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Brief review of regime shift in the North Pacific Ocean and preliminary analysis to investigate relationship between environmental regime shift and North Pacific albacore recruitment [1]

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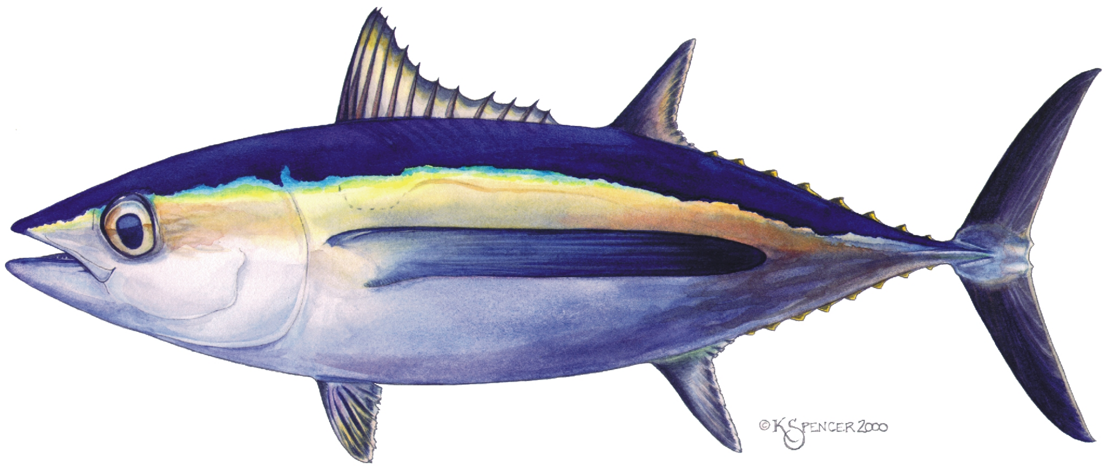

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Brief review of regime shift in North Pacific Ocean

"Regime shift" was first found by Kawaski (1983) with synchronous fluctuations in biomass of three distantly separated sardine population in the Pacific. King (2002) proposed a quantitative definition as "a relatively rapid change from one decadal-scale period of a persistent state to another decadal-scale period of a persistent state". Recent researches such as climate, physical, biological and ecosystem dynamics in the North Pacific Ocean shows any possibilities of regime shift based on their relatively longer time series of data. For example, remarkable changes of phyto-zooplankton biomass in Oyashio area was identified around environmental changes (Chiba et al., 2008). Overland et al. (2008) summarized North pacific regime shifts detected from available climate indices, physical indices and biological indices. It should be noted that several biological indices correspond to the timing of climate and physical indices. Examples of regime shifts in ecosystem not only in North Pacific but other oceans were well summarized in the literature by Jiao (2009). Kurota and Kai (2012) examined long-term time-series of stock status of temperature tunas in the North Pacific and statistically significant regime shifts were detected in RPS (in 1972 and 1992) for BFT, and RPS (in 1988 and 1995) and recruitments (in 1978 and 1988) for NPALB. These researches indicate "regime shift" in North Pacific from lower trophic to tuna are likely scientifically-valid evidence, however, there still remains much difficulties to understand underlying mechanisms between climate, physical and biological regime shift.

Preliminary analysis of NPALB and PDOI

North Pacific albacore recruitment estimated by 2011 stock assessment were used (ISC, 2011) and pacific decadal oscillation (PDOI) index were also employed (http://jisao.washington.edu/pdo/). PDOI is defined as leading principal component of North Pacific monthly sea surface temperature variability (poleward of 20N for the 1900-93 period) (Maunta and Hare, 2002). Detecting regime shift from the north pacific albacore recruitment and winter PDOI, algorithm proposed by Rodinov (2006) was applied. This method was initially based on a sequential t-test that can assess the probability of a shift in realtime, and was further expanded to exclude serial autocorrelation (red noise) by adopting a prewhitening technique (Rodionov 2006). STARS version 3.2 were used (http://www.beringclimate.noaa.gov/regimes/).

Regime shift was detected both of NPALB recruitment and winter PDOI. NPALB recruitment regime shift occurred in 1977/78, 1987/88 and 2004/2005 (Fig.1) and this is consist with the result conducted by Kurota et al. (2012). Regime shift of winter PDOI were identified in 1975/1976, 1987/88 and 2006/2007. Coincidence between NPALB and PDOI in 1987/88 regime shift implies that their relationships cannot be neglected and further quantitative analysis are necessarily to test predictability of NPALB recruitment by change of PDOI or sea surface temperature. Fig.2(a) shows stock-recreuitiment plot separated by low recruitment period (1978-1987: blue) and high recruitment period (1966-1977, 1988-2003; red). Stock-recreuitment relation could be changed under recruitment regime shift which may be affected by the climate or ocean regime shift (Fig.2(b)).

These results are just preliminary and there is no quantitative analysis has been done, however, different recruitment regime caused by ocean conditions probably increase uncertainty of steepness estimation which is one of important parameter in the stock assessment (e.g. Iwata et al., 2010). This also will possibly reflect to the MSY estimates. Although one might say MSY proxies will be alternative biological reference points, there still remains uncertainty that has not been well investigated any effects of regime shift. Further analysis should be conducted to test robustness of any biological reference points under conditions both of recruitment and environmental regime shift. Those profound discussions should also be added to the list of BRPs (pros and cons) summarized in the report of ISC10 (ISC, 2010; Annex 1 in this document).

Several articles has also focused on fishery management under variable environment (Brunel et al., 2010) or regime shift (A'mar, 2009). Although underlaying mechanisms between biological and climate, physical conditions is still unclear, evidences of regime shift in the North Pacific has been recognized widely. This awareness of regime shift needs to be included or discussed on the context of management.

References

A'mar, Z. T., Punt, A.E. and Dorn, M. W. (2009) The impact of regime shifts on the performance of management strategies for the Gulf of Alaska walleye pollock (*Theragra chalcogramma*) fishey. *Can. J. Fish. Aquast. Sci.*, **66:** 2222-2242.

Brunel, T., Piet, G.J., Hal, R. and Rockmann, C. (2010) Performance of harvest rules in a variable environment. *ICES J. Mar. Sci.*, **67:** 1051-1062.

Chiba, S., Aita, M. N. Tadokoro, K., Saino, T., Sugisaki, H. and Nakata, K.
From climate regime shifts to lower-trophic level phenology: Synthesis of recent progress in retrospective studies of the western North Pacific. *Prog. Oceanogr.*, **77:** 112-126.

ISC (2010) Report of the Albacore working group workshop. *Annex 6 in Report of the 10th meeting of the ISC in the North Pacific Ocean*

Iwata, S., Sugimoto, H. and Takeuchi, Y. (2011) Calculation of the steepness for the North Pacific Albacore. *ISC/11/ALBWF/18*

Jiao, Y. (2009) Regime shift in marine ecosystems and implications for fisheries management, a review. *Rev. Fish Bio. Fisheries*, **19:** 177-191.

Kawasaki, T. (1983). Why do some pelagic fish have wide fluctuations in their numbers? Biological basis from the viewpoint of evolutionary ecology. *FAO Fisheries Reports*, **291:**, 1065-1080.

King J. R. (2002) Reort of the study group on fisheries and ecosystem responses to recent regime shifts. *PICES Scientific Report* **28:** 162pp

Kurota, H. and Kai, M. (2012) Characteristics of Historical Population Dynamics of Temperate Tunas in the north Pacific and Implementation for Management. *WCPFC Management Obkectives Workshop.*

Mantua, N. and Hare, S.R. (2002) The pacific decadal oscillation. *J. Oceanogr.*, **58:** 35-44.

Overland, J., Rodionov, S., Minobe, S. and Bond, N. (2008) North Pacific regime shifts: Definition, issues and recent transition. *Prog. in Oceanogr.*, **77:** 92-102.

Rodionov, S. N. (2006) Use of pre whitening in climate regime shift detection. *Geophys. Res. Lett.*, **33:** doi:10.1029/2006GL025904.

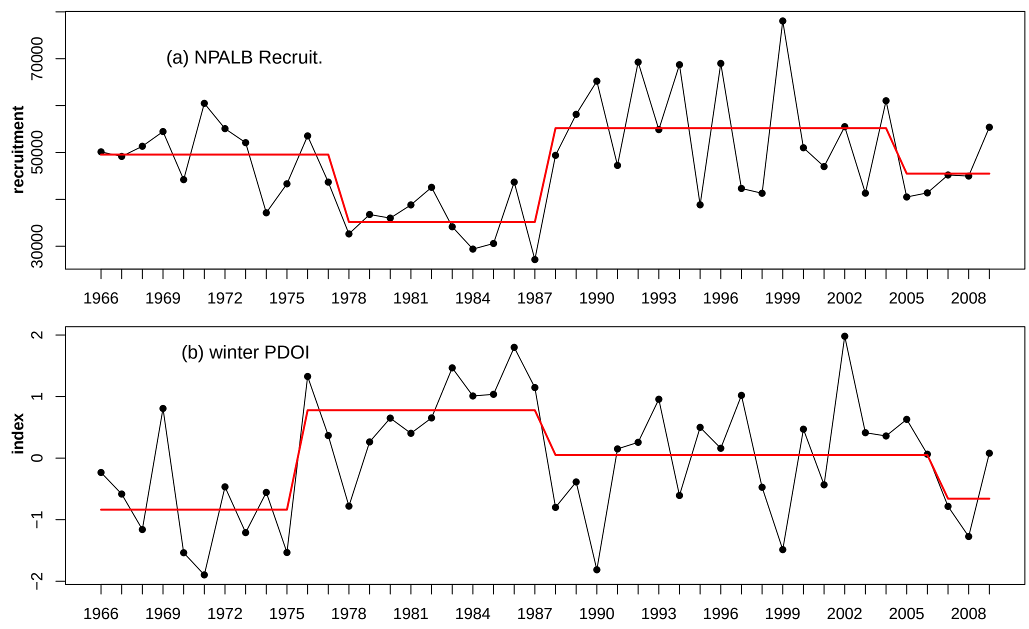
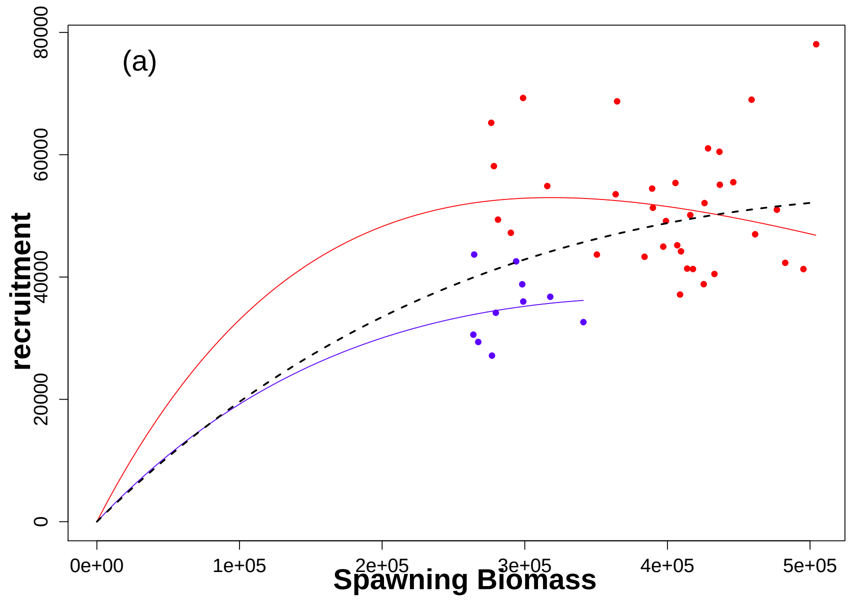


Figure 1. (a) Time series of North Pacific albacore recruitment estimated by SS3 in 2011 stock assessment. (b) winter Pacific decadal oscillation (PDO) index.



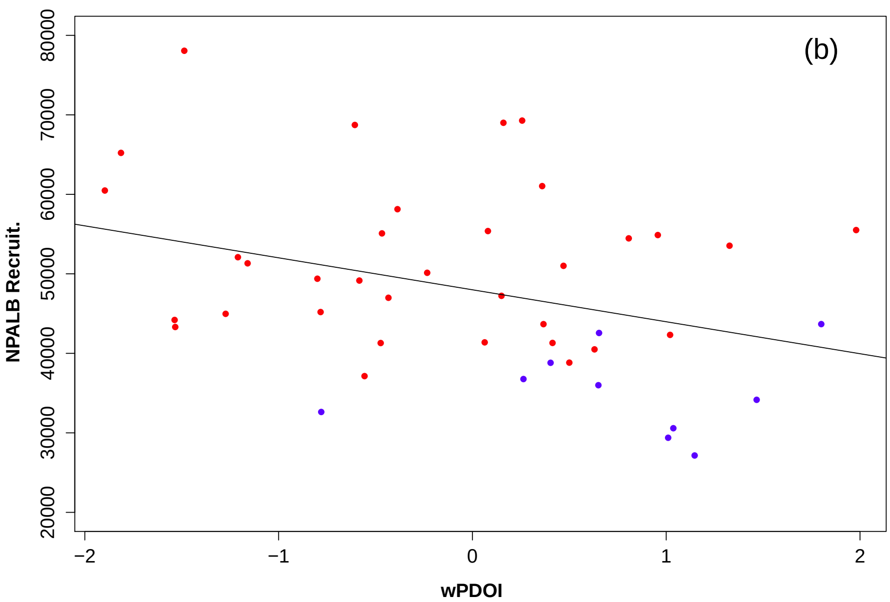


Figure 2. (a) Spawning biomass and recruitment relationships for North Pacific albacore and (b) NPALB and wPDOI plot. (blue: low recruitment period (1978-1987), red: high recruitment period(1966-1977 and 1988-2004).

Annex1. Candidate biological reference points for north Pacific albacore in Annex6 (ISC,2010)

Candidate biological reference points for north Pacific albacore and their characteristics.

BRPs	Recent Estimate (Year)		Description	Data Needs	Model
	50% Prob.	95% Prob.			
F_{MSY}			Fishing mortality rate associated with maximum sustainable yield	Catch, CPUE, life history parameters	Age structured & dynamic-pool models
F_{MED}			Fishing mortality rate corresponding to the median observed recruit/SSB ratio	Catch, CPUE, life history parameters	Age structured & dynamic-pool models
$F_{40\%}$	0.32 (2006)		F that reduces SSB/R to 40% of unfished state	Life history parameters (length-weight, M, size at age, sex ratio)	Age structured model
$F_{35\%}$	0.38 (2006)		F that reduces SSB/R to 35% of unfished state		
$F_{30\%}$	0.45 (2006)		F that reduces SSB/R to 30% of unfished state		
$F_{20\%}$	0.65 (2006)		F that reduces SSB/R to 20% of unfished state		
$F_{0.1}$	0.45 (2006)		F at which slope of Y/R is 10% of value at origin	Life history parameters (length-weight, M, size at age, sex ratio)	Age structured & dynamic-pool models
F_{MAX}	2.07 (2006)		F corresponding to maximum yield per recruit	Life history parameters (length-weight, M, size at age, sex ratio)	Age structured & dynamic-pool models
F_{loss} [A]			Fishing mortality rate expected to keep biomass at Bloss	Catch, CPUE, life history parameters	Age structured model
B_{loss} [A]			Minimum observed biomass (or SSB)	Catch, CPUE, life history parameters	Age structured model
B_{MSY}			Stock biomass associated with maximum sustainable yield	Catch, CPUE, life history parameters	Age structured & dynamic-pool models
SSB_{MSY}			Spawning stock biomass associated with maximum sustainable yield	Catch, CPUE, life history parameters	Age structured & dynamic-pool models

Candidate biological reference points for north Pacific albacore and their characteristics.

BRPs	Recent Estimate (Year)		Description	Data Needs	Model
	50% Prob.	95% Prob.			
F_{SSB}			Fishing mortality rate that ensures future spawning stock biomass (SSB) remains above a specified threshold level with a certain probability.	Configuration of stock assessment model and projection software requires discussion with managers	Age structured & dynamic-pool models
$F_{SSB\text{-}10\%}$	0.70 (2006)	0.55 (2006)	Fishing mortality rate that prevents the SSB from declining below the 10th percentile of observed SSB		
$F_{SSB\text{-}25\%}$	0.66 (2006)	0.51 (2006)	Fishing mortality rate that prevents the SSB from declining below the 25th percentile of observed SSB		
$F_{SSB\text{-}50\%}$	0.56 (2006)	0.39 (2006)	Fishing mortality rate that prevents the SSB from declining below the median (50th percentile) of observed SSB		
$F_{SSB\text{-}ATHL}$	0.75 (2009)		Fishing mortality rate that prevents the SSB from declining below the average of the ten historically lowest observed SSB		
$F_{SSB\text{-}min}$	0.81 (2006)	0.64 (2006)	Fishing mortality rate that prevents the SSB from declining below the minimum observed SSB		

Candidate biological reference points for north Pacific albacore and their characteristics.

BRPs	Recent Estimate (Year)		Description	Data Needs	Model
	50% Prob.	95% Prob.			
F_{SSB}			Fishing mortality rate that ensures future spawning stock biomass (SSB) remains above a specified threshold level with a certain probability.	Configuration of stock assessment model and projection software requires discussion with managers	Age structured & dynamic-pool models
$F_{SSB\text{-}10\%}$	0.70 (2006)	0.55 (2006)	Fishing mortality rate that prevents the SSB from declining below the 10th percentile of observed SSB		
$F_{SSB\text{-}25\%}$	0.66 (2006)	0.51 (2006)	Fishing mortality rate that prevents the SSB from declining below the 25th percentile of observed SSB		
$F_{SSB\text{-}50\%}$	0.56 (2006)	0.39 (2006)	Fishing mortality rate that prevents the SSB from declining below the median (50th percentile) of observed SSB		
$F_{SSB\text{-}ATHL}$	0.75 (2009)		Fishing mortality rate that prevents the SSB from declining below the average of the ten historically lowest observed SSB		
$F_{SSB\text{-}min}$	0.81 (2006)	0.64 (2006)	Fishing mortality rate that prevents the SSB from declining below the minimum observed SSB		

Candidate biological reference points for north Pacific albacore and their characteristics.

BRPs	USE (target/limit)	Pros	Cons	Robustness to M^B	NPALB Comments
		parameters over time and selectivity patterns.			
F_{MAX}	limit	Estimated from Y/R so S/R relationship doesn't need to be known; F > FMAX considered growth overfishing	Difficult to estimate if Y/R curve is asymptotic; not useful for recruitment overfishing	Estimates highly sensitive to changes in M	Life history parameter estimates for albacore are old and need updating; may affect estimates
$F_{loss}{}^{A}$	limit	Ease of calculation relative to F_{SSB}; easy to understand the concept as a limit	Assume equilibrium dynamics which may not be realistic	Estimates relatively sensitive to M assumption	B_{loss} occurred at beginning of time series when backward simulation models do not estimate well. Robustness of estimate based on previous stock assessment questioned; may not be an issue with implementation of SS3 for upcoming stock assessment but requires further research
$B_{loss}{}^{A}$	limit	Ease of calculation relative to Fssb; easy to understand the concept as a limit	Assume equilibrium dynamics which may not be realistic	Estimates relatively sensitive to M assumption	B_{loss} occurred at beginning of time series when backward simulation models do not estimate well. Robustness of estimate based on previous stock assessment questioned; may not be an issue with implementation

Candidate biological reference points for north Pacific albacore and their characteristics.

BRPs	USE (target/limit)	Pros	Cons	Robustness to M[B]	NPALB Comments
					of SS3 for upcoming stock assessment but requires further research
B_{MSY}	target or limit	Considers both S/R and OY concepts; consistent with goals of many management bodies (straightforward); Accounts for changes in life history parameters over time and selectivity patterns.	Difficult to estimate; sensitive to S/R steepness and other structural assumptions; not robust to change in selectivity; productivity changes (e.g., regime shifts) may have unpredictable effects		
SSB_{MSY}	target or limit	Considers both S/R and OY concepts; consistent with goals of many management bodies (straightforward); Accounts for changes in life history parameters over time and selectivity patterns.	Productivity changes (e.g., regime shifts) may have unpredictable effects		
F_{SSB}	target or limit	Flexibility in way it's calculated; flexible based on management goals; increases need to determine	Flexibility in way it's calculated; increases need to determine risk strategy of management; computer	$F_{SSB-10\%}$: insensitive, $F_{SSB-25\%}$: insensitive,	Flexibility in way it's calculated; increases need to determine risk strategy of management; computer

Candidate biological reference points for north Pacific albacore and their characteristics.

BRPs	USE (target/limit)	Pros	Cons	Robustness to M[B]	NPALB Comments
$F_{SSB-10\%}$	Limit/Precautionary	risk strategy of management; Based on concept of avoiding recruitment overfishing Simulation-based; takes into account uncertainties as buffers by quantifying non-equilibrium dynamics, estimates of historical SSB, and parameter estimates in the terminal years.	intensive; Requires specification of: (1) threshold SSB level, (2) probability that stock remains above threshold, and (3) length of projection period. Sensitive to projection period used in simulation, e.g., 5- vs 25-yr. Occurs at beginning of time series when VPA does not estimate old fish well; this may not be true with new SS3 model;	Sensitivity for $F_{SSB-50\%}$ was not tested.	intensive; Requires specification of: (1) threshold SSB level, (2) probability that stock remains above threshold, and (3) length of projection period. Based on concept of Avoiding recruitment overfishing
$F_{SSB-25\%}$	Limit/Precautionary				
$F_{SSB-50\%}$	Target				
$F_{SSB-ATHL}$	Limit/Precautionary			Estimates insensitive to M assumption	Consistent with interim objective for NP ALB;
$F_{SSB-min}$	Limit/Precautionary			Estimates relatively sensitive to M assumption	Occurs at beginning of time series when VPA does not estimate old fish well; this may not be true with new SS3 model;

A – see Kai 2010 - ISC/10-1/ALBWG/09.
B – see Kiyofuji et al. 2010 - ISC/10-1/ALBWG/11.