ISC/18/ALBWG/01

Correlations between Climatic indices (NPGO and PDO) and Abundance of Albacore Tuna in Waters off Northwest Coast of North America[1]

Zane Zhang

Department of Fisheries and Oceans
Pacific Biological Station
3190 Hammond Bay Road
Nanaimo, British Columbia, V9T 6N7, Canada

Email: zane.zhang@dfo-mpo.gc.ca

[1]This working paper was submitted to the ISC Albacore Working Group Intercessional Workshop, 30 April - 5 May 2018, held at the NOAA/SWFSC, CA, USA. Document not to be cited without the author's permission.

Introduction

The Canadian troll fishery on juvenile albacore tuna primarily takes place in the Canadian and U.S. exclusive economic zones (EEZs), and adjacent high seas waters, in July-Sept. Annual abundances of these albacore tuna appear to be rather variable, as suggested by variations in Catch-per-unit-effort (CPUE) (Fig. 1). The objective of this working paper is to examine if the two climatic indices, the North Pacific Gyre Oscillation (NPGO) and the Pacific Decadal Oscillation (PDO), may have any impacts on the variations in these juvenile albacore abundances. The NPGO and the PDO were chosen, as they appear to combine to control low-frequency upwelling and alongshore transport dynamics in the North Pacific sector (Di Lorenzo et al. 2013). In addition, the role of water temperature as measured by Canadian albacore fishing vessels was also investigated.

Material and Methods

Catch data from the Canadian albacore fishery in years of 1995-2016 were used in the study. CPUEs were calculated by dividing total annual catch in metric tons by total number of fishing days by all Canadian fishing vessels in the Canadian EEZ or US EEZ. A multiple linear model was applied on log-transformed CPUE values:

$$\log CPUE_y = \alpha + \beta 1 \times NPGO_{y-t} + \beta 2 \times PDO_{y-t} + \beta 3 \times T_y + \varepsilon$$

where $NPGO$ and PDO are, respectively, annual means of NPGO and PDO indices, T is the mean of water temperatures taken by Canadian albacore fishing vessels in July-September, α, $\beta 1, \beta 2$, and $\beta 3$ are model parameters, ε is a random variate from a normal probability distribution: $\varepsilon \sim N(0, \sigma^2)$, the subscript y denotes year and t indicates the number of years (0-5 years) in a time lag. Significance level was set to be 0.05.

Results and Discussion

There were no significant correlations between $\log CPUE$ and the $NPGO$ with 0-2 years in a time lag in the Canadian EEZ (Figs. 2) or 0-3 years in a time lag in the US EEZ (Figs. 3). However, the correlations were positive and significant with 3-5 years in a time lag in the Canadian EEZ or 4-5 years in a time lag in the US EEZ (Figs. 4). The NPGO closely reflected inter-annual variations in salinity, nutrient upwelling, and surface chlorophyll *a* in the ocean (Di Lorenzo et al., 2008). As a result, the NPGO may have a positive influence on the survival of young-of-the-year and one-year-old albacore, which is in turn reflected in the abundance of 2-4 year old juvenile albacore migrating into the Canadian and US EEZs.

There were no significant relationships between $\log CPUE$ and the PDO with 0-5 years in a time lag in the Canadian or US EEZ, although the correlations appeared to be negative for 2-5 years in a time lag (Figs. 4, 5). No significant relationships between $\log CPUE$ and water temperatures measured by the albacore fishing vessels (Fig. 6). Estimates of the model parameters together with 95% confidence intervals are presented in Tables 1 and 2.

Annual means of the NPGO indices started to continuously decrease in 2013, and annual means of the PDO indices have shown an increasing trend since 2012 (Fig. 7). Coincidentally, the CPUE in the Canadian EEZ dropped in 2016 relative to high CPUE values in 2013-2015, and fell in 2017 to the lowest observed level since 1995 (Fig. 1). Similarly, the CPUE in the US EEZ also dropped in 2016 relative to CPUEs in the previous three years, and further decreased in 2017 (Fig. 1). The study may highlight the importance of considering environmental factors in the Management Strategy Evaluation.

References

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Di Lorenzo, E., Schneider, N., Cobb, K.M., Franks, P.J.S., Chhak, K., Miller, A.J., McWilliams, J.C., Bograd, S.J., Arango, H., Curchitser, E., Powell, T.M., and Rivière, P. 2008. North Pacific Gyre Oscillation links ocean climate and ecosystem change. Geophys. Res. Lett., 35, L08607, doi:10.1029/2007GL032838.

Table 1. Estimates of parameters of the multiple linear model on log-transformed catch-per-unit-effort values in the Canadian EEZ.

Number of Years in a Time Lag	Parameter	Mean	95% Confidence Interval
0 Year	α	-0.30	-10.78, 10.18
	β1	0.04	-0.27, 0.36
	β2	0.03	-0.45, 0.51
	β3	-0.03	-0.68, 0.62
1 Year	α	-2.16	-10.61, 6.3
	β1	0.12	-0.15, 0.39
	β2	-0.06	-0.47, 0.34
	β3	0.08	-0.44, 0.61
2 Years	α	-2.08	-8.56, 4.41
	β1	0.18	-0.04, 0.41
	β2	-0.13	-0.46, 0.2
	β3	0.08	-0.32, 0.48
3 Years	α	1.83	-3.90, 7.56
	β1	0.30	0.09, 0.50
	β2	0.03	-0.27, 0.33
	β3	-0.17	-0.52, 0.19
4 Years	α	1.76	-4.12, 7.64
	β1	0.29	0.09, 0.49
	β2	0.03	-0.27, 0.33
	β3	-0.16	-0.53, 0.2
5 Year	α	2.83	-3.1, 8.76
	β1	0.34	0.14, 0.53
	β2	0.12	-0.18, 0.42
	β3	-0.23	-0.59, 0.14

Table 2. Estimates of parameters of the multiple linear model on log-transformed catch-per-unit-effort values in the US EEZ.

Number of Years in a Time Lag	Parameter	Mean	95% Confidence Interval
0 Year	α	-3.79	-11.7, 4.12
	ß1	0.08	-0.21, 0.38
	ß2	-0.05	-0.44, 0.35
	ß3	0.20	-0.27, 0.66
1 Year	α	-2.74	-9.17, 3.68
	ß1	0.16	-0.1, 0.41
	ß2	0.04	-0.33, 0.4
	ß3	0.13	-0.24, 0.51
2 Years	α	-2.78	-7.82, 2.27
	ß1	0.11	-0.1, 0.31
	ß2	-0.21	-0.5, 0.08
	ß3	0.14	-0.16, 0.43
3 Years	α	0.95	-4.51, 6.41
	ß1	0.15	-0.06, 0.36
	ß2	-0.15	-0.47, 0.17
	ß3	-0.08	-0.4, 0.24
4 Years	α	0.81	-5.04, 6.65
	ß1	0.22	0.01, 0.42
	ß2	-0.01	-0.35, 0.33
	ß3	-0.07	-0.42, 0.27
5 Year	α	0.29	-5.38, 5.96
	ß1	0.27	0.07, 0.48
	ß2	0.15	-0.16, 0.47
	ß3	-0.04	-0.38, 0.29

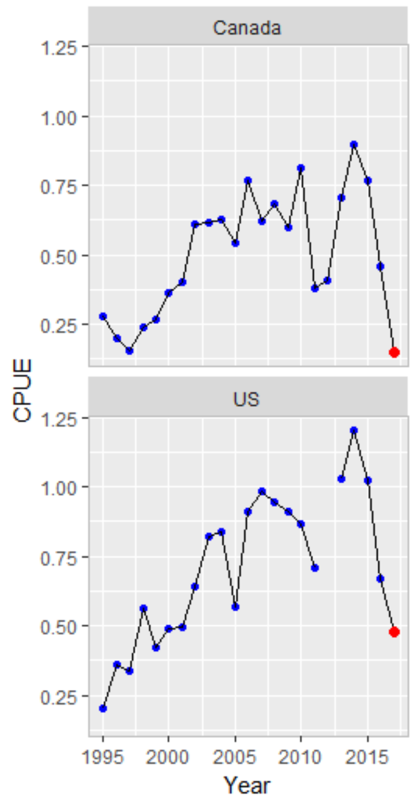

Fig. 1. Catch-per-unit-effort (CPUE) of juvenile north Pacific albacore tuna captured by Canadian harvesters in the Canadian or US EEZ over the years of 1995-2017.

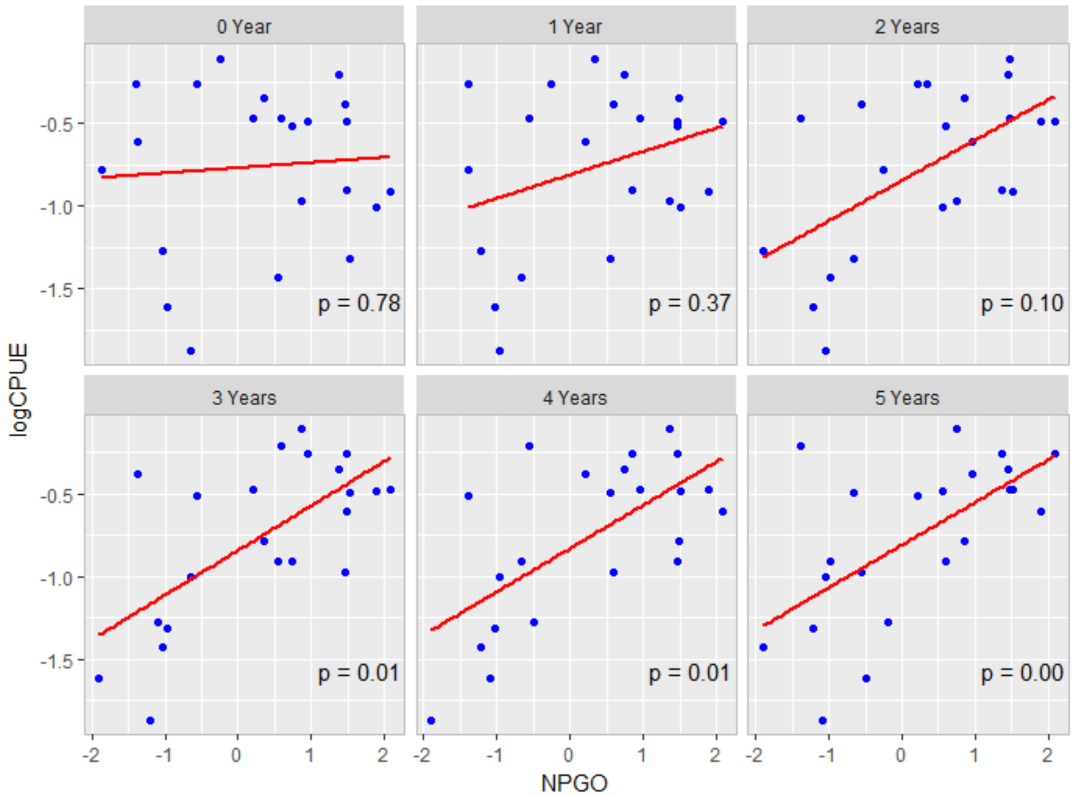

Fig. 2. Correlation between log-transformed catch-per-unit-effort (logCPUE) of juvenile north Pacific albacore tuna captured by Canadian harvesters in the Canadian EEZ and annual means of the North Pacific Gyre Oscillation indices (NPGO) with 0-5 years in a time lag.

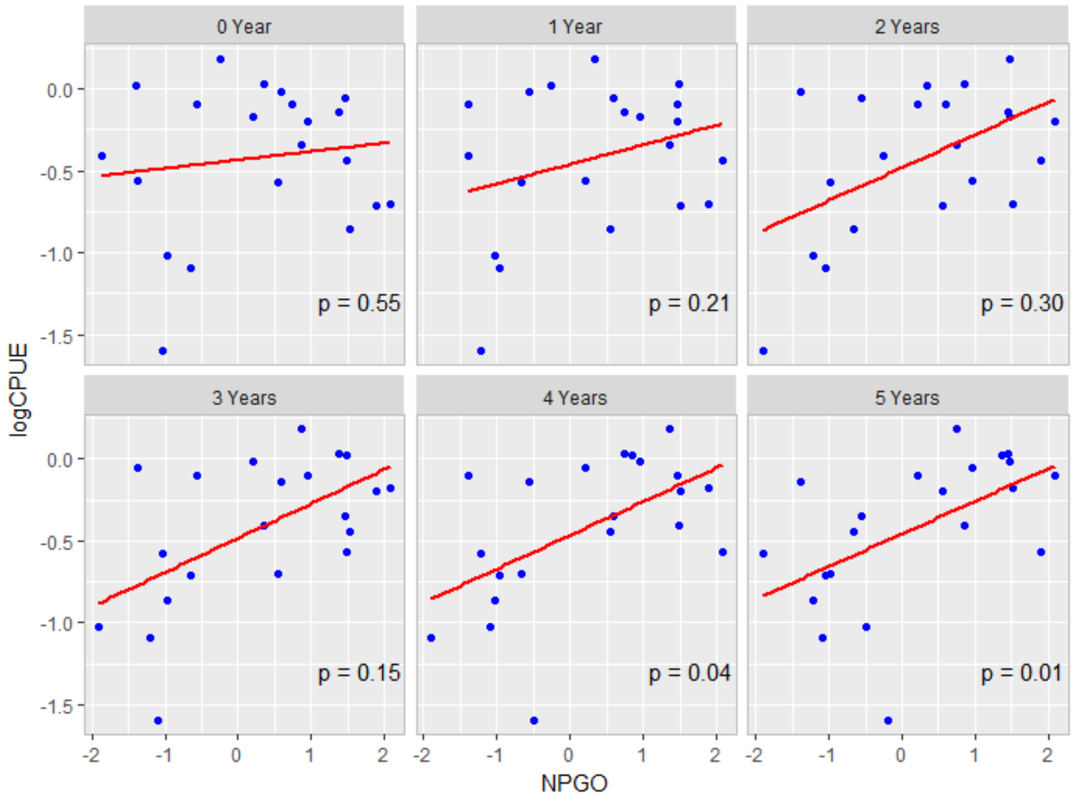

Fig. 3. Correlation between log-transformed catch-per-unit-effort (logCPUE) of juvenile north Pacific albacore tuna captured by Canadian harvesters in the US EEZ and annual means of the North Pacific Gyre Oscillation indices (NPGO) with 0-5 years in a time lag.

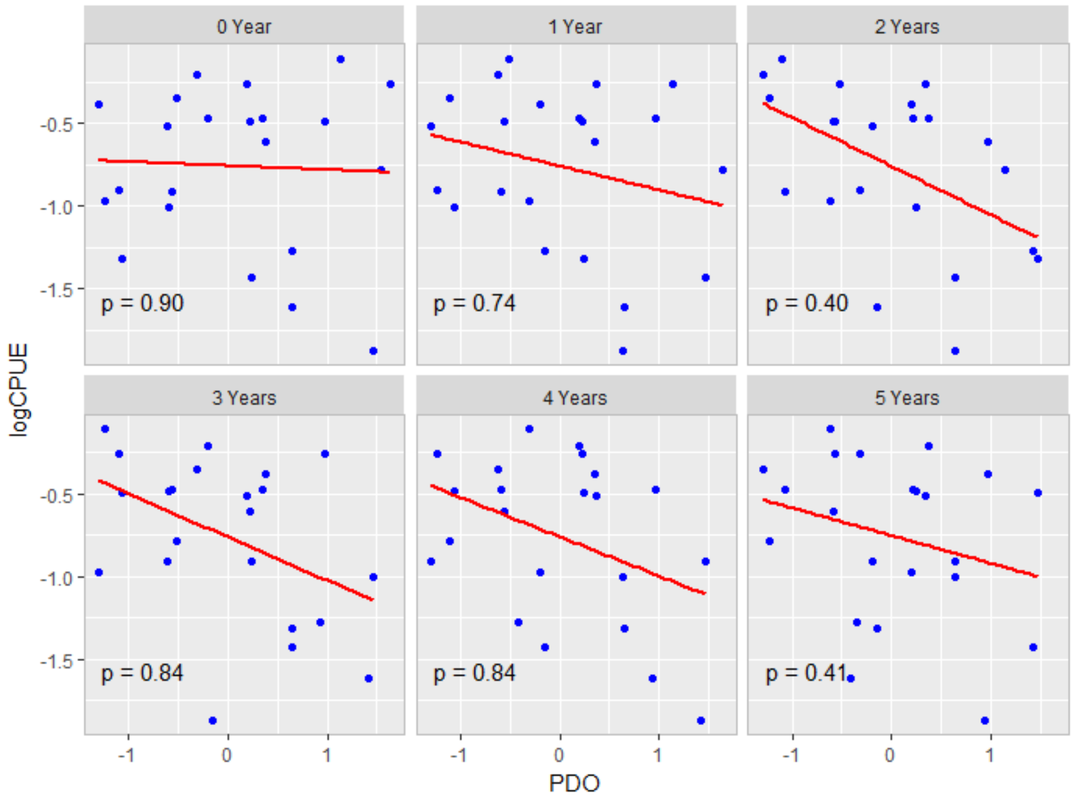

Fig. 4. Correlation between log-transformed catch-per-unit-effort (logCPUE) of juvenile north Pacific albacore tuna captured by Canadian harvesters in the Canadian EEZ and annual means of the Pacific Decadal Oscillation indices (PDO) with 0-5 years in a time lag.

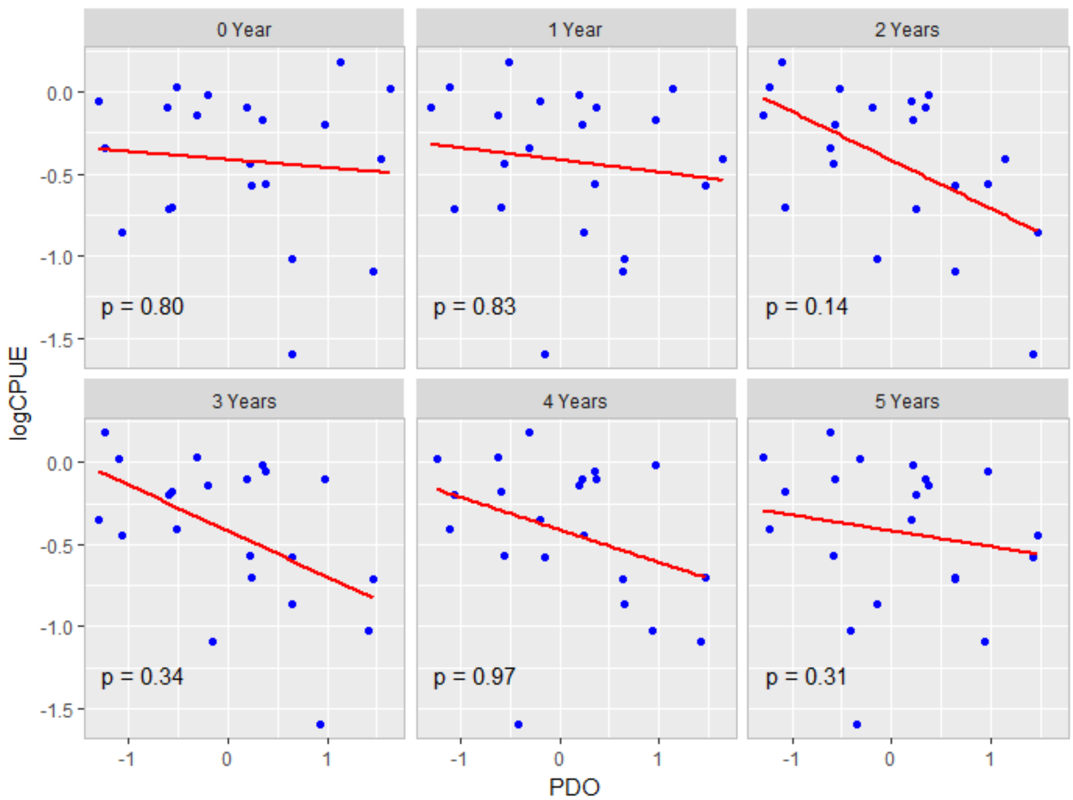

Fig. 5. Correlation between log-transformed catch-per-unit-effort (logCPUE) of juvenile north Pacific albacore tuna captured by Canadian harvesters in the US EEZ and annual means of the Pacific Decadal Oscillation indices (PDO) with 0-5 years in a time lag.

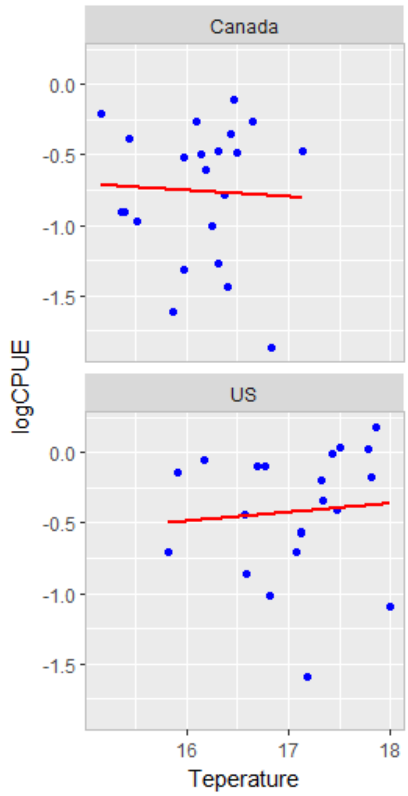

Fig. 6. Correlation between log-transformed catch-per-unit-effort (logCPUE) of juvenile north Pacific albacore tuna captured by Canadian harvesters in the Canadian and US EEZ and means of water temperature in July-Sept. taken by the fishing vessels.

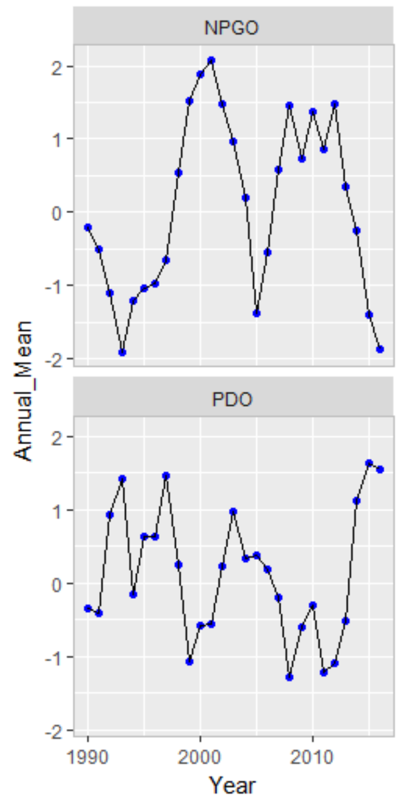

Fig. 7. Variations in annual means of the North Pacific Gyre Oscillation (NPGO) and the Pacific Decadal Oscillation (PDO) indices between 1990 and 2016.