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Pacific-wide Silky Shark (Carcharhinus falciformis) Stock Status Assessment

ADDENDUM

WCPFC-SC14-2018/ SA-WP-08
(8 August 2018)

COMMON OCEANS [ABNJ] TUNA PROJECT

Pacific-wide Silky Shark (*Carcharhinus falciformis*) Stock Status Assessment

Addendum

Funding from the Common Oceans (ABNJ) Tuna Project for shark stock status assessment requires that the studies be scoped to encompass the entire Pacific Ocean. In conformance with this requirement, the assessment team developed a Pacific-wide model and worked collaboratively to draw appropriate conclusions from that model for a report to WCPFC SC14. Since posting of the assessment on 22 July 2018[1], further discussions with external reviewers and amongst the assessment team has led to further consideration of the robustness of a WCPO-only model.

Based on the Pacific-wide model we gained critical new insights regarding the influence of oceanographic conditions on catch rates. However, our attempts to reflect those oceanographic conditions in movement parameters within a multi-region model resulted in a failure to fit both eastern and western Pacific catch rate indices simultaneously. Even when the fit to one region was prioritized over the other, the Pacific-wide model's fit to the prioritized region's data remained poor. In stepping back from the Pacific-wide model an alternative approach emerged involving use of a single-region model (for the WCPO) and the parameterisation of catchability—rather than movement—to reflect oceanographic conditions. Under this approach the model's fit to the primary WCPO CPUE index improved considerably.

There are still important uncertainties in the newly parameterized, single-region (WCPO) model including the relatively short index of abundance time-series (14 years) and our lack of understanding of the relationships between oceanographic conditions and abundance. Nevertheless, this new (2018) WCPO-only model provides an updated perspective from the results of the previous WCPO silky shark stock assessment in 2013[2]:

- The 2018 WCPO-only model estimates that the silky shark population is depleted to 47-50% of its original (virgin) biomass. This level of depletion is less than that determined from the 2013 model which estimated the WCPO stock had been depleted to ~30% of the original biomass.

- The 2018 WCPO-only model also estimates that current biomass is likely to be above the MSY reference biomass (i.e. not overfished) ($Pr(SB_{2016} > SB_{MSY}) = 72\%$). In contrast, the 2013 assessment concluded that it is highly likely that the stock is in an overfished state.

- In terms of fishing mortality (F), the 2018 WCPO-only assessment estimates that current F is 1.6 times the MSY fishing mortality (i.e. overfishing is occurring). This estimate of F_{2016}/F_{MSY} is considerably lower than the 2013 assessment's estimate of 4.48.

It is important to note that point estimates such as these are easy to report and compare, but do not reflect the extent of uncertainty in the results. Confidence intervals around these reported point values remain broad, indicating a high degree of uncertainty in the estimates. In

[1] S. Clarke, A. Langley, C. Lennert-Cody, A. Aires-da-Silva and M. Maunder. 2018. Pacific-wide silky shark (*Carcharhinus falciformis*) stock status assessment. WCPFC-SC14-2018/SA-WP-08.
[2] J. Rice and S. Harley. 2013. Updated stock assessment of silky sharks in the Western and Central Pacific Ocean. WCPFC-SC9-2013/SA-WP-03.

summary, though, the estimates of WCPO silky shark stock status are less pessimistic than characterised by the previous assessment. The differences in the 2018 assessment results are due to the differences in the main data inputs (catch history and CPUE indices) and the treatment of the main CPUE index in the modelling framework (i.e. accounting for environmental variation in catchability).

This study, in both its Pacific-wide and WCPO-only models, has made good progress toward understanding the status of silky sharks. While uncertainty is lower for the WCPO-only model, there remains a critical need for continued data improvement and further model development at both scales. The Pacific-wide and WCPO-model conclusions are consistent and the text presented in the Pacific-wide assessment covering note (WCPFC-SC14-2018/SA-WP-08) is maintained for SC14's consideration.

The remainder of this addendum provides the technical details supporting the additional, WCPO-only model with the environmentally-driven catchability parameterization.

WCPO Model Structure and Results

The WCPO-only model data sets are equivalent to the data included in the WCPO region of the Pacific-wide model. The biological parameters and main structural assumptions, related to recruitment, fishery selectivities and initial conditions, are also equivalent to the Pacific-wide model. The WCPO-only model is configured with a single model region (spatially aggregated). All data from the EPO region of the Pacific-wide model were excluded from the WCPO-only model.

The primary index of abundance for the WCPO-only model is the time series of SP_LL CPUE indices. An *Initial* model option included the CPUE indices with a constant catchability (as in the Pacific-wide model). However, the fit to the SP_LL CPUE indices from the *Initial* model is very poor (Figure 1, blue line) and, on that basis, this model option was rejected.

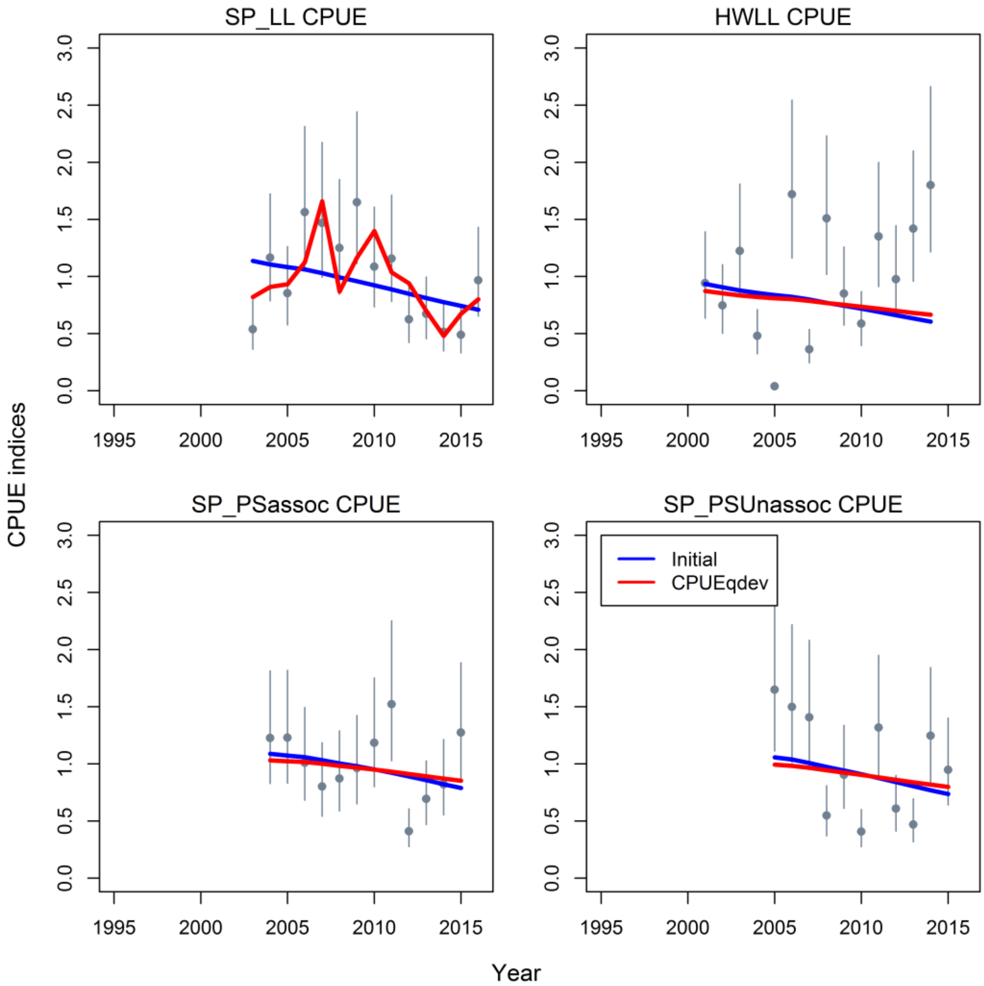

Figure 1. Fit to the CPUE indices included in two WCPO-only model options: the *Initial* model with constant catchability and the *CPUEqdev* model with variation in catchability linked to an environmental variable. Only the SP_LL CPUE index is included in the model likelihood.

Previous analyses revealed a correlation between the SP_LL CPUE indices and SST anomalies in the Nino Index Regions of the Pacific. The SP_LL CPUE indices are negatively correlated with the annual average SST anomaly from Nino4 region in the following year (correlation coefficient = -0.68) (Figure 2).

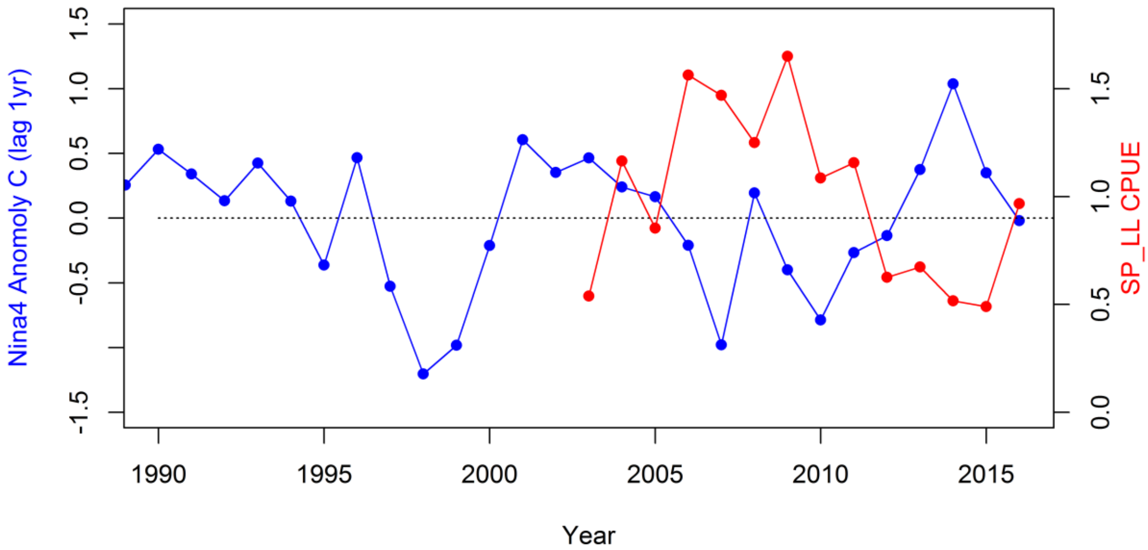

Figure 2. A comparison of the SP_LL CPUE indices and the annual Nina4 SST anomaly.

The model was modified to incorporate variation in the catchability coefficient for the SP_LL linked to the Nino4 environmental index (*CPUEqdev* model). The relationship was parameterised as follows:

$Catchability(y_i) = baseQ + link * env(y_i)$

where:

baseQ is the estimated base catchability coefficient for the SP_LL CPUE index;
link is the estimated parameter linking the environmental covariate (Nino4) to the SP_LL CPUE catchability;
$env(y_i)$ is the value of the environmental variable (Nino4) in year *i* ; and
$Catchability(y_i)$ is the catchability coefficient for the SP_LL CPUE index in year *i*.

For the *CPUEqdev* model, the *link* parameter was estimated to be -0.529 (standard deviation 0.108) which is consistent with the correlation between the SP_LL CPUE indices and the Nino4 environmental index. The inclusion of the environmental variation in the catchability substantially improved the fit to the SP_LL CPUE indices (Figure 1) with a corresponding improvement in the model likelihood (from 513.042 to 501.128). The annual catchability coefficients for the SP_LL CPUE indices vary by a factor of 2.91 over the time series (Figure 3). Nonetheless, there remains some lack of fit to the SP_LL CPUE indices with the model tending to under-estimate the earlier CPUE indices (2004, 2006, 2008 and 2009) (Figure 1).

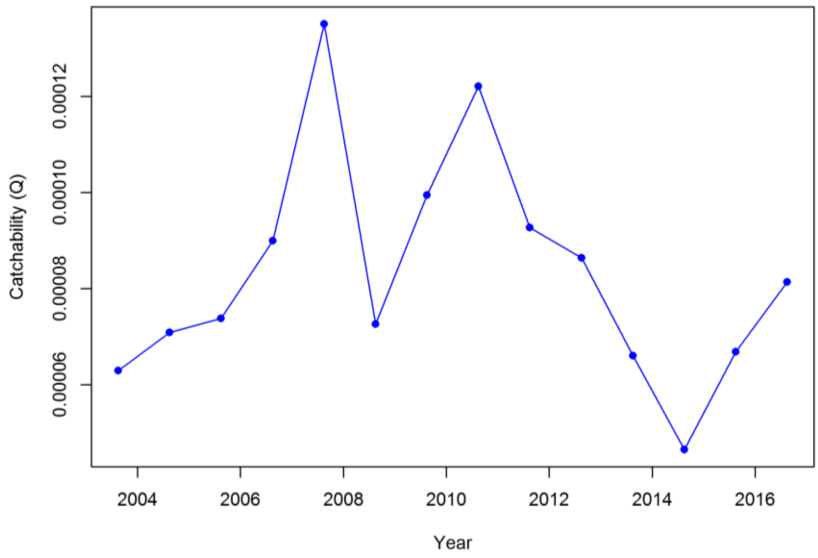

Figure 3. Annual catchability coefficients for the SP_LL CPUE indices from the *CPUEqdev* model.

The trends in stock biomass from the *CPUEqdev* model are inconsistent with the three other sets of WCPO CPUE indices (Figure 1). These other sets of CPUE indices are not included in the model estimation procedure and are presented for comparison only. However, the lack of fit indicates either additional complexity in the spatial structure of the WCPO silky shark population, that the other components of the stock are influenced by different oceanographic conditions, and/or the individual sets of CPUE indices may not adequately represent trends in stock abundance.

There was no appreciable change in the fit to the length composition data from the five data sets with the inclusion of the variation in catchability. As was the case for the Pacific Ocean models, the *CPUEqdev* model provided a reasonable fit to the aggregated length compositions from each fishery while not accounting for the observed temporal variation in the length compositions from each fishery or the length composition associated with the SP_LL CPUE time-series.

For the *CPUEqdev* model, SB_{MSY} is estimated to be 0.398 of the SB_0, reflecting the low productivity of the species (given the assumed value of steepness) (Table 1). The point estimate of current (2016) spawning biomass (0.469 SB_0) is above the SB_{MSY} level, although there is considerable uncertainty associated with the estimate of stock status and there is some likelihood that the stock is below the SB_{MSY} level (Pr ($SB_{2016} < SB_{MSY}$) = 28%).

The model catch for 2016 was 21,932 mt which is substantially higher than the estimates of *MSY*. Correspondingly, current (2016) fishing mortality rates are estimated to be above the F_{MSY} level (Pr ($F_{2016} > F_{MSY}$) = 84%), although the estimate is highly uncertain (F_{2016}/F_{MSY} 95% confidence interval is 0.316-2.810).

Table 1. Estimates of stock biomass, potential and current stock status for the WCPO model options (standard deviations in brackets). The preferred model option is highlighted. Estimates of model uncertainty were derived from the inverse Hessian matrix.

Model	SB_0	SB_{MSY}/SB_0	MSY	SB_{2016}/SB_0		F_{2016}/F_{MSY}	
Initial	9,257	0.399	9,606	0.352	(0.101)	2.523	(0.873)
CPUEqdev	**11,865**	**0.398**	**12,163**	**0.469**	**(0.122)**	**1.607**	**(0.627)**
CPUEqdev/IntialCatch_Level1_SEhigh	11,865	0.398	12,163	0.469	(0.122)	1.607	(0.627)
CPUEqdev/IntialCatch_Level1_SElow	11,609	0.398	11,879	0.484	(0.121)	1.606	(0.627)
CPUEqdev/IntialCatch_Level05_SEhigh	11,559	0.398	11,823	0.488	(0.126)	1.602	(0.630)
CPUEqdev/IntialCatch_Level05_SElow	11,561	0.398	11,805	0.505	(0.121)	1.562	(0.618)

Further model options were investigated to evaluate model assumptions regarding the level of depletion at the start of the model (1995) related to the assumed level of initial equilibrium catch (i.e. Level1, 100% of 1995 catches; Level1, 50% of 1995 catches) and associated uncertainty of those catch levels (i.e. standard error (SE) high or low). The model estimates of current (2016) stock biomass were insensitive to these assumptions (Table 1 and Figure 4).

Overall, the *CPUEqdev* model provides a significantly better fit to the primary WCPO CPUE index compared to the *Initial* model. The change in the parameterisation of the model influences the key stock status indicators (Table 1). Nonetheless, the results of the *CPUEqdev* assessment model should be considered with caution as the model is reliant on a short time-series of CPUE indices (14 years) which is mediated by an environmental covariate that is assumed to be directly linked to the catchability of the fishery. The nature of the relationships between the WCPO oceanographic conditions, variation in SP_LL CPUE, and the overall abundance of the WCPO stock is unknown.

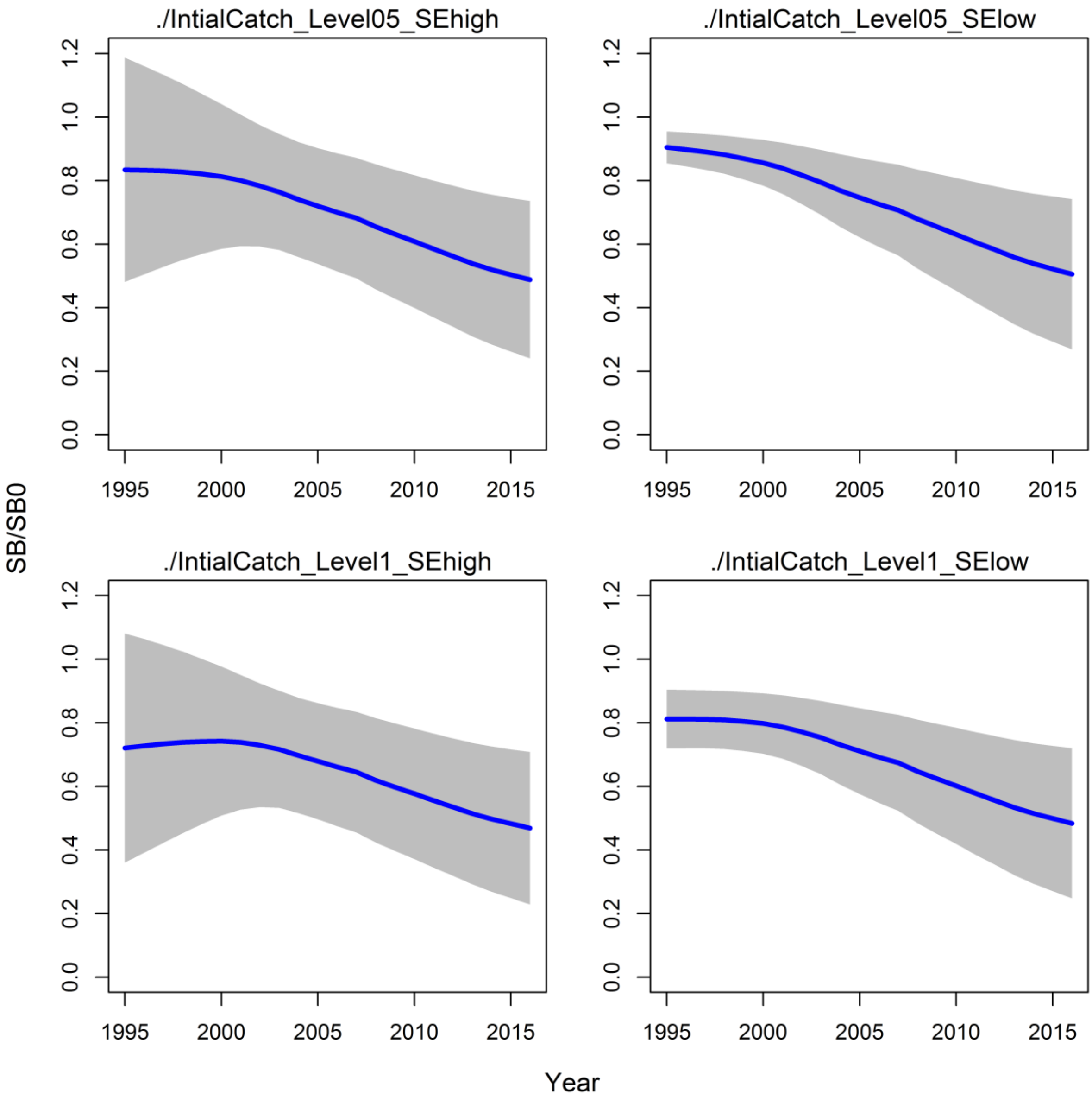

Figure 4. A comparison of model options of the *CPUEqdev* model with different assumptions regarding the magnitude (i.e. Level1 = 100% of the 1995 catches; Level05 = 50% of the 1995 catches) and uncertainty (i.e. SE high or low) of the initial equilibrium catches.