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WCPFC Project 79: Analysis of regional longline catch options for removing bigeye overfishing

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Paper by SPC-OFP

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At SC12, WCPFC project 79 ("Spatial analysis of WCPO longline fishing in support of bigeye tuna management in the WCPFC-Convention Area") was agreed, which tasked SPC-OFP to provide managers information on spatial aspects of regional bigeye depletion due to longline fishing. The full project terms of reference is provided in Appendix 1.

Methodology

To examine the relative longline bigeye catch levels that achieve removal of overfishing, we performed a range of deterministic stock projections from the bigeye reference case model (Harley et al., 2014). Two related analyses were performed:

1. Step 1: Identification of regional longline bigeye catch levels that achieved $F=F_{MSY}$.
2. Step 2: Identification of regional longline bigeye catch levels that also achieve comparable regional depletion levels, which extended the analysis in step 1.

Identification of regional longline bigeye catch levels that achieved $F=F_{MSY}$

The bigeye stock assessment model includes fifteen longline fisheries, across 9 spatial regions (Figure 2). Projections were conducted assuming alternative regional longline bigeye catch levels into the future. Catch scalers (relative to 2012 catches) were applied to groups of longline fisheries operating within each region.

From the evaluation of the tropical tuna CMM 2014-01, in which future purse seine associated (FAD) effort was assumed to equal '2015 choices', a multiplier for 2012 longline catches of 0.84 across all longline fisheries achieved F/F_{MSY} = 1.06, for the fishery as a whole. Therefore it was likely that, on average, a greater level of catch reduction across all longline fisheries would be required to remove overfishing.

The exact combinations of regional longline catch that achieved removal of overfishing depended upon their relative regional impact. Therefore, the decision was taken to run a wide grid of alternative combinations of regional catch scalars, to identify the combinations that achieve F/F_{MSY} = 1 at the end of a 10 year projection period. A challenge with this approach was that in order to obtain all unique combinations of longline catch levels that removed overfishing many scalars need to be examined, with the number of runs required increasing exponentially. For example, with six scalars examined across nine fisheries, the number of runs would be 10,077,696 (6^9). Therefore the problem needed to be constrained.

Preliminary analyses identified that changes in the bigeye catch within the longline fisheries in regions 8 and 9 (archipelagic waters of PNG/Solomon Islands and the Coral Sea region) had a negligible effect on bigeye overfishing (Figure 1). The decision was therefore taken to maintain catches in these regions at 2012 levels. This reduced the number of scalar combinations to be examined.

We investigated longline catch scalers between 0.3 and 0.8 in increments of 0.1 but there was insufficient time to complete all of the runs necessary to calculate every unique combination of scalers across the 7 regions considered (around 280,000 combinations) consequently the individual scalers differ slightly in some cases, for example some runs have employed scalers between 0.4 and 0.8 in increments of 0.2, others between 0.3 and 0.7 in increments of 0.2. However the results are broadly indicative of the range of regional longline catch scalers that would be required to remove bigeye overfishing.

Other projection settings

- Purse seine associated (FAD) effort was set to '2015 choices' (0.95 x 2012 effort), consistent with the analysis of CMM 2014-01 (SPC, 2015). All other fisheries were set to 2012 levels except for longline fisheries in regions 1 to 7, to which a range of catch scalers were applied.
- Future recruitment within these deterministic projections was assumed to equal the average of those actual levels estimated in the most recent period (2002-2011)[1]
- Projections were run from 2012 for 10 years and the F_{2022}/F_{MSY} evaluated. We note that changes in longline catch and purse seine associated effort levels will achieve exploitation rate targets (eg. F_{MSY}) more rapidly than biomass-based targets (SB_{MSY}) since greater time is required for the population to 'grow' to the biomass level.

In total, 50,070 deterministic projection runs were performed across a range of regional longline catch scalers. For those projections that achieved the objective by 2022 (F_{2022}/F_{MSY}=1, 330 runs), the relevant scalars along with their corresponding regional exploitation (F_{2022}/F_{MSY}) and depletion ($SB/SB_{F=0}$) rates are provided in the accompanying spreadsheet.

Caveats and assumptions

A number of important assumptions must be made, particularly when using the MULTIFAN-CL stock assessment model to assess regional patterns. These are:

- The model assumes constant regional movement over time
- The model estimates the pattern of regional recruitment that best fits the data supplied. This pattern of regional recruitment is assumed constant in the future.
- The fleet structures and area based catches projected into the future are based on those of the terminal year of the assessment (2012).
- The reweighting of fleets that have different regional selection patterns will alter the overall selection of the fishery and may consequently lead to changes in MSY (and hence, in combination with the recruitment assumption, the equivalent value of $SB/SB_{F=0}$).
- Catchabilities in each fishery are assumed to remain constant into the future.

We note that the exploitation and depletion rates will only be identified at the end of the time series, and those levels may continue to change following the end of the projection, as the population adjusts to the assumed recruitment and regional exploitation levels.

[1] NOTE: this setting is comparable to – but not exactly the same as – the approach used in bigeye stochastic projection analyses. Therefore results in the current analysis and those in, for example, the evaluation of the tropical tuna CMM will be slightly different, with those in the stochastic projections being slightly more optimistic. In addition we have run 10 year projections here whereas the evaluation of the tropical tuna CMM was based on 20 year projections.

We present the exploitation rate as regional F values (averaged across all ages) and depletion as the regional adult biomass in 2022 divided by the regional adult biomass in the absence of fishing ($SB_{2022}/SB_{F=0}$).

Identification of regional longline bigeye catch levels that also achieve comparable regional depletion levels

The terms of reference additionally requested that the analysis attempt to identify combinations of longline catch scalers that would achieve F_{MSY} within the time frame and also result in similar regional depletion among the assessment regions. Identification of combinations of longline catch scalers that fulfil these requirements is challenging because:

1. recruitment is not equally distributed between regions so some regions will be more sensitive to changes in catch rates than others. Furthermore some regions may not be able to achieve an equivalent biomass depletion, even under zero longline fishing, because of the existing depletion due to purse seine and other gears;
2. fish move amongst regions and therefore changes in catch rates in one region will impact on biomass levels in other regions, and
3. changes in regional catches may change the overall selection pattern, leading to changes in F_{MSY}. This means that the target you are trying to achieve is not stationary.

Using the projection approach described under step 1, we employed an algorithm that iteratively adjusted the longline catch scalers for regions 1 to 7 based on minimising the differences between regional depletion ($SB_R/SBF{=}0_R$, where R represents regions 1 to 7) and the average regional depletion across those 7 regions. As for the first part of this analysis we omitted regions 8 and 9 from the minimisation as they represent only a very small proportion of the total catch, although these regions are still shown in the results. For each iteration, the algorithm ran two phases. The first modified the regional catch scalers, and the second rescaled those adjusted scalers back to those that would achieve F_{MSY}. We applied a tolerance threshold of 0.001 for both the sum of the absolute differences in catch scalers between successive iterations and for the absolute difference between F and F_{MSY}.

We ran the minimisation over 5 scenarios. The first determined catch scalers across all seven of the regions considered. For the remaining 4 scenarios we fixed the catch scaler for region 4 (the region where longline fishing has the greatest relative impact on stock status; see Figure 1) to values of 0.05, 0.2, 0.4 and 0.6.

A similar scenario in which catch scalers that achieved similar exploitation rates across regions was also suggested in the terms of reference. We note that selection patterns differ between regions and it was not clear how an exploitation rate targeted at older, larger individuals in one region could be compared to another region in which younger, smaller individuals were targeted. For this reason we present our results for this section only in terms of regional depletion.

Results

The results of the two analysis steps are presented below.

Identification of regional longline bigeye catch levels that achieved $F=F_{MSY}$

The accompanying spreadsheet shows the 330 combinations of longline catch scalers that exactly achieve F_{MSY} in 2022, as well as estimates of regional depletion and regional exploitation rates. We found that none of the projection scenarios that we considered in the initial grid (scalers between 0.3 and 0.8) provided consistent patterns across regions for either depletion or exploitation rate. Tables 1 and 2 present a selection of potential regional longline catch scalers that achieve the F target by 2022 along with corresponding regional exploitation rate (Table 1) and depletion rate (Table 2) estimates. It shows that changes in regional longline catches have, in many cases, little impact on regional estimates of fishing mortality or depletion. This is likely because longline catches represent only a part of the total removals by the fishery and is also due to the distribution of recruitment and the movement of fish between regions. A much wider range of catch scalers than those considered in our first analysis is required in order to achieve significant changes in regional depletion.

The projections have been based on a 10 year time period. As noted above it may take longer than 10 years for the population to respond to the changes in regional catches. As such, the regional biomass and F values presented here may not reflect equilibrium conditions for the regional longline catch scenarios investigated.

The projections conducted to evaluate CMM2014-01 were run for a 20 year period. Consequently the catch reductions necessary to reach $F/F_{MSY}=1$ in a 10 year period, as determined from this analysis, may be greater than those necessary to reach the target over a 20 year period.

Identification of longline catch scalers that result in similar regional depletion

The results of the five scenarios considered (Table 3) show that even with zero longline fishing in regions 3, 4 and 7, (scenario 1) it is not possible to achieve equal depletion across all regions. Regions 1, 2, 5 and 6 achieve equal depletion rates of around 40% $SB_{F=0}$ but all other regions are below this level. It should be noted that achieving equal depletion across regions 1, 2, 5 and 6 requires a significant increase in catch in some regions (catch scalers of 1.23 in region 1 and of 4.42 in region 2).

As the catch scaler for region 4 is increased to 0.05 (scenario 2) very little changes for the other regions. But at values of 0.2, 0.4 and 0.6 for region 4 (scenarios 3, 4 and 5 respectively) there is a progressive decrease in depletion experienced in regions 1, 2, 5 and 6. The reduced depletion in these regions occurs because the increased catch from region 4 contributes strongly to overall fishing mortality, and in order to reach F_{MSY} across the whole fishery, fishing effort and therefore catch in the other regions must be reduced, leading to increased biomass in regions 1, 2, 5 and 6. Consequently, for a catch scaler of around 0.6 for region 4, catch scalers for other regions need to be reduced to less than 0.4 with corresponding depletion levels for regions 1, 2, 5 and 6 around 60% $SB_{F=0}$ (noting that regions 3, 4 and 7 remain at higher depletion levels).

We note that for scenarios 4 and 5 the tolerance threshold for the sum of the absolute differences in catch scalers between successive iterations was not achieved and that depletion values for region 1 for these scenarios are less consistent. This probably occurs as region 1 approaches its maximum possible $SB/SB_{F=0}$ value.

Conclusions

From the runs considered, the following general conclusions can be drawn.

1. The F/F_{MSY} target could be achieved across a broad range of potential longline catch scalers within a 10 year period.
2. Based on the scaler increments of 0.1 used in the analysis, there were no runs that achieved F/F_{MSY}=1 for which the region 4 longline catch scaler was greater than 0.7 (i.e. a 30% catch reduction), but options exist under that scaler that achieve $F < F_{MSY}$).
3. There are no scaler combinations that achieve equal depletion across all regions because biomass remains too low in some regions even with zero longline fishing.
4. It is possible to achieve approximately equal depletion rates across some of the regions, however, this requires significant increases in longline catch in some regions and that catches be reduced to zero in other regions.

The catch scalers presented in this analysis provide an insight into the scale of regional longline bigeye catches that may achieve F_{MSY} in a 10 year time frame and achieve broadly similar regional depletion levels, under the specified assumptions. We note that the levels of regional catch change implied by the scalers identified in this analysis are hypothetical and may in practice be unfeasible.

References

Harley, S., Davies, N. and Hampton, J. (2014). Stock assessment of bigeye tuna in the western and central Pacific Ocean. WCPFC-SC10-2014/SA-WP-01 Rev1.

Table 1. Example alternative combinations of regional longline bigeye catch scalers that achieve F_{2022}/F_{MSY} =1, where purse seine associated (FAD) effort at 0.95x2012 levels ('2015 choices').

Regional Longline Catch Multipliers							F_{2022}/F_{msy}	$SB_{2022}/SB_{F=0}$	Regional F								
R1	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**			**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**
0.8	0.8	0.6	0.4	0.5	0.7	0.6	1	0.277	0.018	0.007	0.033	0.056	0.021	0.024	0.031	0.075	0.024
0.4	0.8	0.5	0.4	0.8	0.8	0.7	1	0.277	0.017	0.007	0.033	0.056	0.021	0.029	0.031	0.075	0.024
0.7	0.6	0.8	0.4	0.7	0.8	0.5	1	0.278	0.015	0.007	0.029	0.056	0.021	0.029	0.036	0.075	0.024
0.3	0.3	0.3	0.7	0.5	0.5	0.5	1	0.276	0.011	0.007	0.031	0.065	0.012	0.024	0.028	0.075	0.024
0.4	0.8	0.5	0.4	0.8	0.8	0.7	1	0.277	0.017	0.007	0.033	0.056	0.021	0.029	0.031	0.075	0.024
0.4	0.8	0.5	0.4	0.8	0.8	0.7	1	0.277	0.017	0.007	0.033	0.056	0.021	0.029	0.031	0.075	0.024
0.8	0.5	0.5	0.4	0.8	0.4	0.8	1	0.278	0.017	0.006	0.029	0.056	0.021	0.029	0.036	0.075	0.024

Table 2. As for Table 1 but showing regional depletion for minimum scalers

Regional Longline Catch Multipliers							F_{2022}/F_{msy}	$SB_{2022}/SB_{F=0}$	Regional $SB_{2022}/SB_{F=0}$								
R1	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**			**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**
0.3	0.3	0.3	0.7	0.5	0.5	0.5	1	0.276	0.514	0.699	0.234	0.159	0.511	0.481	0.296	0.188	0.388
0.3	0.3	0.3	0.7	0.5	0.5	0.5	1	0.276	0.514	0.699	0.234	0.159	0.511	0.481	0.296	0.188	0.388
0.3	0.3	0.3	0.7	0.5	0.5	0.5	1	0.276	0.514	0.699	0.234	0.159	0.511	0.481	0.296	0.188	0.388
0.7	0.6	0.8	0.4	0.7	0.8	0.5	1	0.278	0.471	0.701	0.239	0.185	0.427	0.428	0.274	0.19	0.386
0.3	0.5	0.5	0.7	0.3	0.7	0.3	1	0.277	0.498	0.768	0.234	0.16	0.434	0.532	0.281	0.187	0.386
0.3	0.7	0.5	0.7	0.7	0.3	0.3	1	0.278	0.495	0.769	0.227	0.183	0.48	0.429	0.258	0.185	0.387
0.3	0.7	0.5	0.7	0.7	0.3	0.3	1	0.278	0.495	0.769	0.227	0.183	0.48	0.429	0.258	0.185	0.387

Table 3. Combinations of regional longline bigeye catch scalers that achieve F_{2022}/F_{MSY} =1.0 across the whole fishery and as close to equal depletion across regions as feasible. Regions 8 and 9 were not included in the minimisation (shaded columns) and catch scalers for region 4 have been fixed at values of 0.05, 0.2, 0.4 and 0.6 (dark shaded boxes). Purse seine associated (FAD) effort was fixed at 0.95x2012 levels ('2015 choices').

Scenario		All Regions	Region								
			R1	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**
1	LL Scaler		**1.23**	**4.42**	**0.00**	**0.00**	**0.90**	**0.86**	**0.00**	**1.00**	**1.00**
	$SB_{2022}/SB_{F=0}$	0.28	0.40	0.40	0.23	0.22	0.40	0.40	0.32	0.19	0.38
2	LL Scaler		**1.21**	**4.40**	**0.00**	**0.05**	**0.90**	**0.85**	**0.00**	**1.00**	**1.00**
	$SB_{2022}/SB_{F=0}$	0.28	0.40	0.40	0.23	0.22	0.40	0.40	0.32	0.19	0.38
3	LL Scaler		**0.80**	**3.77**	**0.00**	**0.20**	**0.70**	**0.75**	**0.00**	**1.00**	**1.00**
	$SB_{2022}/SB_{F=0}$	0.28	0.45	0.45	0.23	0.20	0.45	0.45	0.32	0.19	0.39
4	LL Scaler		**0.29**	**3.00**	**0.00**	**0.40**	**0.47**	**0.63**	**0.00**	**1.00**	**1.00**
	$SB_{2022}/SB_{F=0}$	0.28	0.52	0.52	0.22	0.18	0.52	0.52	0.32	0.18	0.39
5	LL Scaler		**0.12**	**1.99**	**0.00**	**0.60**	**0.23**	**0.46**	**0.00**	**1.00**	**1.00**
	$SB_{2022}/SB_{F=0}$	0.28	0.54	0.61	0.22	0.15	0.60	0.61	0.32	0.18	0.39

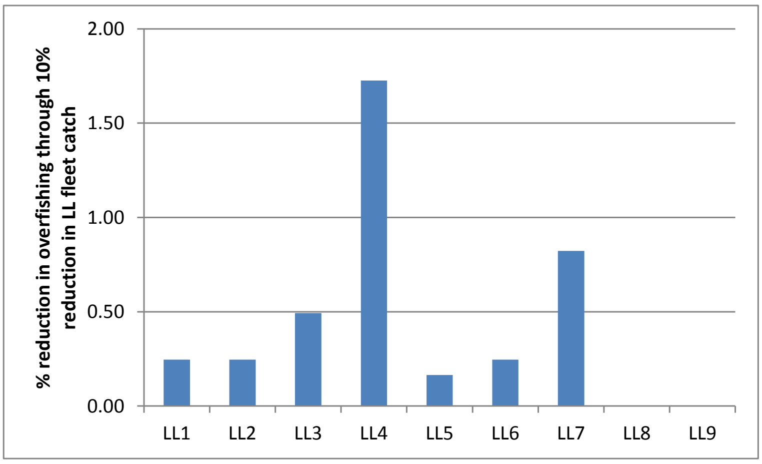

Figure 1. % of bigeye overfishing removed through a 10% reduction in the longline catch in each individual model region.

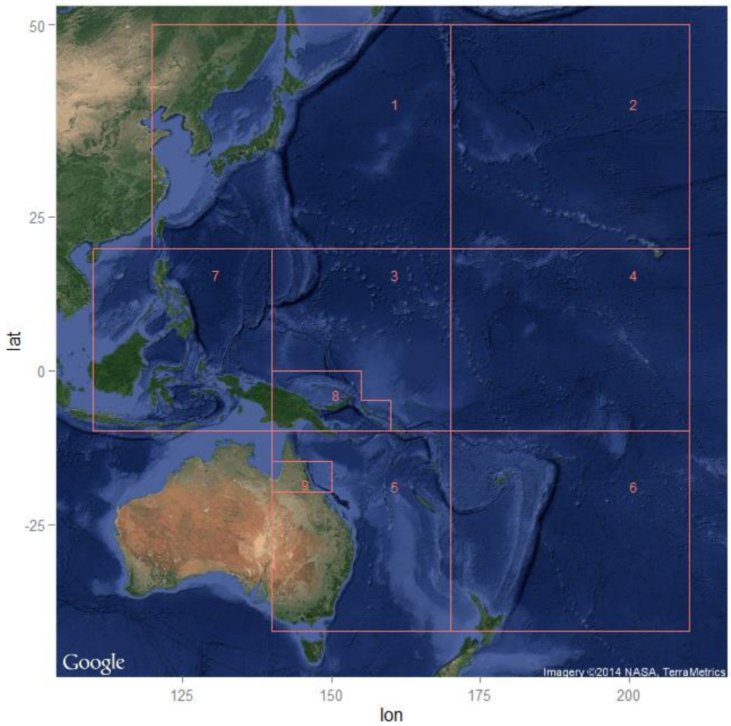

Figure 2. Regional structure of the 2014 bigeye reference case stock assessment model.

TERMS OF REFERENCE

Project 79: Spatial analysis of WCPO longline fishing in support of bigeye tuna management in the WCPFC-Convention Area

BACKGROUND

With regard to fishing mortality, the WCPFC SC, including the previous SC12 meeting, has commented on spatial considerations given the high fishing exploitation rates and fishery depletion in some regions of the MFCL assessments. The SC has expressed concern with regard to depletion in some regions for both yellowfin and bigeye tuna.

Objective

Complete an analysis utilizing MULTIFAN-CL bigeye stock assessment projections to provide managers information on spatial aspects of regional longline depletion.

Scope of work

With the following is assumed:

- Use the 2014 bigeye tuna reference case assessment in the western and central Pacific Ocean with deterministic projections;
- Use of recent average recruitment (2002 - 2011);
- Use of 2015 purse seine choices for future effort levels; and
- Use of 2012 catch in the Philippines and Indonesia.

The consultant will identify alternative levels of regional longline bigeye catch (relative to those in 2012) that achieve fishing mortality at the Maximum Sustainable Yield (Fmsy) level within a certain time frame, such as initially 10 years or additionally in 20 years if computationally feasible. Identified runs could include:

- Scenario 1 - The analysis would identify combinations of longline effort that represent similar regional exploitation rates and estimate a time-series of regional catches that achieved Fmsy in the time frame. Outputs would be a time-series of regional catch and effort and depletion.
- Scenario 2 – The analysis would identify combinations of longline effort that represent similar regional depletion estimates and achieve Fmsy in the time frame. Outputs would be a time-series of regional catch, effort and depletion.

The expected outcome would be an understanding of regional longline bigeye catch levels that achieve Fmsy in the specified time frame, and which may be consistent with similar regional exploitation rates or which achieve similar depletion levels among regions.

Outputs AND SCHEDULE

The principle outputs of the assignment will be:

- Submission to the WCPFC Secretariat of a final project report by 31 October 2016.
- The project report, when finalised, will be distributed to SC Heads of Delegation for review and may be included as an IP for WCPFC14.