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Estimation of Indian Ocean Skipjack Purse Seine Catchability Trends from Bigeye and Yellowfin Assessments

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Acknowledgments

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1 Abstract

Relative abundance indices derived from commercial catch per unit effort (CPUE) are the most important data inputs to most tuna stock assessments (along with total catch removals), but their use is critically dependent on the assumption that one can establish a time series that is related to abundance in a manner that is understood (usually proportional) and consistent over time. The 2017 IOTC skipjack (SKJ) assessment included purse seine log set (PSLS) CPUE, even though the standardization analysis did not identify any evidence that catchability had changed over time (i.e. nominal and standardized CPUE series were essentially the same). Recognizing that this was not consistent with the efficiency improvements expected through technological development, alternative catchability trends of 0 and 1% per year were imposed in the assessment with equal plausibility weighting. These were fairly arbitrary values, not supported by any quantitative analysis. This paper follows up on one of the 2017 WPTT suggestions - to estimate PS catchability trends from assessments for other species which have more reliable data.

The analysis involves adding PSLS CPUE series to the (2016) yellowfin and bigeye assessments (in a manner that is uninformative about the population dynamics) and calculating the PSLS catchability trends that would be consistent with these assessments. The estimates obtained from IOTC bigeye suggest a substantial (4.1% per year compounded annually) PSLS catchability increase. The yellowfin estimates suggest a fairly continuous catchability increase of 1.25% per year. The bigeye and yellowfin trends are similar over the past two decades, but the bigeye trend went through a rapid increase 20-25 years ago. Provided that the recent yellowfin and bigeye assessments are credible, this suggests that PSLS catchability trends are not consistent among species. Recommendations for future skipjack assessments require further consideration. In the absence of other information, this analysis suggests that minimum catchability trends of at least 1.25 % per year might be more defensible than 0-1%.

While this analysis is presented in the spirit of trying to improve the IOTC skipjack assessment, the fundamental point remains - relying on purse seine CPUE as a relative abundance index may be very misleading and is not recommended.

2 Introduction

Relative abundance indices derived from commercial CPUE are the most important data inputs to most tuna assessments (along with total catch removals), but to be useful, there must be a relationship between CPUE and abundance that is consistent over time. Statistical models are used in an attempt to standardize the CPUE to account for variability in fishing methods that change the relationship over time (e.g. changing fishing areas/seasons, search efficiency, increasing use of FADs, set-time, setting depth, line types, etc.). However, it is usually impossible to know whether all of the relevant factors have been properly accounted for. CPUE from purse seine fisheries is particularly difficult to standardize because it is difficult to quantify search effort given the rapid development and uptake of new technologies, and catch might not be closely related to abundance if there is gear saturation and/or the relationship between school size and school abundance is not well understood.

The recent IOTC skipjack assessment (IOTC 2017) included EU floating object purse seine CPUE (defined as catch in mass per set), even though the nominal and standardized (Katara et al. 2017) CPUE series had essentially identical trends (Figure 1). It was noted that WCPO assessments regularly include PS effort in the fisheries models in a manner that allows PS catchability to be estimated. These effort series are not informative (or are negligibly informative) in the assessment precisely because the catchability is allowed to change over time as determined by the other data (notably longline CPUE, because these fleets are assumed to have stationary catchability following standardization). The WCPO assessments have often estimated substantial changes in PS FAD-associated fisheries (e.g. McKechnie et al 2017). However, the IOTC WPTT was reluctant to assume that the catchability trends would be similar in the Indian Ocean, and instead assumed levels of effort creep, at 0 and 1% per annum. This working paper presents a similar PS catchability analysis for the Indian Ocean, based on the recent bigeye and yellowfin assessments of Langley (2016a, 2016b), and discusses some of the implications for future assessments.

3 Methods

The recent IOTC bigeye and yellowfin Stock Synthesis assessments assume that the CPUE index (*I*) is directly proportional to the vulnerable (fishery-selected) biomass (*B*) at time *t*:

1) $$I_t = QB_t \exp(\delta_t)$$

where catchability (Q) is the constant of proportionality and δ_t is assumed to be independent and normally-distributed random (observation) error. Systematic patterns in δ_t would suggest that catchability has changed over time, such that, for this analysis, we are interested in presenting catchability as a time series:

2) $$q_t = \mathrm{Q}\exp(\delta_t)$$

where q_t (or a smoother that describes the important trend) can be calculated from bigeye or yellowfin assessments and imported into skipjack assessments.

The analysis involves refitting recent bigeye and yellowfin assessments (Langley 2016a, 2016b) each with an additional PS-based CPUE index that is uninformative (or minimally informative) in the assessment. The standardized effort (*E*) for all cases was calculated from the standardized CPUE series from Katara et al (2017), and the catch time series from the skipjack assessment (IOTC 2017), $E_t = C_t/I_t$ (Figure 2). The SS assessments are conditioned directly to CPUE (unlike the WCPO Multifan-CL assessments, which fit to effort directly).

For bigeye, we used assessment model configuration *taglambda1* only (as provided by the secretariat). The IOTC bigeye assessment has the western tropical region PSLS fisheries split into northern and southern subunits in the assessment, but the population is aggregated across these two regions (Figure 3). There is a strong negative correlation in the seasonality of the catch and CPUE in these sub-regions (Figure 4 and Figure 5), while the annual trends appear to be similar (with notable exceptions). For the PS catchability analysis, we used a single CPUE series for this region - the aggregated catch divided by the standardized skipjack effort (Figure 5). For model fitting, the predicted PSLS CPUE series was linked to selectivity of the fishery *PSLS1* (southern sub-region)

For yellowfin, we used assessment configuration *YFT_SS\update2016* only (as provided by the secretariat). The relevant catch time series is adopted from the PSLS fisheries 8, 22 and 24 from region 1b (Figure 3). Note that these 3 fisheries are actually the same fishery, split into time blocks to admit the potential for variability in selectivity over time. For model fitting, the predicted PSLS CPUE series was linked to selectivity of fishery 24 (post-2006 time period). The resulting CPUE time series is shown in Figure 6.

To calculate the PSLS fishery catchability time series, we used the Stock Synthesis analytical q option, with the likelihood term for the PSLS CPUE series down-weighted (λ=0). In this way, mean catchability is a model output, but there are no PSLS CPUE likelihoods, parameter priors or penalties contributing to the objective function. This could also be achievable with PSLS catchability deviations or a random walk parameterization with very large CVs (as in WCPFC assessments), but initial attempts to do this appeared to be less numerically stable (particularly for yellowfin).

Refitting the model in this way resulted in a very similar objective function minimum to that achieved with the original assessment configuration. The dynamics (e.g. biomass and recruitment time series plots) were visually indistinguishable for BET, and very similar, but subtly different for YFT.

4 Results and Discussion

The bigeye PSLS predicted and observed CPUE is clearly a very poor fit (Figure 7), while the yellowfin fit appears at least qualitatively consistent (Figure 8) given the high variance.

The bigeye assessment estimates a strong increasing trend in PSLS catchability, with an overall trend of 4.1% per year (if compounded annually in a manner analogous to the recent skipjack assessment assumptions). The trend is not continuous - there was a rapid increase around 20 years ago (Figure 9). In contrast, the yellowfin assessment estimates a lower and more continuous trend of 1.25% per year (Figure 10). The smoothed catchability trends from the two are overlaid on the same scale in Figure 11, suggesting a similar trend in the most recent 20 years. Note that the R package *r4ss* (version 1.24.0) produces plots with a label that appears to have a similar intent to Figure 9 and Figure 10, but these plots are qualitatively very different from the plots calculated using equations (1) and (2) above, and may be a bug. The bigeye CPUE series represents a quick attempt to pool data across two heterogeneous regions (i.e. asynchronous seasonal patterns), and we might expect this to introduce systematic biases to the analysis.

To the extent that we believe the yellowfin and bigeye assessments, this suggests that PSLS efficiency has generally been increasing. But the estimated catchability trend is substantially different between the two, so we would not be surprised if skipjack was also different.

Conclusions and Recommendations:

- In the absence of other information, this analysis suggests a best guess for skipjack catchability increases would be higher than the 0-1% per year assumptions adopted for the 2017 skipjack assessment (e.g. 1.25% per year could be adopted as a minimum for the central tendency).
- The catchability trends for yellowfin and bigeye estimated for the most recent 20 years appear similar. If there is an explanation for a change around 20 years ago that might have differentially affected yellowfin and bigeye, this might increase confidence in the application of these sorts of analyses among species. The PSLS fishery is the obvious priority for such an analysis, but the potential for problems in the longline CPUE (and corresponding assessments) should not be entirely dismissed.
- The variability in the estimated time series suggests that catchability can increase or decrease substantially for several consecutive years, even after the overall increasing trend is accounted for. If PSLS CPUE is used in the skipjack assessment, or for operating model conditioning, or a Management Procedure, this source of variability should not be overlooked (e.g. perhaps it might be added as auto-correlated observation error).
- Routinely including uninformative PSLS CPUE data in future yellowfin and bigeye assessments would provide this result as an almost effortless by-product, including uncertainty if the assessment consists of a model grid. The feasibility of extending the analysis to PS free school sets, and the Maldivian PL fishery (at least for yellowfin) might be considered.

- This analysis is presented in the spirit of trying to improve the IOTC SKJ assessment, but the fundamental point remains - relying on purse seine CPUE as a relative abundance index may be very misleading and is not recommended.

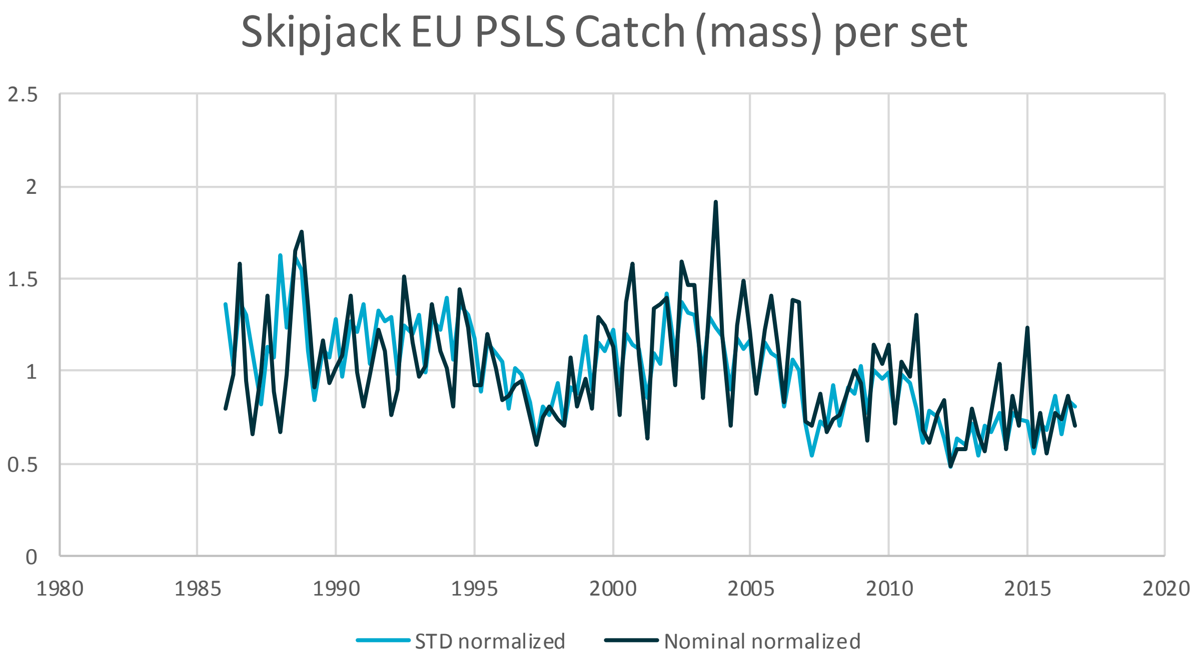

Figure 1. Nominal and standardized skipjack PSLS catch-per-set CPUE form Katara et al (2017), each re-scaled to a mean of one.

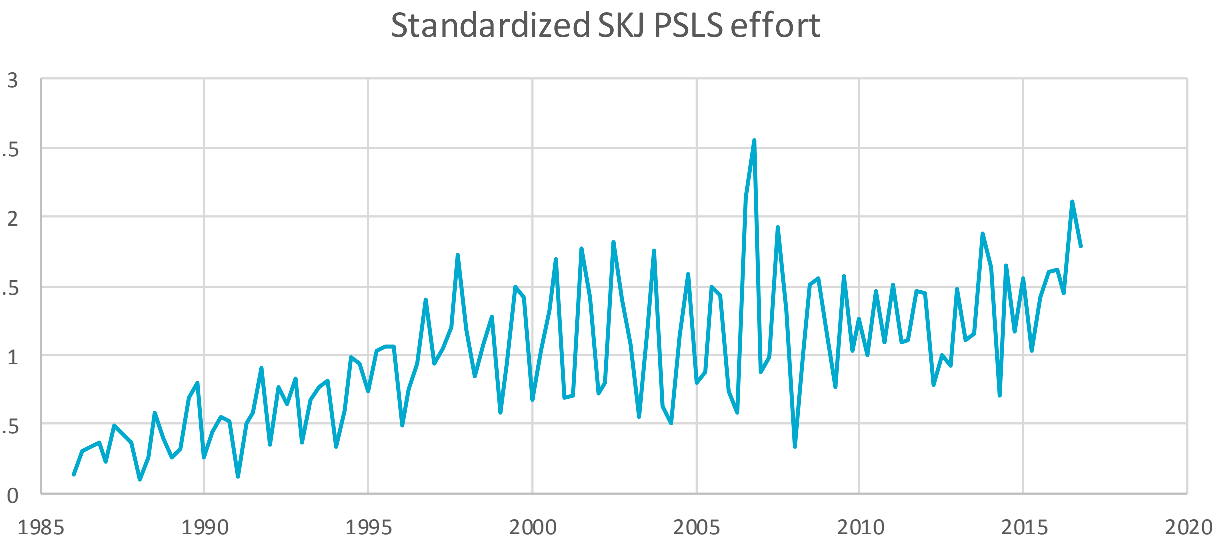

Figure 2. Standardized PSLS effort calculated from the Katara et al (2017) CPUE standardization, and the PSLS skipjack catch used in the 2017 assessment, normalized to a mean of one.

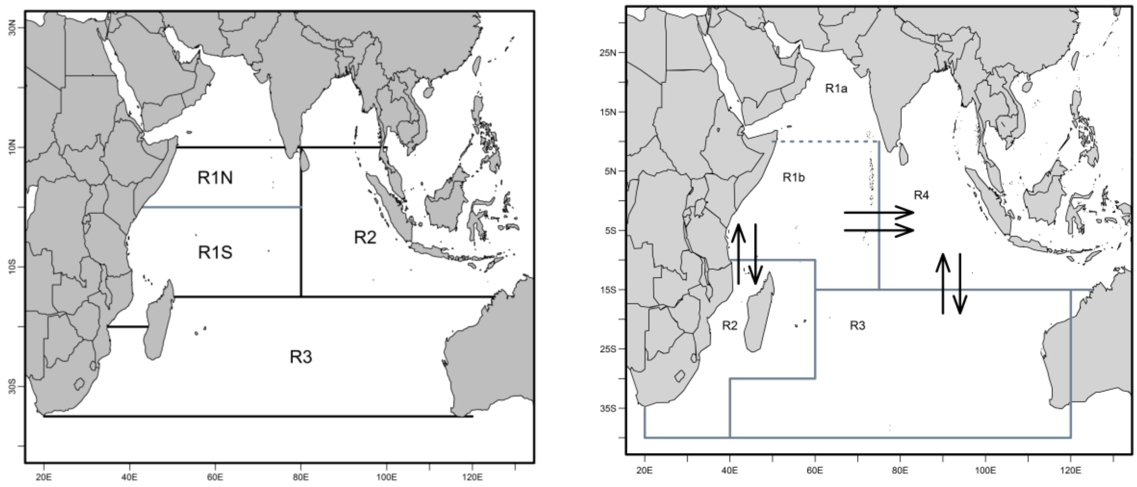

Figure 3. Spatial structure for recent IOTC bigeye (left, from Langley 2016b) and yellowfin (right, from Langley 2015) tuna assessments. The EU purse seine fishery of interest operates in the western equatorial regions.

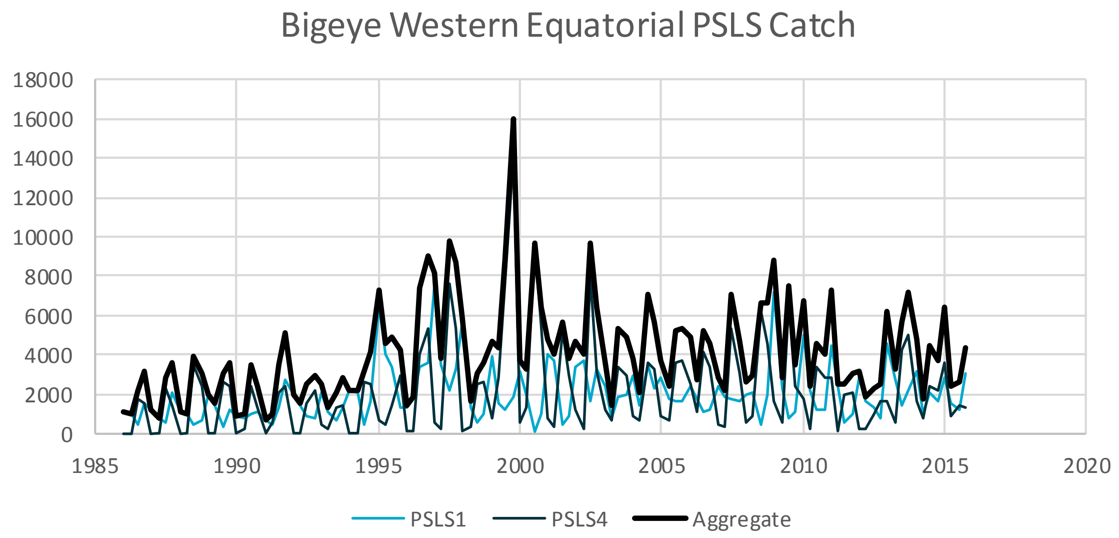

Figure 4. Bigeye PSLS Catch from fisheries PSLS1S, PSLS1N and the sum of the two ("Aggregate").

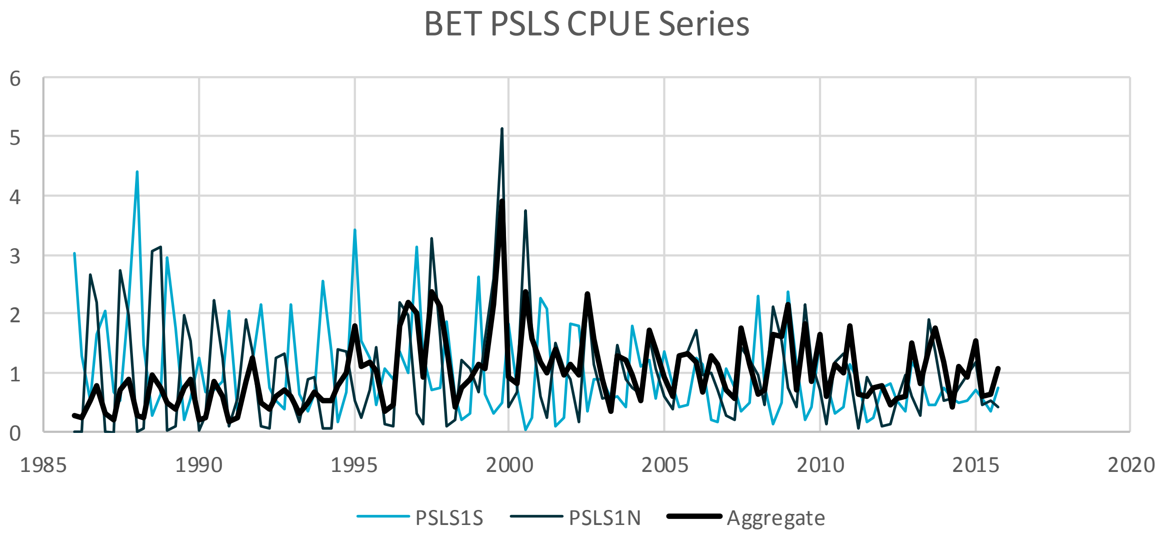

Figure 5. Bigeye PSLS CPUE, where catch is from PSLS1S, PSLS1N or the sum of the two ("Aggregate") and effort is calculated from the skipjack CPUE standardization (and skipjack catch data). All series are independently normalized to a mean of 1. The aggregate CPUE series is input to the bigeye model.

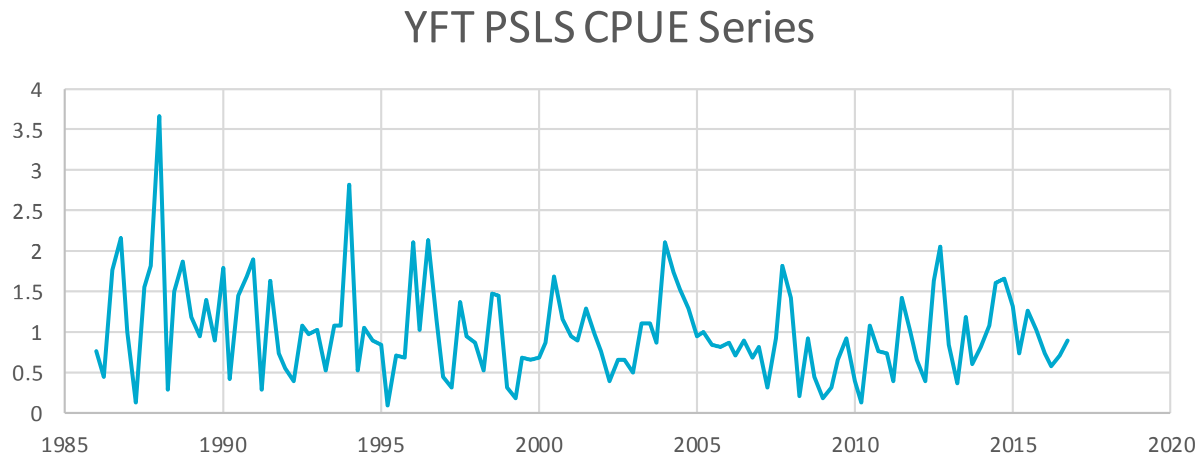

Figure 6. Yellowfin PSLS CPUE normalized to a mean of one, input to the yellowfin model.

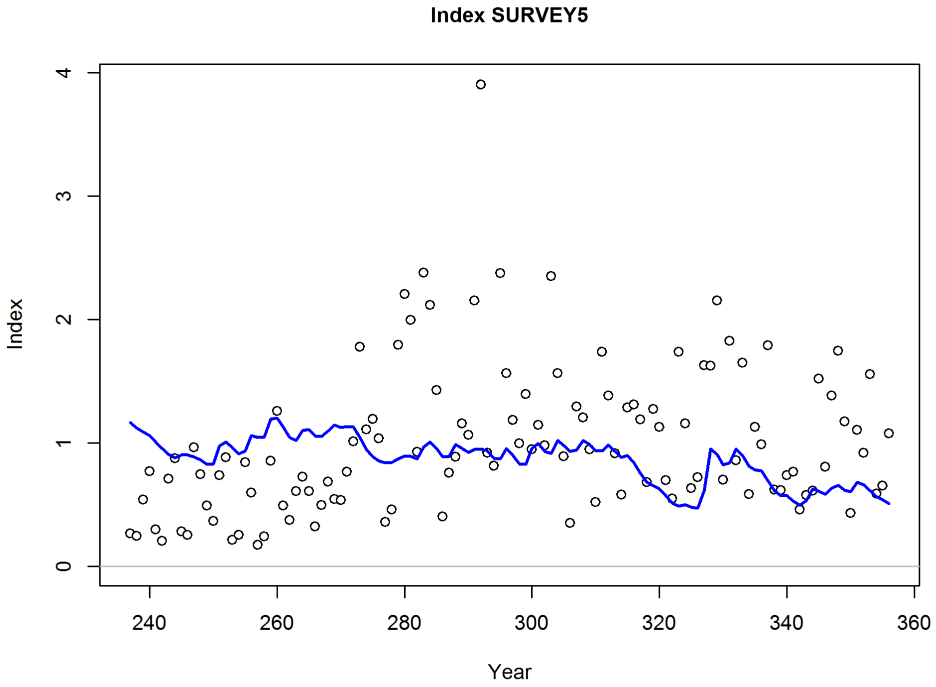

Figure 7. Predicted and observed bigeye PSLS CPUE (in these r4ss plots, "Years" are actually quarters ending in 2015, due to the convention of structuring model years as calendar quarters for these assessments).

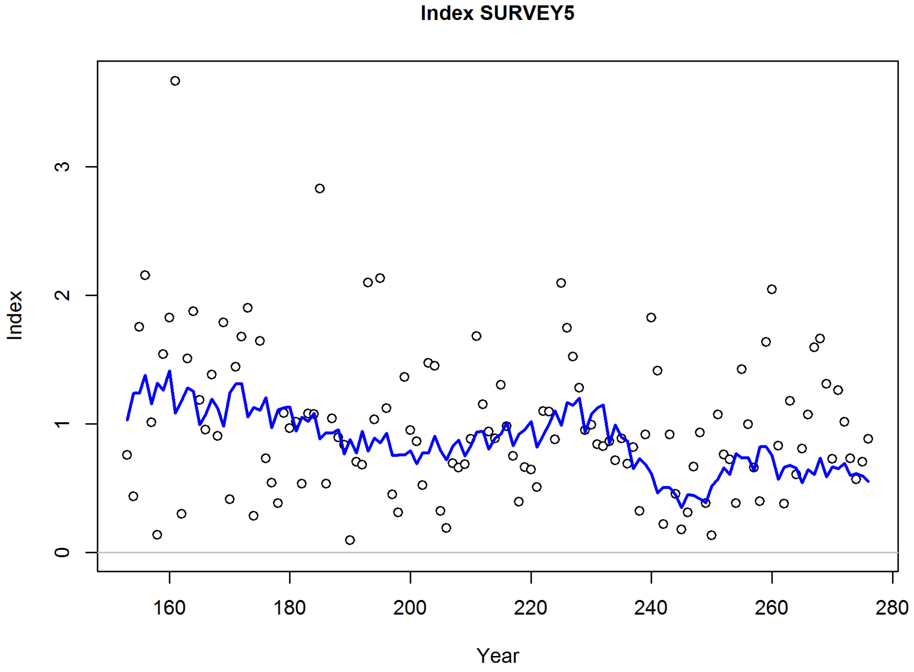

Figure 8. Predicted and observed yellowfin PSLS CPUE (in these r4ss plots, "Years" are actually quarters ending in 2016, due to the convention of structuring model years as calendar quarters for these assessments).

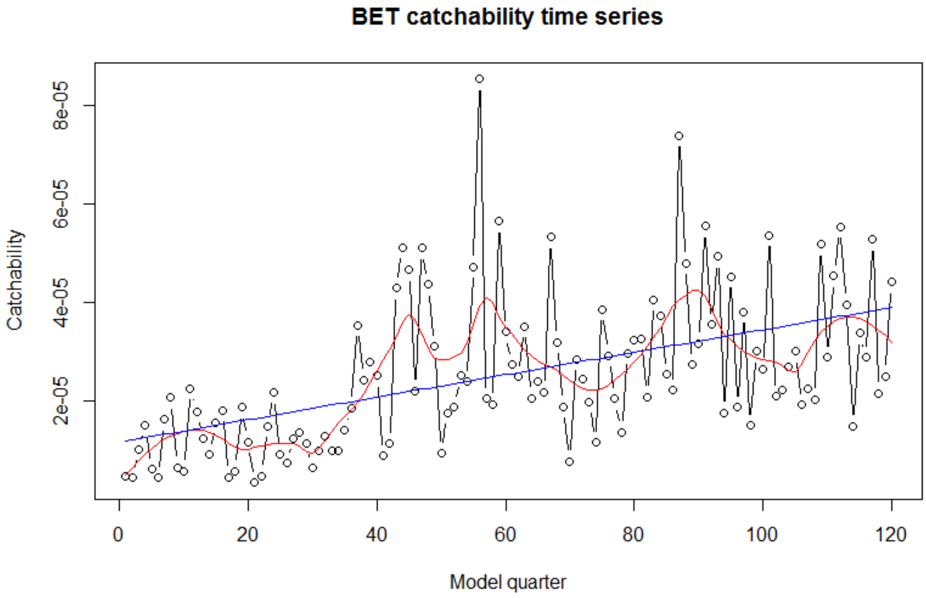

Figure 9. Time-varying catchability estimates for the bigeye PSLS fishery. Red line is a loess smoother, blue line is a linear regression fit, with a slope that corresponds to a 4.1% per year trend (compounded annually over a 30 year period).

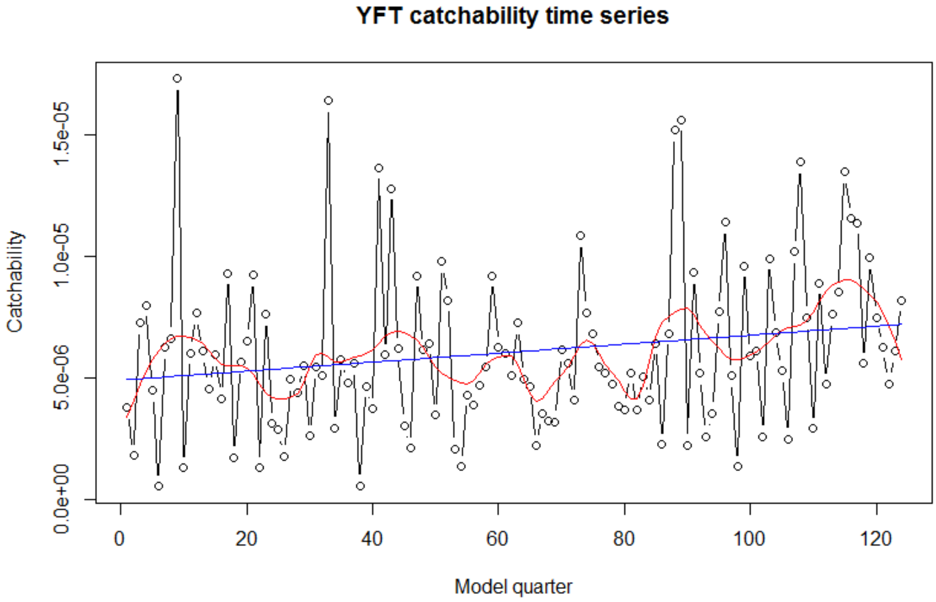

Figure 10. Time-varying catchability estimates for the yellowfin PSLS fishery. Red line is a loess smoother, blue line is a linear regression fit, and corresponds to a 1.25 % per year trend (compounded annually over a 30 year period).

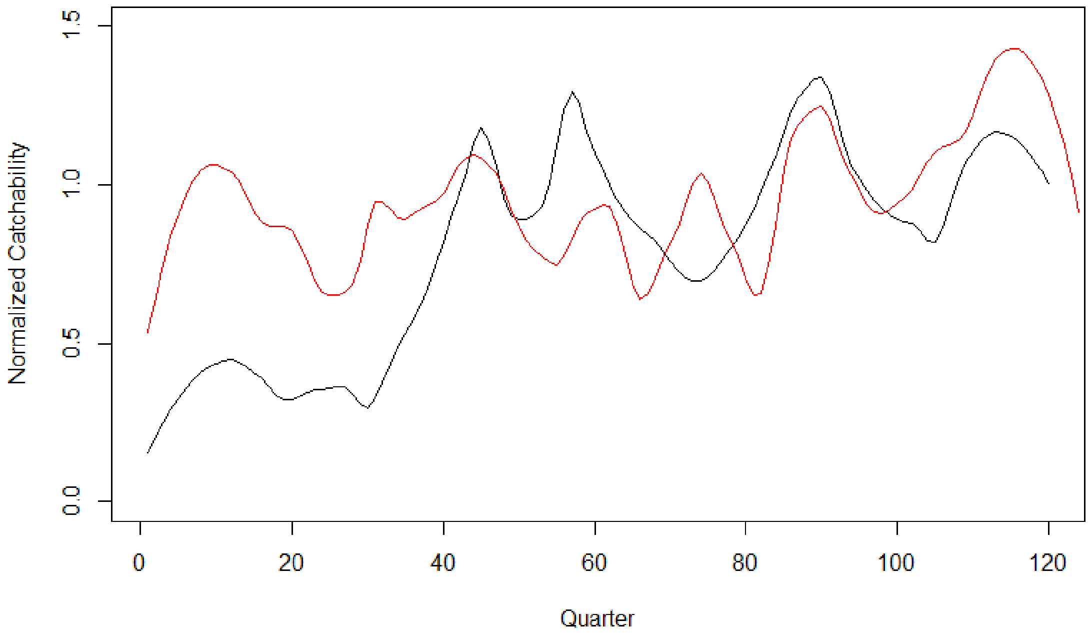

Figure 11. Comparison of PSLS catchability trends (loess smoothed) estimated from the bigeye (black) and yellowfin (red) assessments, re-scaled to the respective means over the most recent shared 20 year period.

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