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Construction of tagging data input files for the 2016 skipjack tuna stock assessment in the western and central Pacific Ocean

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1 Executive Summary

This report documents the construction of the tagging files used in the 2016 skipjack stock assessment in the western and central Pacific Ocean. Methods closely follow those used by Berger et al. (2014) with several improvements made to the construction process, particularly simplifying and generalising the process and code.

The procedure for producing tagging data for stock assessments carried out by the Pacific Community involves the extraction and filtering of data, including assignment of tag recaptures to fisheries defined in the stock assessment model, and the subsequent formatting of data for the software MULTIFAN-CL. A significant aspect of the process involves attempting to correct the number of releases downwards to account for tag shedding, tag-induced mortality and the prevalence of unusable tag recaptures (those with missing information that prevents them from being assigned to recapture fisheries), all of which lead to fisheries mortality estimates being biased low if left unmodified.

The most significant change from the previous assessment of this stock (in 2014) was the exclusion of all Japanese tagging data prior to 1998. These data lack measured release lengths of tagged fish, and the data previously used to approximate these length compositions of tagging events was unavailable for the current analyses, making it difficult to assign fish to the categories required by MULTIFAN-CL. Minor changes were also made to the data extraction process to improve estimates of the usability ratio of recaptures, and to the algorithm that implements the downwards correction of releases based on the usability ratio.

An additional 15 tagging events were added to the tagging file since the last stock assessment, contributing an extra 16,851 effective releases and 2,994 usable recaptures. The corrections of tag releases for usability, tag shedding and tag-induced mortality reduced the effective number of releases to 0.79, 0.61, 0.54 and 0.57 of the raw releases for the SSAP, RTTP, PTTP and JPTP tagging programmes respectively, giving a total of 277,562 effective releases and 52,929 usable recaptures in the updated tagging file.

Due to the difficulties in reproducing an updated tagging file using the 2014 methodology we recommend determining the influence of the new methodology earlier in the stepwise model progression of the stock assessment. For example, it may be desirable to progress from the 2014 reference case model straight to a model with the 2014 structure, input and control files, but with the new tagging file (truncated to finish at the end of 2012 to be comparable to the old file), and then fully updating the assessment (catch and effort, length compositions, and tagging data for 2013–2015, and updated cpue standardisations) to ensure the impacts of the tagging modifications presented herein have been fully assessed.

2 Introduction

Tagging data are an influential component of the integrated population models used to assess commercially important tuna stocks in the Western and Central Pacific Ocean (WCPO) carried out by the Secretariat of the Pacific Community (SPC). This is particularly the case for skipjack tuna for which a very large number of fish have been tagged, and a significant number of recaptures have occurred and been reported. Tagging data influences several aspects of an assessment model including movement rates, fishing and natural mortality, and absolute stock size, and previous assessments have emphasised the importance of tagging data in influencing important model quantities, including those used in providing management advice (Hoyle et al., 2011; Rice et al., 2014).

Despite their value, the tagging data pose several problems for inclusion in a stock assessment. For a recapture to be included in the tagging input file it must not only be caught, but also reported, and have relevant details of the recapture available so that they can be assigned to a fishery and model time-step (see below). Non-reporting of recaptures is undesirable but can be addressed to some extent by tag reporting rate parameters estimated within the stock assessment in conjunction with analyses of tag seeding experiments (Peatman et al., 2016).

However, another issue that must be overcome is the occurrence of unusable recaptures; those lacking information necessary to attribute them to a release event, and further, to a recapture category within that release event. The minimal information required is the recapture time-step (generally - year and quarter), location (at the assessment-region-scale) and recapture gear (e.g. purse seine vs longline). If assessment fisheries are split by flag or fleet within a gear-type, for example longline fisheries in the bigeye/yellowfin tuna stock assessments are divided into distant water and offshore/domestic fleets (Harley et al., 2014; Davies et al., 2014), then information on recapture flag or fleet is also necessary.

It is commonplace for one or more of these data fields to be unavailable for an often significant proportion of recaptures. If these unusable recaptures are not accounted for then recapture rates will be underestimated, and the model will estimate fishing mortality and population size that are biased low and high, respectively. For this reason attempts have been made to correct for "usability" of tags in previous stock assessments (Berger et al., 2014).

How these corrections of tagging datasets are made and input to MULTIFAN-CL[3] (MFCL; Fournier et al., 1998; Hampton and Fournier, 2001; Kleiber et al., 2014) has been determined by ongoing developments of that software. The penultimate assessment of the WCPO skipjack tuna stock (2011; Hoyle et al., 2011) applied corrections for usability, tagging mortality (including tagger effects) and tag shedding to the reporting rate penalties. However, between 2011 and the skipjack stock assessment in 2014 (Rice et al., 2014), MFCL was modified to allow non-integer numbers-at-

[3] http://www.multifan-cl.org

length of fish released in the tagging file. By assuming that these sources of bias in recapture rate generally occur relatively soon after tagging, the corrections could then be applied by adjusting the numbers released downwards (Berger et al., 2014), which is preferable to including them as penalty terms to which the model has more latitude to adjust to fit to other sources of data.

Corrections for these sources of bias are only one of the several components to analyses of tagging data for use in MFCL, and the full range includes:

1. Extraction and filtering of release/recapture data.
2. Correction of releases for base tagging-induced mortality and additional tagging event mortality.
3. Correction for tag shedding.
4. Correction for tag recaptures that are unusable in a stock assessment (missing information such as recapture fishery).
5. Consideration of grouping of fisheries/tagging programmes for tag recaptures and reporting rates.
6. Construction of tag reporting rate penalties from tag seeding experiments.

The additional tagging event mortality (in 2.) was estimated by Berger et al. (2014), and due to few additional tagging events becoming available since that analysis, these estimates were retained in the formulation of tagging files for the 2016 skipjack stock assessment. We direct readers to Berger et al. (2014) for further details of the modelling approaches they utilised to produce these correction factors. The construction of tag reporting rate penalties (6.) are outlined in Peatman et al. (2016), and as they are included in MFCL assessments as standalone penalties rather than in the construction of the tagging file itself, they are not discussed in detail herein.

This report therefore addresses the remaining components outlined above and their preparation for use in the 2016 stock assessment of skipjack tuna in the WCPO (McKechnie, 2016). The intention of this report is to provide the necessary information needed to fully interpret the 2016 skipjack stock assessment, with respect to the tagging data inputs. Furthermore we seek to improve the reproducibility of the construction of tag files for future stock assessments by outlining methods and decisions whose previous documentation could be improved upon.

3 Methods

3.1 The tagging process

Over the course of a tagging programme, one or more tagging cruises occur in a year, with the cruise usually targeting a certain area for tagging and releasing fish. The cruise may last for a substantial period of time (often several months) with tagging occurring when schools of fish - either free-school or on fish aggregation devices (FADs) are encountered. A "tag school" is defined as a discrete period of tagging activity on a school of fish, or FAD, during which time tagging is relatively continuous and no transit of the tagging vessel is undertaken. Often a tag school will relate to a daily tagging event on a specific aggregation of fish, but it is common to have tagging of two or more tag schools in a day if transit occurs between periods of tagging activity, and further schools of fish are encountered after the original school is left, or lost.

While tagging data is often assigned to tag schools, the unit of tagging data that is the focus of MFCL is a "tagging event", which is all tagged fish aggregated to the level of tagging programme, assessment region and time-step (typically year-quarter for pelagic species in the WCPO). Generally this will include data aggregated over numerous tag schools, and potentially multiple tagging cruises if more than one cruise occurs in that region, in that model time-step. If an individual tagging cruise crosses a stock assessment region boundary, or extends over the boundary of a model time-step, then that cruise will contribute more than one tagging event to the assessment.

3.2 Tagging programmes with data available

Skipjack tagging data held by SPC are the result of several discrete tagging programmes; the Skipjack Survey and Assessment Programme (SSAP; 1977–1982), the Regional Tuna Tagging Project (RTTP; 1989–1992) and the Pacific Tuna Tagging Programme (PTTP; 2006–ongoing). These programmes are typically restricted to the tropical area of the WCPO - regions 2–5 of the stock assessment regions (Figure 1). Further tagging programmes that are available but are not used in the skipjack stock assessment (due to the low numbers or absence of skipjack tagged) include the Coral Sea bigeye tuna tagging project (Evans et al., 2008) and the Hawaiian tagging project (Adam et al., 2002). There are subtle differences between each programme, most notably all programmes are now discontinued except for the PTTP, and furthermore, recording systems are often different among programmes and database fields show some variation, and so several aspects of the construction of the MFCL tagging file are conducted on programmes separately.

Additional data are available for the ongoing Japanese tagging programme (JPTP), but these data are not held by SPC and updated datasets are provided just prior to each stock assessment. Due to numerous differences between these data and those from programmes held by SPC, they are processed separately, and the methods used for the JPTP are presented in detail in section 3.6.

3.3 Extraction of data and the occurrence of "unusable" tags

SPC-held data is stored in two databases; the RTTP and SSAP data are held together in a historical database on the SPC network, and the PTTP is held in a live, private web-based database that continues to be updated as tag releases and recoveries occur. The bespoke software for extracting data from SPC databases (catch, effort, size composition and tagging), known as MUFDAGER and written in FoxPro (Long, 1994), is used to extract, aggregate and correctly format input files for MFCL (known as the .frq and .tag files). The process it uses for the tagging data is displayed graphically in Figures 2 and 3 and is briefly summarised as follows:

1. Make temporary copies of the two SPC-held tagging databases (step [a]; Figure 2).
2. Perform separate SQL queries (one each for releases and recaptures, and separately for PTTP and SSAP/RTTP) that extract the appropriate data and perform some filtering, for example removing releases without locational data (step [b]; Figure 2).
3. Undertake further filtering of data using FoxPro scripts to remove data that cannot be assigned correctly to model release events or recapture categories (step [c]; Figure 2).
4. Aggregate all usable data to categories required by MFCL and assign recaptures to stock assessment model-defined fisheries (step [c]; Figure 2).

The previous corrections of the tagging dataset were performed entirely in R, with the full, raw dataset extracted and all filtering, aggregation and assignment of fisheries occurring in that language. This is an entirely valid approach but suffers from a lack of generality across species/tagging programmes, requires a substantial amount of coding with more latitude for coding or logical errors, is difficult for analysts new to the code to follow, and is more difficult to compare to the output of MUFDAGER to ensure consistency.

A much simpler methodology was adopted for the 2016 skipjack stock assessment. It aims to reduce coding, retain consistency with MUFDAGER and allow generality over species/programmes so that future generation of tagging files for all stock assessments in the WCPO will be more efficient.

Instead of a full recreation of MUFDAGER within R, two separate versions of each SQL query are performed for each of the tagging databases (Figure 2). One is identical to that used by MUFDAGER and is only executed to ensure the output matches the MUFDAGER tagging file (to prevent occurrences such as mismatches in data extractions if fisheries were changed, or new recaptures were added to the live database). The second query (step [d]; Figure 2) is identical to the first but relaxes the conditions of the filtering such that all recaptures (including those missing recapture locations, dates or identity of fishing gear they were recaptured by) from valid releases are retained in the dataset not just those that can be assigned to MFCL's required recapture categories. The basic premise of correcting for this usability is to then calculate the ratio of usable recaptures (taken straight from the tagging file produced by MUFDAGER) relative to total recaptures (from the second query with additional processing in R) at the most appropriate scale, and then adjust the associated releases by this ratio (step [e]; Figure 2) so that the observed recapture rate more accurately reflects the recapture rate occurring in practice. Further corrections for tag shedding and tag-induced mortality are also applied to the releases (step [f]; Figure 2). The specifics of this entire process will now be detailed in the following section.

3.4 Correction of release numbers

A more detailed description of how the correction of release numbers for usability, tag shedding and tag-induced mortality at the scale of the MFCL release event is as follows.

The basic unit of the tagging data is an individual released fish R, where

$$R_{i,l,s,t,r} \tag{1}$$

is fish i, in length bin l, released from tag school s, at time step t in region r. The unit used for a release event in MFCL is the number of released fish in length bin l, in region r at time step t which is simply

$$R_{r,t,l} = \sum_i \sum_s R_{i,l,s,t,r} \quad . \tag{2}$$

A very low proportion of released fish ($< 1\%$) are unusable due to factors such as the absence of either a release length, location or date, they were released outside the stock assessment area, or were physically damaged during tagging. These fish (and any subsequent recaptures of them) are simply excluded from the dataset.

Similarly, recaptured fish can also be aggregated to the release event scale, although to be used by MFCL it is required that they are also attributed to a fishery f, and the time step of recapture p, and so usable recaptures are defined $T^u_{r,t,l,p,f}$. For later calculations the number of usable recaptures, T^u, for each tagging event is required and is simply the aggregate over all recapture fisheries and time-steps, i.e., $T^u_{r,t,l} = \sum_p \sum_f T^u_{r,t,l,p,f}$.

The impacts of tagging conditions, over and above a base rate of tagging-induced mortality, were estimated by Berger et al. (2014) at their definition of "tagging event" level, which corresponds closely to the definition of school in section 3.1 above. Thus, a correction factor to apply to releases at the scale used by MFCL is calculated as the weighted mean over the schools within an MFCL-defined tagging event, e.g.

$$C_{r,t} = \frac{\sum_s n_s C_{r,t,s}}{\sum_s n_s} \tag{3}$$

where n_s is the number of fish tagged, and $C_{r,t,s}$ is Berger et al. (2014)'s estimate of the correction factor (defined as the proportion of fish surviving tagging relative to tagging under ideal conditions), both for tag school s. Note that we have excluded notation for the length-bin of fish as all quantities were calculated at the school-scale (fish from all length-bins pooled).

For release events for which there was no estimate of tagging-induced mortality (insufficient data for estimation, lack of covariate data to fit models etc., see Berger et al., 2014 for further details) the median correction factor for that tagging programme was assumed. The median correction factors for the RTTP and PTTP were assumed for the SSAP and JPTP tagging events, respectively, as no estimates were available for either of these programmes.

The correction factors of Berger et al. (2014) are additional to a base rate of tag mortality, K, which is set at the constant value of 0.07 (Berger et al., 2014). The tag shedding rate, H, is also set at a constant value of 0.059 which was estimated by Hampton (1997).

The final component of the correction of releases is based on the ratio of usable to unusable tags, as outlined in general terms in section 3.3. If we denote the number of usable recaptures for a length-bin within a release event (i.e. summed over recapture categories: region, time-step, recapture fishery), $T^u_{r,t,l}$ (see blue box - "Usable"; Figure 2), and the total number of recaptures for a length-bin within a release event, $T^t_{r,t,l}$ (see blue box - "Total"; Figure 2), then the full correction of release numbers is implemented by the following rules that depend on the nature of the total and usable recaptures

$$\grave{R}_{r,t,l} = \begin{cases} R_{r,t,l}(1-K)(1-H)C_{r,t}\,\frac{T^u_{r,t,l}}{T^t_{r,t,l}} & \text{for} \quad T^u_{r,t,l} > 0 \quad \text{and} \quad T^t_{r,t,l} > 0 \\ R_{r,t,l}(1-K)(1-H)C_{r,t} & \text{for} \quad T^u_{r,t,l} = 0 \quad \text{and} \quad T^t_{r,t,l} = 0 \\ 0 & \text{for} \quad T^u_{r,t,l} = 0 \quad \text{and} \quad T^t_{r,t,l} > 0 \end{cases} \quad . \tag{4}$$

The rules are: 1) if the counts for both usable and total recaptures are greater than zero then the usability ratio is included in the correction; 2) if there are no captures of either type no adjustment for usability is necessary and so only the other correction types are applied; and finally, 3) if there is a positive count for total, but zero usable recaptures, then the usability ratio is undefined.

The previous approach (Berger et al., 2014) was to apply the median usability ratio calculated over the focal release event to 3), but this has relatively little relationship with the true recapture rate for tags in that length-bin/release event, and so in the current analyses these releases are considered to provide no information fishing mortality and are effectively removed via the correction factor. It is important to note that this situation is very infrequent, affecting less than 1% of releases and recoveries, respectively.

A final condition was imposed to prevent the occurrence of more recaptures than releases for a release length bin within a tagging event (a potential consequence of adjusting release numbers downward, though very rare at <1% of releases), which was achieved by setting

$$\check{R}_{r,t,l} = \begin{cases} \grave{R}_{r,t,l} & \text{for} \quad \grave{R}_{r,t,l} >= T^u_{r,t,l} \\ T^u_{r,t,l} & \text{for} \quad \grave{R}_{r,t,l} < T^u_{r,t,l} \end{cases} \tag{5}$$

where the final, corrected number of releases, $\check{R}_{r,t,l}$, are termed the number of "effective releases" as they are an attempt to estimate the effective number of fish that are susceptible to fishing mortality, after release.

Finally, all data from release events with less than 10 raw releases ($R_{r,t,l}$) were excluded to prevent low sample sizes from producing spurious results.

3.5 Cut-off for including release events

There is limited value in including tagging data for release events very close to the end of the stock assessment time period as few recaptures will be included in the likelihood, especially if a mixing period of greater than one quarter is used. Furthermore, there is a delay between a fish being caught, the tag being reported and the data being entered into SPC databases. If this delay is significant (longline caught bigeye tuna for example) then reported recapture rates for release events in the terminal year(s) will be biased low and will impact estimates of fishing mortality in those years. The situation for skipjack tuna is less severe than for other species, as recapture rates are highest in the several quarters immediately after tagging, subsequently decrease rapidly, and the majority of recaptures occur in purse seine fisheries which have a relatively prompt reporting rate. We therefore retain all release events before the end of 2014, which led to 4 release events being excluded from the 2016 assessment (Table 1).

3.6 The separate treatment of the Japanese tagging programme data

3.6.1 Background

Japanese scientists from the National Research Institute of Far Seas Fisheries [4] have maintained an extremely valuable long-term tagging programme of tropical and temperate tunas which has run since the 1960's and is ongoing. These data are particularly valuable for skipjack tuna stock assessments in the WCPO due to the temporal coverage, numbers tagged and the spatial distribution of tagging events. Tagging data would essentially be absent from region 1 (McKechnie, 2016; Figure 1) without the contribution of this tagging programme and so it is a major contributor to estimates of fishing mortality, movement patterns and population size in that and other regions.

There are several aspects of this tagging programme that require special handling including: live databases of the programme are not accessible to SPC; data formatting; fields and definitions of important fields such as recapture flag and gear are specific to this data; and lengths of fish released for much of the programme's duration are unavailable. In addition, JPTP data are currently only utilised in skipjack tuna stock assessments. For these reasons the procedure of processing raw data into a usable format for MFCL is carried out separately to the other tagging programmes.

3.6.2 Comparison with 2014 methods

Processing of JPTP tags for the 2016 skipjack stock assessment differed significantly from the methods employed in the previous assessment (Rice et al., 2014). In 2014, Japan provided tagging data in raw form for recent years (since 1988) and this was processed using methods very similar to those presented in section 3.4. However, there are very few fish with measured lengths-at-release

[4] Japan Fisheries Research and Education Agency

in the JPTP dataset before 1998, and as this is a requirement for inclusion in MFCL, Rice et al. (2014) were unable to assign these data to length bins within release events and length-at-release bins in the recapture records. Consequently, for the 2014 assessment data prior to 2000 were taken from the tagging files from the 2011 assessment and tag shedding and base mortality corrections were applied to the release numbers. The exact methods with which the data in these early release events were processed are not fully documented, but it appears that released fish (with missing release lengths) were assigned to release bins based on the length distribution of untagged fish retained onboard the research vessel during the tagging event. Release lengths of recaptured fish then appear to have been estimated based on recapture length, and presumably by back calculation using time-at-liberty and an assumed growth function.

The JPTP data files available for the 2016 skipjack assessment presented the same issues. Release lengths were unavailable before the late 1990's (Figure 5). It is essential for a robust stock assessment that all methods to run the assessment and also construct the input file are documented and fully reproducible. Therefore, data prior to 1998 were excluded when constructing the tagging dataset for the 2016 assessment due to: the absence of the raw data on retained length compositions prior to 1998; the limited documentation of the methods used to assign releases and recaptures to release length bins for those release events; it being impossible to apply corrections for unusable recaptures for these data; and difficulties in assigning these release events to assessment regions if region boundaries are changed.

3.7 Processing of JPTP tags

Every attempt was made to ensure consistency with the approach used for SPC-held tagging data when processing the JPTP tags. The same methods as presented above were utilised with the exception that recaptures had to be assigned to fisheries using R code rather than within MUFDAGER. The outline of the filtering applied to the JPTP tags is presented in Figure 4, with most filtering of releases and recaptures relating to duplicated records, tags of other species, electronic tags and tags without reliable date and location estimates. Corrections for unusable tags were again accounted for by comparing the total number of recaptures and the usable number of recaptures (those with date, gear recapture, location information; Section 3.4). After processing, the JPTP tagging events were added to the MFCL tagging file that already included the SSAP, RTTP and PTTP tagging data.

3.8 Tag fishery and reporting rate groupings

For the tagging component of the objective function, MFCL requires that observed and predicted recaptures can be compared. Ideally this would occur at the fishery level but for the tropical tunas in the WCPO it is often impossible to determine whether a purse seine vessel caught a specific tag on an associated or unassociated set, which is the basis for splitting purse seine fisheries within regions. The observed and model-predicted recaptures are therefore aggregated over associated and unassociated fisheries within a region and all purse seine recaptures in the region are simply assigned to the associated fishery. This choice is relatively arbitary and does not affect assessment results due to the grouping of the two fisheries for tag recapture calculations. In MFCL this is achieved by defining tag fishery groupings for model fisheries and these are outlined in Table 3 of McKechnie (2016) for the 2016 skipjack tuna stock assessment.

Fisheries can also be grouped together with respect to reporting rates of tags. If multiple fisheries are expected to have similar reporting rates then the number of model parameters can be significantly reduced by implementing this grouping. Typically these reporting rates are allowed to vary between different tagging programmes due to differences in tag recovery efforts, for example deployment of tag recovery officers or variable tag reward schemes. Tag seeding studies provide some information on the magnitude of tag reporting rates and can be used as reporting rate penalties in the stock assessment (see Peatman et al., 2016 for details of how these are estimated). The aggregation of fisheries into programme-specific tag fishery groupings for the 2016 skipjack tuna stock assessment are outlined in Table 3 of McKechnie (2016).

4 Results

The 2016 skipjack tagging file is comprised of 277,562 effective releases in total from 205 tagging events, reduced from 462,842 raw releases before corrections for tagging mortality, tag shedding and usability were accounted for (-40 %). Significant sample sizes of tagged fish were available for all regions (Figure 6) and while there were observed movements between all combinations of release and recapture regions (with the exception of no fish tagged in region 1 being re-caught in region 5), in most cases tagged fish were re-caught in the same region that they were released in (Figure 7). The most prevalent observed movement between regions was from region 2 to region 5, and to a lesser degree between those regions in the opposite direction (Figure 7).

By excluding JPTP tagging events before 1998 we remove 73 events, 59,731 effective releases and 1,972 recaptures that were present in the 2014 tagging file. These would represent 26 and 18 % of events and releases, but only 3.6 % of recaptures, if they were to be included in the final 2016 tagging file.

An additional 15 tagging events (4 PTTP, 11 JPTP; Table 1) were added to the tagging file since the cutoff date used in the last stock assessment (quarter 2, 2012), representing an additional 16,851 effective releases and 2,994 recaptures.

A more detailed description of the number of releases and recaptures, and the effective correction factors, by tagging programme are shown in Table 2. The location of recaptures of JPTP- and SPC-released fish are presented in Figures 8 and 9.

5 Discussion

Minor differences in methodology to the previous analyses of tagging data (Berger et al., 2014) were undertaken in 2016, for example setting releases to zero instead of using a median correction ratio when total recaptures are greater than zero and usable recaptures are zero (see line 3 of equation 4), and ensuring maintenance of consistent rules across programmes on the types of corrections applied. These modifications relate to ongoing improvements to the process of generating tagging files required by MFCL, although they concern a small number of fish relative to the number of releases and recaptures at the programme scale, and so are expected to have a very limited impact on the stock assessment results.

A more profound difference from previous production of tagging files for skipjack stock assessments is the handling of the JPTP data. We see the exclusion of the pre-1998 data as a positive step towards fully reproducible stock assessments and reliance on only the most reliable data. Further collaborative work is required to make processing of the JPTP data more efficient, and should be seen as a priority if these data are to be included in the yellowfin stock assessment proposed for 2017. Coding structures are now in place for the SPC-held tagging programmes that are general over species and can quickly and efficiently produce tagging datasets ready for MFCL, which will significantly increase the efficiency of future stock assessments (such as the proposed assessments of bigeye and yellowfin tuna in 2017). We propose that these systems be extended to include the JPTP data in collaboration with Japanese scientists so that data filtering and aggregation can be quickly applied to the latest JPTP datasets as they continue to be updated with additional tagging events and recaptures by Japan, and to maintain full reproducability of the construction of tagging files for each assessment (which has not been the case for previous assessments).

Due to the changes made to the tagging files, we recommend careful consideration of these files in the stepwise updating of the 2016 skipjack stock assessment. Usually the process would involve the construction of two tagging files updated until the end of the stock assessment period; one using the old, and one the new methodology. The stepwise progression from the old (2014) to new (2016) assessments would involve updating all datasets and running the updated model with the updated tagging file. Due to the difficulties in reproducing an updated tagging file using the 2014 methodology we recommend determining the influence of the new methodology earlier in the model progression. For example, progress from the 2014 assessment straight to a model with the 2014 structure, input and control files but with the new tagging file (truncated to finish at the end of 2012 to be comparable to the old file, though noting that the old file contains data from 1988– rather than from 1998– for the new file), and then fully updating the assessment (catch and effort, length compositions, cpue standardisations) once the impacts of the tagging modifications have been assessed.

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6 Tables

Table 1: Summary of the new tagging release events and subsequent recaptures that have become available since the cutoff date of the 2014 assessment (quarter 2, 2012), and whether they are included or omitted from the 2016 assessment

Programme	Region	Year	Qtr	Releases	Recaptures	Retained
PTTP	3	2012	3	5	0	Omitted
PTTP	3	2012	4	15	2	Included
PTTP	5	2013	2	23,397	2,564	Included
PTTP	3	2013	4	29	1	Included
PTTP	3	2014	3	12	0	Included
JPTP	2	2012	3	28	0	Included
JPTP	1	2012	4	8	0	Omitted
JPTP	2	2012	4	263	1	Included
JPTP	4	2012	4	34	1	Included
JPTP	1	2013	1	3,823	368	Included
JPTP	4	2013	1	8	1	Omitted
JPTP	1	2013	2	807	18	Included
JPTP	1	2013	4	4	0	Omitted
JPTP	2	2013	4	176	2	Included
JPTP	1	2014	1	744	6	Included
JPTP	4	2014	1	21	0	Included
JPTP	1	2014	2	450	30	Included
JPTP	1	2014	4	92	1	Included
JPTP	2	2014	4	60	0	Included
JPTP	4	2014	4	4	0	Omitted
JPTP	1	2015	1	1,793	314	Omitted
JPTP	2	2015	1	35	1	Omitted
JPTP	4	2015	1	31	6	Omitted
JPTP	1	2015	2	936	92	Omitted

Table 2: Summmary of the tagging file used in for the 2016 reference case model, showing the raw number of usable releases, the corrected effective number of releases, the correction ratio and the raw and effective recapture rates

Programme	Raw	Effective	Recaptures	Correction	Raw rate	Effective rate
JPTP	39,169	22,277	2,103	0.57	0.05	0.09
PTTP	246,493	132,193	35,013	0.54	0.14	0.26
RTTP	93,275	56,978	11,092	0.61	0.12	0.19
SSAP	83,905	66,114	4,721	0.79	0.06	0.07
Total	462,842	277,562	52,929	0.60	0.11	0.19

7 Figures

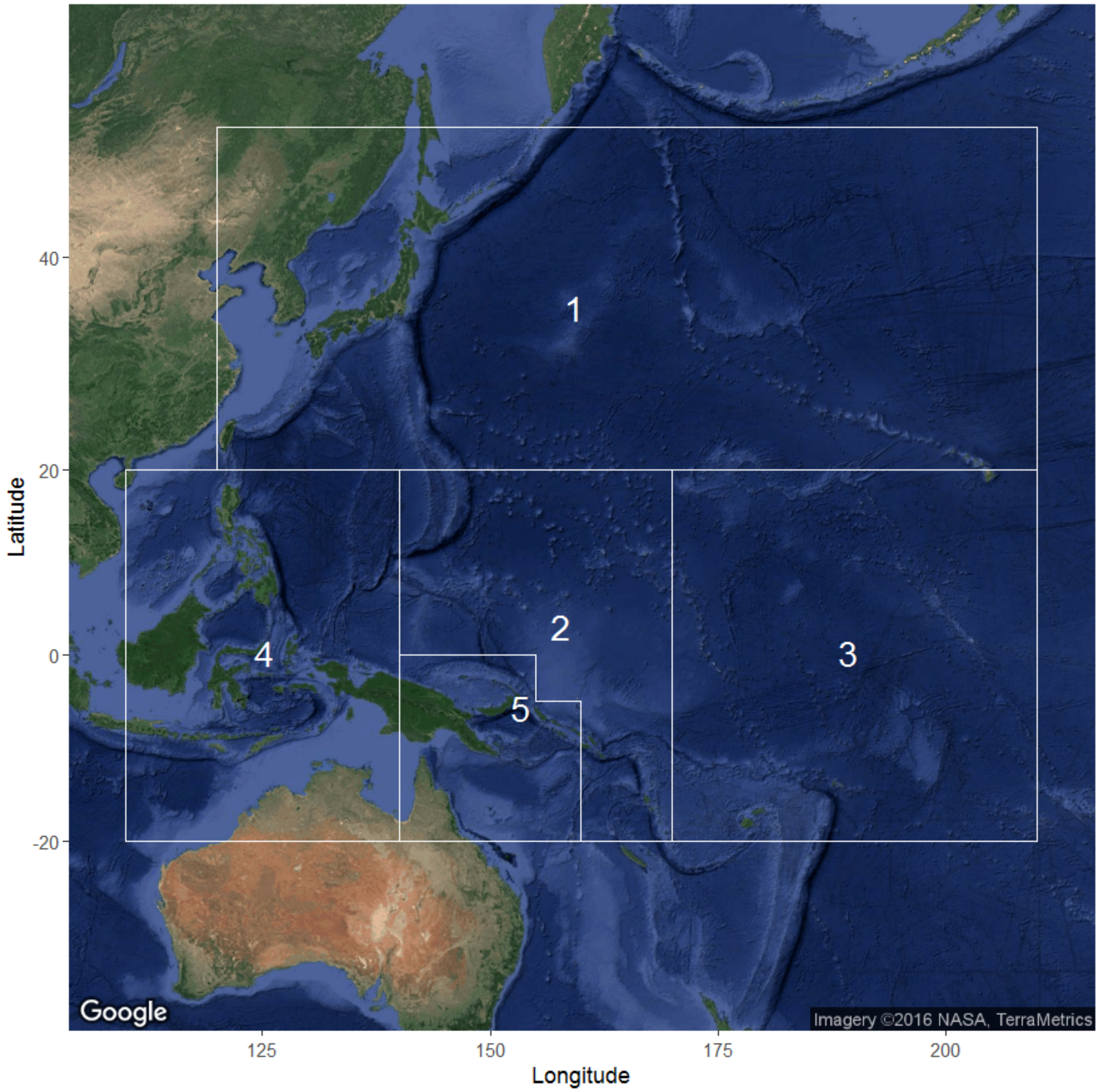


Figure 1: Regional structure of the reference case model for the 2016 stock assessment of skipjack tuna.

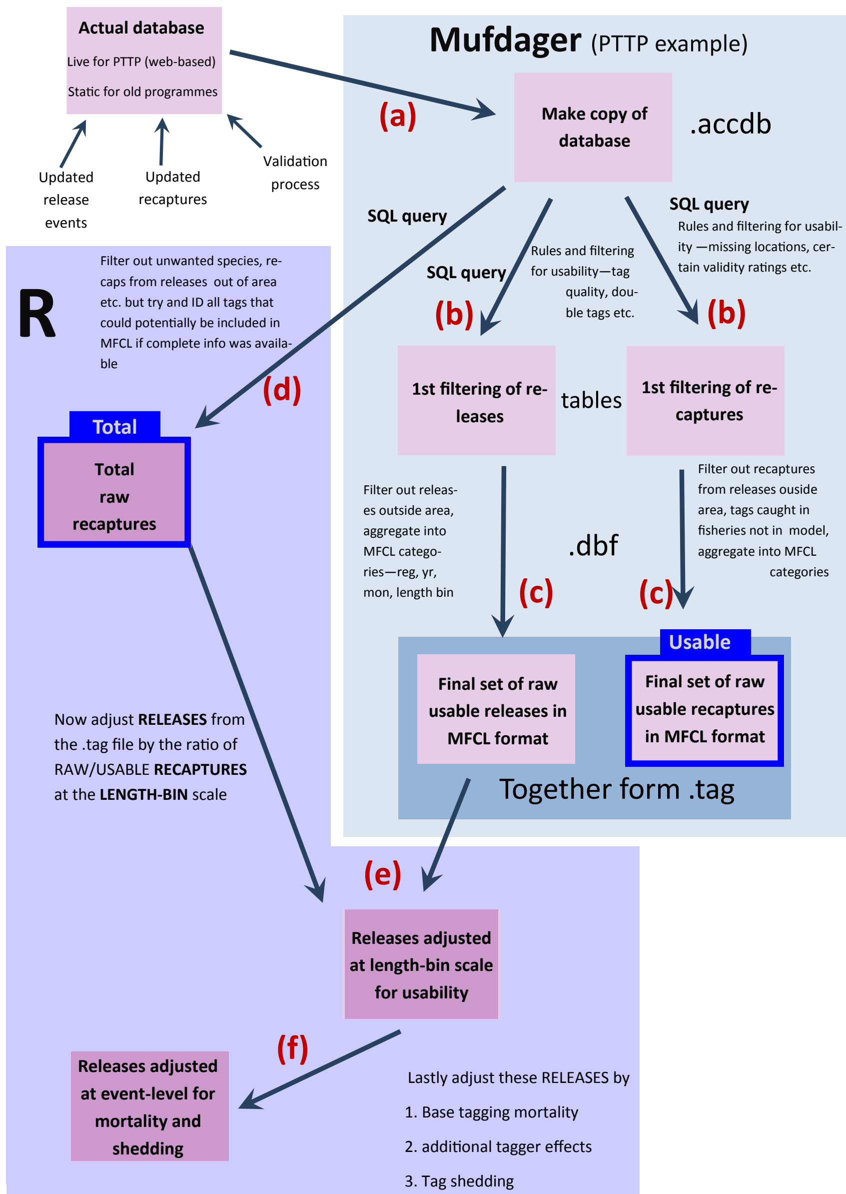


Figure 2: Diagram showing the process by which MUFDAGER produces a tagging file that includes the number of usable recaptures, how R is used to simultaneously calculated the total number of recaptures for a release event, and how the ratio of these sets of recaptures is used to adjust the number of releases. The usability ratio is the ratio of "usable" and "total" recaptures (blue boxes) at the length bin scale within release event.

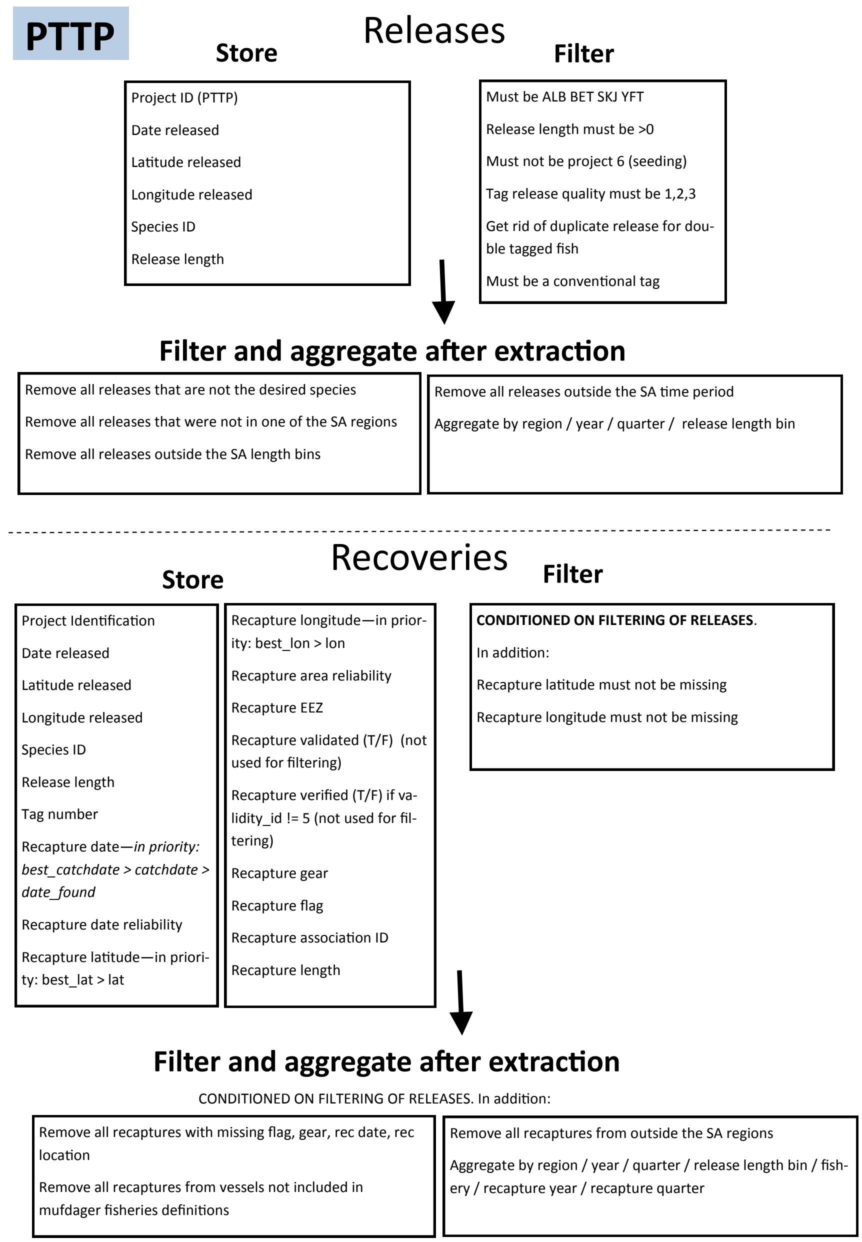


Figure 3: Diagram depicting the process by which MUFDAGER extracts data using SQL queries for releases and recaptures and then performs further filtering and aggregation using FoxPro code. Shown is an example for the PTTP but the process is very similar for the SSAP/RTTP.

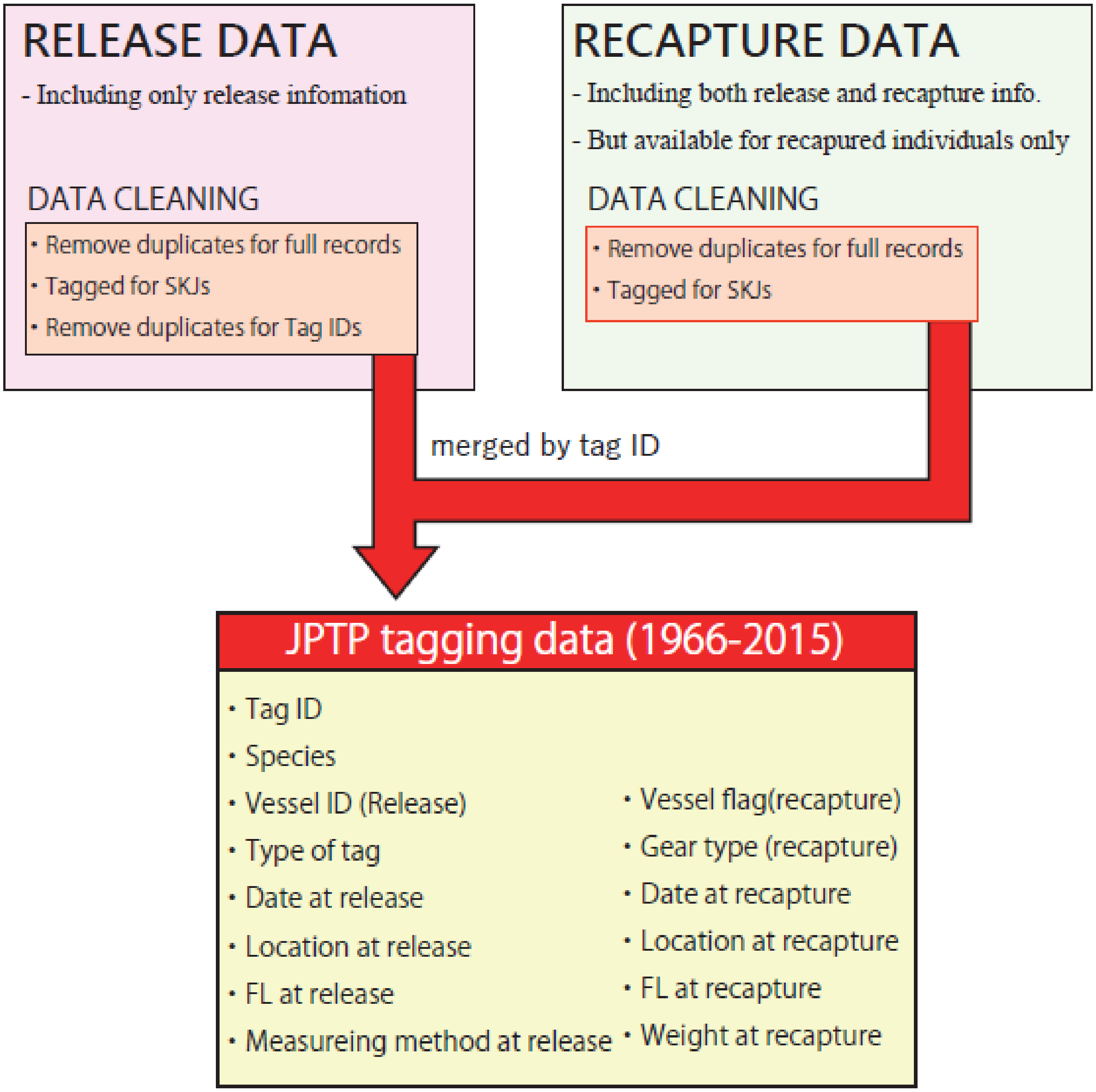


Figure 4: Diagram of the process of constructing the JPTP component of the tagging file used in the 2016 skipjack stock assessment reference case model.

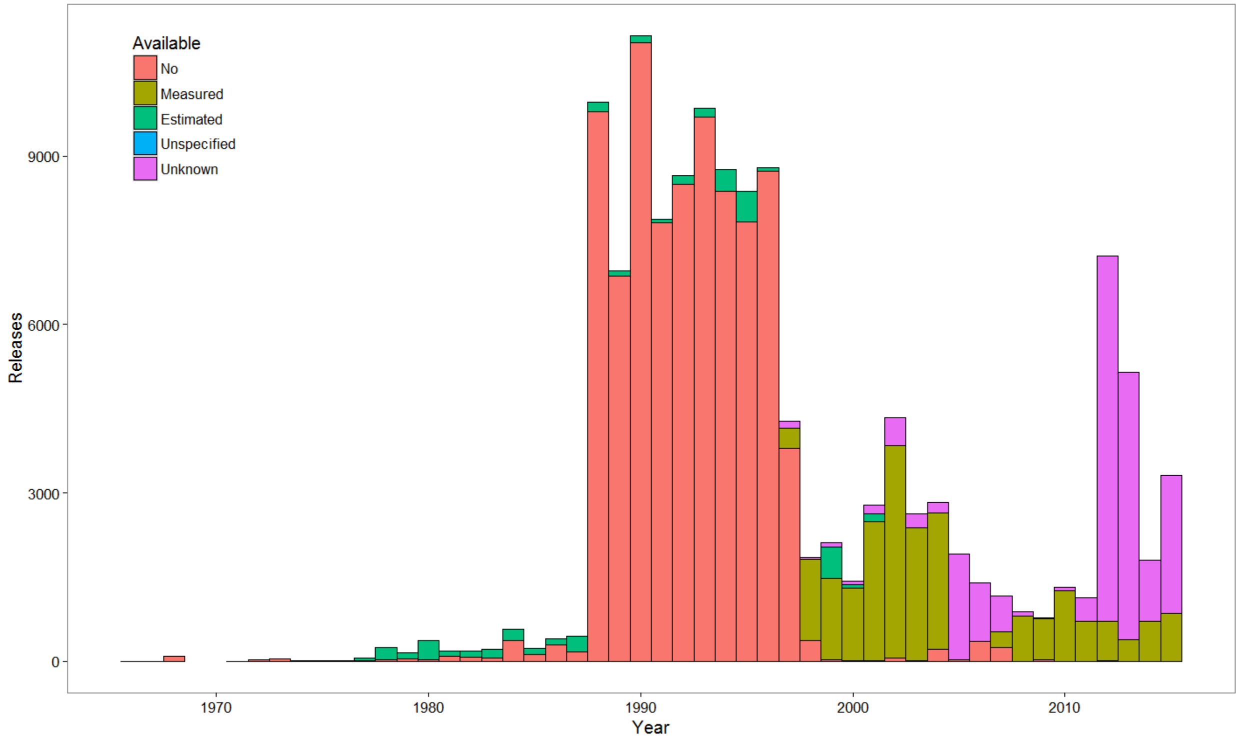


Figure 5: Details of the releases of skipjack tuna in the Japanese tagging programme with the colours indicating whether release lengths were available, and if so, how they were determined. The y-axis is the number of fish tagged.

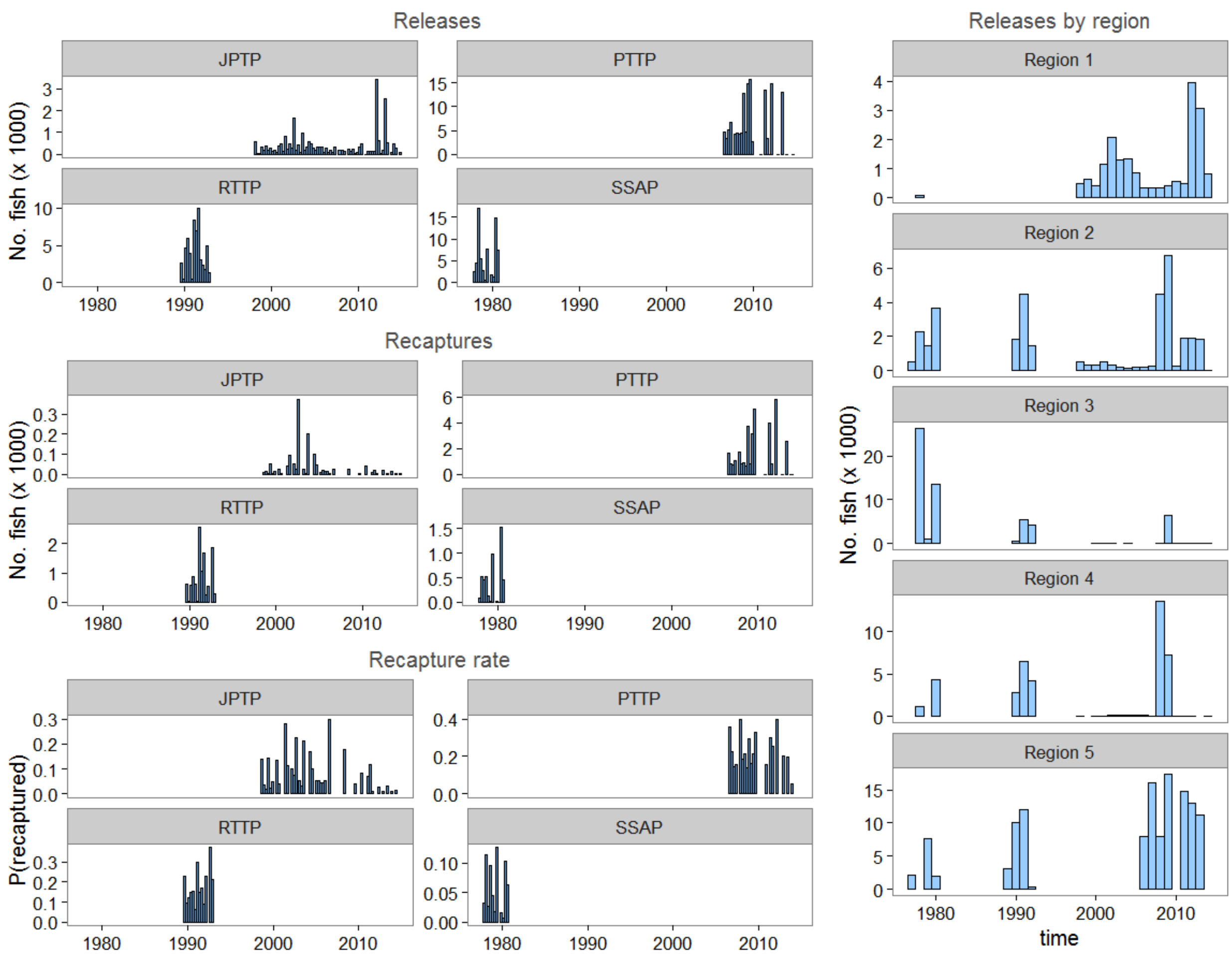
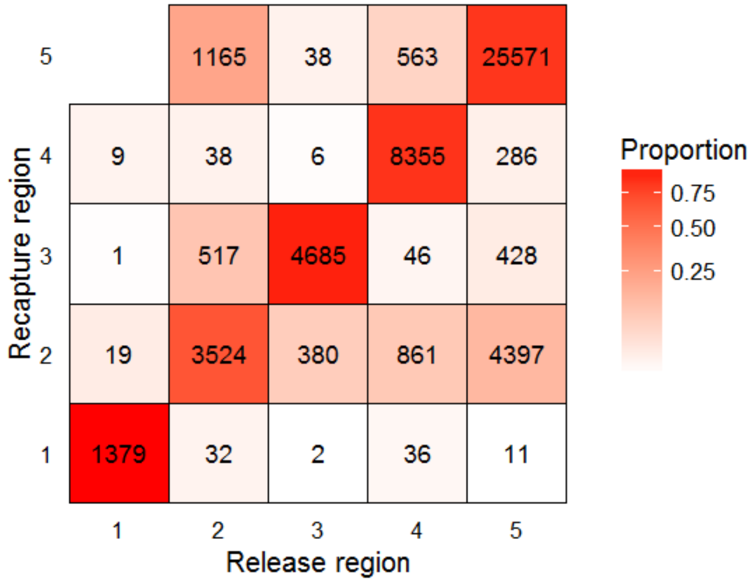


Figure 6: Summary of the .tag file used in the reference case of the 2016 stock assessment of skipjack tuna by tagging programme, region and year.



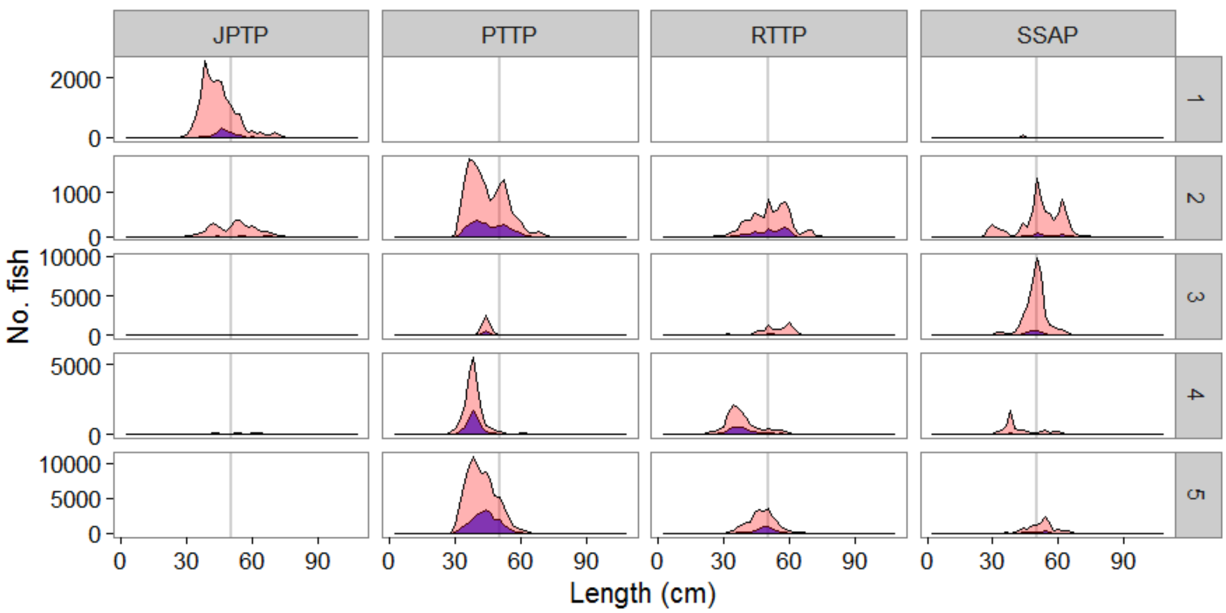
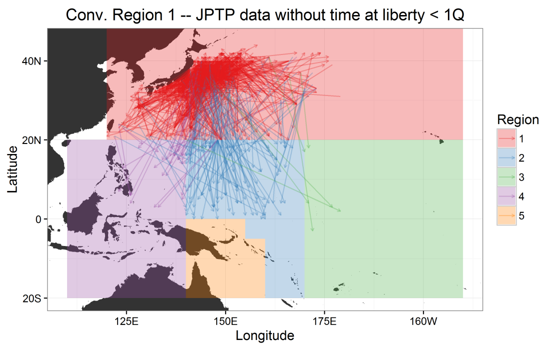
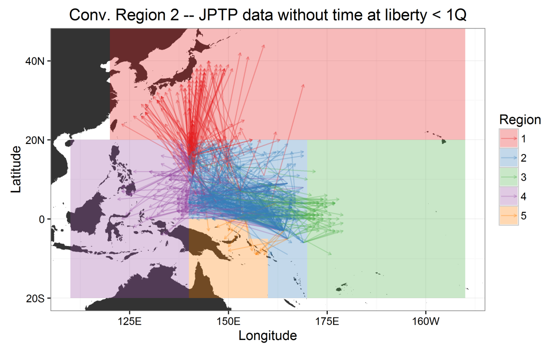


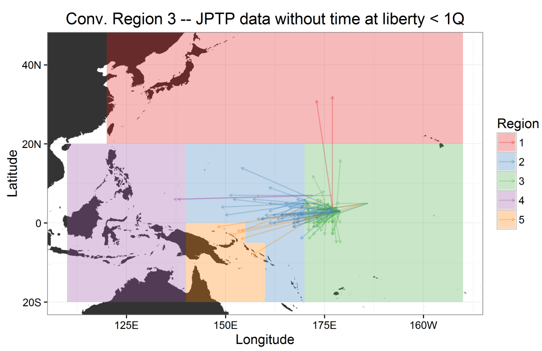
Figure 7: Summary of the .tag file used in the reference case of the 2016 stock assessment of skipjack tuna. The upper panel shows the observed movement of tagged fish; the x-axis is the region of release and the y axis is the region of recapture, with the number in each cell being the number of fish recaptured for that combination of release/recapture regions. The colour of the cell indicates the proportion of recaptures released in that region (x-axis) that were recaptured in that region (y-axis). The lower panel shows the length composition of released (pink) and recaptured (purple) fish for the different tagging programmes (x-axis panels) and regions (y-axis panels).



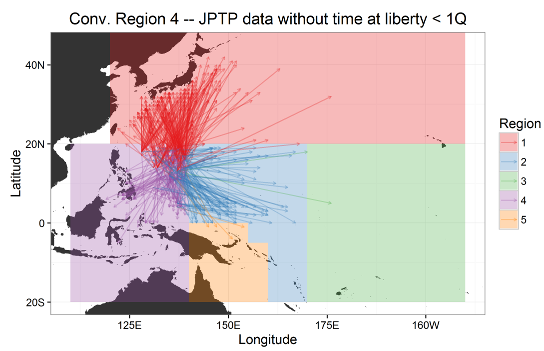
(a) Region 1 releases.



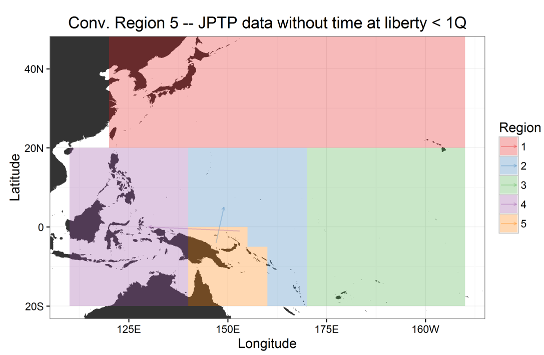
(b) Region 2 releases.



(c) Region 3 releases.

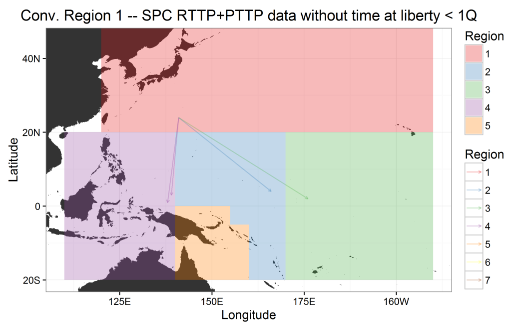


(d) Region 4 releases.

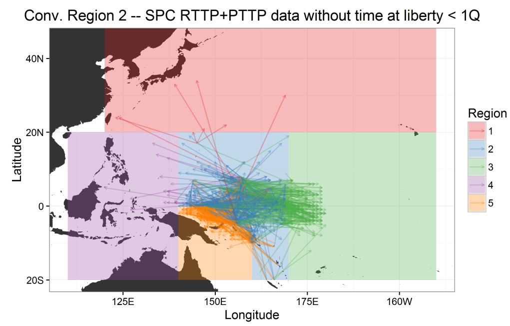


(e) Region 5 releases.

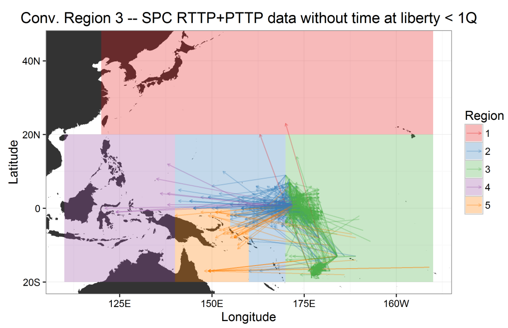
Figure 8: Plot of tag recaptures for the JPTP in released in the 5 stock assessment regions



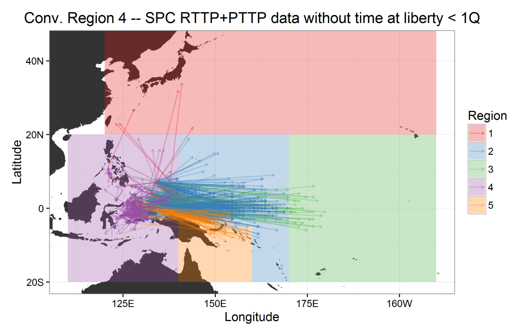
(a) Region 1 releases.



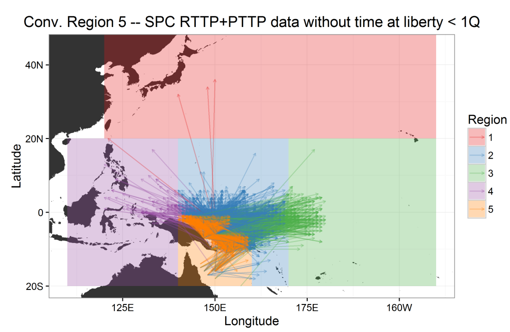
(b) Region 2 releases.



(c) Region 3 releases.



(d) Region 4 releases.



(e) Region 5 releases.

Figure 9: Plot of tag recaptures for the PTTP and RTTP in released in the 5 stock assessment regions