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SPATIAL STOCK ASSESSMENT MODEL OPTIONS FOR BET IN THE EPO AND BEYOND

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CONTENTS

1. INTRODUCTION

Bigeye tuna (*Thunnus obesus*) are caught along tropical to temperate oceanic waters of the Pacific Ocean with largest catches taken towards the eastern and western ends of the ocean basin (Figure 1). There is evidence of extensive movement of bigeye (BET) across the nominal Western and Central Pacific Fisheries Commission (WCPO)/EPO boundary of 150W (Figure 2). The consequences of this directional movement for estimates of stock status in the WCPO were assessed in the 2015 Pacific-wide bigeye stock assessment (McKechnie et al., 2015) and the results suggested the current approach of modelling BET in the WCPO was robust to this process (McKechnie et al, 2017). In contrast, the impact of BET movements across the 150W on the robustness of the EPO BET assessment has not been evaluated yet. Recent research has resulted in a proposed new spatial structure for EPO BET assessment models (Minte-Vera *et al.*, 2019) along with alternatives (Valero *et al.* 2019). The new proposed spatial structure (Figure 3) was the basis of recent research on BET spatial modeling with and without movement within the EPO (Valero *et al.* 2019). Other recent research investigated alternative systematic spatial partitions within the EPO (Figure 4) to which age structured production models (*sensu* Punt *et al.* 1995) were implemented (Valero *et al.* 2018). The main driver in the developing of recent alternative BET stock assessment related modeling in the EPO is a recurrent feature of bigeye assessments in the EPO since 2003 (Harley et al. 2005; Fonteneau and Ariz 2008; Aires-da-Silva 2017): a sudden increase in the estimated recruitment starting in the mid-1990s, and resulting in an apparent "two-regime" pattern in recruitment, with estimates after 1993 about double those before that year.

One of the main challenges in implementing spatial stock assessments for BET in the EPO is the very limited information on juvenile movement and even more scarce information for adult bigeye. This has resulted in accounting for spatial processes / structure to some extent by using a "fleet-as-areas" approach in Stock Synthesis (see, for example, Cope and Punt 2011; Hurtado-Ferro *et al.* 2014), which assumes several fisheries that are defined by partitioning the data in space and act on the stock with different catchabilities and selectivities. In contrast, the BET assessment conducted by the WCPFC is a spatial model with movement, implemented in Multifan-CL. The most recent assessment (McKechnie *et al.* 2017) had 9 areas (Figure 5). The model is fit to a large tagging dataset which are used in conjunction with other data to estimate BET movement inside the integrated model. The equatorial areas were defined based on the recent tagging study by Schaefer et al (2015) and were redefined to be between 10°N and 10°S, instead of 20°N to 20°S as it was done previously. This structure was also proposed to reflect the spatial division of the equatorial purse seine fishing zone and areas dominated by longline fishing. This preliminary report focus on recent progress made on implementing spatial stock assessment models for EPO bigeye tuna. Since some of the work on spatial models for EPO BET has already been reported as part of the investigations on potential sources of causes of misspecification-induced regime shift in recruitment (Valero *et al.* 2019), this report will briefly focus on progress made on models linking the EPO and the adjacent area west of 150W (Figure 6).

2. METHODS

Alternative BET models were implemented in Stock Synthesis (v3.3.12) using a 6-area spatial structure resulting from the combination of the 4-area structure proposed by Minte-Vera *et al.* (2019) and the corresponding 2 adjacent WCPFC spatial areas (areas 4 and 6 of McKechnie *et al.* 2017) to the west of 150W (Figure 7). The very limited information on juvenile movement and even more scarce information for adult bigeye within the EPO, coupled with unquantified movement rates of neither juveniles nor adults across the 150W WCPFC and EPO limit necessitated assuming alternative movement scenarios for the Central and Eastern Pacific Ocean (CEPO) models. In addition to a no-movement scenario, we report here on 4 movement scenarios that were tried (Figure 8).

3. RESULTS AND DISCUSSION

Models were highly sensitive to the assumed movement rates and overall movement patterns, as expected, both on the time series of total spawning biomass (Figure 9) and the relative magnitude of biomass among the different areas (Figure 10). There were some model stability and convergence issues (Table 1), run times for the 6-area models ranged from 8 hours to 22 hours. None of the models removed the recruitment shift (Table 1) and resulted in larger R_{shift} (around 2.5) than the one estimated for the EPO base case model (R_{shiftl}= 1.97) except for the 6-area model with assumed no movement between areas (R_{shiftl}= 1.36) and the scenario that limited movement to only juveniles (R_{shiftl}= 1.18) across the 150W line for the EPO area with the largest recruitment shift (area 1 in Figure 7) and the adjacent central equatorial area (area 5 in Figure 7). However this last scenario run did not converge (very large gradient).

In addition to the lack of information on movement patterns and movement rates across the 150W, another challenge when building BET models beyond the EPO is the variation in estimated BET growth (particularly on L2) across the Pacific basin (see results from the IATTC 2019 Growth Workshop). Within the EPO we also found differences in estimated L2 among the areas proposed by Minte-Vera *et al.* (2019), Figure 11 and Figure 12.

4. REFERENCES

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5. TABLES

Table 1. 6-area models for BET in the Central and Eastern Pacific Ocean (CEPO) under different assumed movement scenarios, compared to the BET base case in the EPO with a lambda of 1 for composition data to make it comparable to the CEPO models.

Run	Description	R_{shift}	Observations
EPO Base	1 Area	1.97	
CEPO_2	6 area, No movement	1.36	Converged ?
CEPO_3	6 area, Movement Juveniles eastward, Adults Westward	2.55	Converged ?
CEPO_4	6 area, Movement Juveniles eastward, Adults move E and W	2.45	Converged ?
CEPO_5	6 area, E and W movement between C4 and A1, juveniles only	1.18	Not converged

6. FIGURES

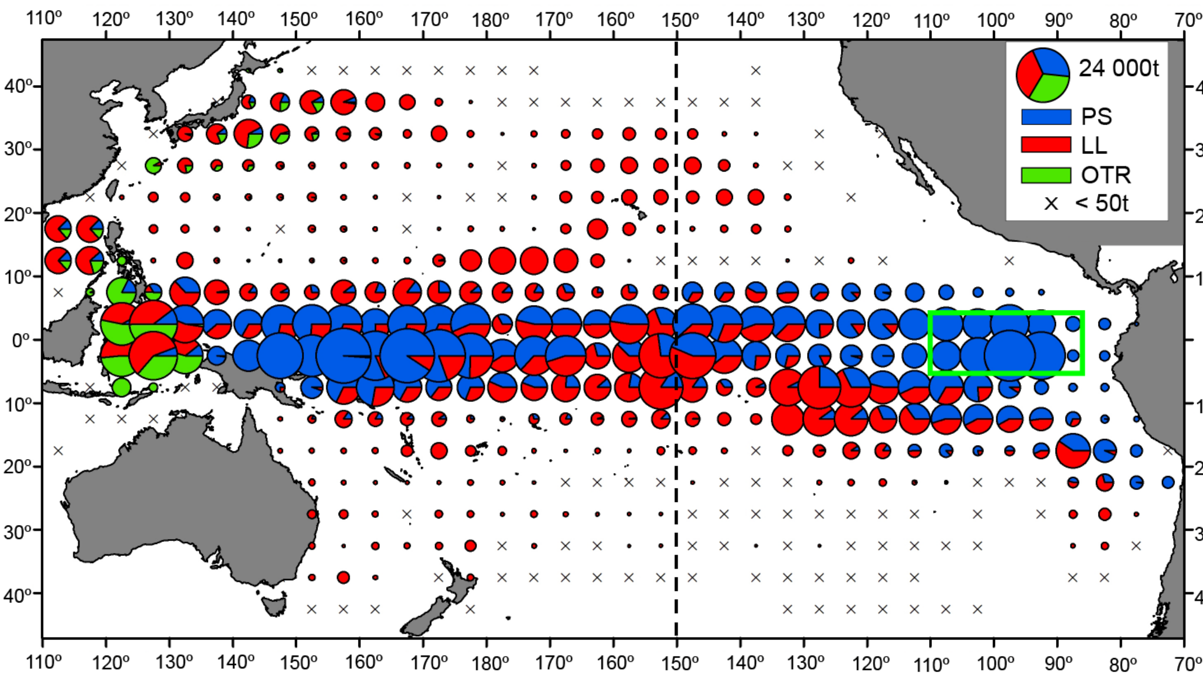

Figure 1. Distribution of the catches of bigeye tuna in the Pacific Ocean, by 5° x 5° area and gear type, 2008-2012. The sizes of the circles are proportional to the catch. The vertical dashed line at 150°W marks the western boundary of the eastern Pacific Ocean (EPO). The green rectangle represents the Central area used Valero et al. 2018. PS: purse seine; LL: longline; OTR: other gears.

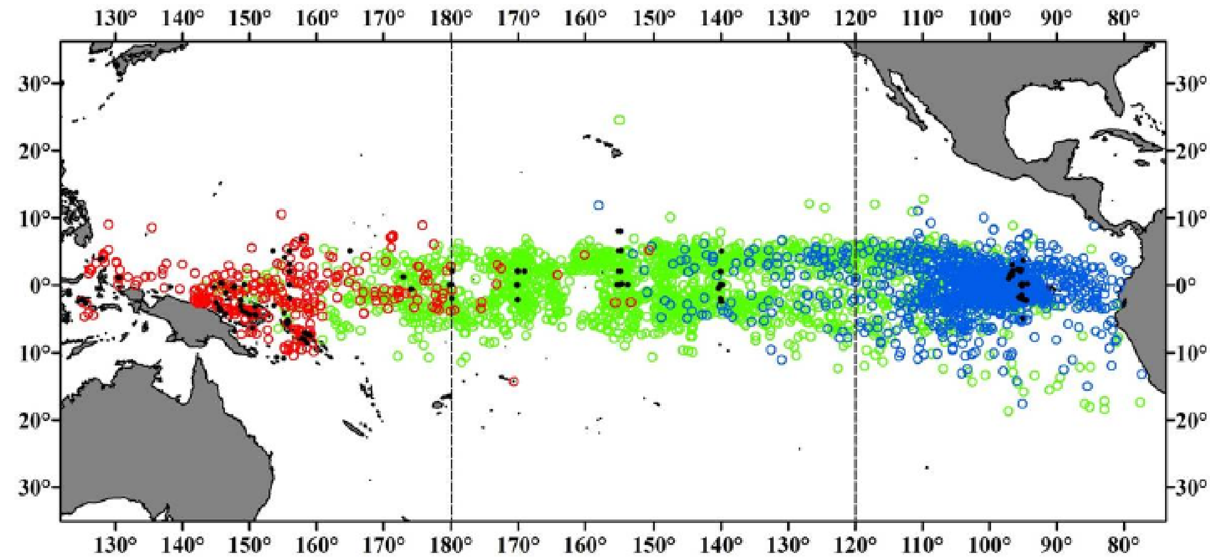

Figure 2. Map of BET tag releases (black points) and tag recoveries across three regions from Schaefer et al. (2015). The red points are the recapture locations of fish released in the western region, the green points are the recapture locations of fish released in the central region and the blue points are the re-capture locations of fish released in the eastern region.

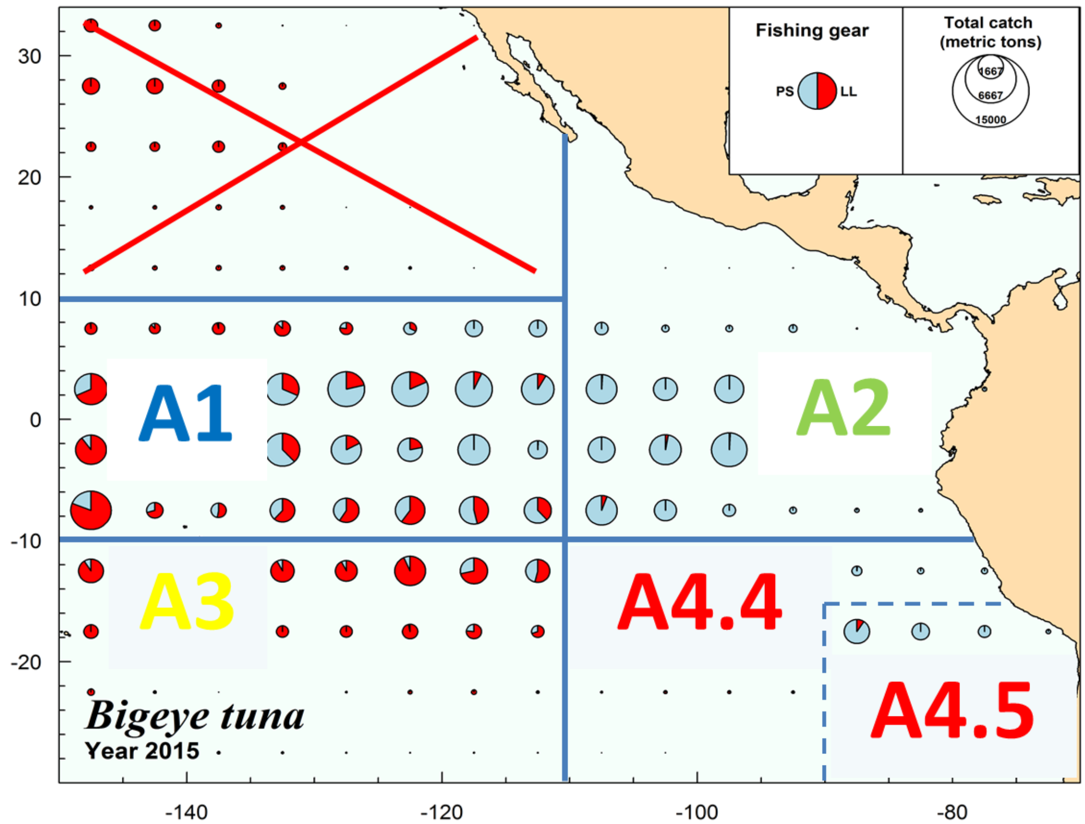

Figure 3. “Default” spatial structure configuration for BET in the EPO described in Minte-Vera *et al.* (2019).

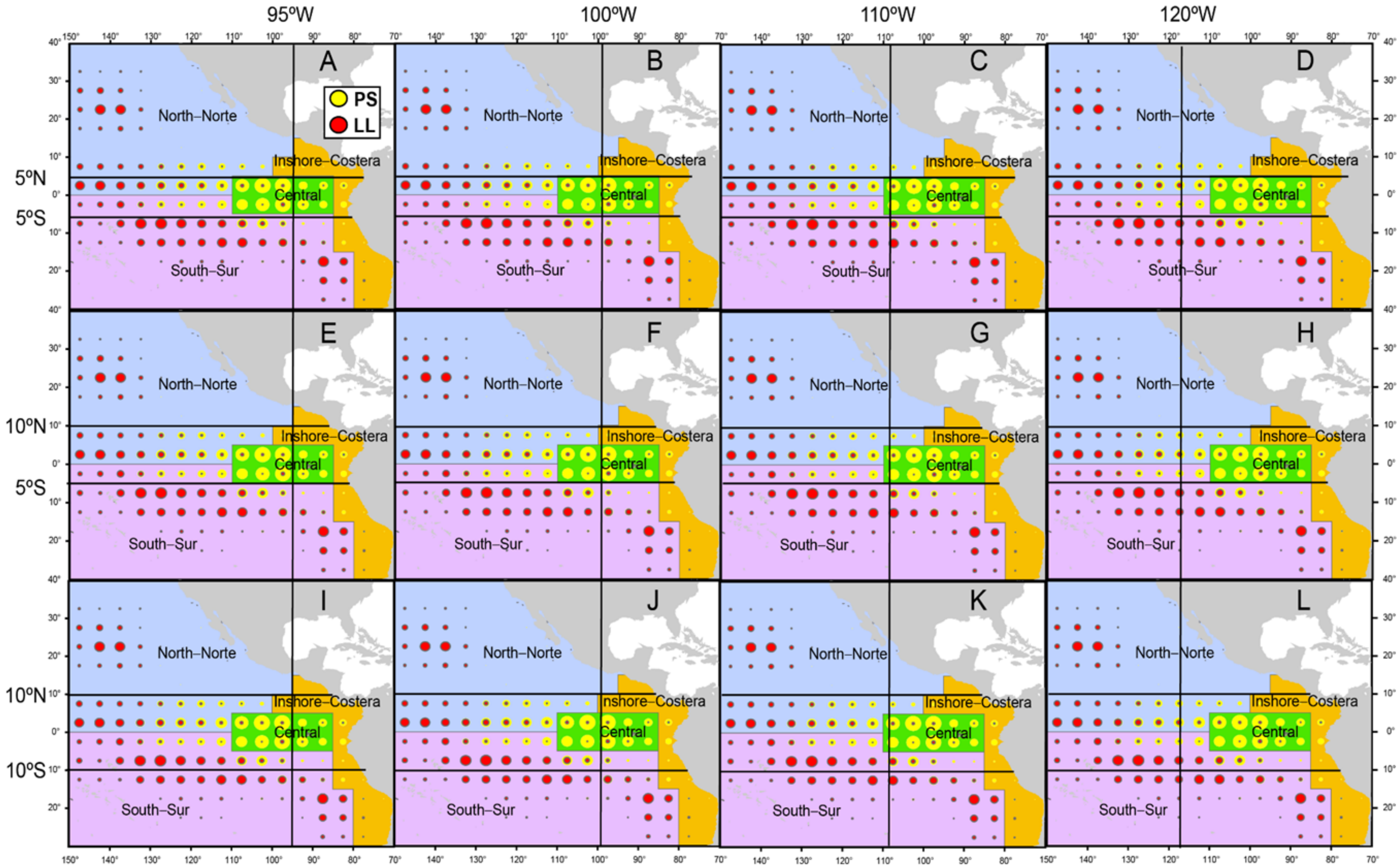

Figure 4. The 72 combinations of 12 grids (A-L) and six areas used for the age-structured production models (ASPM) conducted in Valero *et al.* 2018. PS: purse seine; LL: longline. From Valero *et al.* (2018).

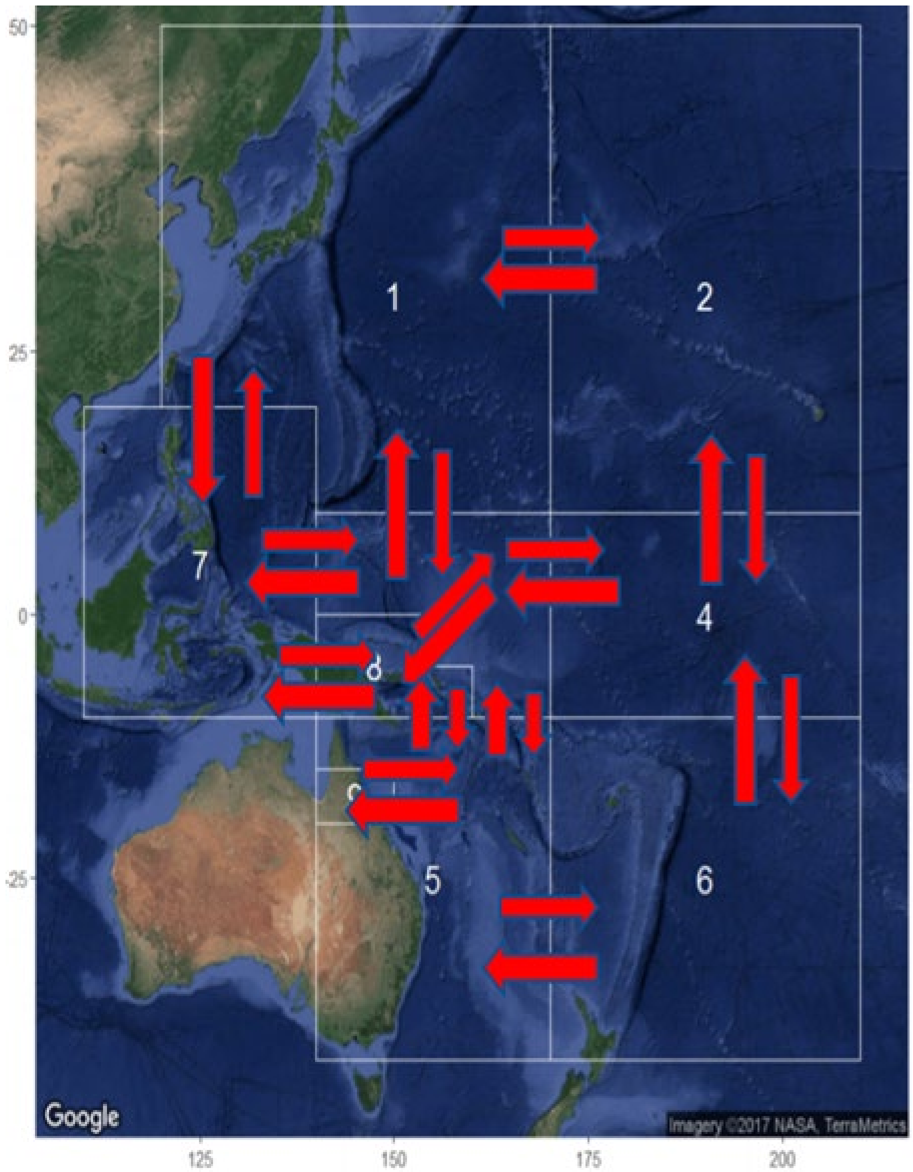

Figure 5. The geographical area covered by WCPO BET stock assessment, the boundaries for the 9 regions when using their "2014 regional structure" and movement patterns between the areas from McKechnie *et al.* 2017.

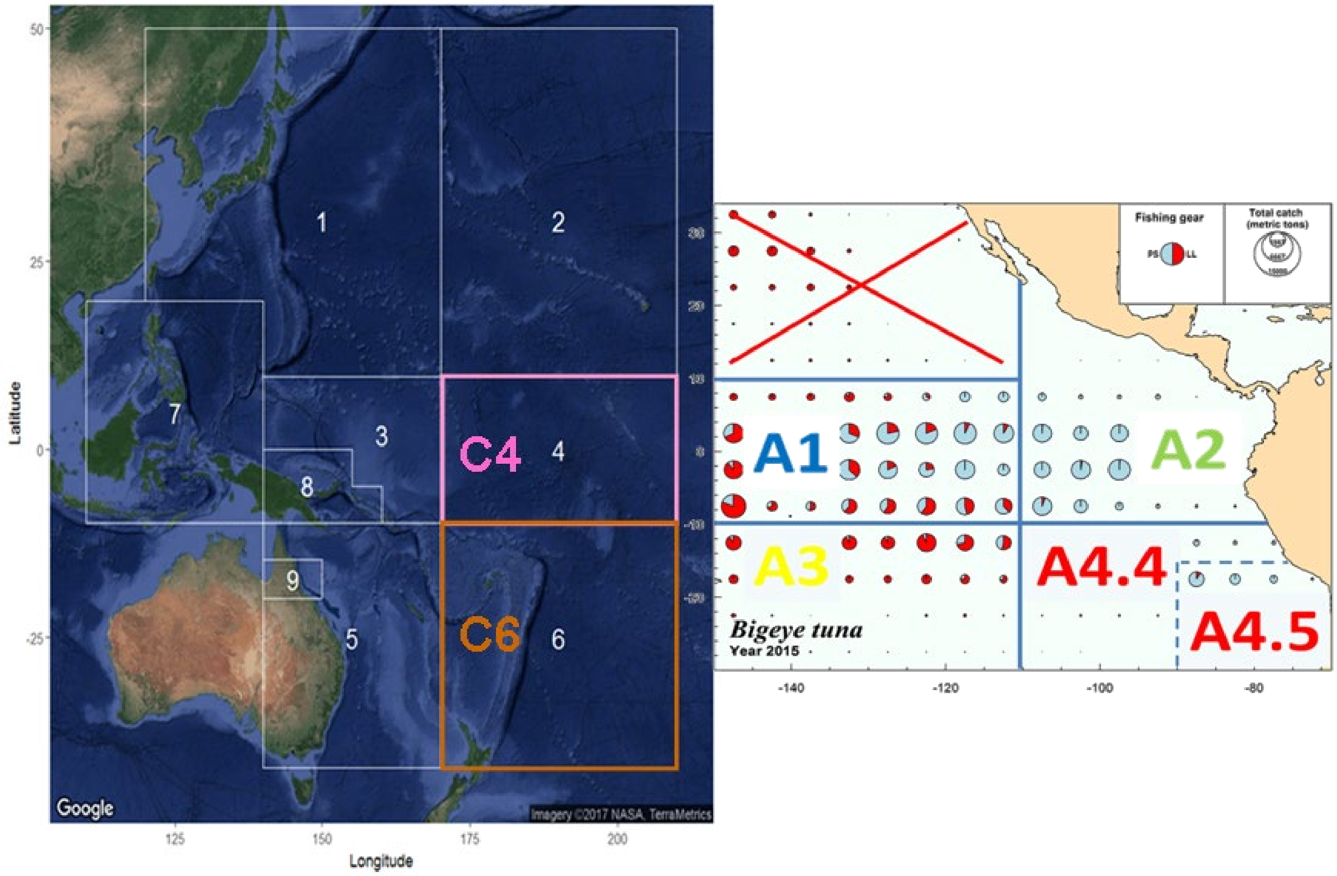

Figure 6. Spatial structure used in the most recent BET assessment in the WCPFC (Left panel)(McKechnie et al, 2017) and proposed spatial structure for BET modeling in the EPO (Right panel)(Minte-Vera *et al.* 2019).

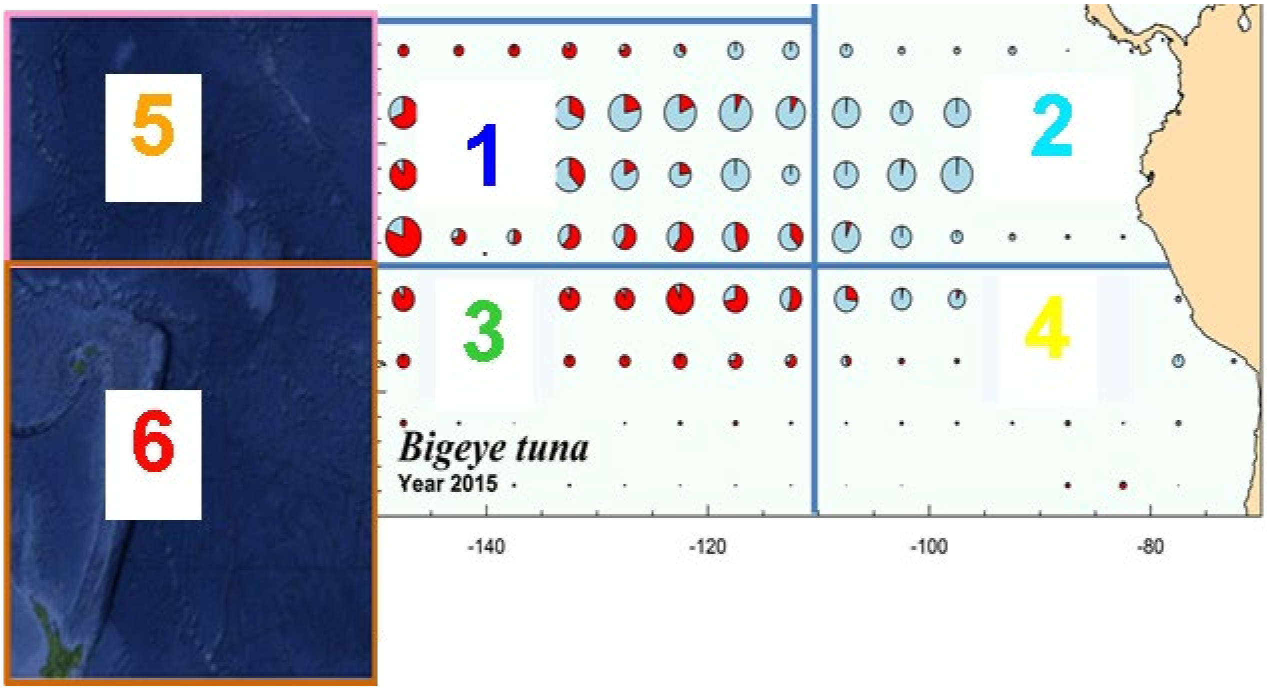

Figure 7. 6-area spatial structure resulting from the combination of the 4-area structure proposed by Minte-Vera et al. (2019) and the corresponding 2 adjacent WCPFC spatial areas to the west of 150W.

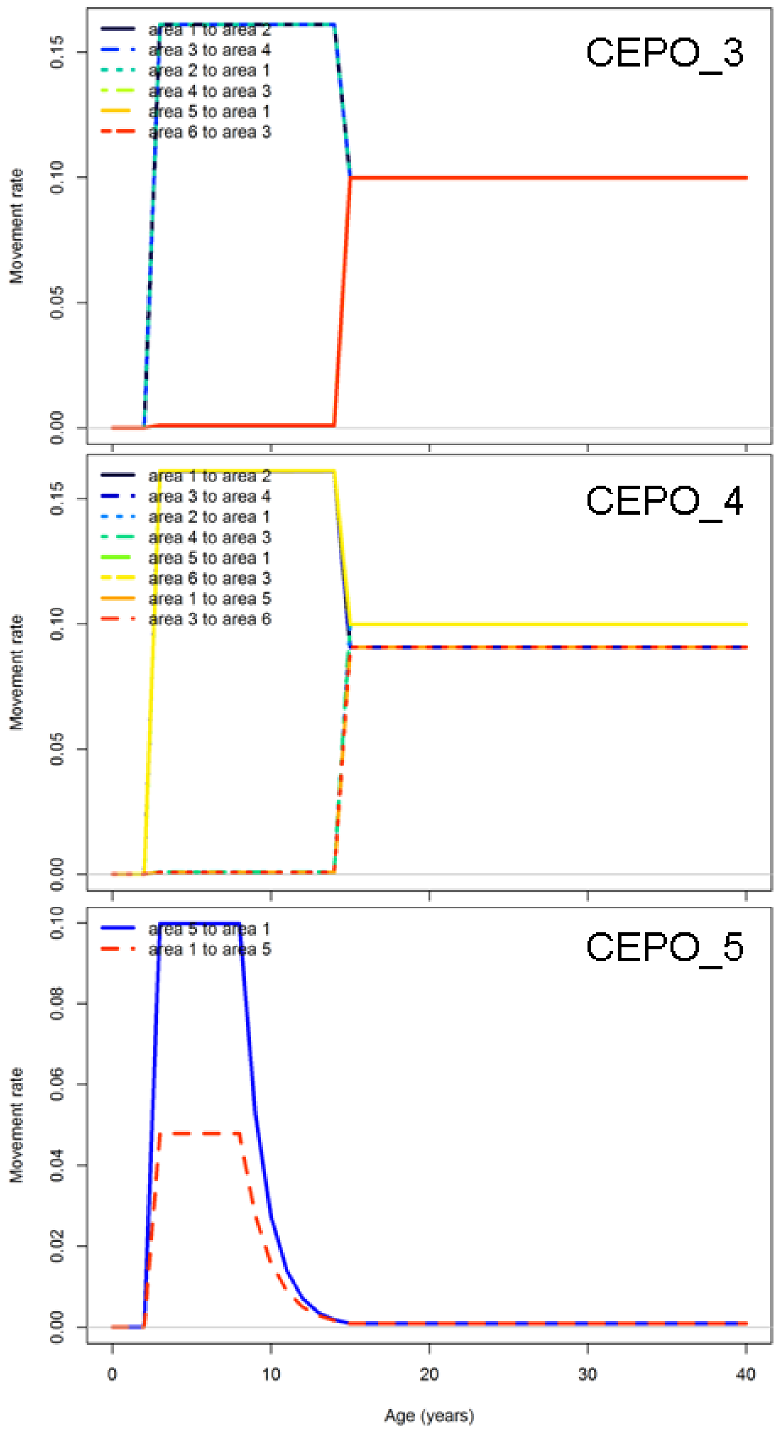

Figure 8. Assumed movement scenarios for alternative Central and Eastern Pacific Ocean (CEPO) BET spatial models.

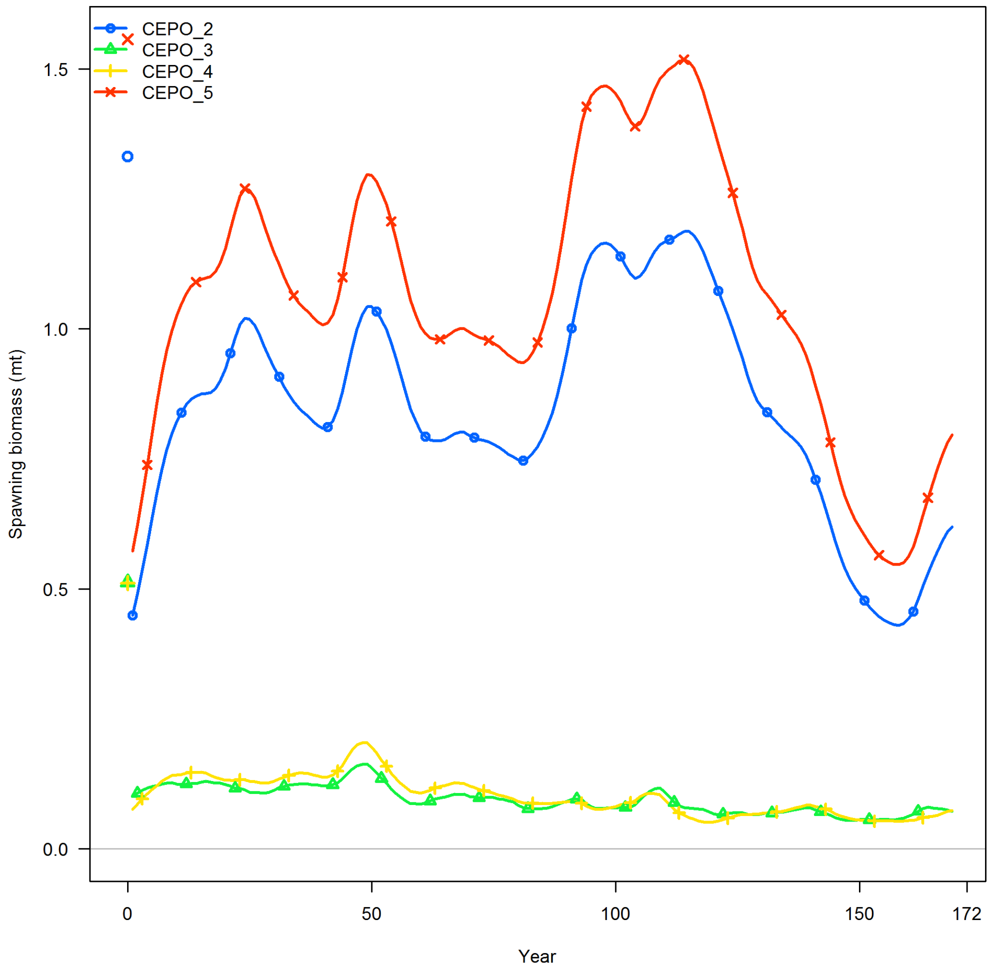

Figure 9. Estimated time series of spawning biomass for Central and Eastern Pacific Ocean (CEPO) models under different assumptions about BET movement.

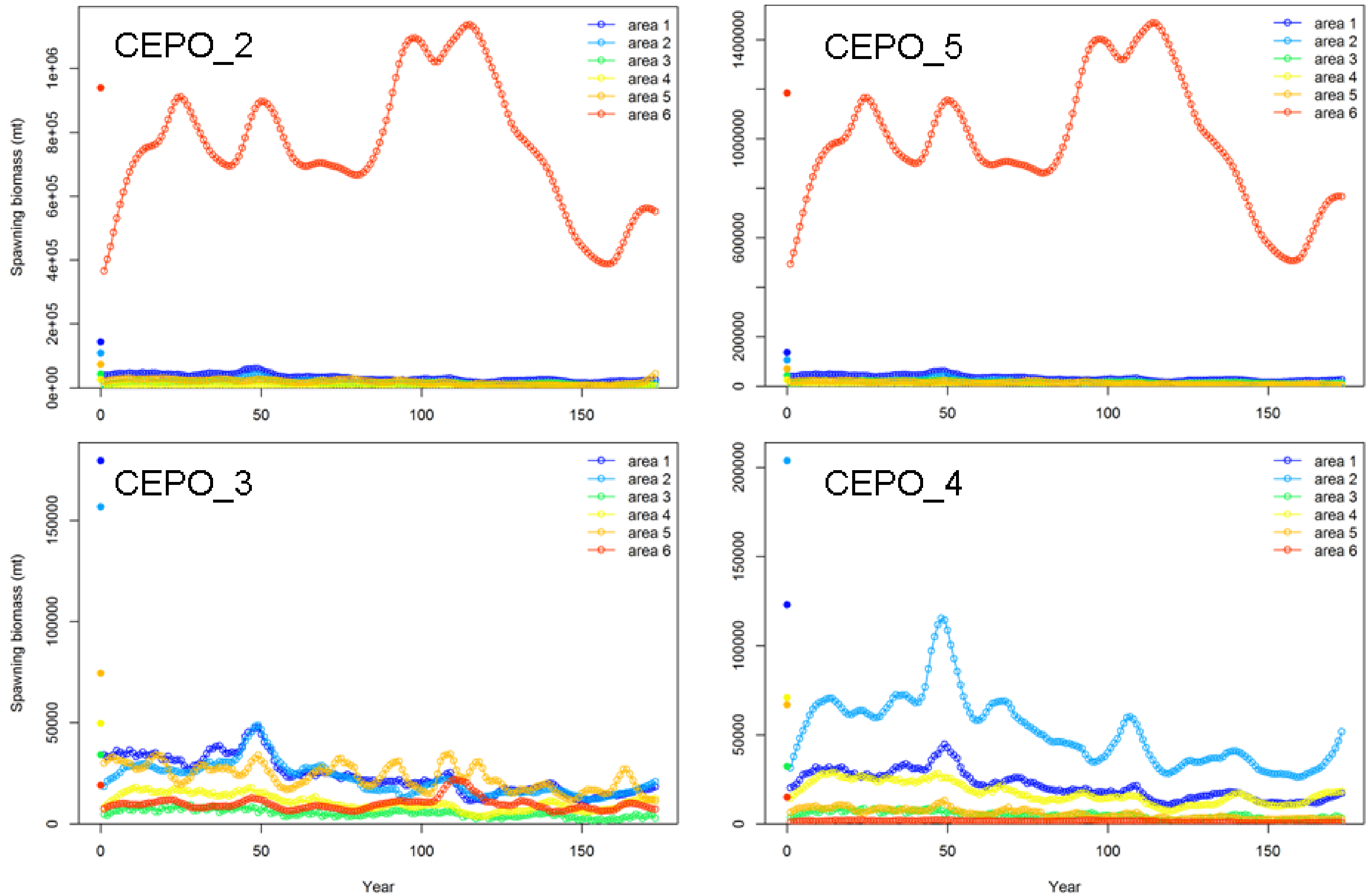

Figure 10. Estimated time series of area-specific spawning biomass for Central and Eastern Pacific Ocean (CEPO) models under different assumptions about BET movement.

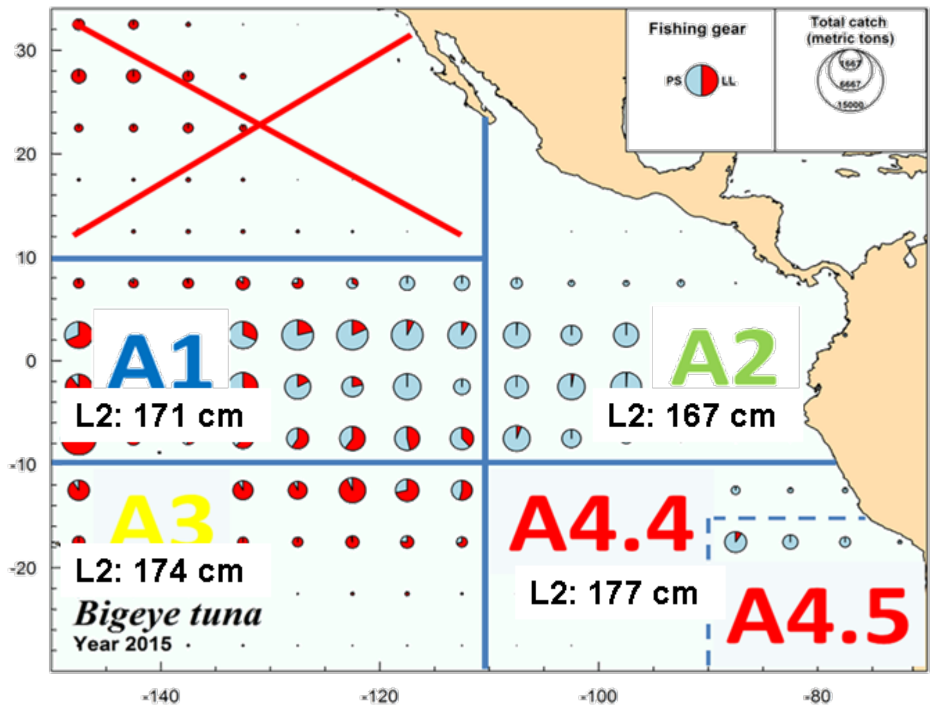

Figure 11. Spatial variation in estimated growth L2 among the four areas of the spatial structure proposed by Minte-Vera et al. (2019). CVs of the variation of length-at-age not estimated.

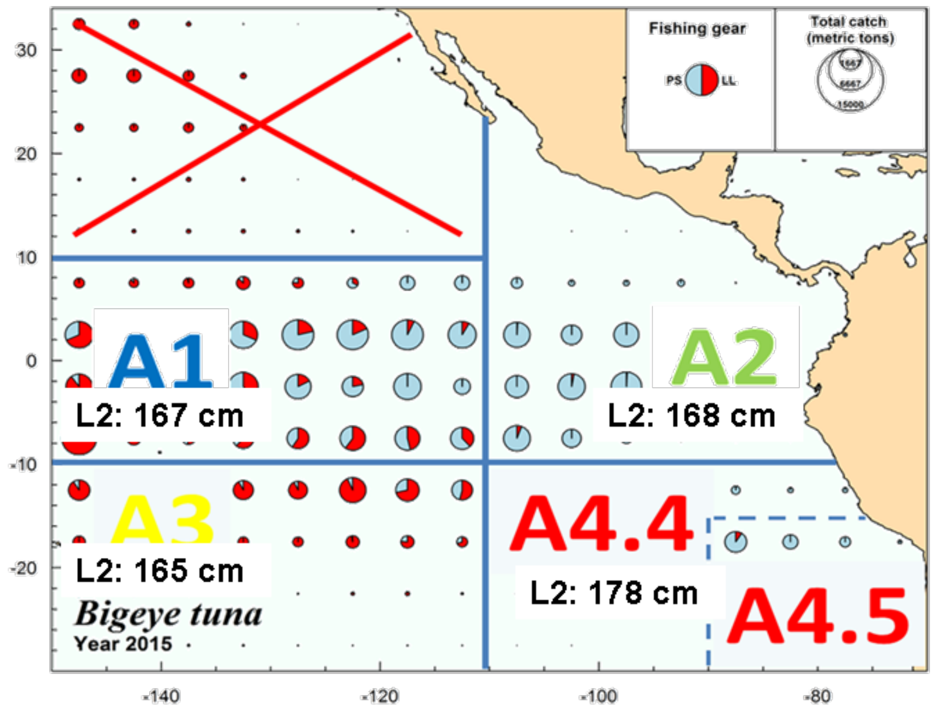

Figure 12. Spatial variation in estimated growth L2 among the four areas of the spatial structure proposed by Minte-Vera et al. (2019). CVs of the variation of length-at-age estimated.