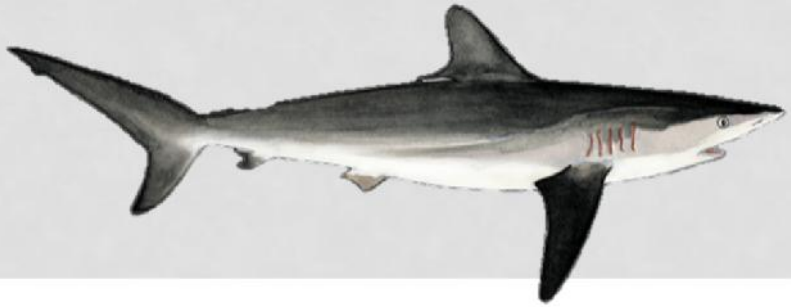

STOCK STATUS OF PACIFIC SILKY SHARK (SA-WP-08+ADDENDUM)

S.CLARKE, A.LANGLEY
C.LENNERT-CODY, A.DASILVA & M.MAUNDER

Western and Central Pacific Fisheries Commission

COMMON OCEANS

FAO FIAT PANIS

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BACKGROUND

- One of four Pacific-wide assessments funded by the ABNJ Tuna Project
- Designed to improve assessment tools for data-poor species
- Collaboration with IATTC on a species of mutual interest

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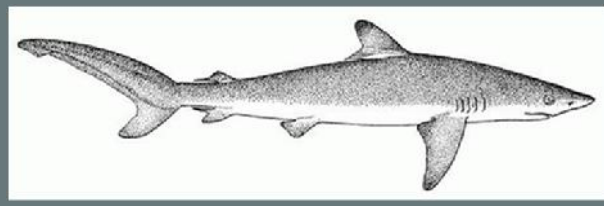
STATE OF PLAY

- WCPFC stock assessment 2013
  - No-retention (CMM 2013-08)
  - Cited in support of CITES, CMS and IUCN listings

- IATTC attempted a stock assessment in 2014; annual indicators thereafter

WCPFC ASSESSMENT (2013)

- SS3 model for WCPO only; data from 1995-2009
- Six equally-weighted CPUE series: LL_bycatch, LL_target, HI_LL, JPRTV_LL, PS_#, PS_mt
- Conclusions based on a grid of >2500 scenarios with reference case (LL_bycatch) chosen from the highest weighted models



$F_{current}/F_{MSY}$ = 4.48 (1.41-7.96)

$SB_{current}/SB_{MSY}$ = 0.70 (0.51-1.23)
$SB_{current}/SB_{virgin}$ = 0.272

IATTC ASSESSMENT (2014)

- Conducted in collaboration with national fishery agencies who contributed data from their own databases
- SS3 model, EPO only; data from 1993-2010
- Principle CPUE index: PS associated (OBJ)
- The results of the assessment modelling were not considered reliable:

> *"IATTC staff concludes that the reconstructed time series of historic catches of silky sharks is inconsistent with the observed trends in the CPUE-OBJ index and the life-history information for the species."*

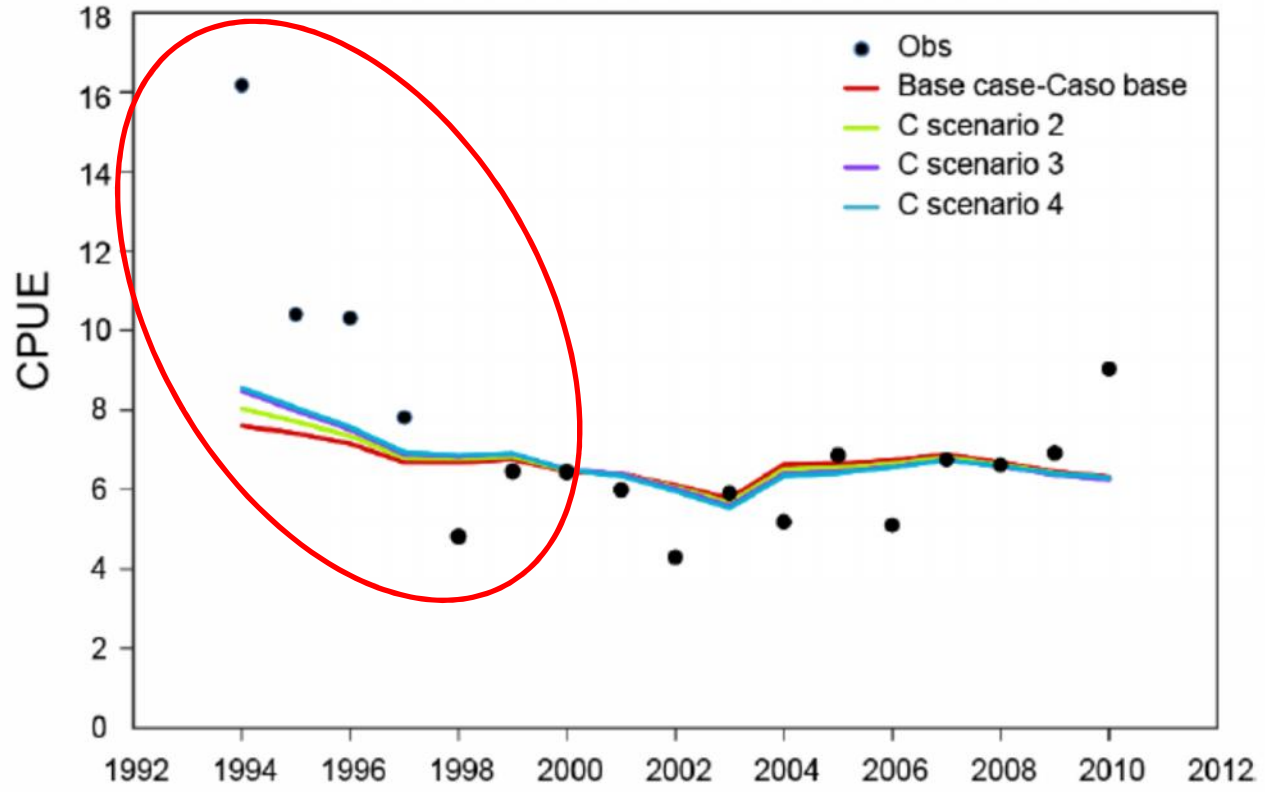


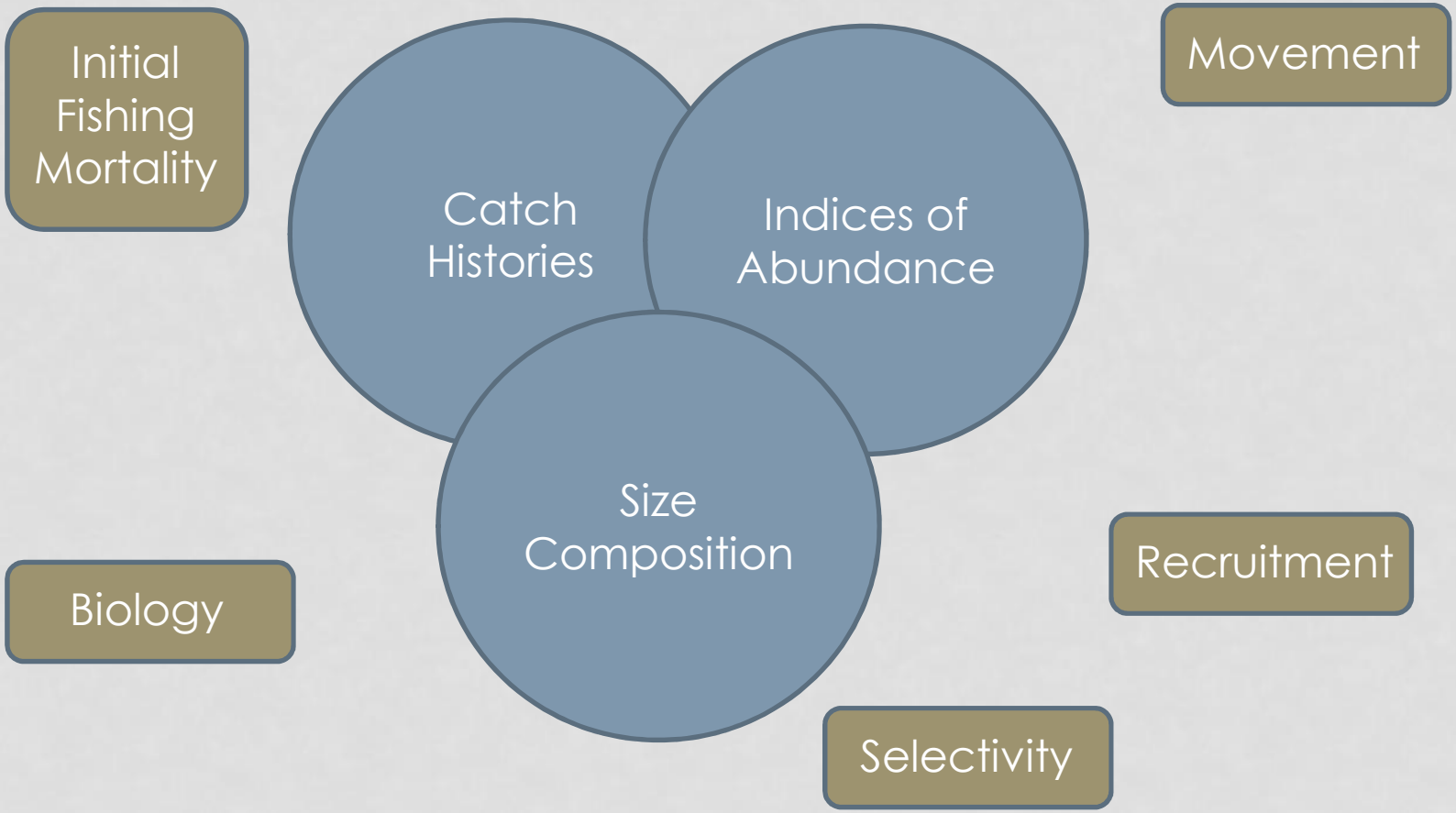
FIGURE 18. Model fits to the CPUE-OBJ index for the various scenarios, assuming different levels for the pre-2004 catches (C scenarios) by the Central American non-coastal fleet (Figure 17).

Difficulties encountered in fitting the sharp decline in the CPUE indices in the late 1990s

2018 ASSESSMENT: DATA

- Purse Seine
  - WCPO ROP
  - IATTC observer programme
- Longline
  - WCPO ROP + 12 national programmes
  - United States (HI and AS)
  - Japan

STOCK SYNTHESIS MODEL



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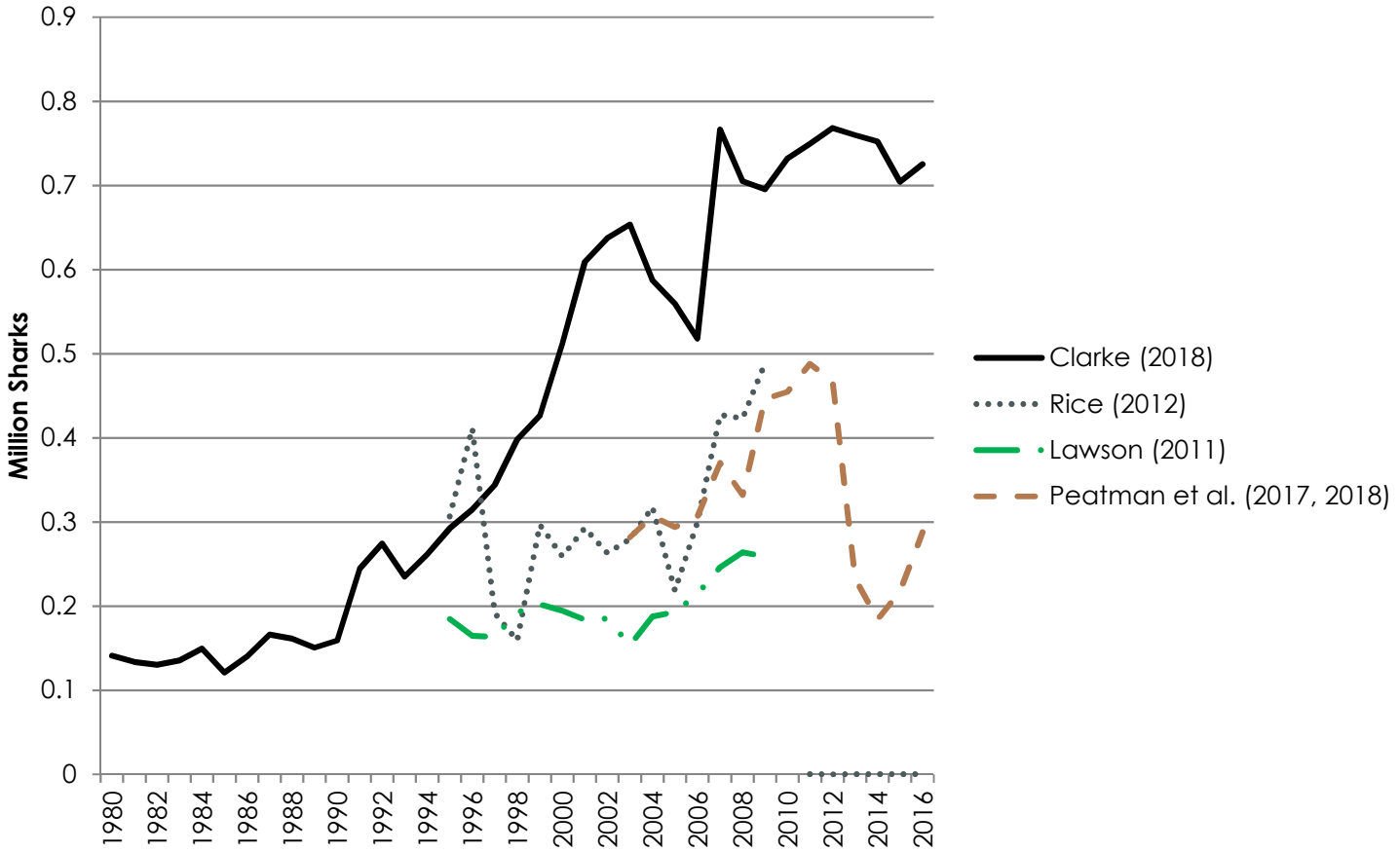
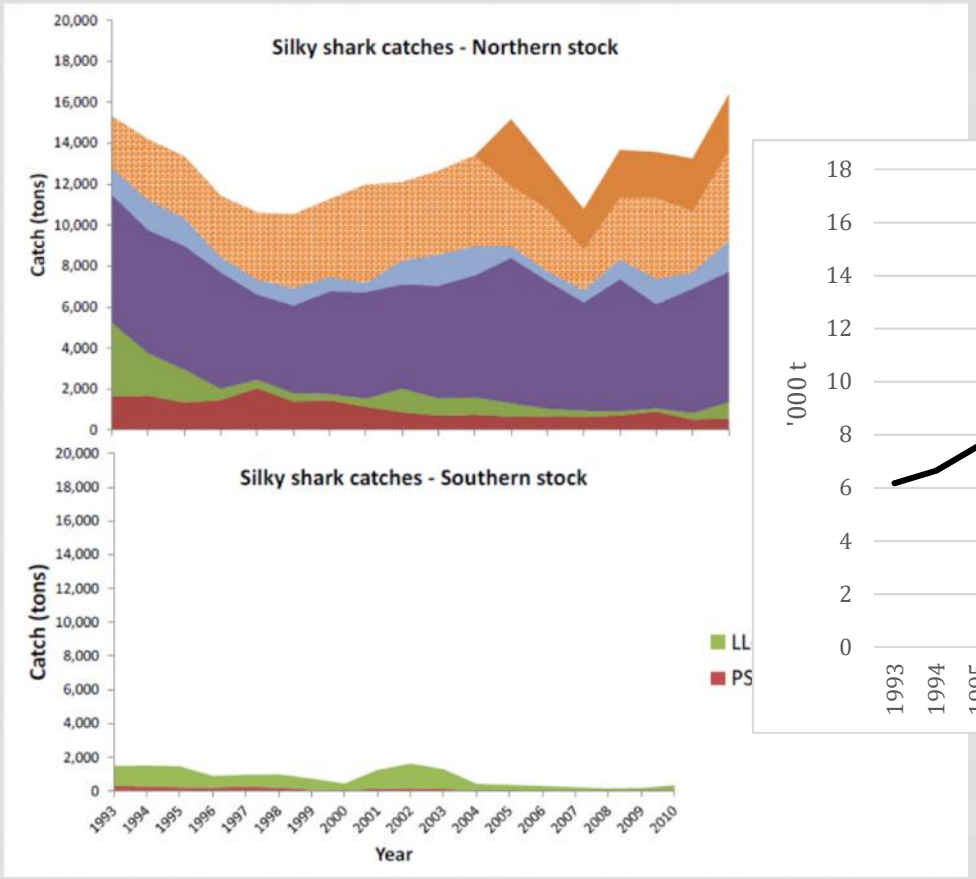
CATCH HISTORIES

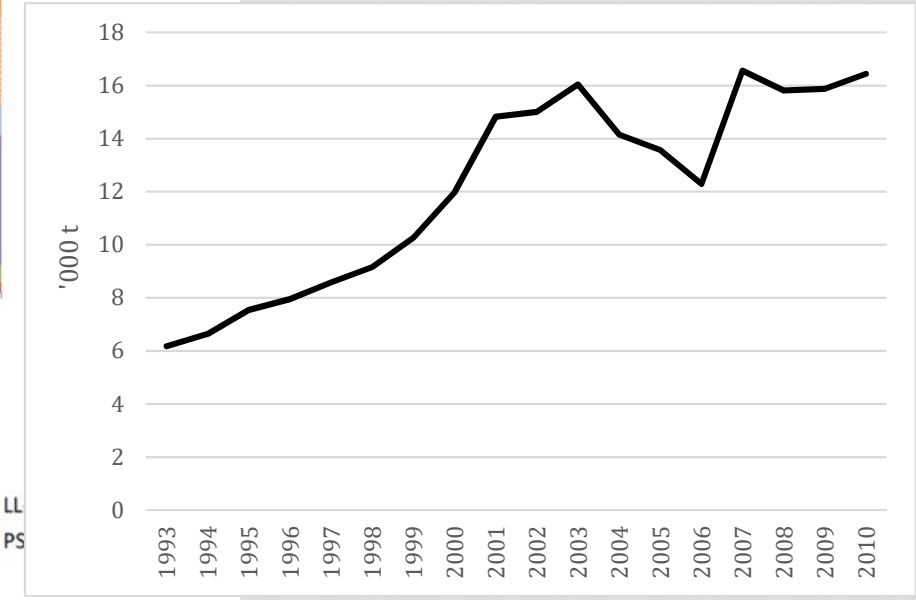
- WCPO trade-based higher than observer-based (SA-IP-09)



CATCH HISTORIES

- EPO trade-based estimates closely follow IATTC's reconstruction





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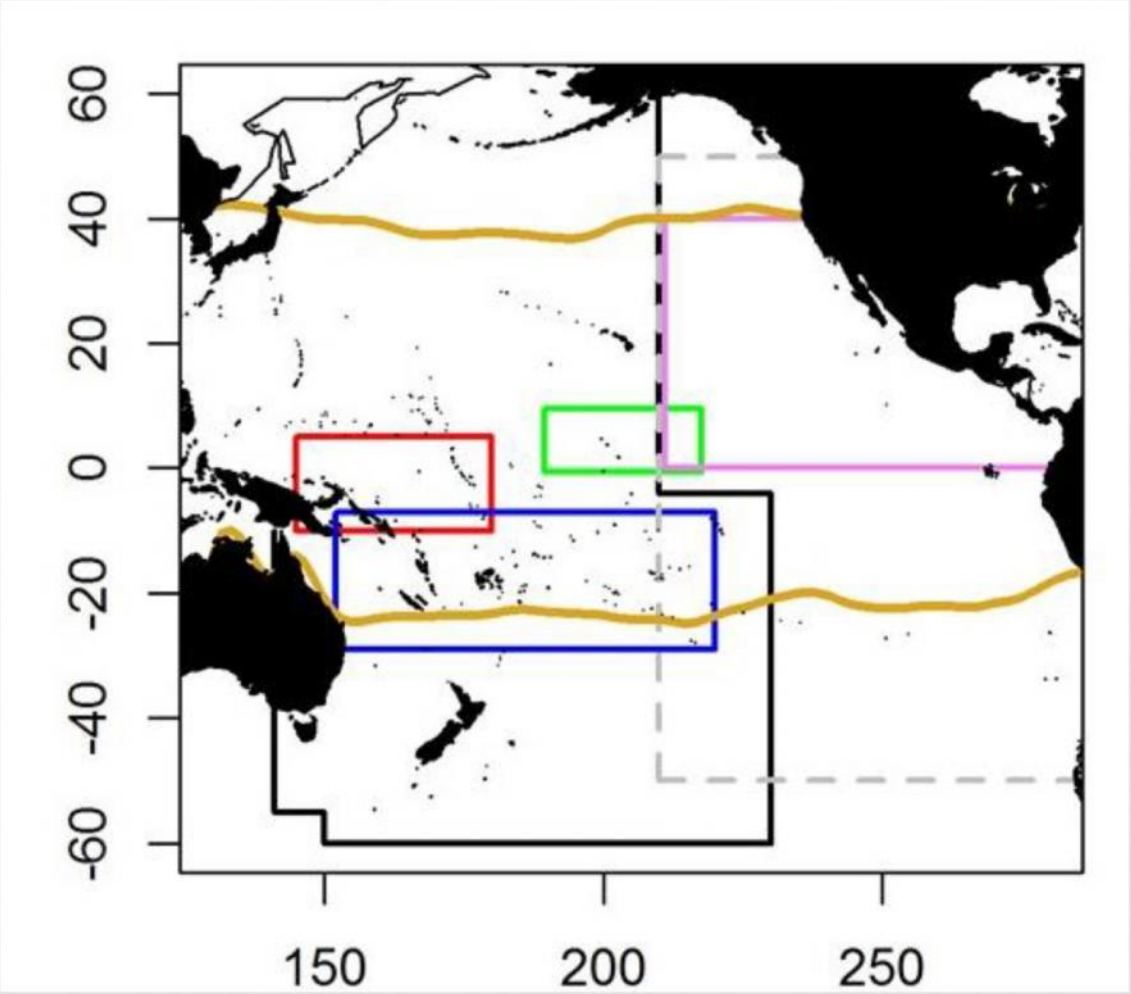
INDICES OF ABUNDANCE



WCPO Purse Seine (Associated)

WCPO Longline*

Hawaii Longline

EPO Purse Seine* (Associated, North)

Silky Shark Habitat (FAO map)

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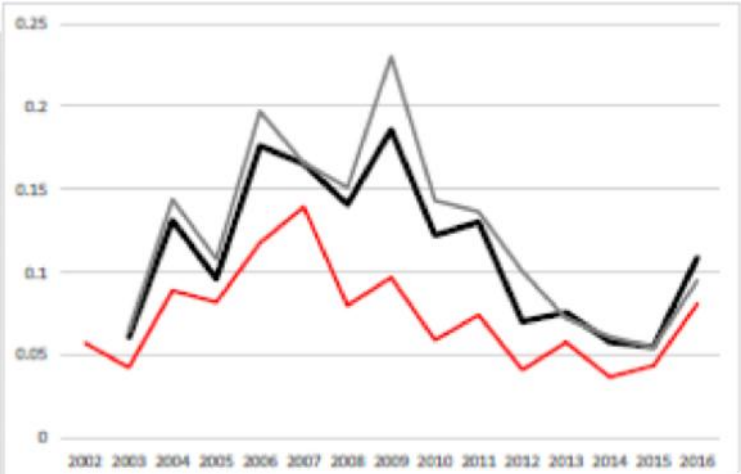
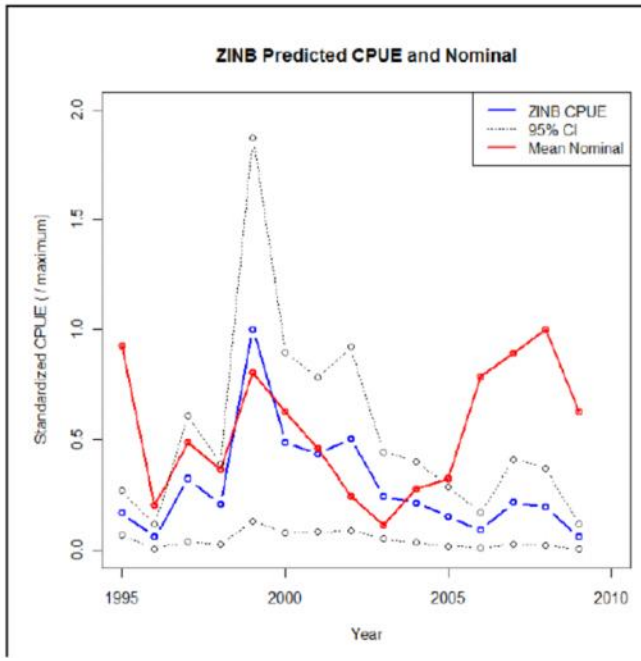
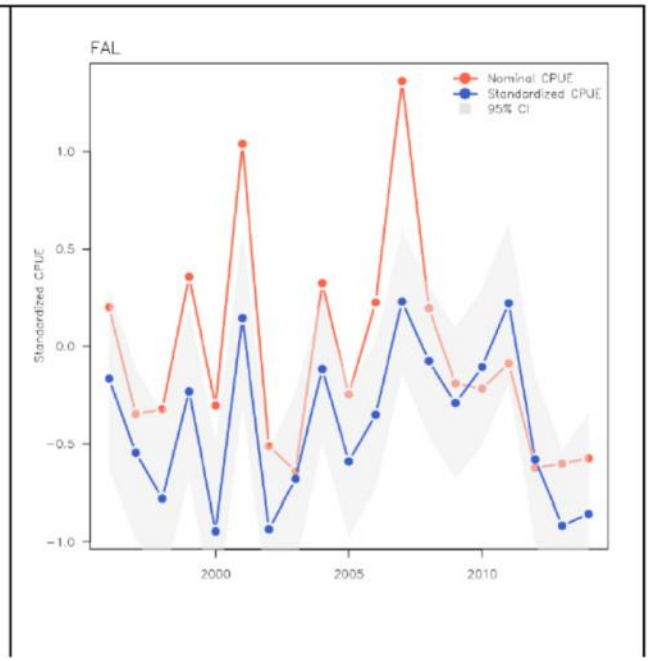
INDICES OF ABUNDANCE



WCPO LL (ZIP model)
Reference case for the assessment; different from previous CPUEs (Rice 2013; Rice et al. 2015)





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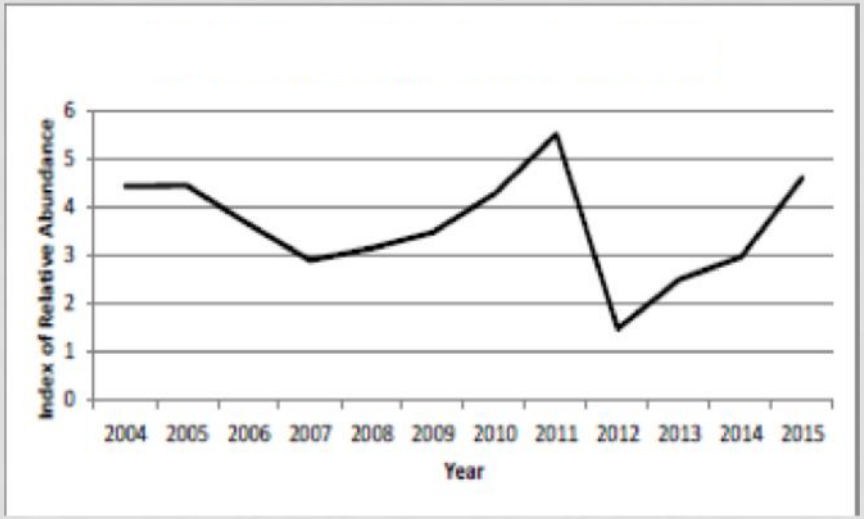
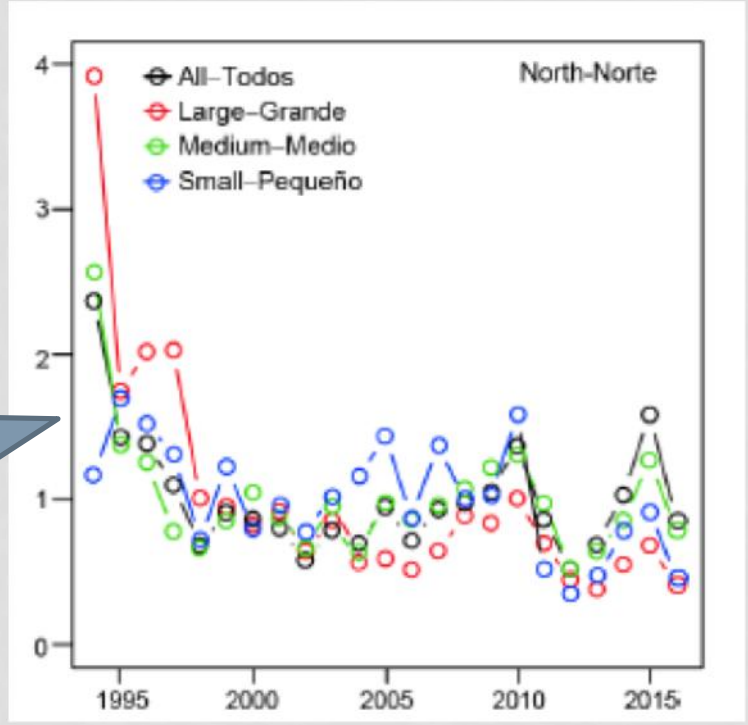
INDICES OF ABUNDANCE



WCPO PS Associated (ZINB model)

EPO PS Associated North Large



Strongly influenced by oceanographic conditions
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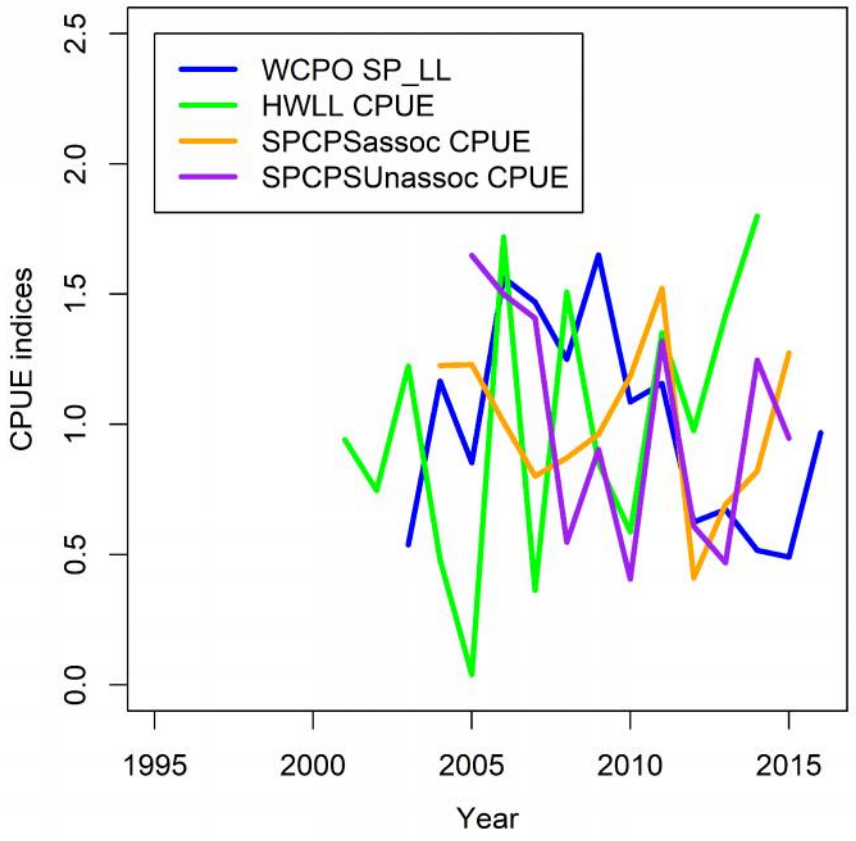
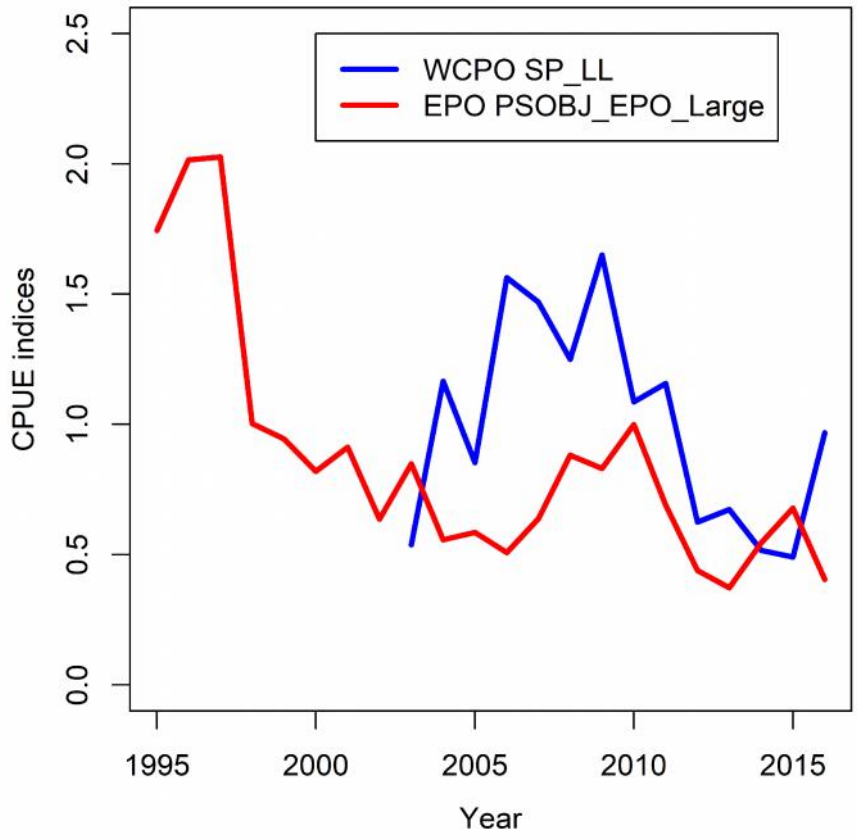
INDICES OF ABUNDANCE (IN NUMBER)





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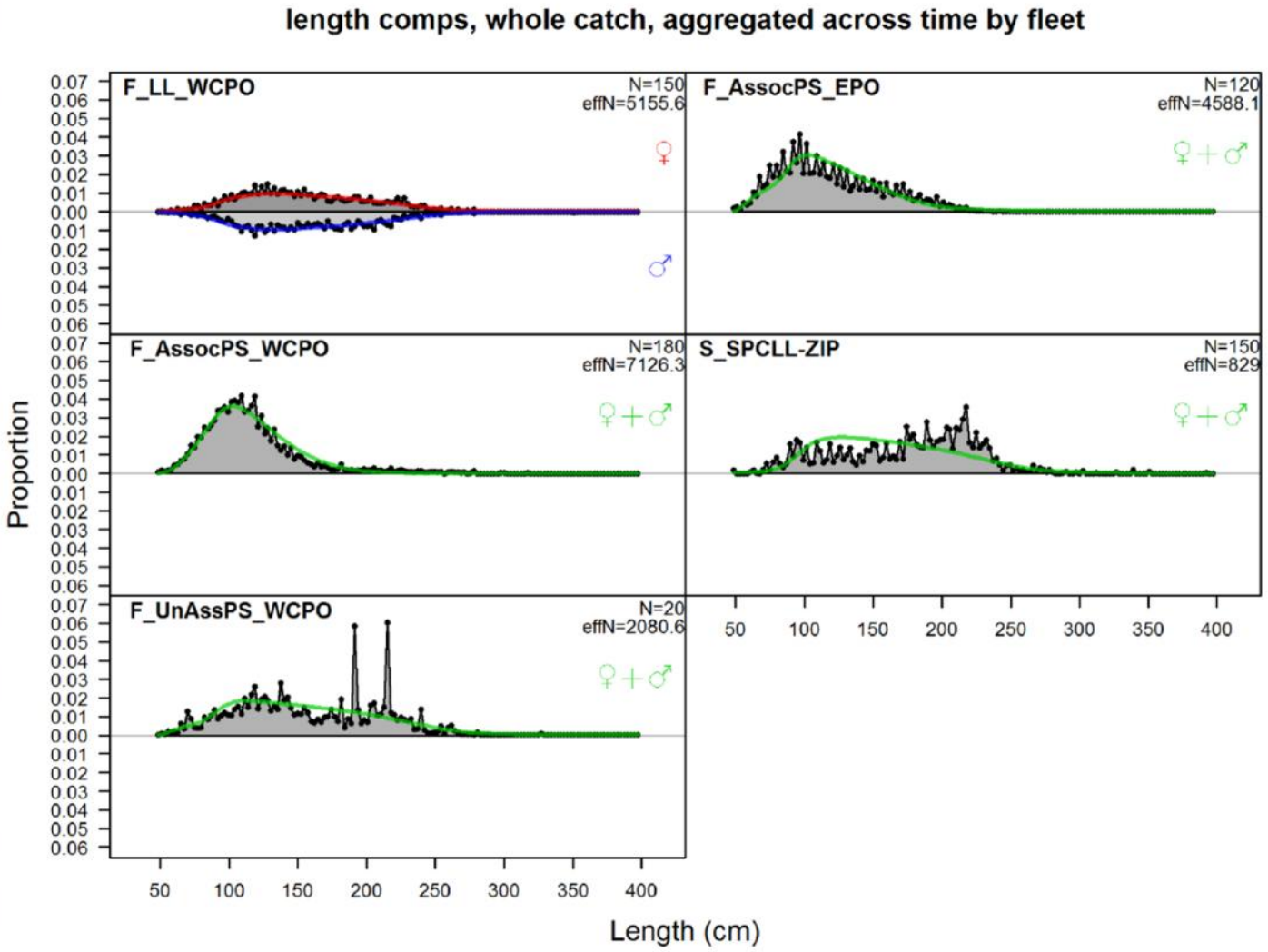
Comparison of all WCPO CPUE indices

Comparison of principal EPO and WCPO CPUE indices

SIZE COMPOSITION



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ENVIRONMENTAL INFLUENCES

- *EPO purse seine CPUE of small and medium silky sharks strongly influenced by prevailing oceanographic conditions (IATTC 2018 SAC-09-13). Also considerable variation in CPUE* EPO PS Associated North Large.
- *WCPO CPUE indices vary considerably. Some correlation with SOI variables that suggest CPUE is influenced by prevailing oceanographic conditions.*

ENVIRONMENTAL INFLUENCES

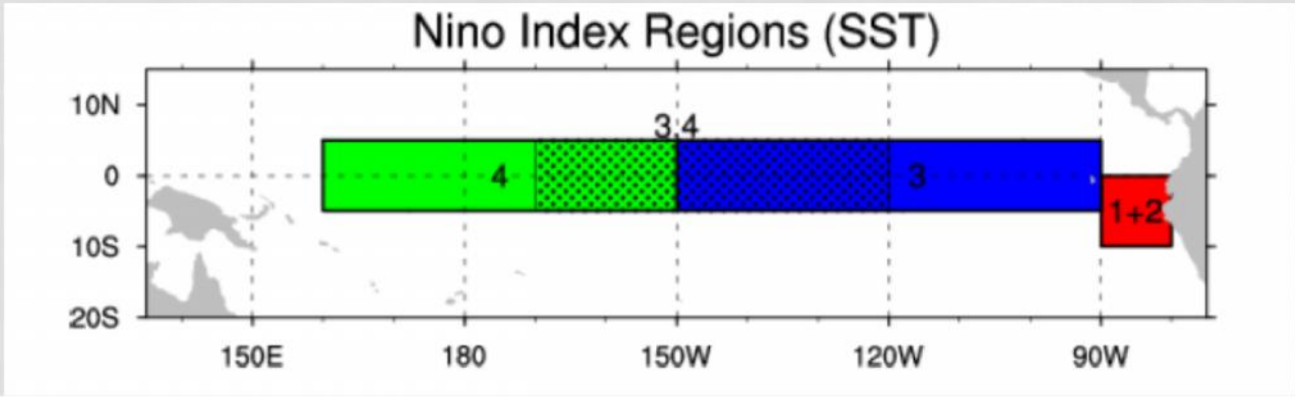
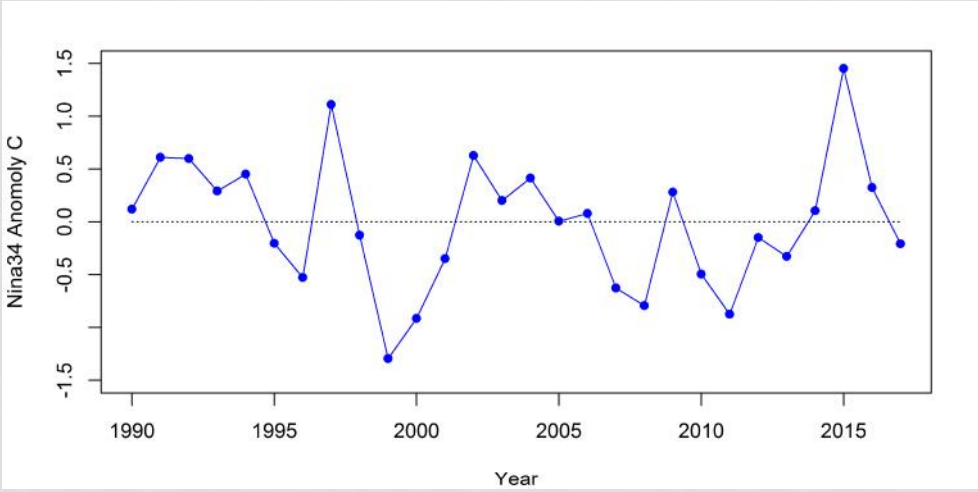


Table 3. Correlation coefficients between the five sets of CPUE indices and the annual Niño3.4 environmental index lagged by specified annual intervals (from 3 years to -4 years).

Year lag	CPUE index				
	SP_LL	HWLL	WCPO PSAssoc	WCPO PSUnassoc	PSOBJ_EPO Large
3	-0.329	0.313	-0.526	-0.255	-0.509
2	-0.509	0.094	-0.432	-0.379	-0.206
1	-0.663	0.405	-0.045	0.074	0.059
0	-0.358	-0.146	0.156	0.110	0.013
-1	-0.178	-0.311	0.467	0.345	-0.063
-2	0.323	0.023	0.429	0.784	0.156
-3	0.398	-0.342	-0.273	0.321	0.335
-4	0.625	0.113	-0.253	-0.078	0.423

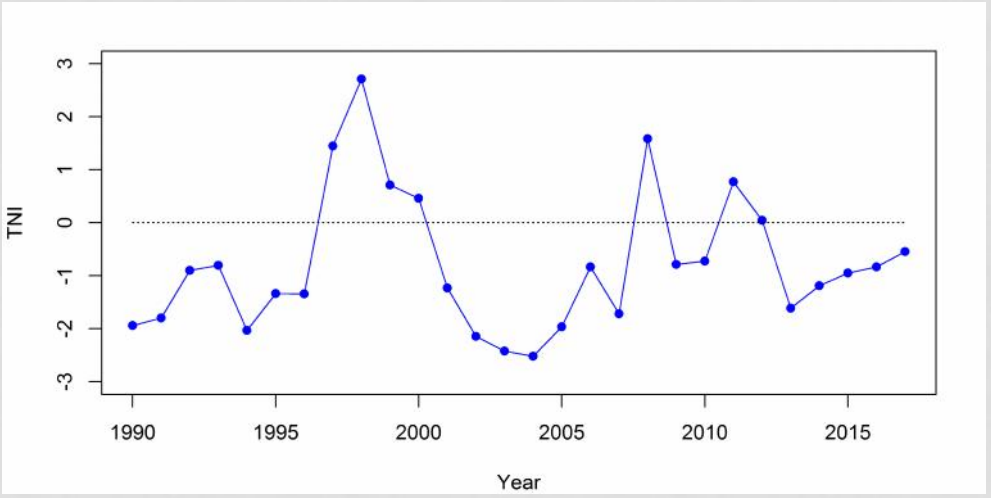
ENVIRONMENTAL INFLUENCES

Nina34
Annual average anomaly



Trans Nino Index (TNI)

(=difference in anomalies between Nino1.2 and Nino4)



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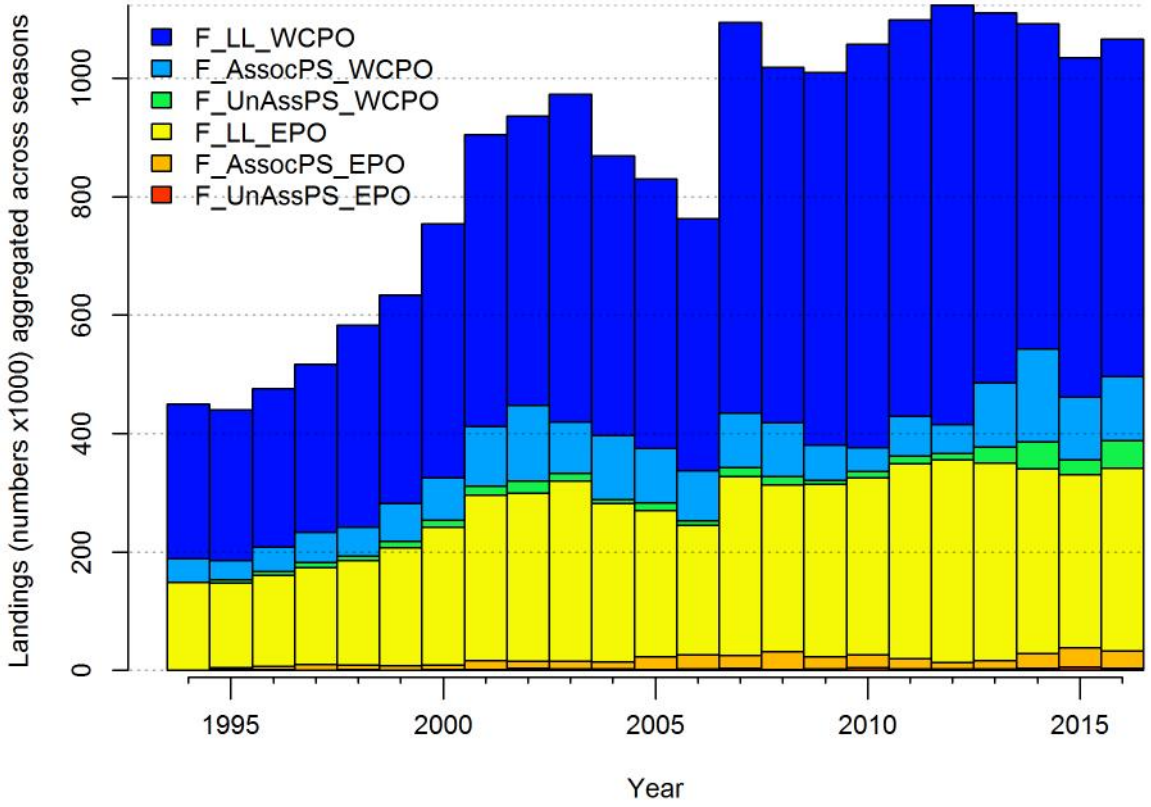
MODEL STRUCTURE

- Pacific-wide assessment.
- Regional structure. Two regions: WCPO and EPO. Defined based on available catch histories, defined fisheries and CPUE indices.
- EPO fisheries: LL, PS Assoc, PS Unassoc.
- WCPO fisheries: LL, PS Assoc, PS Unassoc.
- CPUE indices: SP_LL (WCPO), PSOBJ_EPO_Large (EPO).
- Can regional structure accommodate different trends in CPUE in the two regions?

MODEL STRUCTURE

Catch history, by fishery

Catches in numbers.



MODEL STRUCTURE

- Configured in Stock Synthesis SS-V3.24Z.
- Two sexes, 25 year (age) classes. 4 seasons.
- Two regions. Annual movement.
- Model period 1995-2016 (represents period for which more reliable catch data are available).
- Initial (1995) conditions: equilibrium, exploited. Initial Fs estimated.
- Movement (juvenile, adult) assumptions – extensive testing, including enviro covariates.

MODEL STRUCTURE

Biological parameters.

- Equivalent to Rice & Harley 2013.
- M=0.18 (WCPFC-SC11-2015/EB-IP-13)
- VB growth (Joung et al. 2008)
- Maturity ogive (Joung et al. 2008).
- Length-wt. (Joung et al. 2008).
- BH SRR Steepness (0.401 fixed).
- FL to TL conversion (Joung et al. 2008).

MODEL STRUCTURE

Recruitment.

- Total annual recruitment based on SRR (R0 and steepness).
- No temporal variation in recruitment (SigmaR 0).
- Regional distribution in recruitment (estimated) and temporal variation in regional distribution.
- Recruitment distributed evenly amongst seasons.

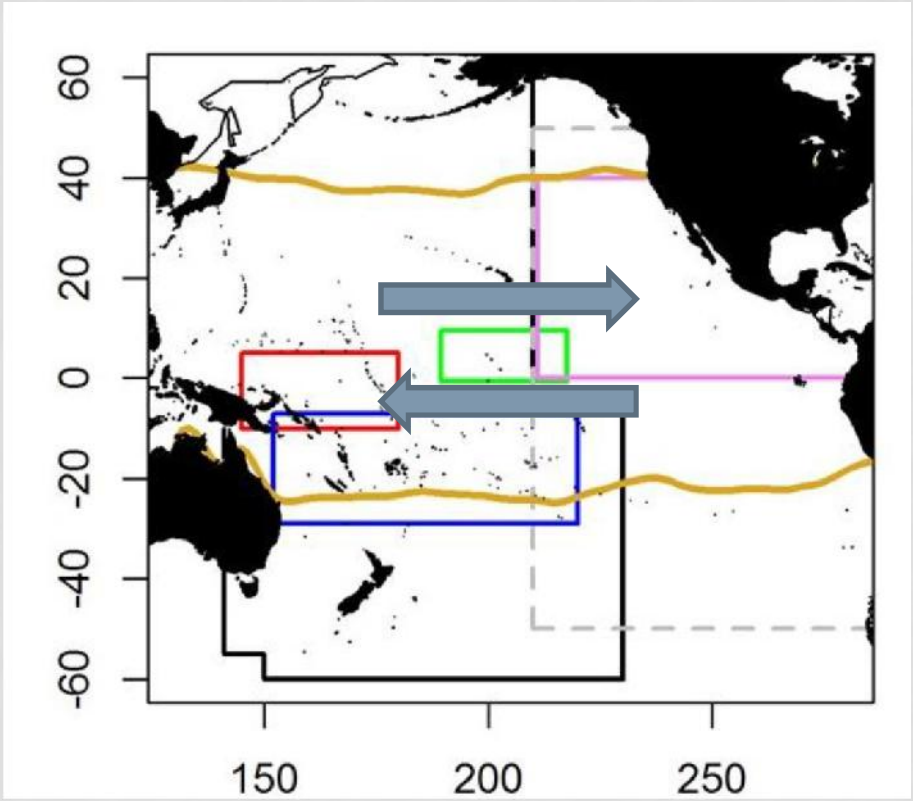
MODEL STRUCTURE

Fisheries, Surveys.

- Fishery selectivities: all fisheries have estimated double normal selectivity functions, except EPO_LL (fixed, logistic).
- Main CPUE selectivities: SP_LL logistic (estimated), PSOBJ_EPO_large (fixed based on >150cm size category).
- CPUE CV 20%.
- Other CPUE indices also included in model (but not in likelihood).
- Selectivity parameterization informed by weak priors.
- Length Comp Effective Sample Size 10 (all obs).
- Initial Fs informed by assumed level of initial equilibrium catches (=1995 catch).

MODEL STRUCTURE

Movement – Juvenile and Adult



Proportion moving ~ exp(move_parm)

Include environmental covariate:
Move_parm(y) = move_parm + link * env(y)
link = enviro link parameter
env(y) = enviro variable in year y.

Range of environmental variables Nina34, TNI, different lags (+/- 2 yr)

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MODEL RESULTS

Table 6. Model log likelihoods for selected model runs investigating different movement parameterisations. The likelihood values in italics were not included in the total likelihoods (i.e. lambda 0).

Name	Movement WCPO to EPO	Movement EPO to WCPO	Likelihood component					CPUE likelihoods		
			LF	Survey	Total	SP_LL	HWLL	WCPO PSasso	WCPO PSuna	EPOOBJ
NoMove	No movement	No movement	294.54	-18.96	285.28	1.98	*163.88*	*-3.85*	*10.10*	-20.94
MoveNoEnviro	no enviro covar	no enviro covar	282.86	-13.25	279.52	1.51	*167.59*	*-4.00*	*9.70*	-14.76
MoveEPOTNI1_ WCPONino341	TNI, lag -1 year	Nino34, lag -1 year	280.43	-13.72	278.04	-1.55	*168.54*	*-3.65*	*11.96*	-12.17
MoveEPOTNI1	TNI, lag -1 year	no enviro covar	282.16	-13.31	279.07	0.55	*168.16*	*-3.98*	*9.96*	-13.86
MoveEPOTNI2	TNI, lag -2 year	no enviro covar	285.14	-15.96	278.19	2.28	*164.60*	*-4.30*	*9.35*	-18.24
MoveEPOTNI	TNI no lag	no enviro covar	282.80	-14.60	278.50	0.92	*165.53*	*-3.98*	*10.30*	-15.52
MoveEPOTNI_ WCPOTNI1	TNI no lag	TNI, lag -1 year	288.20	-19.96	279.41	1.73	*166.19*	*-2.68*	*10.57*	-21.69
MoveEPONino34x1	Nino34, lag +1 year	no enviro covar	282.71	-13.17	279.62	1.54	*167.07*	*-4.00*	*9.81*	-14.71
MoveEPONino34	Nino34, no lag	no enviro covar	282.64	-13.76	279.19	1.22	*166.15*	*-4.03*	*10.15*	-14.97
MoveEPONino341	Nino34, lag -1 year	no enviro covar	283.89	-15.86	278.48	0.49	*165.73*	*-4.09*	*10.75*	-16.35
MoveEPONino342	Nino34, lag -2 year	no enviro covar	282.22	-14.74	277.78	-1.56	*171.58*	*-4.01*	*11.96*	-13.18
MoveWCPOTNI	no enviro covar	TNI no lag	286.64	-21.02	276.49	2.69	*164.86*	*-3.43*	*11.03*	-23.72
MoveWCPOTNI1	no enviro covar	TNI, lag -1 year	284.45	-15.84	279.15	1.58	*166.70*	*-4.15*	*10.31*	-17.42
MoveWCPOTNI2	no enviro covar	TNI, lag -2 year	282.01	-16.21	274.90	3.30	*168.95*	*-3.68*	*8.37*	-19.51
MoveWCPONino34	no enviro covar	Nino34, no lag	280.91	-13.31	278.59	0.20	*172.84*	*-4.40*	*9.37*	-13.51
MoveWCPONino341	no enviro covar	Nino34, lag -1 year	289.27	-16.49	283.11	-10.27	*175.45*	*1.14*	*22.29*	-6.22
MoveWCPONino342	no enviro covar	Nino34, lag -2 year	279.63	-16.89	273.73	-2.48	*166.49*	*-4.37*	*12.24*	-14.41

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Initial model selection.

Emphasis on movement parameterisation to fit both sets of CPUE indices. Based on an examination of residuals from *MoveNoEnviro*.

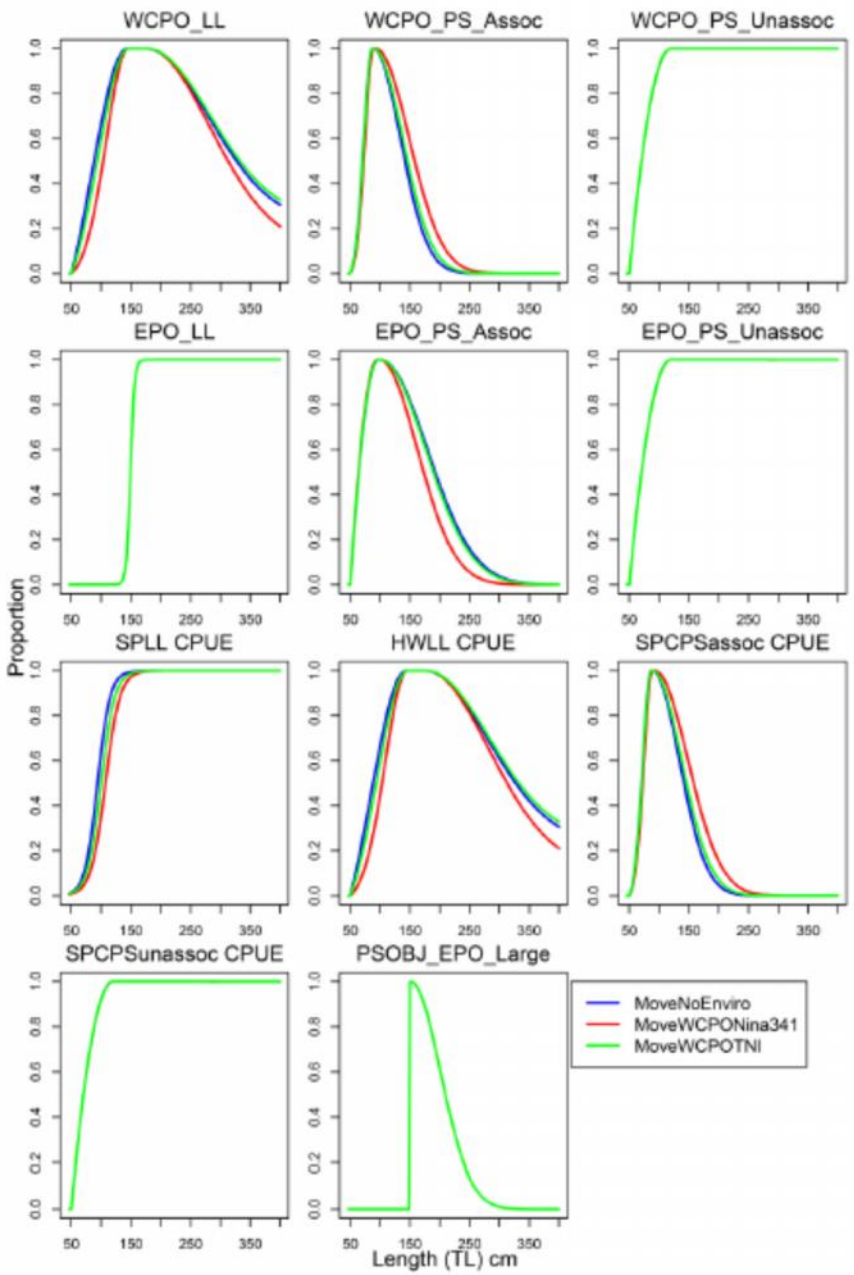

Figure 25: Selectivity functions for the fisheries and CPUE indices included in the three selected model options.

Selectivity functions

Also sensitivity including declining selectivity for EPO_LL (shared WCPO_LL).

MODEL RESULTS

Estimated movement dynamics.

High movement from WCPO to EPO. Also linked to regional recruitment distribution.

Differences in movement from EPO to WCPO to accommodate the two different sets of CPUE indices.

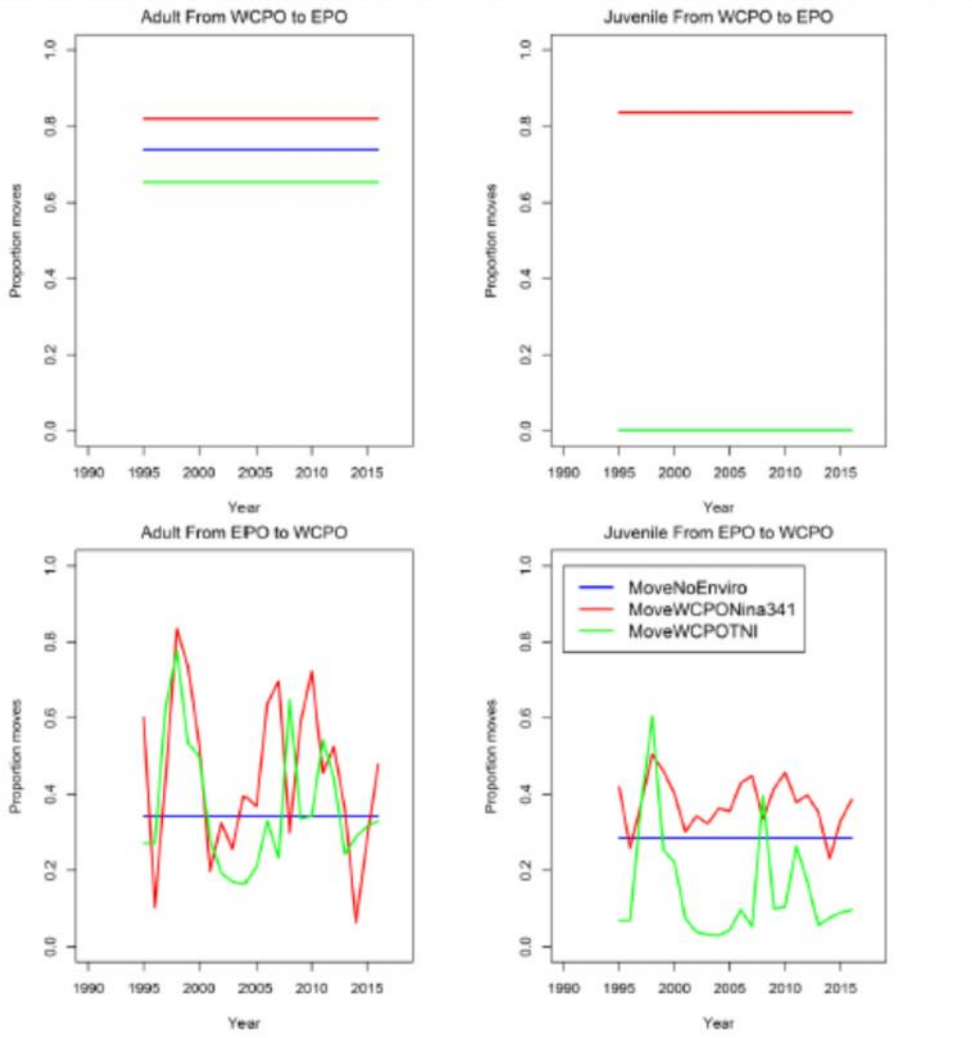

Figure 27. Estimated annual movement rates of juveniles (right panels) and adults (left panels) from WCPO (top panels) and from EPO (lower panels).

MODEL RESULTS

Only SP_LL and PSOBJ_EPO_Large CPUE indices included in likelihood.

None of the model options adequately fit both sets of indices.

None of the model options adequately fit the other sets of WCPO indices.

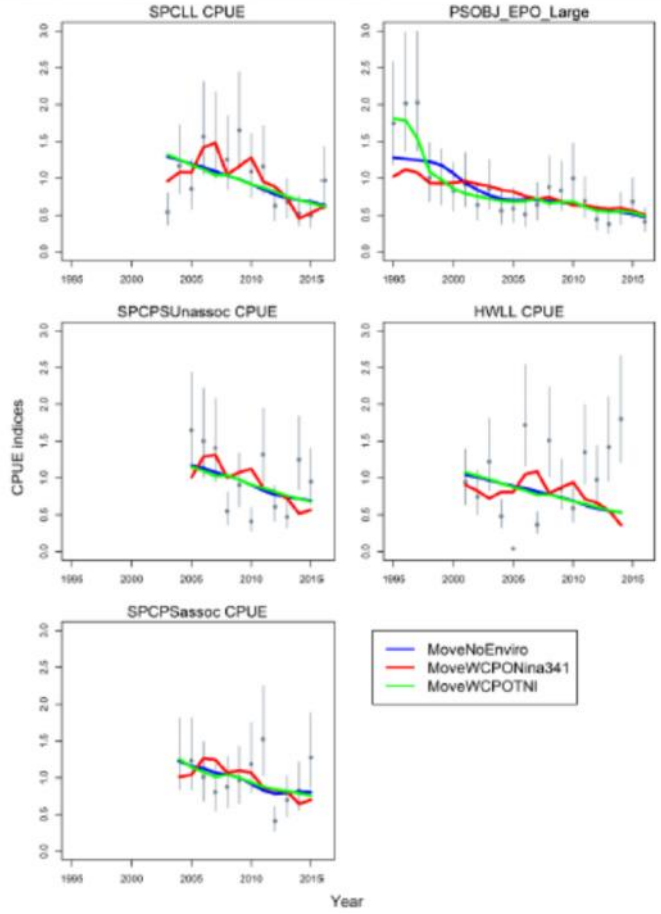

Figure 28. A comparison of the five sets of CPUE indices (points) and the corresponding trends in specific vulnerable biomass (in numbers) for the base model. Only the WCPO_LL and PSOBJ_EPO_Large indices are included in the model likelihood. The other two sets of indices are presented for comparative purposes. The confidence intervals represent 95% confidence intervals (assumed CV 20%).

MODEL RESULTS

Variable length composition data from some fisheries.

Models do not fit variations and/or trends in length composition (related to constant selectivity and recruitment assumptions).

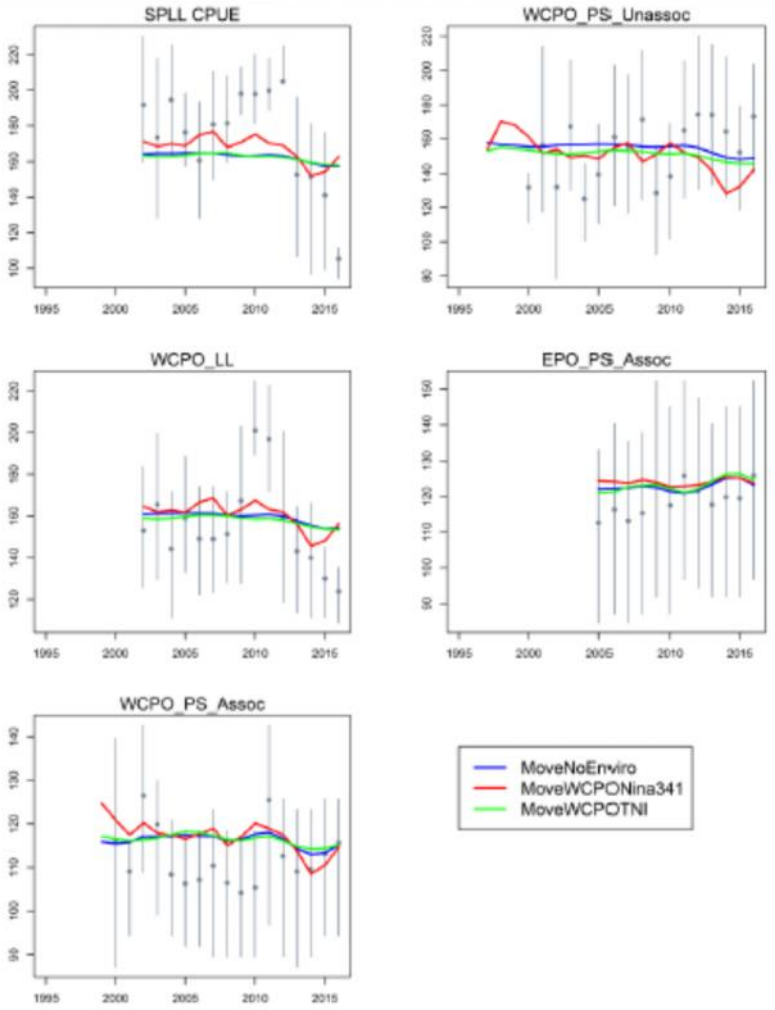

Figure 30. Comparison of the annual average length and interquartile range from the length compositions (grey points and segments) and the predicted average length from the three model options.

MODEL RESULTS

Initial Fs were estimated to be low (in 1995).

Best fit to regional CPUE indices occurs when biomass in specific region is low.

WCPO best fit to SP_LL CPUE from the MoveWCPONina341 model.

EPO best fit to PSOBJ CPUE from the MoveWCPOTNI model.

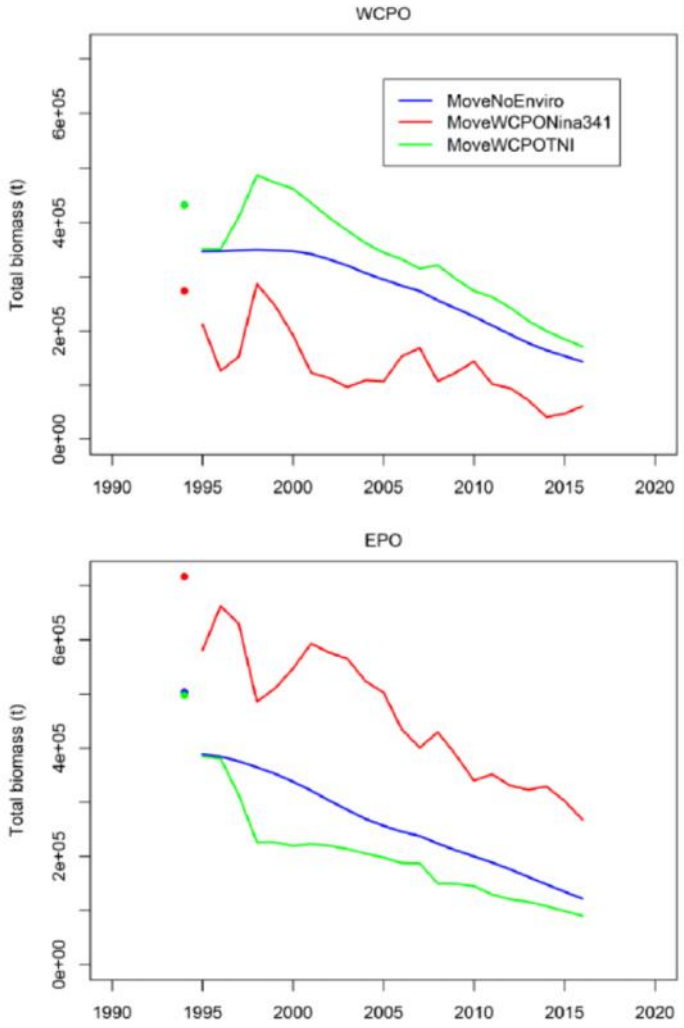

Figure 32. Annual total biomass for WCPO region (top) and EPO region (bottom) for the three model options. The points denote the virgin biomass level.

MODEL RESULTS

Table 9. Comparisons of model estimates of virgin biomass (SB_0 in tonnes), Maximum Sustainable Yield (MSY in tonnes), current (2016) biomass (relative to SB_0) and current (2016) fishing mortality relative to F_{MSY}. Standard errors are provided in brackets for selected options.

Model option	SB_0	MSY	SB_{2016}/SB_0	F_{2016}/F_{MSY}
MoveNoEnviro	14,096 (s.e. 851)	16,504 (s.e. 1193)	0.221 (s.e. 0.043)	4.01 (s.e. 0.71)
MoveWCPOTNI	14,005 (s.e. 942)	16,801 (s.e. 1544)	0.222 (s.e. 0.046)	4.15 (s.e. 0.83)
MoveWCPONino341	14,928 (s.e. 918)	17,031 (s.e. 1096)	0.270 (s.e. 0.044)	3.33 (s.e. 0.55)
CPUEexEPO	18,403	20,379	0.398	2.02
CPUEexWCPO	11,836	12,976	0.089	8.12
EPO_PScatch	13,346	15,666	0.222	3.95
EPO_LLselect	12,584	12,825	0.248	3.80
LFdownwt	14,591	16,196	0.315	2.99
LFupwt	15,567	17,182	0.294	2.94
SteepnessEst	15,824	13,062	0.250	5.23
ThreeRegion	14,622	16,418	0.271	3.32

Comparable model results over range of model scenarios.
Represents an averaging of the two sets of CPUE indices in model.
None of the model options provide a reasonable fit to CPUE/LF data.
Relatively small influence from initial conditions.
Low productivity species SBMSY ~ 40% SB0.

PACIFIC-WIDE MODEL CONCLUSIONS (1)

- Short time series for all CPUE indices, esp. WCPO (14 years).
- Uncertainty in catch histories.
- Variation in CPUE. Correlations with oceanographic variables indicate changes in availability.
- Model options unable to simultaneously fit primary WCPO and EPO CPUE indices. Not adequately accommodated by regional structure and movement dynamics.
- Inconsistent trends in other WCPO CPUE indices.
- Need to revisit stock structure assumptions.

PACIFIC-WIDE MODEL CONCLUSIONS (2)

- Limited data to inform selectivities. Considerable variation amongst years. Change in availability may differ by size? Or variation in sampling (spatial distribution of sample collection).
- Estimates of depletion (for PO) strongly influenced by the PSOBJ_EPO_Large CPUE indices, especially three higher values early in series (1995-1997).
- <u>These exploratory models are not considered sufficiently robust to provide an assessment of stock status for silky sharks in the Pacific Ocean as a whole or at either regional scale.</u>

HOW ABOUT A WCPO-ONLY MODEL?

Addendum

- WCPO region only (exclude EPO data).
- Single region, SP_LL primary CPUE index.
- Other assumptions equivalent to Pacific-wide model.
- Incorporate variation in catchability for SP_LL CPUE index (enviro link). SP_LL primary CPUE index negatively correlated with Nina4 SST in following year (corr coef -0.68).

*Catchability(y) = baseQ + link * env(y)*

- Investigate initial conditions (equilibrium catch and SE).
- Uncertainty from inverse Hessian matrix.

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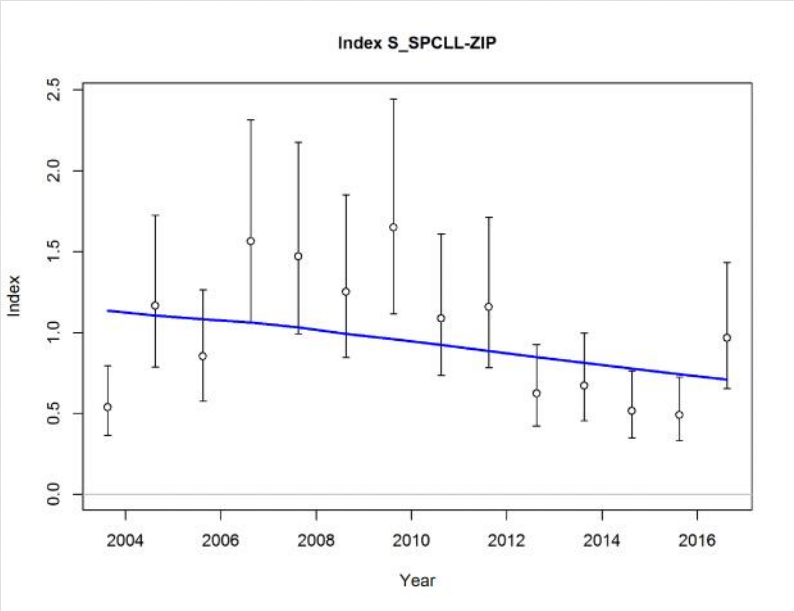
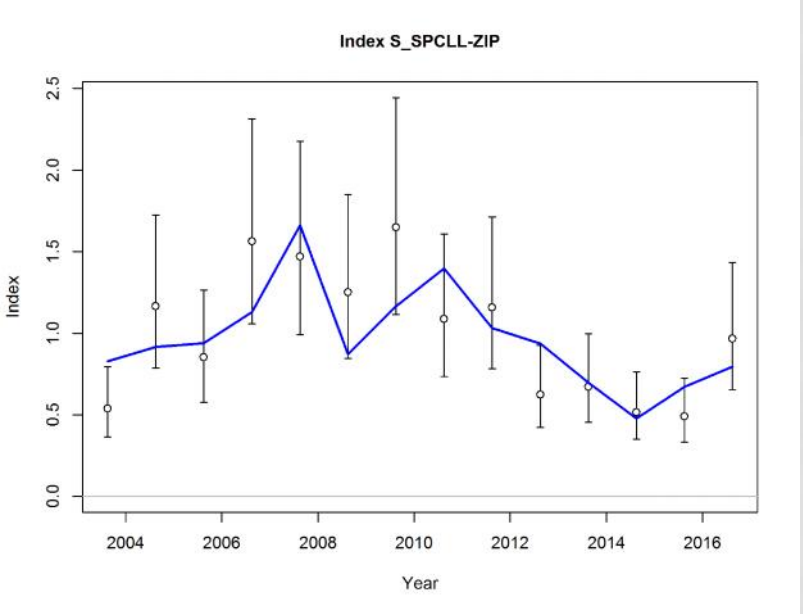
WCPO MODEL

Model		Q dev	Initial Eq catch	SE catch
Initial WCPO		No	100% 1995	High
CPUEqDev	IntialCatch_Level1_SEhigh	Yes	100% 1995	High
	IntialCatch_Level1_SElow	Yes	100% 1995	Low
	IntialCatch_Level05_SEhigh	Yes	50% 1995	High
	IntialCatch_Level05_SElow	Yes	50% 1995	Low

WCPO MODEL

Fit to SP_LL CPUE indices

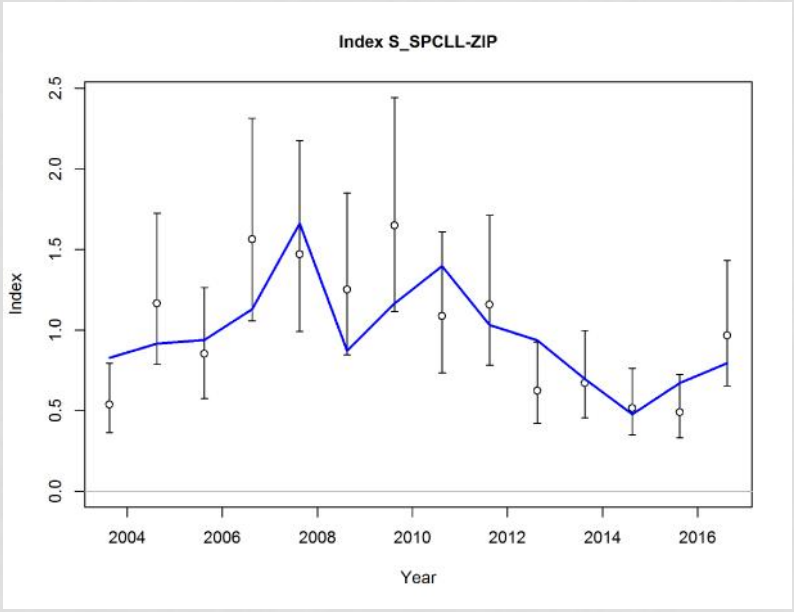


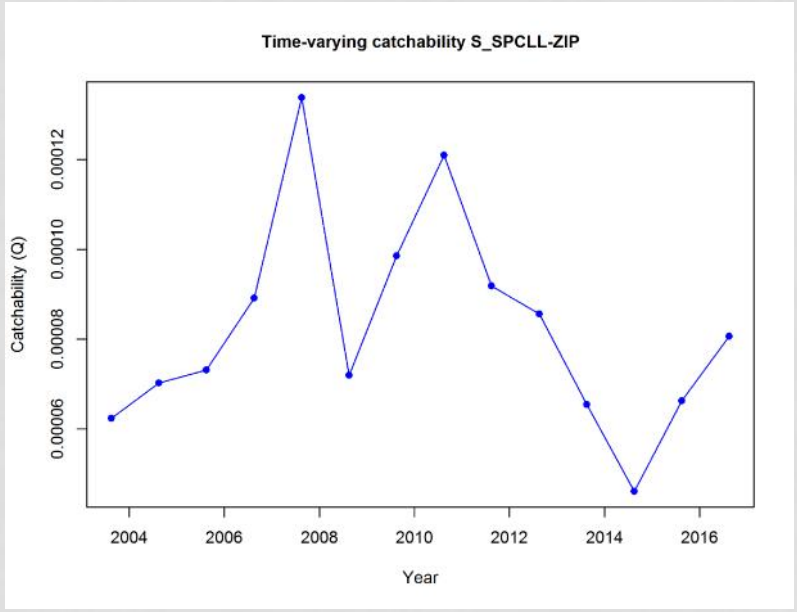


Initial WCPO model

CPUEqDev model
Considerable improvement in model likelihood.

WCPO MODEL





CPUEqDev model

Annual catchability
Link parameter = -0.528973
(Catchability range 2.9 fold)

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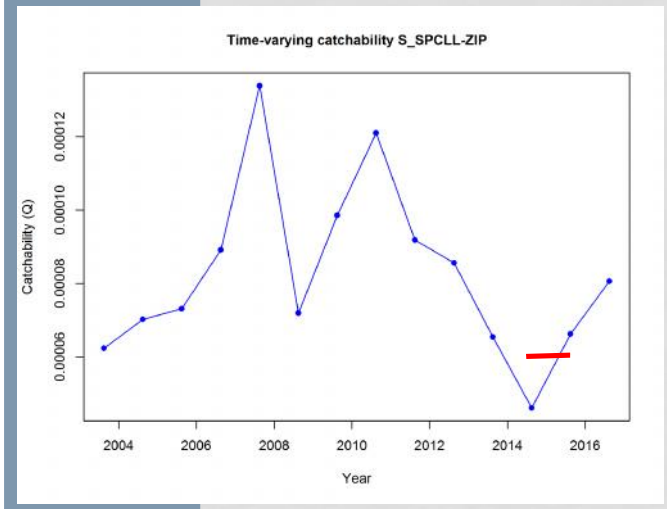
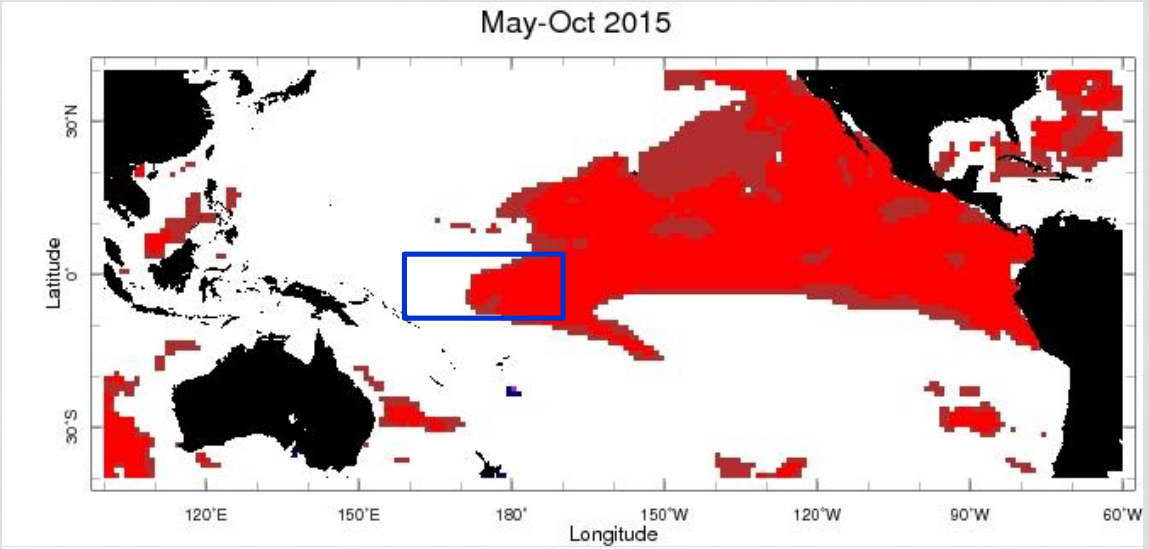
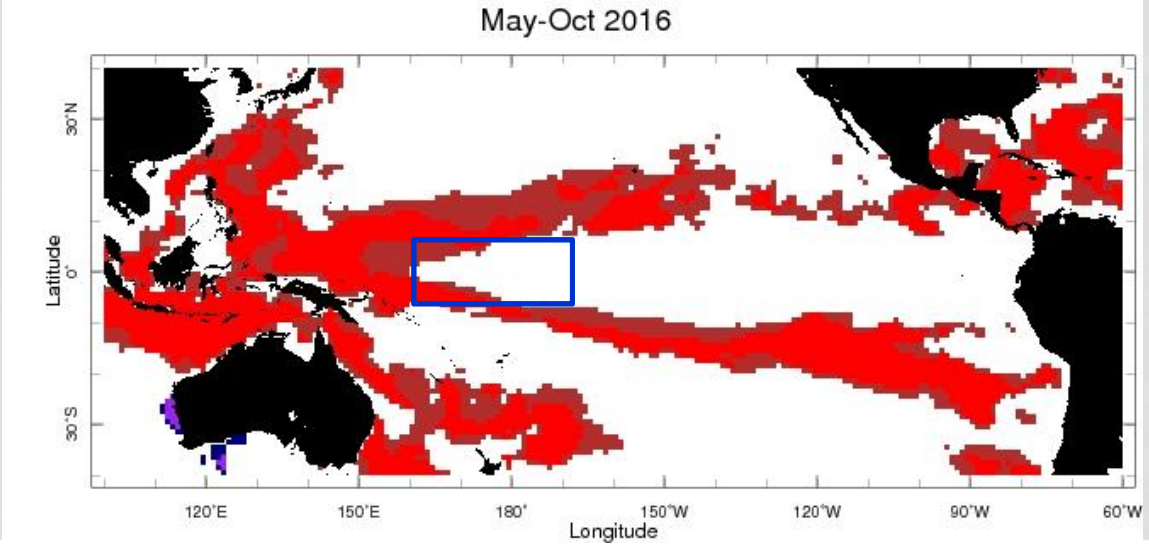
WCPO MODEL







Red denotes positive SST anomalies.

High SST = Lower Q in preceding year. (2014 and 2015)

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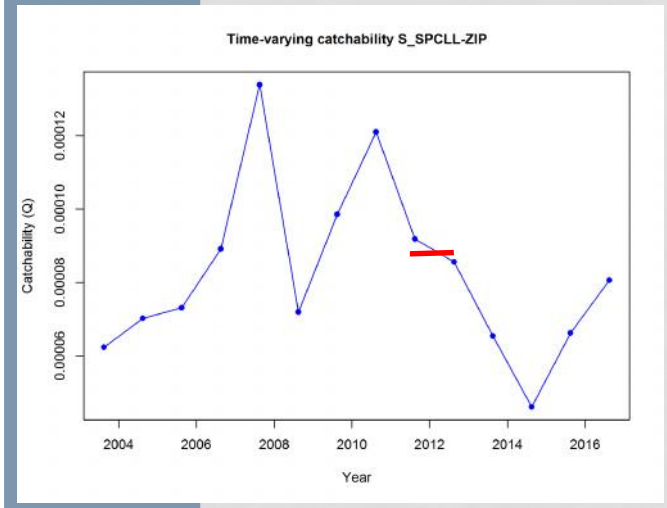
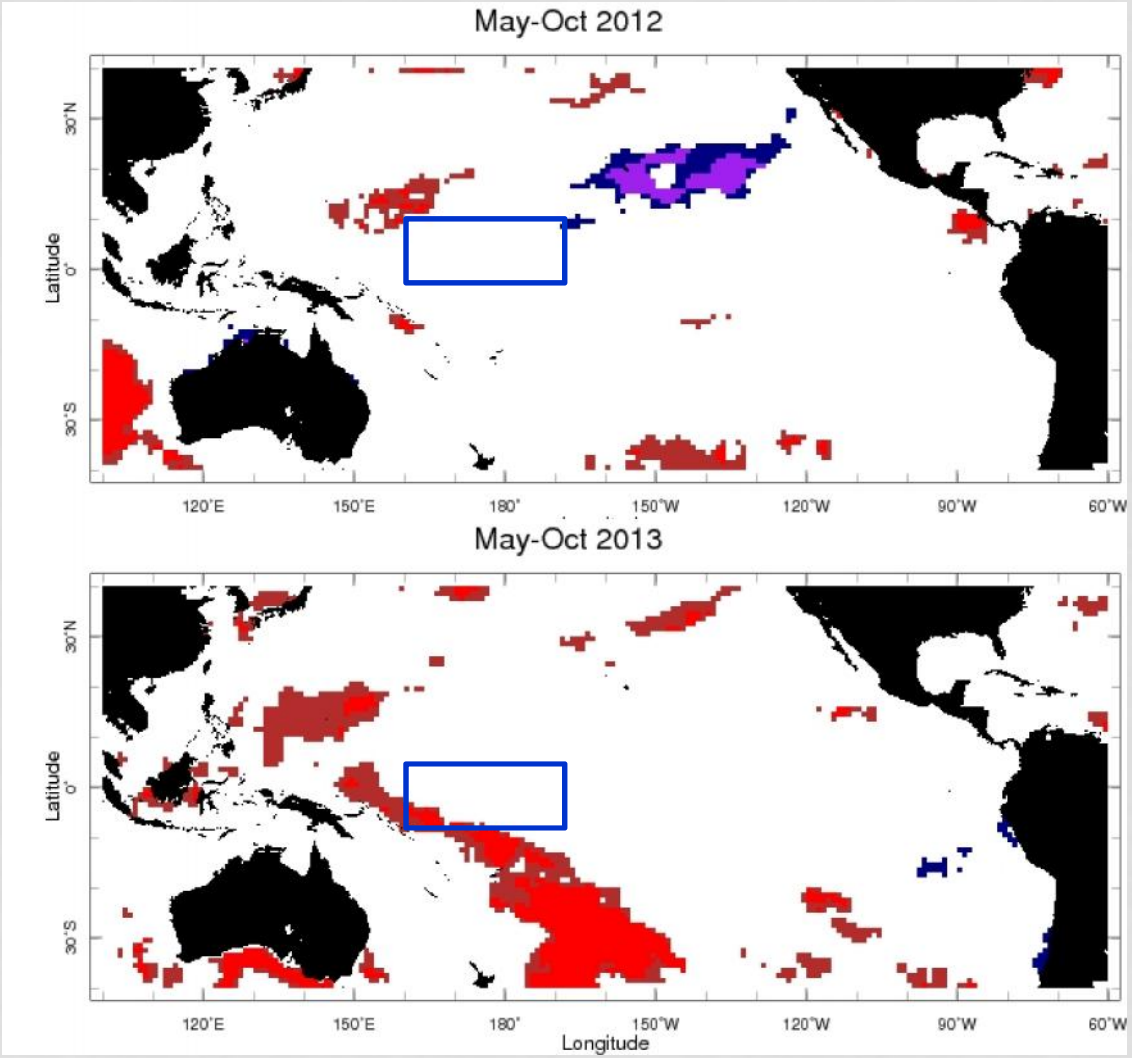
WCPO MODEL





Blue/purple denotes negative SST anomalies.

Lower SST = Higher Q in preceding year.
(2011 and 2012)

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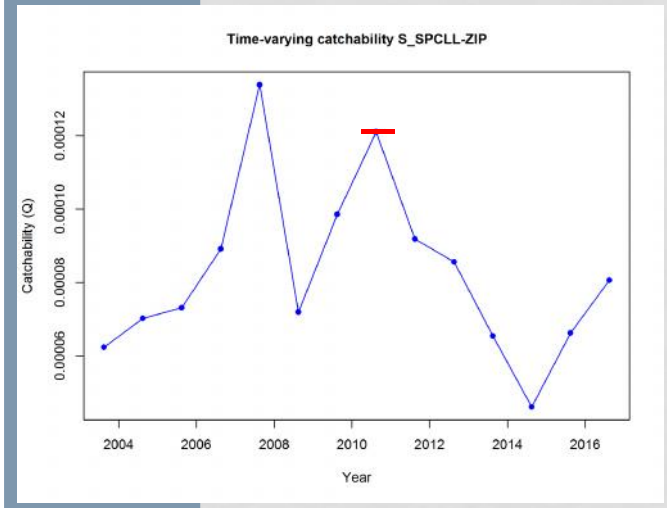
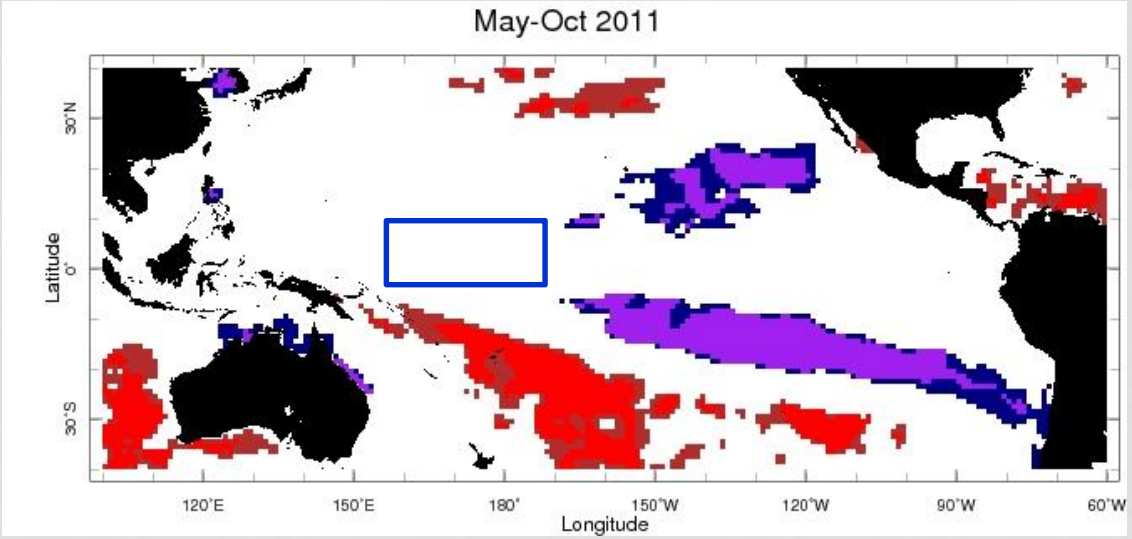
WCPO MODEL





Blue/purple denotes negative SST anomalies.

Lower SST = Higher Q in preceding year (2010)

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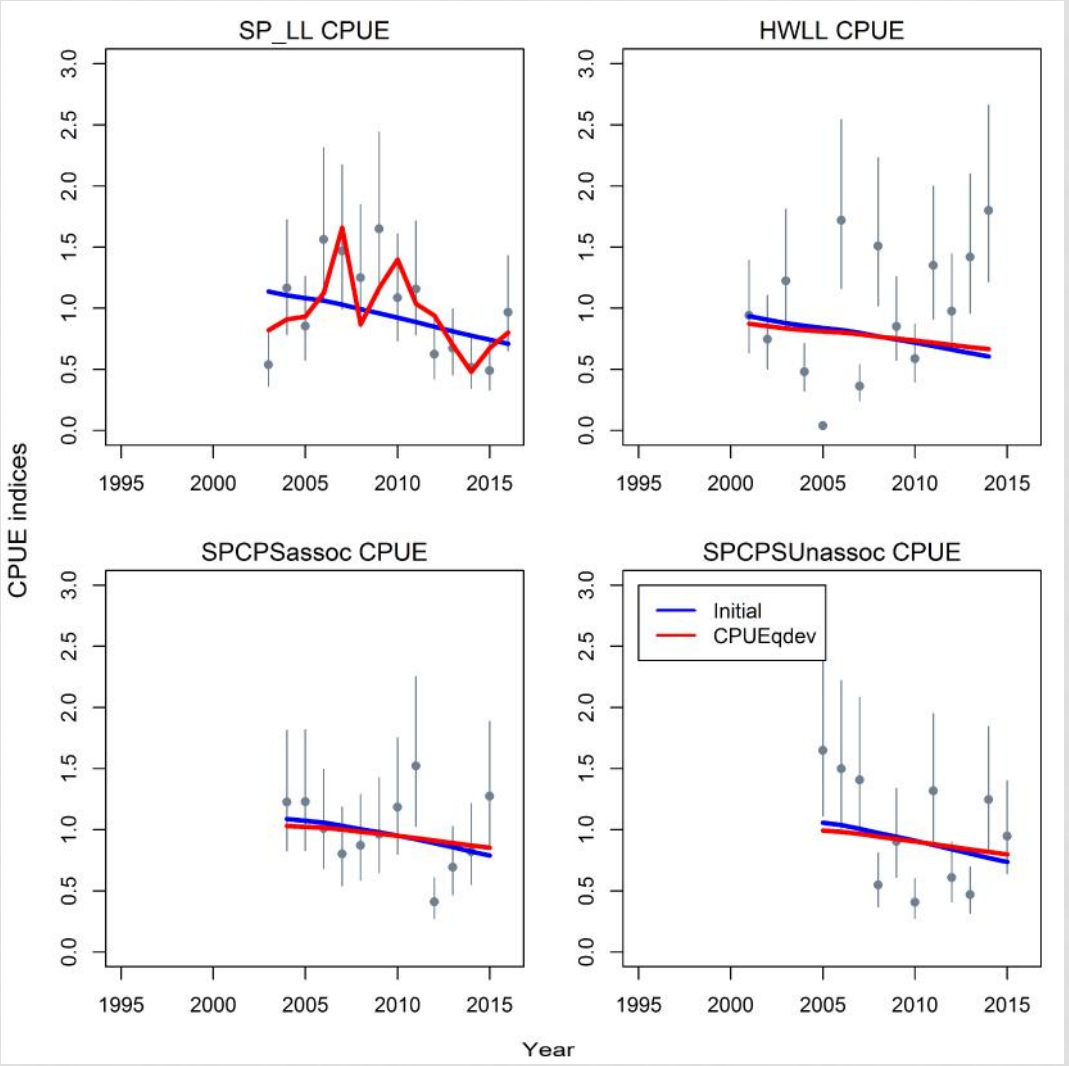
WCPO MODEL

All WCPO CPUE indices

No improvement in fit to the other CPUE indices.



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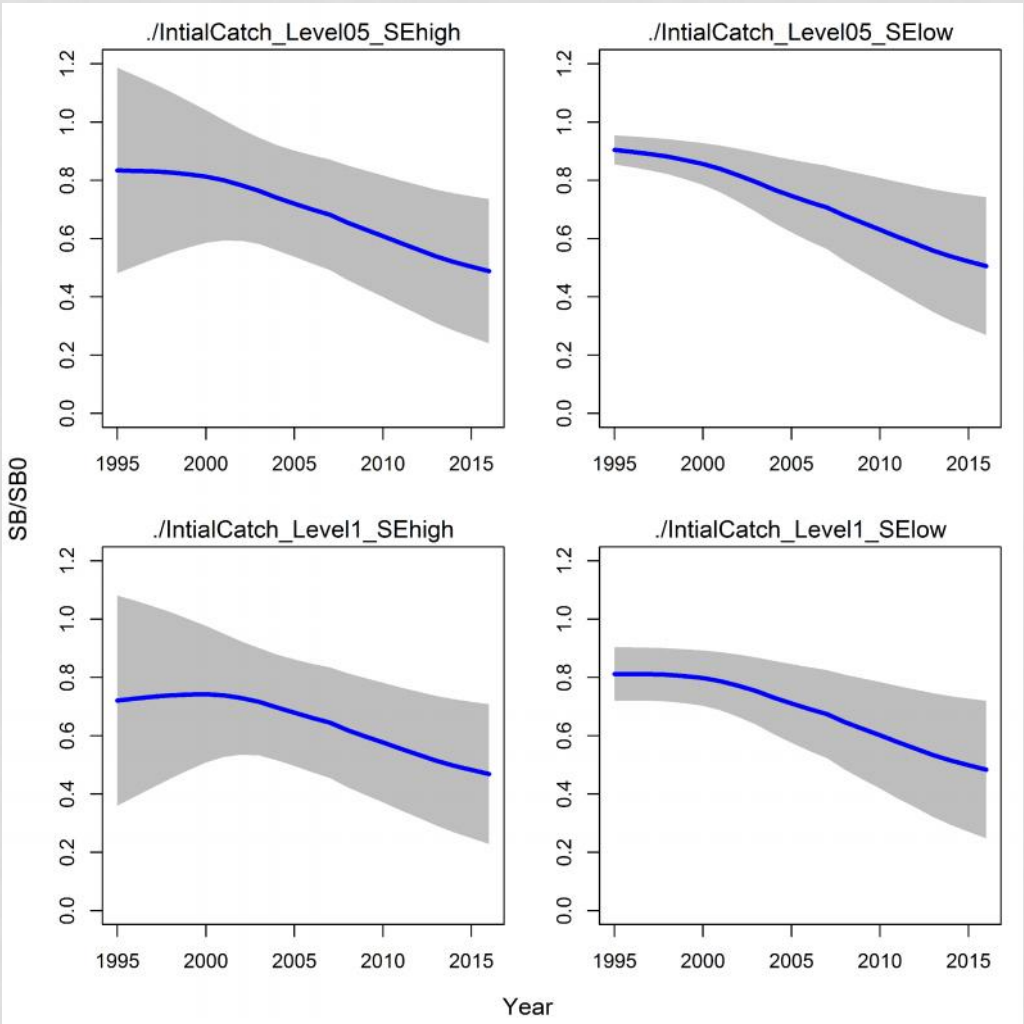
WCPO MODEL

Initial conditions.

Related to Initial Equilibrium Catch and associated SE.

Current (2016) level of depletion relatively insensitive to initial catch assumptions (SB_{2016}/SB0 ~ 0.47-0.50).

95% confidence intervals.
Fishery Initial F is estimated.



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WCPO MODEL

Model	SB0	SBMSY/SB0	MSY	SB2016/SB0	F2016/FMSY		
Initial	9,257	0.399	9,606	0.352	(0.101)	2.523	(0.873)
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)

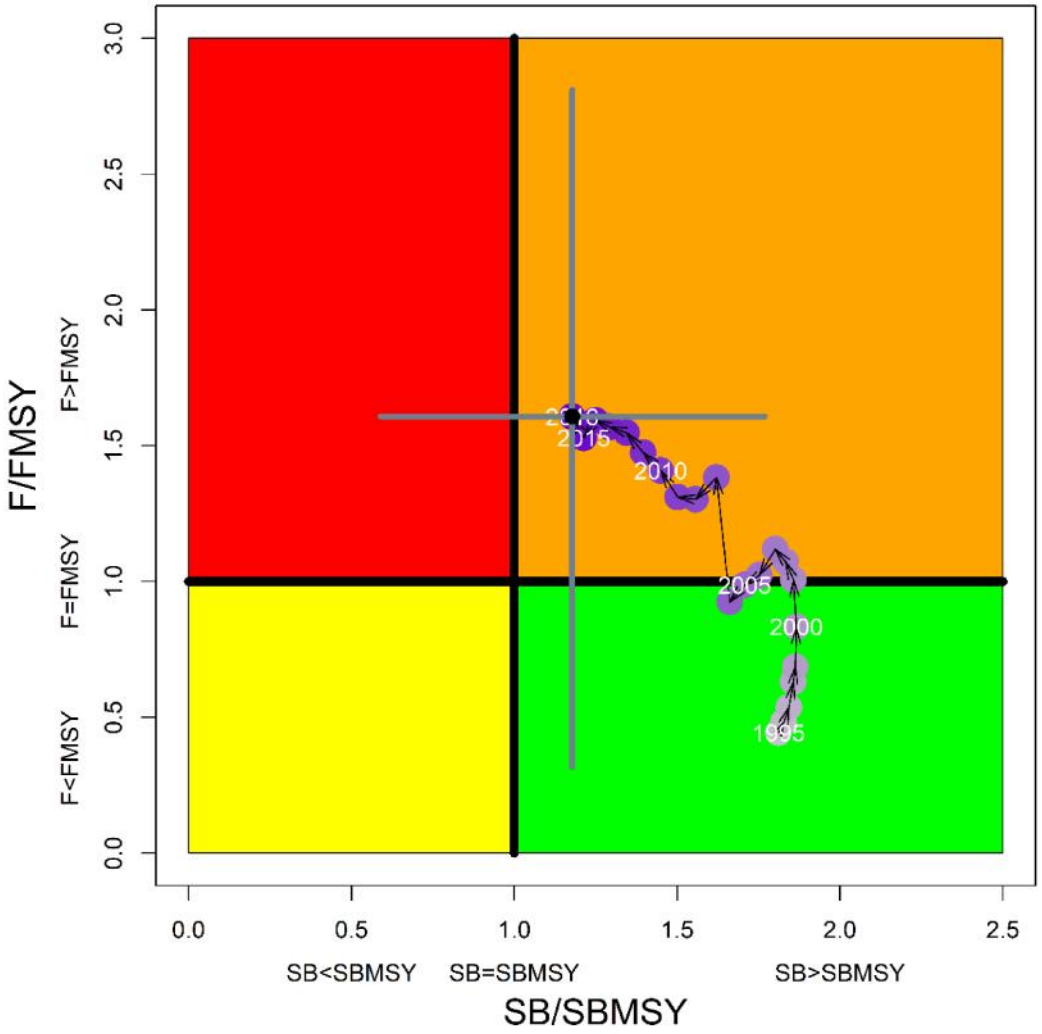
(Standard deviations in brackets)

CPUEqdev models provide point estimate of SB2016 is slightly higher than SBMSY (= 39.8% SB0) (Pr SB2016 > SBMSY = 72%), although significant probability (~28%) of being below SBMSY.

Fishing mortality in 2016 considerably higher than FMSY but very uncertain. High probability (84%) of exceeding FMSY.

Comparison with Rice & Harley (2013) SBcur/SB0 = 0.27 (0.20-0.47) and F/FMSY = 4.48 (1.41-7.96) (Table 8). Scale of biomass is considerably higher from current models due to differences in WCPO catch history.

WCPO MODEL



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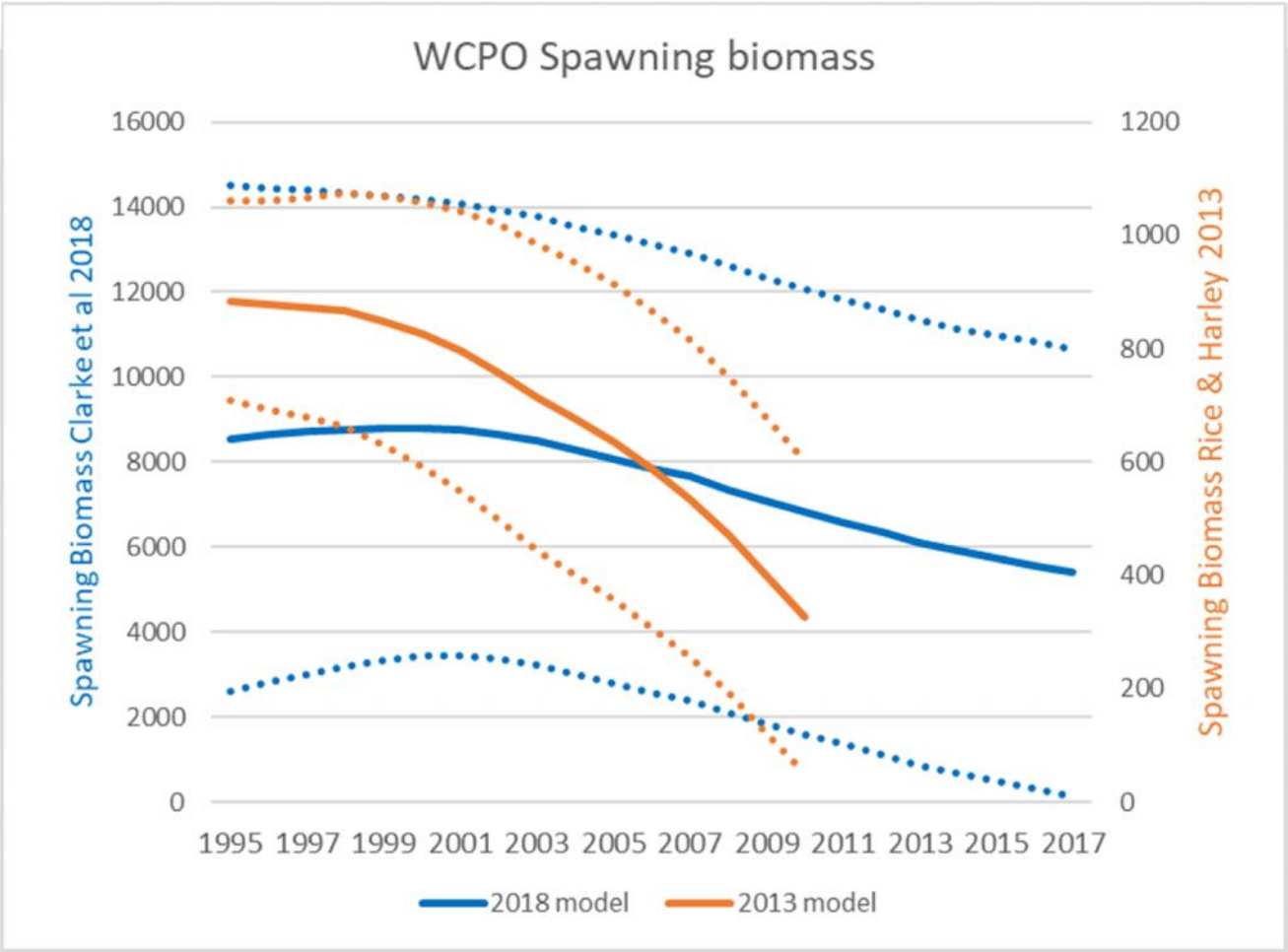
WCPO MODEL CONCLUSIONS

- Reliant on short SP_LL CPUE time series .
- Catchability-Environmental relationship may not be reliably determined (selection of enviro variable, short CPUE time series, & mechanism poorly understood).
- Inconsistent trends from other CPUE indices.
- Variation in length comp not accommodated in model.
- Uncertainty in other parameters (steepness, etc) not included.
- Initial conditions. Different from those of Rice & Harley 2013 (fixed initial Fs, Initial Eq Catch negligible, SE 0.01, exclude catch from likelihood) but impact on stock status estimates is negligible.

WCPO MODEL



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Compare SB (scale and trend) between WCPO *CPUEqdev* and Reference model from Rice & Harley (2013) (higher uncertainty from grid).

FURTHER WORK FOR BOTH MODELS

- Revisit spatial domain and regional structure (partition catches accordingly) and movement; e.g. EPO tag release/recovery data and PS_OBJ CPUE for small/medium sharks.
- Explore influence of oceanographic conditions on distribution and densities within WCPO and Pacific-wide
- Analysis of variation in size data (esp WCPO LL).
- Additional LF data from specific fisheries (e.g. HWLL).
- Incorporation of additional EPO data sets (collaboration with IATTC and other agencies).
- Consideration of appropriate reference points (MSY vs other).
- Incorporate any new biological information.

SC14 CONSIDERATIONS

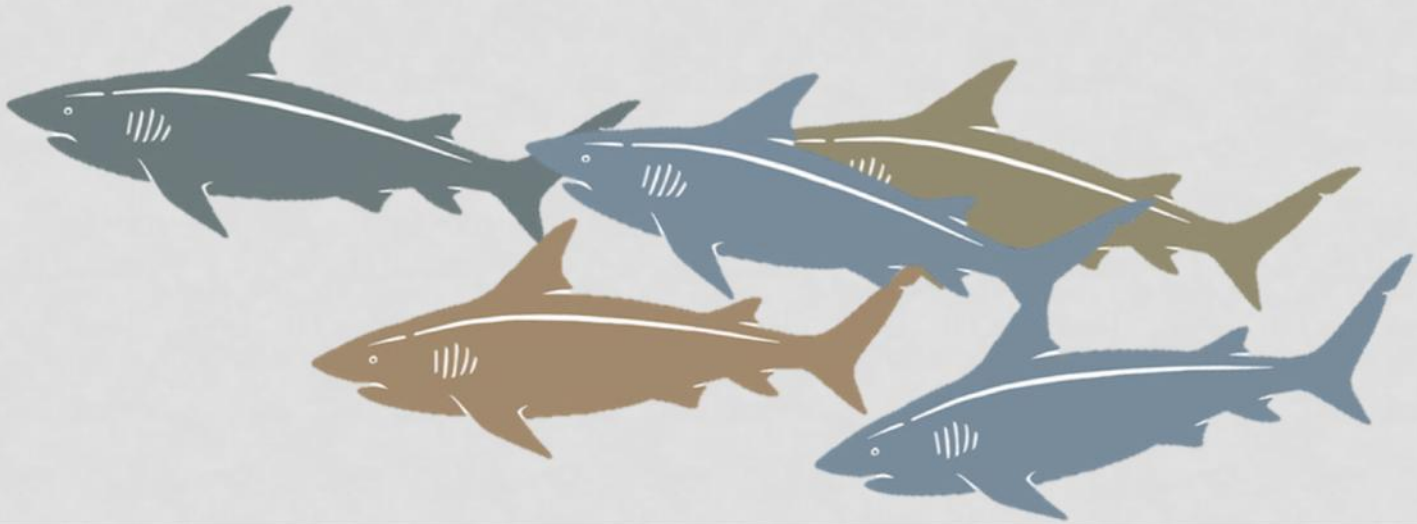
1. Best available science?
2. Although estimates of B and F for Pacific-wide are unreliable, accept WCPO-only estimates?
3. If so, conclude that overfishing is occurring but stock is not overfished?

SC14 CONSIDERATIONS

4. Maintain no-retention CMM as a precautionary measure?
5. Improve observer and tagging data?
6. Revisit this assessment no later than 2021?

ACKNOWLEDGEMENTS

- SPC and IATTC staff
- NOAA PIFSC
- 13 WCPFC CCMs for non-ROP data



EXTRA SLIDE: WCPO MODEL

Initial conditions – comparison with Rice & Harley (2013) reference model (SB_cur/SB0 = 0.30).

Step		SB2016/SB0	Standard Error
	Base = CPUEqdev	**0.469**	**0.12**
1	Fix Initial Fs	0.298	0.05
2	Initial Equilibrium Catches negligible	0.144	0.02
3	Exclude Equilibrium Catches from likelihood	0.477	0.11
4	Catch SE negligible	**0.477**	**0.11**

Very similar results when use model formulation equivalent to Rice & Harley (2013) (Step 4).