SCIENTIFIC COMMITTEE
FOURTEENTH REGULAR SESSION

Busan, Republic of Korea
8-16 August 2018

Generating Pseudo Data in MULTIFAN-CL

WCPFC-SC14-2018/ MI-IP-03

Scott R.[1], F. Scott[1], N. Davies[2], G. M. Pilling[1] and J. Hampton[1]

[1] Oceanic Fisheries Programme, The Pacific Community

[2] Te Takina Ltd

Executive Summary

The generation of pseudo data by MULTIFAN-CL is currently implemented for future catch, effort, length composition and tag release and recapture data. In this document we generate pseudo data for each data type and compare the results with the original input data. We use the 2016 skipjack reference case assessment as the basis for the analysis.

This document represents an update of previous analyses to investigate the generation of pseudo data using MULTIFAN-CL. Further to previous analyses it considers the generation of pseudo tag release and recapture data and the benefit these data provide when refitting MULTIFAN-CL to an extended time series created from pseudo generated data.

Based on the results of this analysis we highlight areas that require further investigation and make some tentative recommendations for the ongoing work for the generation of pseudo data within the MSE framework.

1 Introduction

The MSE simulation framework comprises two main components: an operating model, that represents the true underlying dynamics of the stock and the fishery; and a management procedure, that comprises the methods used to estimate the status of the stock as well as the harvest control rules (HCRs) that determine what management action should be taken for a given estimate of stock status (Figure 1).

The operating model is the mathematical representation of the system to be managed. It represents the biological components of the stock as well as the fishery that operates on the modelled population. It also includes models for the generation of data and the procedures for implementation of management regulations. In this paper we focus specifically on the data generation component of the operating model. We note that the results presented in this paper are preliminary and represent initial outputs of ongoing work.

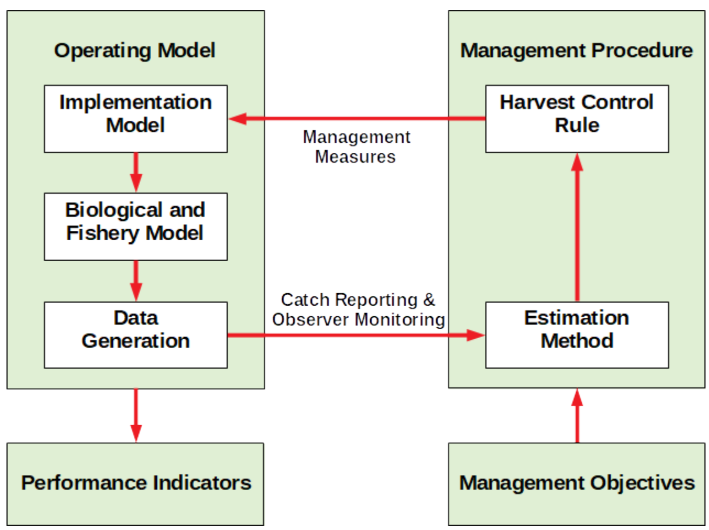

Figure 1: Conceptual diagram of the MSE framework.

The generation of pseudo data by MULTIFAN-CL is currently implemented for future catch, effort, length composition and tag release and recapture data. In this document we generate pseudo data for each data type and compare the results with the original input data. We use the 2016 skipjack reference case assessment as the basis for the analysis.

This document represents an update of previous analyses to investigate the generation of pseudo data using MULTIFAN-CL (Scott et al., 2017). Further to previous analyses it considers the generation of pseudo tag release and recapture data and the benefit these data provide when refitting MULTIFAN-CL to an extended time series created from pseudo generated data.

2 Generation of pseudo data for WCPO skipjack

Using MULTIFAN-CL, fishery specific catch and effort were generated from a relatively simple stochastic projection with additional variability included via a user defined standard deviation. A separate standard deviation can be specified for either catch or effort, but cannot be applied to individual fisheries. In other words, the catch standard deviation would apply to all catch projected fisheries and the effort standard deviation to all effort projected fisheries. The mean value of the future catch or effort is determined by the projection settings.

Quarterly, fishery specific length composition data are generated from a multinomial sample by applying the fishery selection pattern to the projected population, in the region corresponding to the fishery, and a user defined effective sample size.

Tagging data have been generated based on the multinomial probabilities of recapture given the estimated age-specific fishing mortalities and the reporting rate probabilities for each tagging event.

The following examples have been generated from the projection settings detailed in Table 1. Purse seine fisheries have been projected based on effort and all other fisheries based on catch at the mean value of the last five years of observed catch or effort (2011 to 2015). Stochasticity in future recruitment was incorporated through random sampling of deviates from a fitted Beverton and Holt stock recruitment relationship.

2.1 Pseudo data specifications

Fishery specific, quarterly, future catch and effort are determined from the projection with observation error based on a coefficient of variation (c.v.) of 20%.

Size composition data have been generated from a multinomial sample of predicted catches for each fishery, derived from the fishery specific selection pattern applied to the projected population in the region in which that fishery operates. The multinomial sample is based on a fleet specific effective sample size which is held constant through time and is based on the estimated effective sample size determined from a model fit using the self scaling multinomial option in MULTIFAN-CL (Table 2).

Pseudo tag recapture data have been generated assuming a single release event for all fisheries in the second quarter of the first projection year (2016). 1500 tagged individuals were released for each fishery with subsequent recaptures over the 10 year projection period.

2.2 Catch and effort data

Figures 2 to 4 show historical and future catch and effort for those fleets that are projected by either catch or effort. Five iterations are shown for the future, pseudo generated data. Future catch and effort was based on the average fishery specific catch and effort levels in 2015 and for some fisheries these represent some of the highest or the lowest values in the time series. For many fisheries the quarterly variation in catch or effort is substantially greater than the variability introduced by the 20% c.v.

Catches in the pole and line fisheries (Figure 2) have declined to low levels in recent years in most of the assessment regions. In addition, the relatively strong seasonal pattern in catches that is apparent in the early time series has also become less evident, particularly in regions 3, 4 and 5, although the seasonal pattern remains in regions 1 and 2.

In contrast, the historical catches of the domestic fisheries in region 4 (Figure 3) show no seasonal variability (probably due to data collection processes) and annual catches vary substantially over the averaging period (2011 to 2015). The simulated data have much greater seasonal variability and look quite different to the historical time series. A similar situation occurs for the long-line fisheries for which historical catches are fixed at 500 individuals. The generation of pseudo catch data is probably not necessary for these fleets and it may be more sensible to maintain all future catch values for these fleets at the same level assumed for the historical period.

Simulated effort data for the purse seine fisheries (Figure 4) are also dominated by strong seasonal patterns that overshadow any variability introduced by the 20% cv. A larger figure showing effort for only the unassociated purse seine fishery in region 2 is shown in Figure 5 to illustrate the scale of the seasonal variability in relation to the observation error.

2.3 Length composition data

Comparisons between fishery specific length composition data associated with future catches and those observed in the historical period, averaged over all years, (Figures 6 to 9) show the future, pseudo generated, length compositions to be broadly consistent with the historical data for some fisheries but show consistent bias in others. Length composition data generated for the purse seine fisheries in regions 2, 3,and 5 are broadly consistent with the historical observations in terms of modal distribution (Figure 6), however, length composition data generated for long-line fisheries are, in all cases, biased towards smaller fish (Figure 8).

A comparison between the historically observed and future generated length compositions (individual years) for the associated purse seine fishery in region 2 (Figure 10) show the observed length frequency data to have smoother distributions with greater autocorrelation than the simulated data which often have more observations in the tails and less autocorrelation. Modal variation in the pseudo generated data appears to be less pronounced than for the observed data although some annual modal variation is shown to exist (Figure 11). The extent of annual modal variation in the pseudo generated length compositions is due to the temporal variability in the age structure of the projected population resulting from recruitment and exploitation rate.

2.4 Tagging data

2.4.1 Tag release data

Under the current implementation of the generation of pseudo tag data within MULTIFAN-CL releases of tagged fish are fishery specific and the length distribution of the released fish corresponds to that of the fishery from which the releases are assumed to occur. In this example we have used the estimated selection patterns for the pole and line fisheries in each of the five regions to determine the length composition of the released fish. In practice, however, fish are typically tagged by a dedicated tagging research vessel. Skipjack captured for the purpose of tagging are predominantly caught using pole and line gear. The length distribution of the tag releases (Figure 12) shows a modal shift between the different release programmes with the PTTP and JPTP programmes releasing generally smaller fish than the SSAP and RTTP. In comparison, the pseudo generated tag releases have median length similar to the earlier tagging programmes and a wider length distribution that includes smaller and larger fish than have been observed in any of the tagging programmes.

A number of factors may explain the difference in tag release length compositions between the tagging programs including the spatial distribution of releases, the state of the stock and the design of the cruise sampling program. Early tagging cruises (SSAP, RTTP) covered a wider geographic area, including higher latitudes where larger fish may occur, whereas more recent tagging cruises (PTTP) have focused specifically on the tropical region of 10° N to 10° S and have modified the sampling program to try to increase the numbers of yellowfin that are tagged and released. The SSAP, RTTP and PTTP operate predominantly in the tropics and are characterised by large numbers of releases from relatively few trips whereas the JPTP operates mostly outside of the tropics and typically releases fewer fish from a larger number of tagging trips. Another factor that may contribute to variability in length compositions of released fish between the different tagging programs is the status of the stock during the period of the tagging program. The most recent skipjack stock assessment (McKechnie et al., 2016) indicates a pattern of increasing recruitment particularly in regions 2 and 3, where recent tagging cruises have been focused, that may account for the recent shift toward smaller fish being tagged and released.

2.4.2 Tag recapture data

Observation error is introduced into tag recapture data based on the operating model estimation of the multinomial probability of recapture given the release samples and the estimated age-specific fishing mortalities in projection fishing incidents. The number of tags that are released by year, season and region and the fishery selection pattern that will determine the length composition of the releases is defined by the user when constructing the input files to the pseudo data generation process (see Table 1). In addition, the fishery specific tag reporting rate that applies to the generated tag recaptures is also specified by the user. Specifying a low tag reporting rate reduces the numbers of pseudo tag recaptures for a given number of pseudo releases.

3 Re-fitting MULTIFAN-CL

Previous investigations of the generation of pseudo data in MULTIFAN-CL have attempted to re-fit the assessment model to an extended time series made up of historical observations and a future period of pseudo generated data. Comparison of the results with the original assessment provides some indication of the appropriateness of the pseudo generated data and the sensitivity of the assessment to them. Poor fits of the model or inconsistent estimates of model quantities might indicate mis-specification of the pseudo data.

A similar approach was taken to that employed in previous analyses (Scott et al., 2017) except that, with the most recent developments to MULTIFAN-CL, it is now possible to generate pseudo tag release and recapture data. Models with identical parameter settings were fit to four iterations of pseudo data with variability in catch effort, length composition and tag release and recapture data (Table 1). Parameter settings and the model fitting approach were unchanged from the 2016 reference case assessment, except that the period over which the stock recruitment relationship was fitted was increased to include the extended year range of the new data.

Estimates of adult biomass from the four model fits (Figure 14) are similar to those of the reference case assessment, although estimated to be slightly lower in some regions and quarters (most notably region 3). In addition, biomass estimates in region 1 increase considerably as the model transitions from real observations to pseudo data. We note that these initial results are more illustrative of a proof of concept and that further work will be required to determine more appropriate settings.

4 Discussion

The results are still very preliminary and work is ongoing to determine appropriate settings for the generation of pseudo data. However, these preliminary results highlight the importance of tag data within the assessment for WCPO skipjack. Similar analyses in which tag data were omitted (Scott et al., 2017) resulted in poor convergence of the model and estimates of adult biomass that increased to unrealistic levels with increasing function evaluations.

The re-fitted model used in this example was the full reference case assessment model which, using the latest version of MULTIFAN-CL, took around six hours to reach a converged solution. As has been noted previously, this is too long for the full assessment to be used within the simulation framework. The ability of the model to achieve consistent estimates of model quantities when refit to an extended time series of data is reassuring and we consider this an important step in progress towards generating pseudo data within the simulation framework. However, an alternative approach still needs to be found for the estimation model that will be used within the management procedure.

A recent addition to the MULTIFAN-CL software is the ability to generate pseudo data for the estimation period (historical) as well as for the projection period (future) (Davies et al., 2018). This will enable projections to be conducted using a consistent pseudo data set for the entire time period rather than a combinaton of true observations and pseudo observations. We have not examined this feature here, but will continue to investigate this and further options for pseudo data generation as the harvest strategy work continues.

Based on the results of this analyses we make some tentative recommendations for model settings and propose a number of modifications that might be considered for the future development of pseudo data within MULTIFAN-CL with specific consideration for skipjack.

- The introduction of catch and effort variability may not be necessary for all fisheries represented in the assessment, in particular for long-line fisheries for which catches are fixed at nominal low levels and expressed in numbers rather than weight. Where these fisheries are included in projections and in the generation of pseudo data, it is recommended that their future catches continue to be specified at fixed low levels. The apparent bias in the generated size composition data for long-line fisheries requires further investigation to determine both the source of the bias as well as the scale of its impact on the assessment.

- Currently within MULTIFAN-CL there is no option to specify fishery specific observation error. A single observation error is defined by the user for catch or effort which applies to all fisheries in the projection. The possibility to define fishery specific observation error would give greater flexibility to the generation of pseudo data, however, we note in Scott et al. (2018) that stochastic projections that incorporate re-sampling of the effort deviations would provide a more comprehensive simulation approach and would separate the sources of error more appropriately between observation error and process error. This feature of MULTIFAN-CL is currently under development but once implemented would be the preferred approach.

- It is not currently clear to what extent the length distribution of released tagged fish impacts on the ability to refit an assessment to pseudo data. Several aspects of the pseudo data with regard to tag data remain to be further tested, including the appropriate specification of reporting rates, the regional distribution of tag releases and the selection pattern to use when determining the length distribution of the releases.

We note, again, that the results presented in this paper are preliminary and represent initial outputs of ongoing work. Further information on the technical details of the generation of pseudo data within MULTIFAN-CL is detailed in Davies et al. (2018).

Acknowledgments

We gratefully acknowledge funding for this work from the New Zealand Ministry of Foreign Affairs and Trade (MFAT) funded project "Pacific Tuna Management Strategy Evaluation"; from the European Union through their funding support for the WCPFC "Simulation testing of reference points" and from Project 75 (Technical Support for the Development of Harvest Strategies". In addition we thank the Center for High Throughput Computing (CHTC UW-Madison) for generously providing access to their computing resources.

References

Davies, N., Fournier, D. A., Takeuchi, Y., Bouye, F., and Hampton, J. (2018). Developments in the MULTIFAN-CL software 2017-2018. WCPFC-SC14-2018/SA-IP-02, Busan, South Korea, 9–17 August 2018.

McKechnie, S., Hampton, J., Pilling, G. M., and Davies, N. (2016). Stock assessment of skipjack tuna in the western and central Pacific Ocean. WCPFC-SC12-2016/SA-WP-04, Bali, Indonesia, 3–11 August 2016.

Scott, R. D., Davies, N., Pilling, G., and J., H. (2017). Generating pseudo-data in MULTIFAN-CL. WCPFC-SC13-2017/MI-IP-02, Rarotonga, Cook Islands, 9–17 August 2017.

Scott, R. D., Scott, F., Davies, N., Pilling, G., and Hampton, S. (2018). Selecting and conditioning the operating models for WCPO skipjack. WCPFC-SC14-2018/MI-WP-03, Busan, South Korea, 5–13 August 2018.

Tables

Table 1: Projection Settings

Projection Setting	Value	Pseudo Data Setting	Value
N projection years	10	Catch c.v.	0.2
N projection sims	5	Effort c.v.	0.2
Tag pooling periods	300	Length dist ESS	see table 2
Av. catch and effort range	2011-2015	Tag release number	1500
First SRR year	1982 q1	Tag release regions	all
Last SRR year	2015 q1	Tag release fisheries	pole & line
SRR bias correction	off	Tag recap rep rate	0.9
Av. F calculation	2011-2014		

Table 2: Fishery specific projection settings: caeff values indicate whether a fishery is projected by catch (1) or effort (2). Effective sample sizes (ess) have been estimated from a MULTIFAN-CL fit using the self scaling multinomial without random effects.

	name	region	caeff	scaler	ess
1	PL	1	1	1	55
2	PS	1	2	1	29
3	LL	1	1	1	7
4	PL	2	1	1	14
5	PS-ASS	2	2	1	44
6	PS-UNA	2	2	1	39
7	LL	2	1	1	12
8	PL	5	1	1	22
9	PS-ASS	5	2	1	38
10	PS-UNA	5	2	1	35
11	LL	5	1	1	10
12	PL	3	1	1	14
13	PS-ASS	3	2	1	47
14	PS-UNA	3	2	1	40
15	LL	3	1	1	49
16	Dom-PH	4	1	1	26
17	Dom-ID	4	1	1	21
18	PS	4	2	1	42
19	PL	4	1	1	16
20	PS-ASS	4	2	1	12
21	PS-UNA	4	2	1	10
22	Dom-VN	4	1	1	43
23	LL	4	1	1	6

Figures

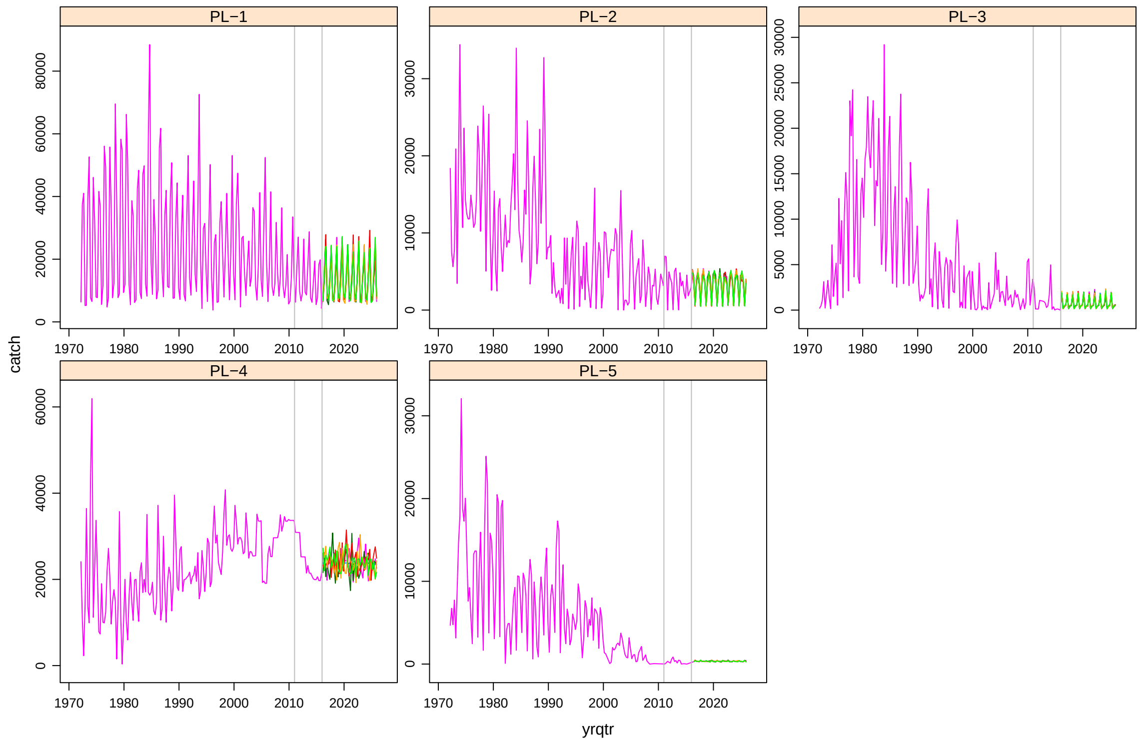

Figure 2: Catch for catch projected pole and line fisheries. Future period (2016 to 2025) shows all 5 iterations of the pseudo generated data. Vertical lines show the period over which average catch and effort have been calculated.

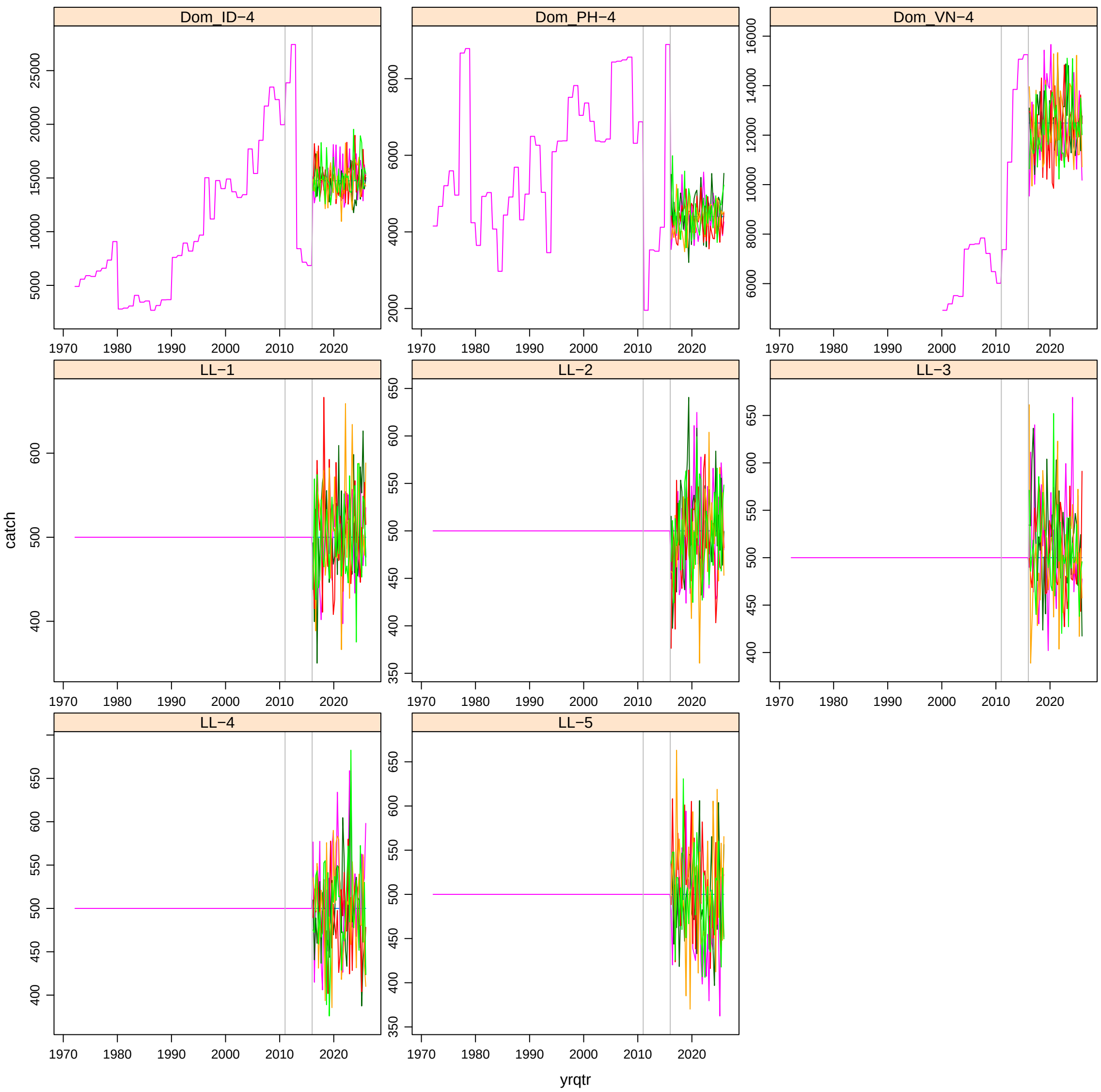

Figure 3: Catch for other catch projected fisheries. Future period (2016 to 2025) shows all 5 iterations of the pseudo generated data. Vertical lines show the period over which average catch and effort have been calculated.

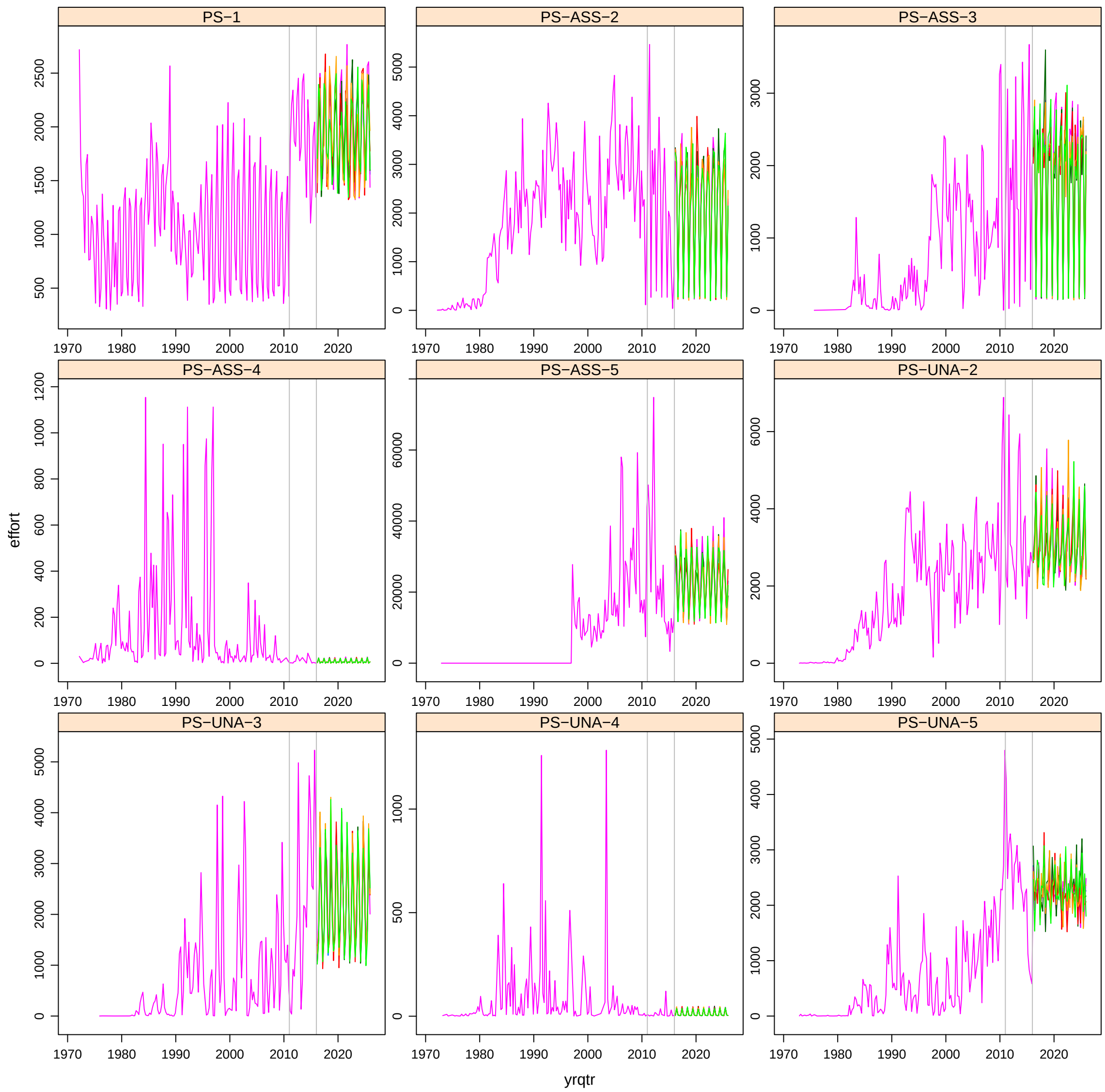

Figure 4: Effort for effort projected purse seine fisheries. Future period (2016 to 2025) shows all 5 iterations of the pseudo generated data. Vertical lines show the period over which average catch and effort have been calculated.

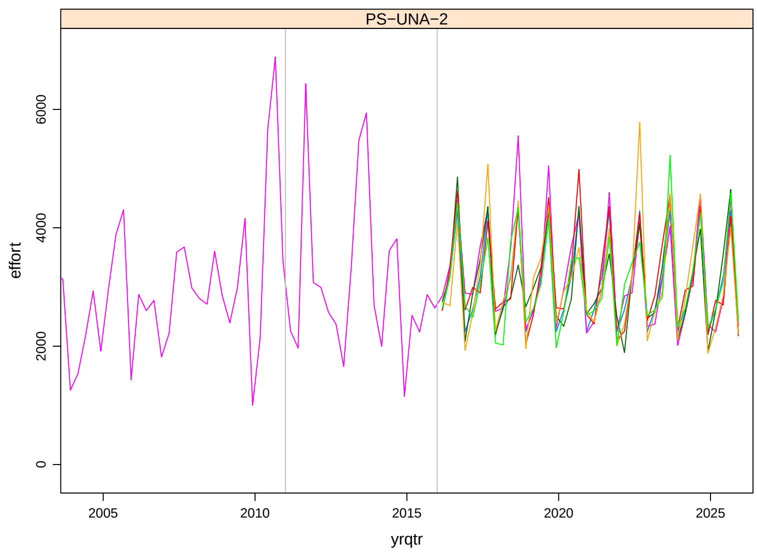

Figure 5: Effort for the unassociated purse seine fishery in region 2. Future period (2016 to 2025) shows all 5 iterations of the pseudo generated data. Vertical lines show the period over which average catch and effort have been calculated.

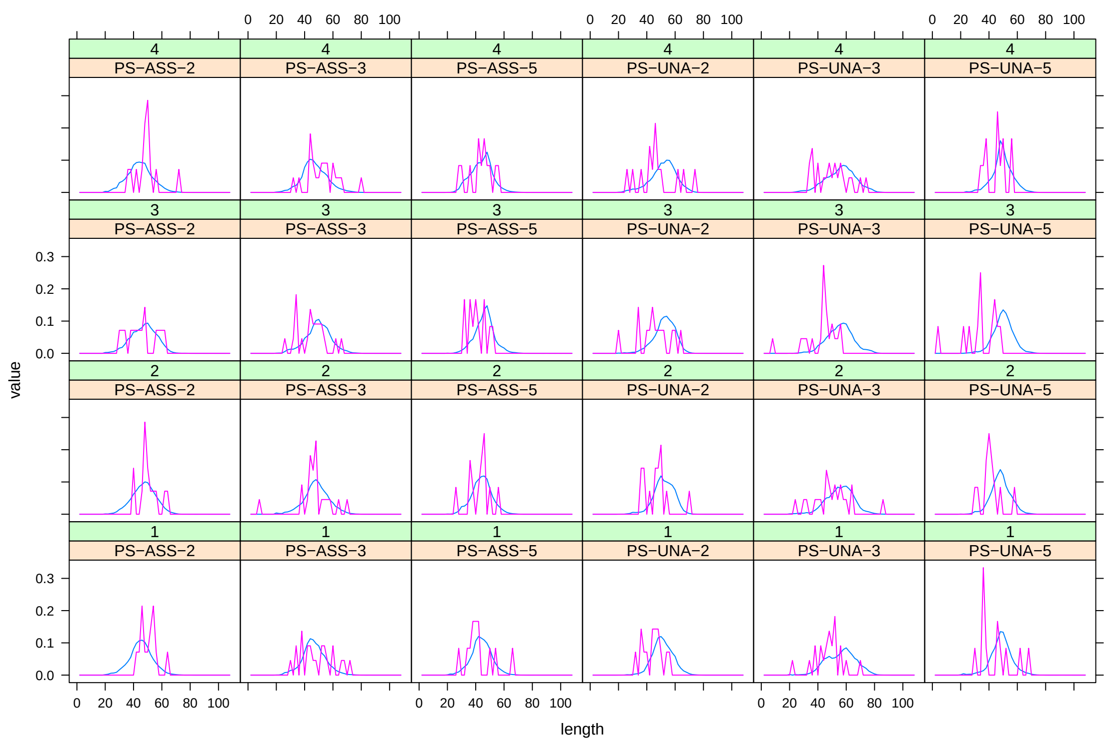

Figure 6: Length frequency comparisons for purse seine fisheries by fishery (columns) and quarter (rows). Historical observed length compositions (averaged over the full time series of available data, blue), single iteration of pseudo data (red).

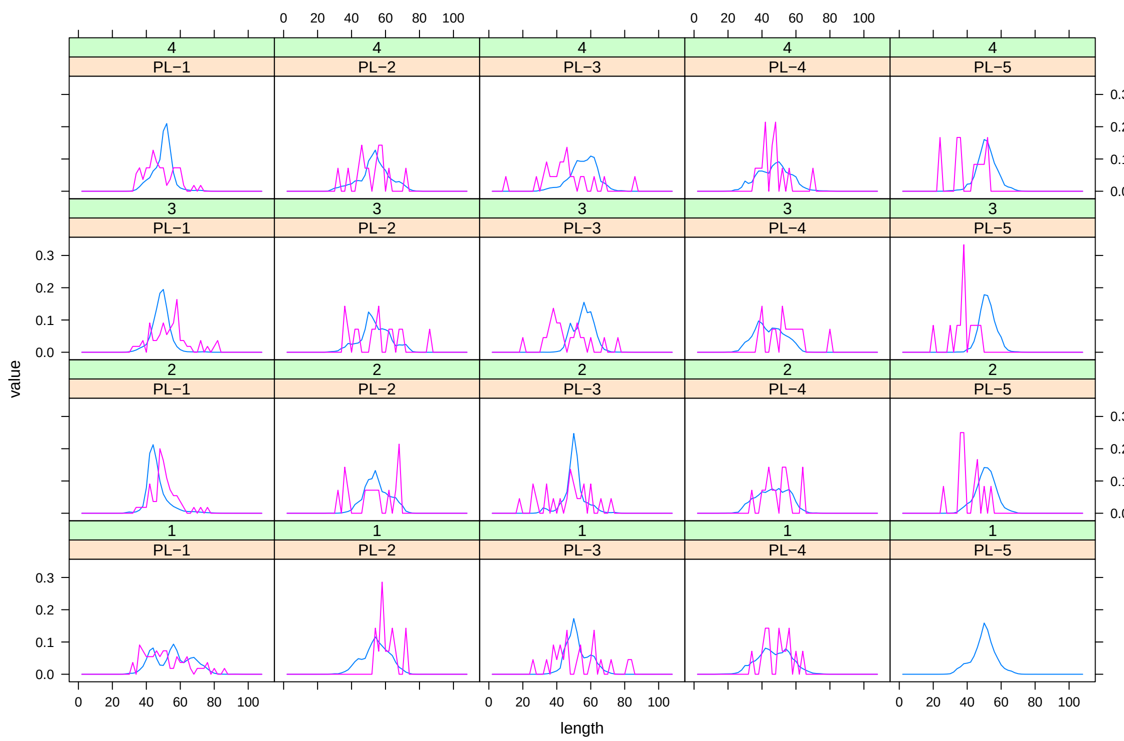

Figure 7: Length frequency comparisons for pole and line fisheries by fishery (columns) and quarter (rows). Historical observed length compositions (averaged over the full time series of available data, blue), single iteration of pseudo data (red).

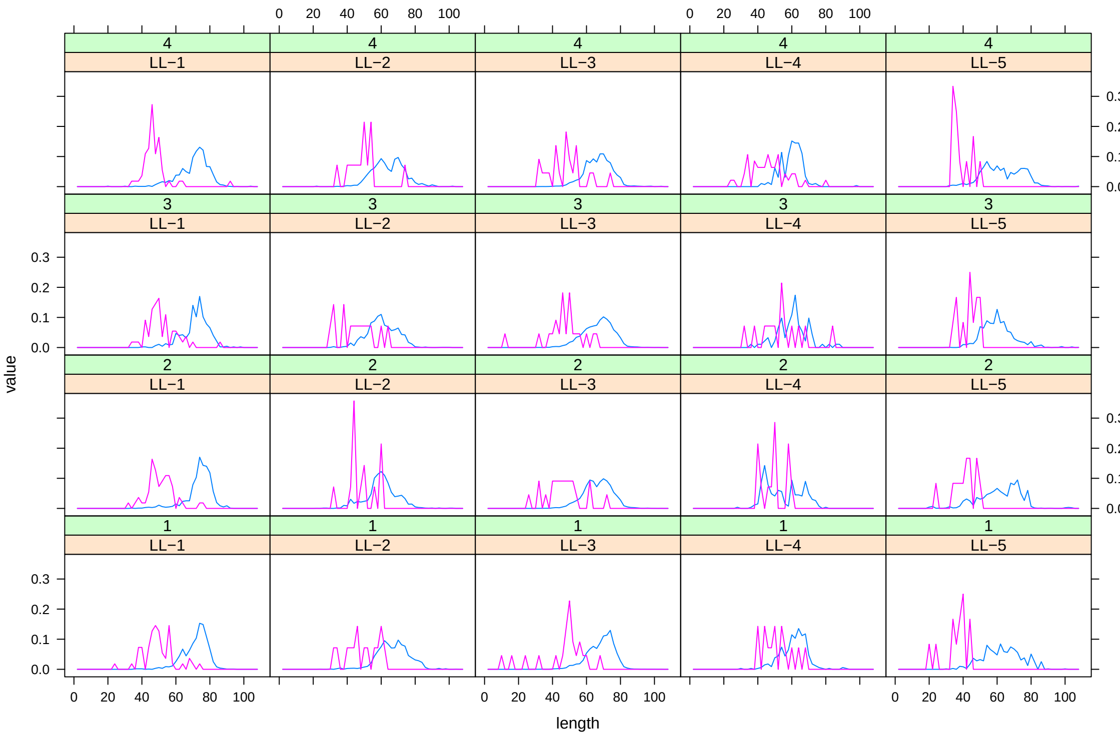

Figure 8: Length frequency comparisons for long-line fisheries by fishery (columns) and quarter (rows). Historical observed length compositions (averaged over the full time series of available data, blue), single iteration of pseudo data (red).

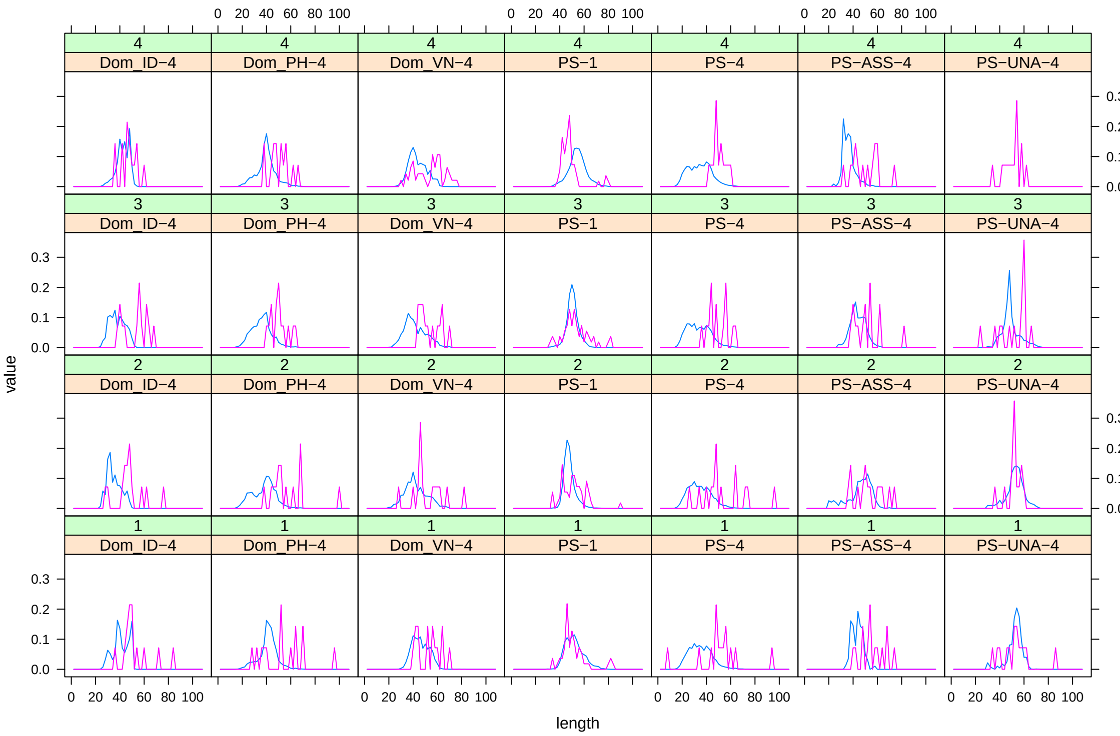

Figure 9: Length frequency comparisons for 'other' fisheries by fishery (columns) and quarter (rows). Historical observed length compositions (averaged over the full time series of available data, blue), single iteration of pseudo data (red).

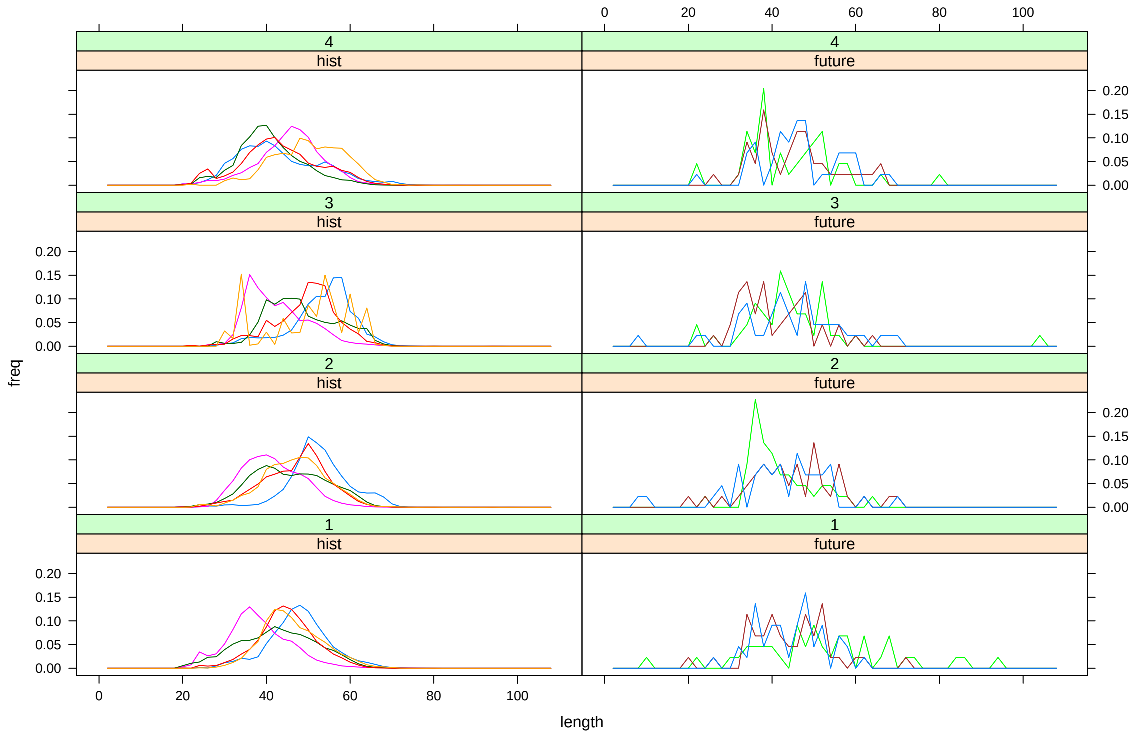

Figure 10: Length frequency comparisons for the associated purse seine fishery in region 2 for historical and future periods (columns) and quarter (rows). Individual historical observed length compositions are shown for the year range 2011 to 2015 (left column). A single iteration of pseudo data for 2016 to 2018 are shown for the future data (right column).

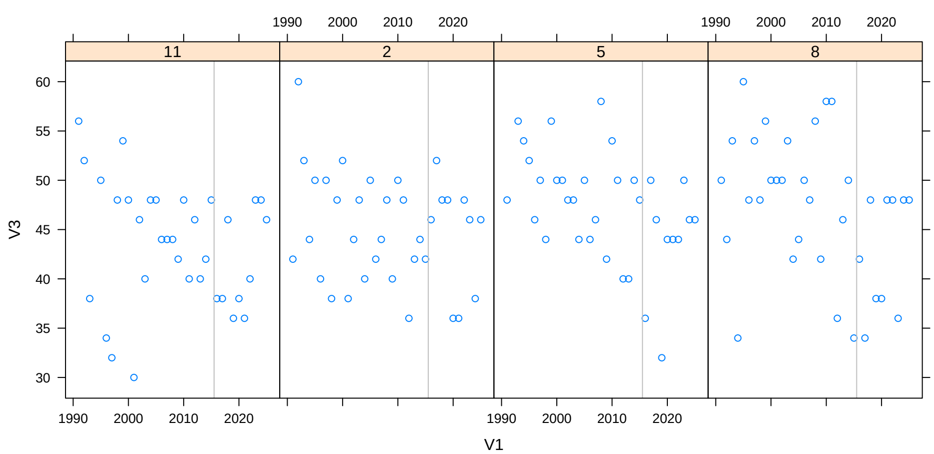

Figure 11: Modal length for the associated purse seine fishery in region 2, quarters 1 to 4, for historical and future periods. Where two modes occur, only the first (lowest) is shown

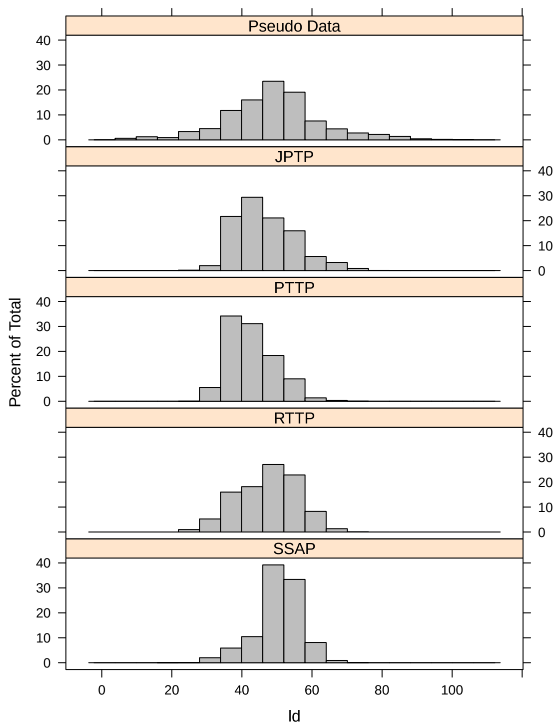

Figure 12: Tag release length distributions

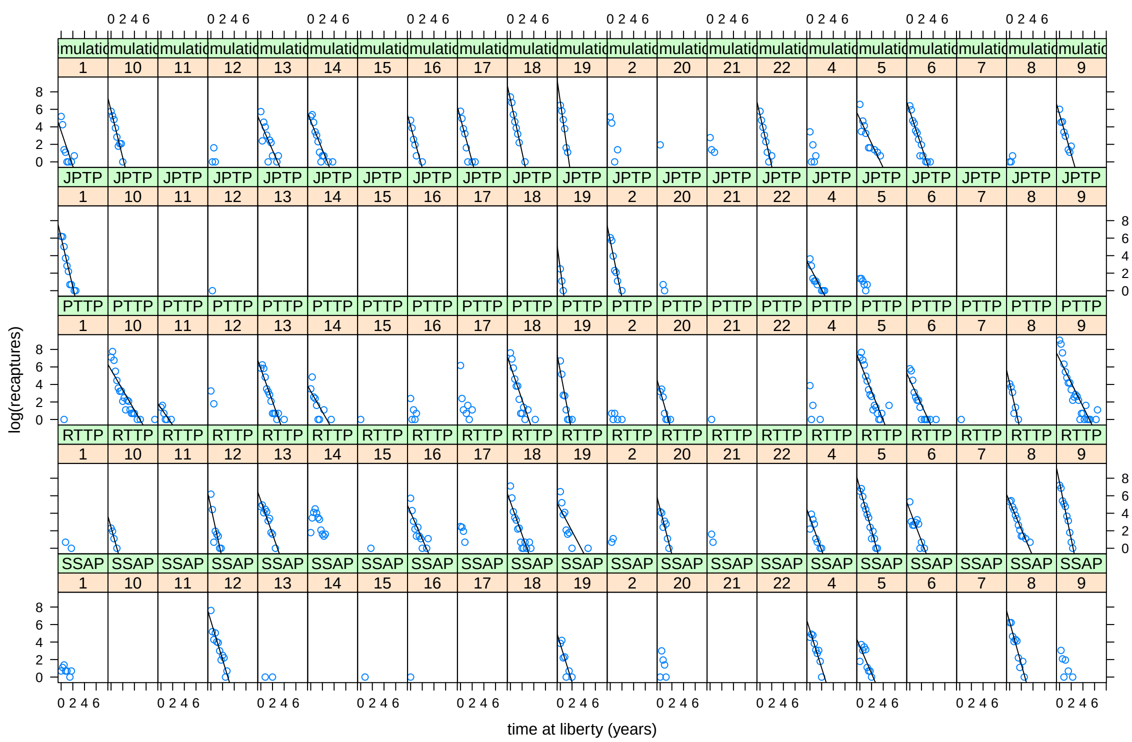

Figure 13: Tag recaptures against time at liberty by fishery and tag program. Simulated tag recaptures shown in top panel.

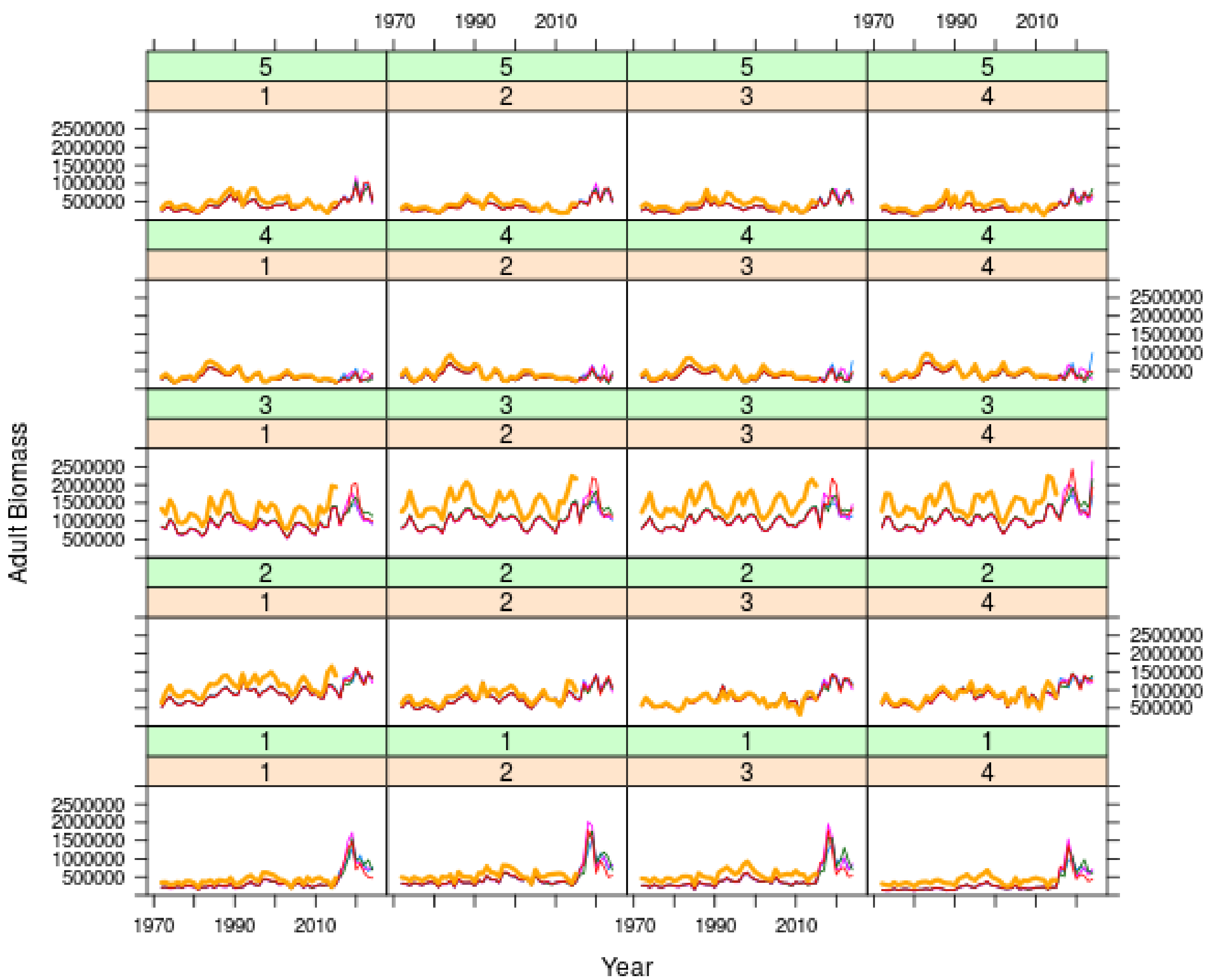

Figure 14: Adult biomass by region (1 to 5) and quarter (1 to 4) from the 2016 reference case assessment refit to four iterations of an extended time series of pseudo data. 2016 reference case estimates are shown in yellow.