TAG DATA PROCESSING FOR IOTC TROPICAL TUNA ASSESSMENTS

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SUMMARY

IOTC maintains a database for the tagging data collected from the Indian Ocean Regional Tuna Tagging Programme, and the tag release/recapture observations have played a critical role in the stock assessments of the IO tropical tuna species. This report summarises how the tagging dataset were processed for incorporation into the recent Stock Synthesis assessments for yellowfin, bigeye, and skipjack tuna. The procedures and processes are very similar among the species/assessments (they generally included filtering of dubious records, correction for potential tag loss, and adjustment for under-reporting of recaptures), but there are some differences or inconsistency due to historical reasons (evolvement of individual assessments overtime, different researchers being involved in the analysis, etc). The report documents the assumptions and criteria being applied to ensure the reproducibility and transparency, and thus provides a basis for establishing a unified and consistent procedure for the processing of the tagging data for future assessments of IO tropical tuna species.

1. INTRODUCTION

In 2003, IOTC initiated the implementation of the Regional Tuna Tagging Programme in the Indian Ocean (RTTP-IO), a project fully funded by the EU (Hallier and Million 2009). Between 2005 and 2009, over 150000 tagged tropical tuna (50% skipjack, 32% yellowfin, and 18% bigeye tuna) were released from Tanzania, Seychelles and Mozambique Channel under the RTTP-IO project with returns coming primarily from the purse seine fishery in the western Indian Ocean. The percent of tag returns is approximately 15% for all three tropical tuna species. There has been a low number of returns from other fisheries, probably due in most part to non-reporting (Eveson 2012 et al.). In addition to the large-scale project, a series of pilot and small-scale tagging projects were developed from 2002 and 2009. All these projects were implemented or supervised by the IOTC under the framework of the Indian Ocean Tuan Tagging Programme.

The tagging data recorded during the IOTTP Programme have been used in a suite of analyses including growth, migration, mortality, and exploitation rate estimations (Hillary et al. 2008, Edwards et al. 2009, Eveson 2009, Eveson et al. 2012, Fonteneau 2014). Tropical tuna assessments have integrated the tagging data to inform population size and movement dynamics and these data are highly influential for estimates of stock levels and reference quantities (Kolody 2011, Langley 2015, 2016a, 2016b, Fu 2017, 2019, Fu et al. 2018).

Currently the stock assessment for IOTC tropical tuna species are implemented using the Stock Synthesis platform (SS3). In SS3 models, tag releases were stratified by release region, time period of release and the age classes, and the returns from each tag release group were classified by recapture fishery and recapture time period. The model predicts expected recaptures by fishery for each release group. In general, the population dynamics of the tagged and untagged populations are governed by the same model structures and parameters. The tagged populations (tag groups) are monitored over time intervals following release. The predicted number of tags in each region and subsequent time intervals are derived based on the movement parameters, natural mortality and fishing mortality.

The integration of tagging data in the assessment model is a complicated process. Essentially the number of recaptured tags conveys information on the size of the fish population, and the rate at which the recaptures decline informs mortality (fishing and natural mortality). Assuming homogeneous mixing of tagged fish at the relevant spatial scale, a high return rate usually indicates a low population size or a high exploitation rate, and conversely, a low rate of return indicates a high population size or low exploitation rate. However, there are various events or processes (e.g. tag shedding) that might influence the interpretation of the observed tag release/recoveries, and thus cause significant bias in estimates of key model parameters. The Stock Synthesis model allows some of these processes to be explicitly accounted for. For example, initial tag morality and chronical tag shedding parameters can be specified for every tag release group, and the reporting rate parameter can be defined for each fishery/fleet. In practice these parameters are often estimated externally and were used to calibrate the tag observations before they are included in the assessment model. For example, *Stock Synthesis* cannot represent temporal variability in reporting rates, the observed number of tag recoveries can be adjusted to account for the differential tag reporting rates to estimate the full number of tag recoveries that should have been made (such that the reporting rates can be set to 100% in the model).

The IOTC tagging data is maintained in a Microsoft Access database. The database was developed around 2009 to 2011, with regular updates for tag recoveries reported to the Secretariat. The IOTC Secretariat prepares an extract of the tagging data from the tagging database including all the essential information (date, location, size, etc. for each release and recovered tag) before each tropical tuna assessment. The data were processed by the assessment scientist into suitable format be included in the SS3 model. The processes include filtering of erroneous/dubious records, adjustment for potential tag loss, and correction for under-reporting of recaptures, etc. The procedures are very similar among the species/assessments, but there are some differences or inconsistency, mostly due to historical reasons (evolvement of individual assessments overtime, different researchers being involved in the analysis, etc). Below sections document the assumptions and criteria being applied and summarise how the tagging datasets were processed for incorporation into the recent Stock Synthesis assessments for yellowfin, bigeye, and skipjack tuna.

2. REVIEW OF THE PROEDURE

2.1 Data extract

The most recent extract for the yellowfin tuna tagging data was conducted during the 2015 assessment (Langley 2015). The same data were also used for subsequent assessments of yellowfin tuna in 2016 (Langley 2016a), 2018 (Fu et al. 2018), and 2019 (Ijurcon et al. 2019). The most recent extract for the bigeye tuna was conducted in 2016 (Langley 2016b) and was also used for the 2019 assessment (Fu 2019). There have been no new tag recoveries being reported for yellowfin and bigeye tuna since 2015. The scripts for processing the data extract into the SS3 assessments were developed by Langley (2015, 2016b), and revised by Fu et al. (2018) and Fu (2019).

For skipjack tuna, the 2017 assessment (Fu 2017) used the same tagging data extracted for the 2011 assessment (Kolody 2011). The same data have also been used for the 2012, 2014 assessments (Sharma et al. 2012, 2014). The original data were sourced from a series of excel spread sheet – the tag releases were aggregated by year, season, and length class, with associated recoveries by location (at sea or land), gear, year, and season. It is not clear if these data were originally extracted from the Access database (the database was under development at the time), as there is no documentation nor script. An attempt to reproduce the extract from the Access database resulted in a few, but minor discrepancies. However, the scripts to further process the Excel dataset into SS3 inputs was available.

The original data extract contained 54688, 34572, and 78333 releases for yellowfin, bigeye, and skipjack respectively from the RTTP-IO program, with 9921, 5720, and10458 recoveries made for each species respectively. The cumulative effects of data processing resulted in 54392, 24104, and 58420 releases, and 10474, 6578, and 11642 recoveries to be included in the assessments for each species (Table 1). Both yellowfin and bigeye assessments have only considered RTTP-IO tagging data, whereas the skipjack assessment has also used the small-scale tagging data in a subset of models. The small-scale program has a much smaller number of tags, released by less experienced taggers. There has been no comprehensive analysis of these small-scale tag release/recovery data and in particular there is no tag shedding estimates for the fleets conducting the small-scale tagging programs and there is no information available concerning the fishery specific reporting rate of these tags (Kolody 2012, Langley 2016a). The document concerns only the RTTP-IO data.

Table 1: A summary of tagging data processing for YFT, BET, and SKJ assessments (Langley 2015, 2016b, 2, Fu 2017). The first four rows summaries the total number of releases and recoveries from the RTTO-IO program, the number after error filtering and the final processed number included the assessment. The rest of the rows summarised whether in the processing is done by making correction to the data (data), or through configuring the parameter in the model (model).

	YFT		BET		SKJ	
	Release	Recovery	Release	Recovery	Release	Recover
Data period	2005–07	2005–15	2005–07	2005–15	2005–07	2005–09
Total number	54688	9921	34572	5720	78333	10458
Error filtering	54392	9822	34478	5679	77893	10248
Processed number	54392	10474	24104	6578	58420	11642
Assigning fishery	–	data	–	data	–	data
Assigning age	data	–	data	–	data	–
Initial tag mortality	model	–	data	–	data	–
Chronic tag loss	model	–	–	data	model	–
Reporting rate - Landed outside SEY	–	model	–	data	–	data
Reporting rate - seeding experiment	–	data	–	data	–	data

2.2 Error filtering

The error filtering criteria are similar among assessments for the three species: observations (release and associated recapture) with missing release date, length at release, recovery date, or recovery gear were removed. In the skipjack assessment recoveries that were made by the same release vessel were also removed.

2.3 Fishery assignment

The assessment model estimates the number of tags expected to be recovered from each fishery. Therefore, each tag recovery observation was assigned to a model fleet/fishery defined in the assessment. The model fishery refers to a specific set of gear/country/area combinations and the mapping between the assessment model fisheries and the fisheries recorded in the tagging database are usually straightforward. For all species, the majority of tags were recovered by the EU Purse Seine fleet. The yellowfin and bigeye assessments have also included the recoveries made by other fisheries (the reporting rates for other fisheries were unknown and were therefore estimated within the model). Skipjack assessment included only the PS recoveries for most models (the models that considered small-scale data also included Maldives PL recoveries).

Tags recovered from the Purse Seine fisheries are separated into those from the associated sets (PSLS) or those from free schools (PSFS). For all three species, there are a significant number of tags with set type unknown.

For yellowfin the tag recoveries with set type unknown were assigned to either the free-school or log fishery based on the expected size of fish at the time of recapture; i.e. fish larger than 80 cm at release were assumed to be recaptured by the free-school fishery; fish smaller than 80 cm at release and recaptured within 18 months at liberty were assumed to be recovered by the log set fishery; fish smaller than 80 cm at release and recaptured after 18 months at liberty were assumed to be recovered by the free-school fishery, based on analysis of Langley (2012).

For bigeye, these tag recoveries were assigned to either the free-school or FAD fishery based on the assumed age of the fish at the time of recapture; i.e. based on the age assigned to the release group and the period at liberty. Fish "older" than 12 quarters were assumed to be recaptured by the free-school fishery; "younger" fish were assumed to be recovered by the FAD set fishery.

For Skipjack the EU PS tag recoveries of unknown set-type were assigned a set-type according to the total proportion of known FS and LS set types in the PSFS and PSLS fisheries (See Table 2).

Table 2: The proportion of catch by associated sets among EU purse seine catches (PSLS/(PSLS+PSFS)) by year and quarter from 2003 to 2009.

Year	Quarter	Proportion
2003	1	0.81
2003	2	0.73
2003	3	0.90
2003	4	0.84
2004	1	0.77
2004	2	0.76
2004	3	0.93
2004	4	0.90
2005	1	0.81
2005	2	0.56
2005	3	0.87
2005	4	0.81
2006	1	0.85
2006	2	0.41
2006	3	0.95
2006	4	0.94
2007	1	0.80
2007	2	0.57
2007	3	0.93
2007	4	0.91
2008	1	0.73
2008	2	0.74
2008	3	0.98
2008	4	0.95
2009	1	0.90
2009	2	0.88
2009	3	0.97
2009	4	0.96

2.4 Age assignment

For incorporation into the assessment model, tag releases were aggregated in release groups defined by release region, time period of release and age class. For yellowfin and bigeye, the age was defined on a quarterly basis as the model treated the quarter as a calendar year. For skipjack, the annual age was used.

Yellowfin and skipjack used a similar method where the age of each individual tag was estimated from the mean of the growth curve. This is a simple 'cohort-slicing' approach that is sometimes used to infer catch-at-age from catch-at-length data.

For bigeye, the numbers of fish in each age at release were determined by applying an age-length key to the length composition of the tagged fish. The age-length key was derived by assuming an equilibrium population age-length structure based on the age-specific natural mortality, average length-at-age from the bigeye growth function and the standard deviation of length-at-age (CV 0.1). Release groups with less than five (5) fish were excluded, representing the removal of a small number of tags.

The age-length key approach intended to admit the uncertainty in the size distribution at age. However, the probabilistic conversion from age to length for individual tag observations would result in multiple realisations of the tagging datasets which have different recovery history for a given release length. Fu (2019) suggested that the uncertainty arising from the length-age conversion could be evaluated using a bootstrap approach where the age at tag release is resampled from the underlaying age-length key for an ensemble of models.

2.5 Initial tag induced mortality

The mortality induced by tagging effectively reduces the number of tag releases, and therefore biases estimates of fishing mortality and abundance if not properly accounted for. SS3 allows initial mortality rate to be defined as an input parameter for each release group (age, season, area).

For the yellowfin tuna, earlier assessments assumed the initial tag loss rate to be 0.9, based on estimates by Gaertner and Hallier (2008). A study conducted by Hoyle et al. (2015) using the tagging data from the RTMP database suggested that this rate should be closer to 27.5%. The issue was discussed at the WPTT20 in 2018. Given that there was a lack of consensus at the time, the 2018 assessment of yellowfin tuna included both estimates.

The WPTT21 in 2019 further clarified the study on covariates of release mortality and tag loss in large-scale tuna tagging experiments, and agreed that the values of release mortality and tag loss for the three tropical tuna species suggested Hoyle et al. (2015) are the best available estimates currently and should be adopted for the assessment of the tuna stocks in the Indian Ocean (IOTC–WPTT21 2019)

For the bigeye tuna, the recent assessments applied an initial tag loss of 30.5%, based on the initial tag mortality estimate of 20.5% (Hoyle *et al* 2015), with a further 10% increase to account for an assumed level of tag mortality associated with the best (base) tagger (Hoyle *et al.* 2015). The adjustment was made by reducing the observed numbers in each release group by 30.5% (rather than through the use of parameters in the control file).

For skipjack tuna, the 2017 assessment uncertainty grid considered two alternative options for the initial tag mortality: 15% and 25%. The adjustment was made by discounting the numbers in each release group in the data.

2.5.1 Chronic tag loss

Similarly, chronic tag loss (shedding) reduces the size of the tagged population overtime. The model will overestimate the biomass if the tag loss is not accounted for. SS3 allows the tag shedding rate parameters to be defined for each release group in the control file,

Tag shedding for yellowfin tuna was estimated to be approximately 20% at 2000 days at liberty, based on an update of the analysis of Gaertner and Hallier (unpublished). The assessment has configured the chronical tag loss parameter to an annual rate of 0.03, which is approximately 15% at 2000 days at liberty.

Tag shedding rates for bigeye tuna were estimated to be approximately 1.7% per annum (Gaertner and Hallier 2015). The correction was made to the observed numbers of recoveries in each recovery group, rather than through the chronical tag loss parameter in the control file:

$$R' = R\frac{1}{0.993\exp(-0.017 * \Delta t)}$$

where $R'$is the adjusted number of recoveries in a recovery group is, R is the observed number, Δt is the time-at-liberty.

Following Gaertner and Hallier (2009), the tag shedding rate for skipjack tuna was assumed to be 0.015 y^{-1}. The assessment configured the chronical tag loss parameter to an annual rate of 0.015.

2.6 Reporting rate

Estimates of reporting rates of tag recaptures were only available for the Purse Seine fishery. No information is available from the other (non-PS) fisheries although some of these fisheries returned a substantial number of tags. For bigeye and yellowfin, reporting rate for other fleets were estimated in the model. For skipjack, reporting rate for other fleets were fixed to be zero (recovery observations from other fleets were not included in the model).

The results of the tag seeding experiments conducted during 2005–2008 in Seychelles, have revealed considerable temporal variability in tag reporting rates from the IO purse-seine fishery (Hillary *et al.* 2008a, b). For yellowfin and bigeye, the number of tag returns from the purse-seine fishery were corrected using the respective estimate of the annual reporting rate – 57% for 2005, 89% for 2006, and 94% for 2007 onwards. For skipjack, the correction was made using respective estimate of quarterly reporting rate (Table 3) for the tags recovered from Seychelles, and for tags recovered at sea, a 100% reporting rate was assumed.

Further adjustment was made concerning the proportion of the PS catches that are not landed in Seychelles (therefore not examined for tags). For bigeye and yellowfin assessments, a constant proportion of 10% was assumed for catches landed outside of Seychelles. For skipjack, instead of assuming a constant proportion, the adjustment was made on a quarterly basis, based on the estimated proportions of EU PS landings in Seychelles (Table 4), and the adjustment was only made to the tag returns recovered in Seychelles. For example, the adjusted number of observed recaptures for a PSLS fishery as input to the model, R'_L was cacluated using the following equation:

$$R'_L = R_L^{sea} + \frac{R_L^{sez}}{P^{sez} r^{sez}}$$

where

R_L^{sea} = the number of observed recaptures recovered at sea for the PSLS fishery.
R_L^{sez} = the number of observed recaptures recovered in Seychelles for the PSLS fishery.
r^{sez} = the reporting rates for PS tags removed from the Seychelles
P^{sez} = the scaling factor to account for the EU PS recaptures not landed in the Seychelles, estimated by the mean of the quarterly proportions of EU PS catch landed in the Seychelles relative to the total EU PS catch (Table 4).

The adjusted number of observed recaptures for a PSFS fishery was calculated similarly.

Table 3: Estimates of reporting rates (by quarter) form the tag seeding experiments conducted during 2005–2008 in Seychelles (Hillary *et al.* 2008b)

2005	1	0.595
2005	2	0.696
2005	3	0.597
2005	4	0.754
2006	1	0.918
2006	2	0.946
2006	3	0.918
2006	4	0.959
2007	1	0.972
2007	2	0.982
2007	3	0.972
2007	4	0.986
2008	1	0.945
2008	2	0.964
2008	3	0.946
2008	4	0.973
2009	1	0.97
2009	2	0.98
2009	3	0.97
2009	4	0.985

Table 4: Estimated of proportion of EU PS catches landed in Seychelles

2005	1	0.816
2005	2	0.621
2005	3	0.908
2005	4	0.951
2006	1	0.921
2006	2	0.896
2006	3	0.979
2006	4	0.958
2007	1	0.934
2007	2	0.563
2007	3	0.975
2007	4	0.985
2008	1	0.877
2008	2	0.631
2008	3	0.953
2008	4	0.981
2009	1	0.518
2009	2	0.584
2009	3	0.956
2009	4	0.966

3. SUMMARY

The report summarised the procedures used for processing the tag data in the most recent IOTC tropical tuna assessments. Some important aspect of these procedures included filtering of erroneous records, correction of tag induced mortality, chronical tag loss, and adjustment of observations for under reporting. These corrections aimed to minimize the bias in the assessment model caused by various processes that affect the interpretation of tag releases and recaptures. The procedures applied are generally very similar among the species/assessments, but there are some differences or inconsistency, either in the parameters or criteria being applied, or the ways in which the correction was applied. Recent assessments have been working towards developing a unified procedure for processing of the tagging data to eliminate inconsistency among species. It will also be beneficial to evaluate the impact of alternative assumptions, criteria, and parameters in the tag processing on the stock assessments.

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