same time (steelhead tagging started after conventional tagging and largely replaced it), time and tag type were highly confounded in the model. Steelhead tags were returned at a higher rate (Figure 3), but when time was added to the model the difference was not statistically significant (Table 3).

Reporting rates varied significantly by flag, but many flags' rates were highly uncertain (Figure 2).

For the RTTP, the same reporting rate distributions were used for all species and regions.

MFCL reporting rate priors for the PTTP were estimated using the flag-level captured-tag reporting rates, based on the model that included flag and tag type. The captured-tag reporting rate component of the overall reporting rates for the RTTP did not include flag and so resulted in the same estimates for each species and region. Estimates and their probability distributions were obtained for each species, tagging program, and equatorial region (Table 5).

Discussion

Return rates were estimated based on tag seeding and other available information, for application in MFCL. Flag was used as the main indicator. Reporting rates may be more likely to vary by fish processor than by vessel flag, but we currently lack comprehensive information on the fish processor from which the tags were returned. The volume of skipjack processed by each processor is also required, and the best possible information about the processor destination of the fish on each seeded vessel.

The results of the analysis were quite uncertain, and support the need for ongoing tag seeding. A power analysis would be useful to identify how much tag seeding is needed, and how it should be allocated across time, flags and processors. Further investment in tag seeding will improve the utility of data collected from tagging programs, given the critical nature of RRs in directly scaling fishing mortality.

Tag type was clearly an important factor but, due to confounding with time, the estimate of relative reporting rate by tag type is currently uncertain. Better estimates might be obtained if steelhead and conventional tags were seeded simultaneously on the same vessel trip. Double tagging individual fish with both conventional and steelhead tags would also be helpful.

Tagging mortality is unknown, but new tag types may provide a way to estimate this parameter. For example, small and relatively cheap pop-up tags are now available that can be inserted like conventional tags.

It was assumed that a) seeded steelhead tags were shed in the vessel at the same rate as captured conventional tags, and b) steelhead tags were not recognized as different by industry and treated differently. Some captured tags are shed on the vessel, so if steelhead tags are shed less then they would have a higher return rate than captured tags. Double tagging with steelhead tags would enable their loss rate to be estimated.

These results directly scale all the reporting rates in the model. A 20% higher reporting rate implies a 20% higher biomass estimate (though other data in MFCL moderate this). Reporting rate is one of the most important parameters in the model.

Acknowledgements

Thanks to Graham Pilling and Shelton Harley for providing comments on the manuscript.

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Tables:

Table 1: Releases and recoveries by flag of seeded conventional and steelhead tags to December 2010.

	Steelhead		Standard		Total releases	Total recoveries
Flag	**releases**	**recoveries**	**releases**	**recoveries**		
CN	-	-	37	12	37	12
MH	-	-	73	27	73	27
NZ	-	-	40	1	40	1
PG	170	137	237	158	407	295
PH	50	48	83	64	133	112
TW	-	-	30	10	30	10
US	268	160	143	49	411	209
VU	25	20	-	-	25	20
Grand Total	**513**	**365**	**643**	**321**	**1156**	**686**

Table 2: Analysis of variance for the model flag + tag type

	LR Chisq	Df	Pr(>Chisq)
Flag	29.6585	7	0.00011
Tag type	7.2051	1	0.00727

Table 3: Analysis of variance for the model flag + tag type + release date

	LR Chisq	Df	Pr(>Chisq)
Flag	39.392	7	1.65E-06
Tag type	1.342	1	0.2466
Time (spline, 5 df)	17.298	5	0.0040

Table 4: Comparison of model 1 (flag + tag type) and model 2 (flag + tag type + release date). Adding a time effect significantly improved model fit.

Resid. Df	Resid. Dev	Df	Deviance	F	Pr(>F)
48	289.55				
43	211.31	5	78.242	3.3441	0.01223

Table 5: Reporting rate estimates for the overall purse seine fleet, with standard error and the penalty used in MFCL

Species	Region	PTTP mean RR	SE	penalty	RTTP mean RR	SE	penalty
yft	3	0.56	0.11	40	0.47	0.09	66
	4	0.46	0.19	14	0.47	0.09	66
skj	2	0.53	0.12	34	0.47	0.09	66
	3	0.45	0.18	16	0.47	0.09	66
bet	3	0.56	0.11	43	0.47	0.09	66
	4	0.44	0.24	9	0.47	0.09	66

Figures:

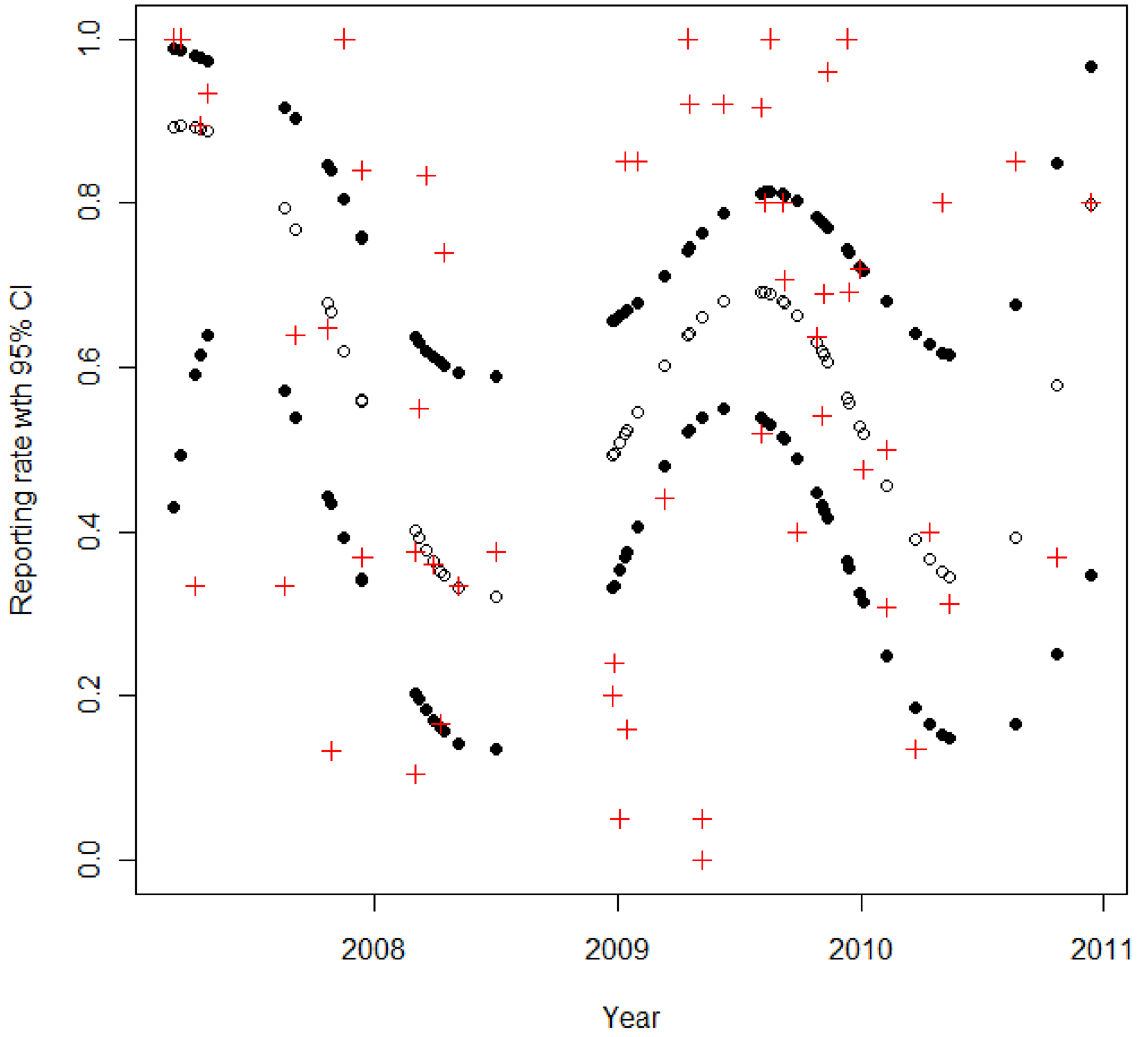

Figure 1: Estimated variation through time in tag reporting rate, from a model that included flag, tag type, and release date.

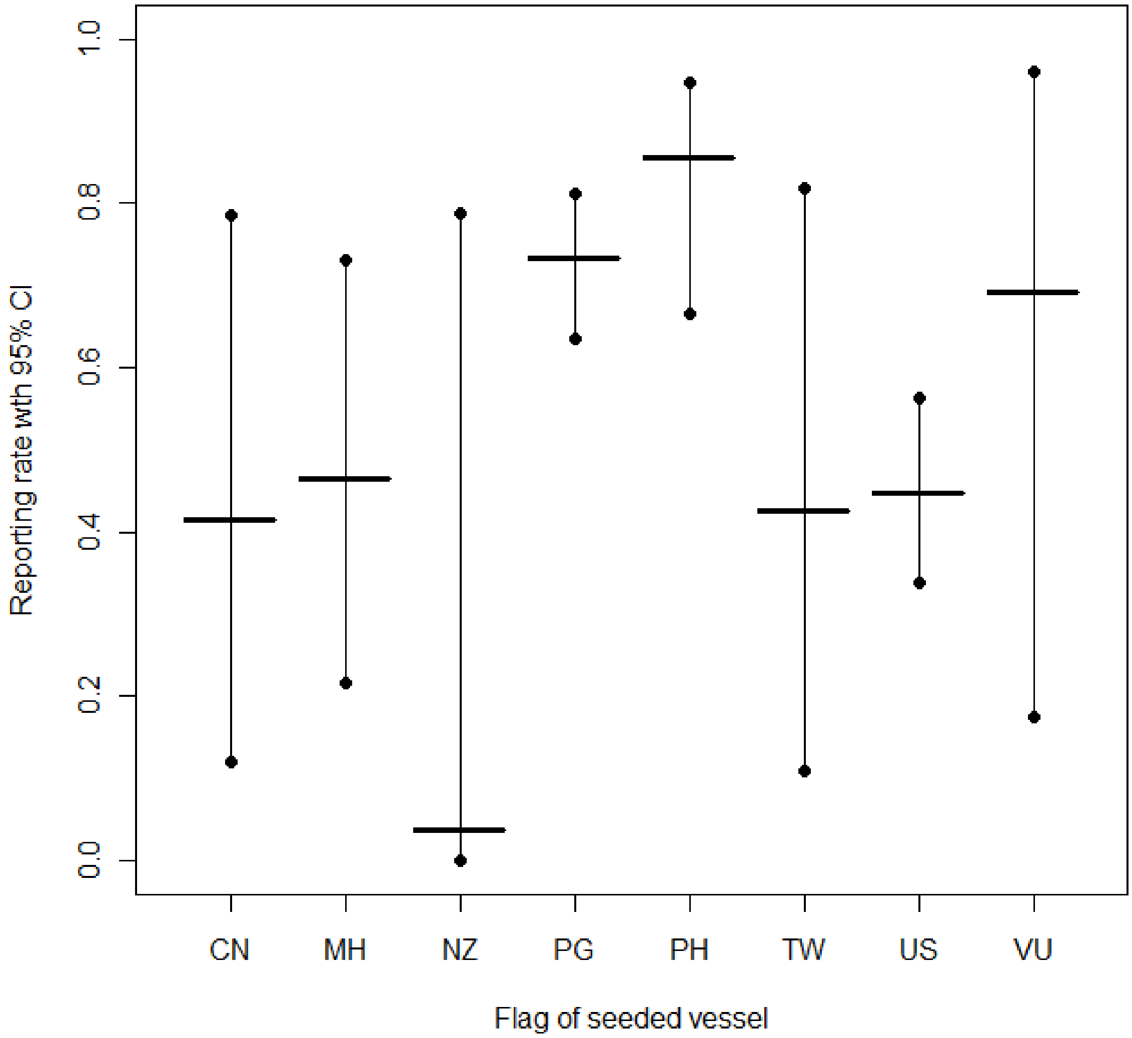

Figure 2: Relative return rate by flag, based on a model that includes flag, tag type, and release date.

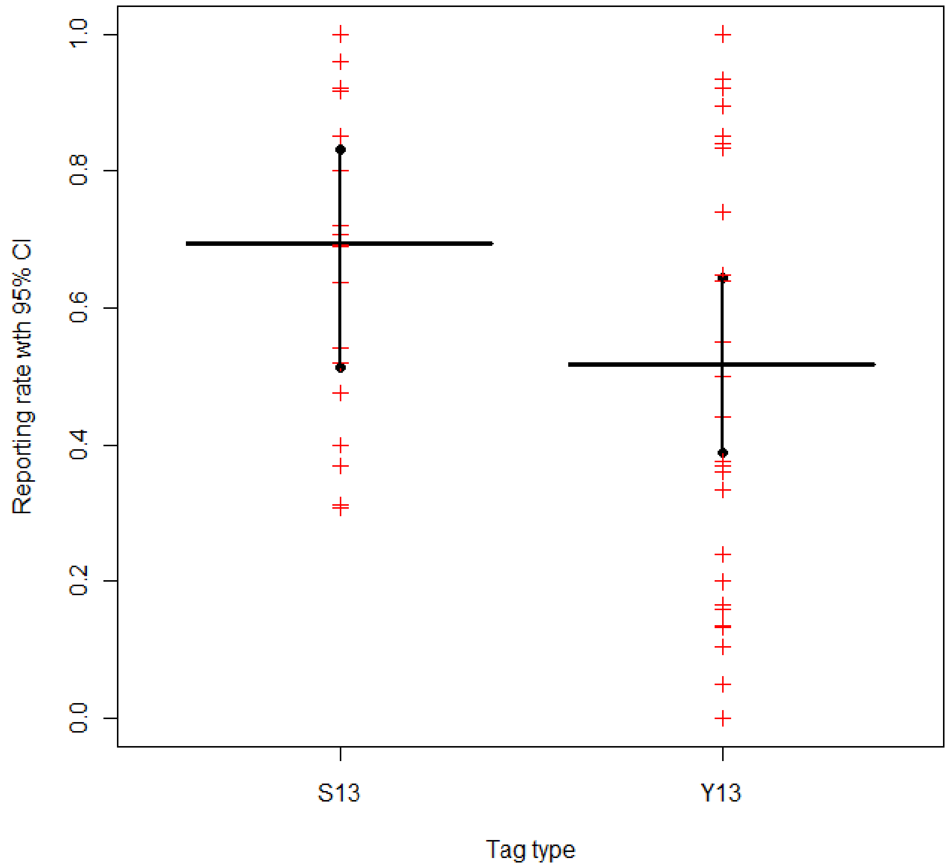

Figure 3: Relative tag return rate by tag type based on a model that includes flag, tag type, and release date