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Estimation of the Influence of Some Climatic Factors on the Abundance of Asian Pink and Chum Salmon

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Salmon stock abundance currently shows unusual growth against the background of changing climate conditions on the Earth, especially in the North Pacific. The patterns described by these processes raise lively interest and discussion among researchers. Some experts believe that fish production responds to climate-ocean changes (Klyashtorin and Lyubushkin 2007; Beamish 2008; Kaeriyama et al. 2009; Kotenev et al. 2010). Others consider current processes as normal and to be within observed natural variation of long-term processes at the ecosystem level (Shuntov and Temnykh 2009). Clearly all research indicates that the influence of biotic and abiotic factors on a particular species or ecosystem is complex and mostly indirect.

We analyzed pink and chum salmon in our research because both species are highly abundant in Asia. Russia and Japan are the countries that catch all of the pink and chum salmon commercial catch in the region. In the last 100 years, pink and chum salmon catches have fluctuated from 50 to 400 million fishes (Irvine et al. 2009). We think that commercial catch statistics can be used as a reliable indicator of stock abundance and that it can represent the long-term trends in abundance dynamics.

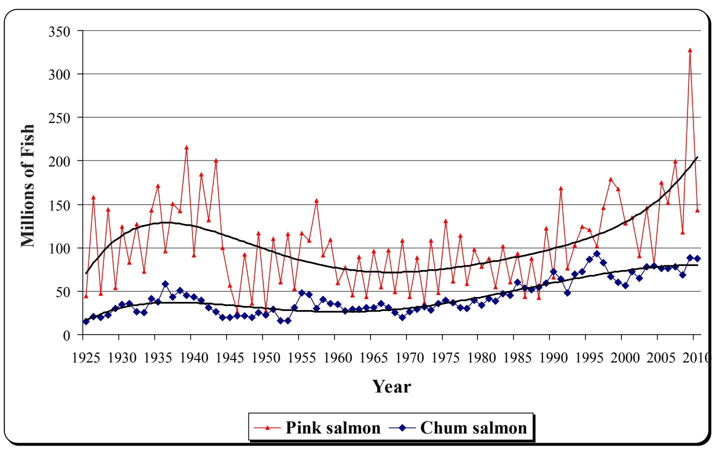

Fig. 1. Dynamics of the combined river, near shore, and drift-net catches of Asian pink and chum salmon (millions of fish), 1925-2010.

This analysis was a kind of test, and it should be noted that research like this often provides preliminary insight. Experts in different countries often correlated one or two climate indices to production of particular species in a geographic region. When close correlations were not revealed, researchers often ignored the use of alternative climate indices. When associations were found, investigators tried to estimate the correlations for particular time intervals. We tested nine climate indexes (AFI, ALPI, NP, PCI, GLB.Ts+dSST, N.HEMI, PDO, LOD, Sun Spot) that reflect meteorological and ocean conditions in the North Pacific, independent of whether associations with salmon catches had been found previously, or not. With this exploration, we did not intend to give an explanation for the nature of associated patterns between salmon abundance and climate.

We analyzed the dynamics of pink and chum salmon catches in Asia in 1925-2010 (Fig. 1). Trends in the catch density of pink and chum salmon were similar. Pink salmon catches showed more extensive fluctuations at the beginning and at the end of the time interval. The pink salmon stocks are almost entirely from the Russian Far East because the abundance of wild and hatchery pink salmon produced in Japan is low in comparison. As for chum salmon, the situation is different. The principle increase in the abundance in the 1990-2000s was due to a contribution of approximately 70% by Japanese hatchery production.

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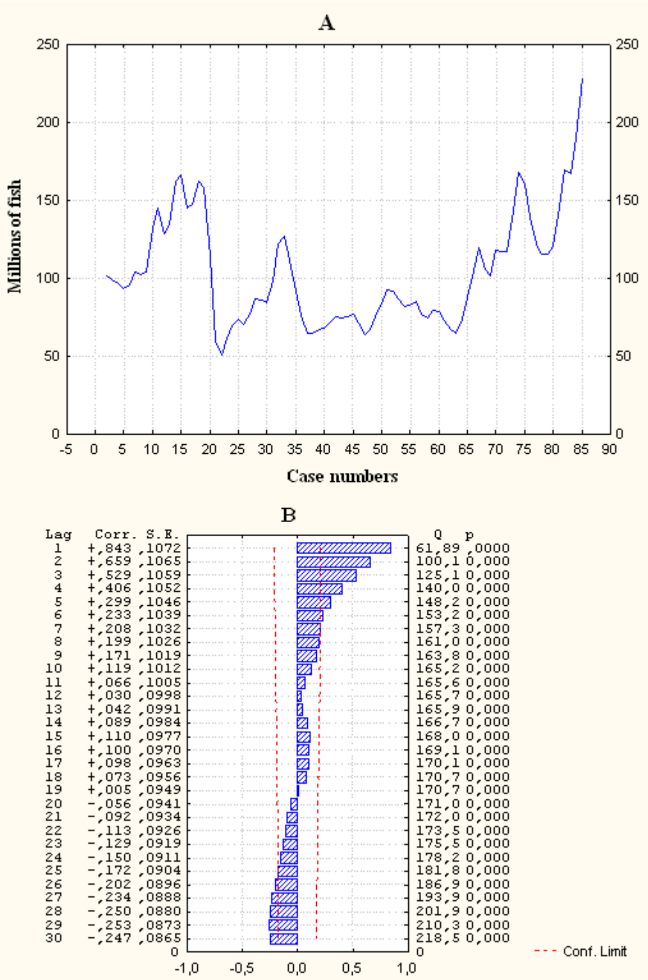

Fig. 2. Diagrams showing the Asian pink salmon catch time series for 1925-2010 using a 2-point moving average (A, upper panel), and averaged autocorrelation function (B, lower panel). Lag is the time lag, Corr. is the correlation, S.E. is the standard error, Q is the white-noise estimate, P is the probability.

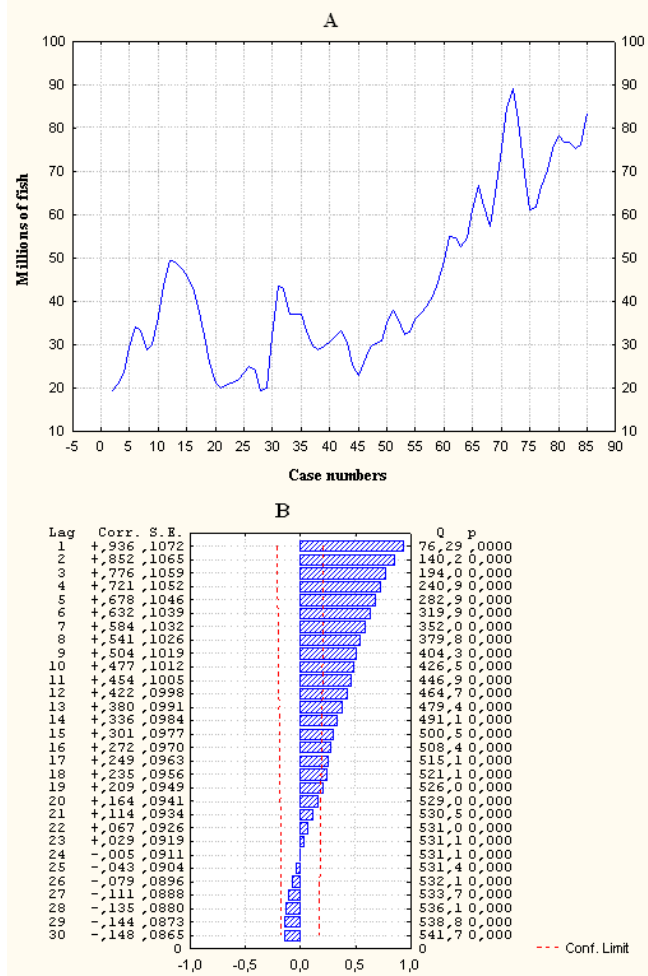

Fig. 3. Diagrams showing the Asian chum salmon catch time series for 1925-2010 using a 2-point moving average (A, upper panel), and averaged autocorrelation function (B, lower panel). Lag is the time lag, Corr. is the correlation, S.E. is the standard error, Q is the white-noise estimate, P is the probability.

Table 1. Pearson's correlation coefficients obtained from comparison of the catches of Asian pink and chum salmon and climatic indices based on a 2-point moving average. $N_{1\ line} = 84$, $p < 0.001$.

Indexes		Pink	Chum	Pink + Chum
№	Code			
1	AFI	0.30	0.28	0.33
2	ALPI	0.18	0.25	0.23
3	NP	-0.18	0.03	-0.12
4	PCI	0.17	-0.38	-0.03
5	GLB.Ts + dSST	**0.54**	**0.89**	**0.74**
6	N.HEMI	**0.64**	**0.82**	**0.78**
7	PDO	0.21	0.30	0.27
8	LOD	-0.41	-0.06	-0.32
9	Sun Spot	-0.19	-0.13	-0.19

Time-series analysis has demonstrated that more accurate results can be obtained by using the 2-point sliding mean (Figs. 2 and 3). We used the 2-point sliding mean for the time sequence of salmon catch and climate indices. This approach helped remove low- and high-frequency components of the time-series and smoothed the data with no loss in general dynamics.

The function of pink salmon autocorrelation was shaped in a sinusoidal wave (Fig. 2). The fading sequence demonstrated an alternation of sign at the 20th lag (step). The unstable sequence can be used in further analysis because biological periodicity in pink salmon abundance fluctuations in even- and odd-numbered years could be excluded. The time sequence for chum salmon is stable in even- and odd-numbered years, making it suitable for further correlation analysis (Fig. 3).

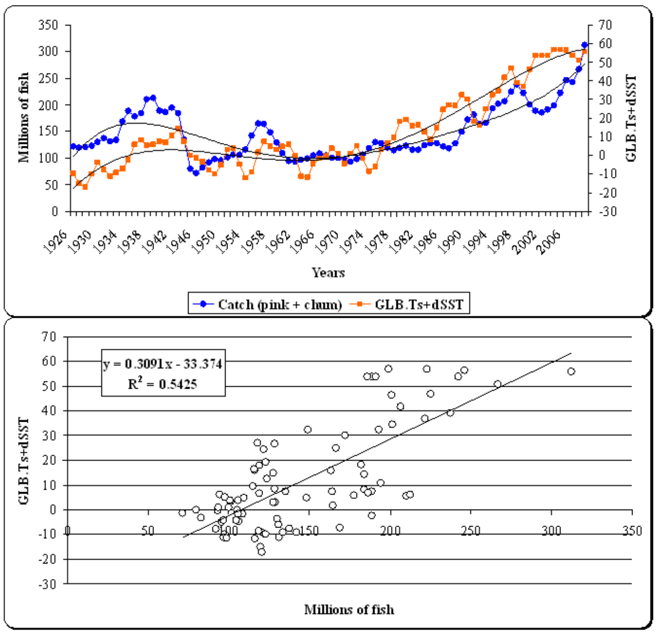

Fig. 4. Diagrams showing the influence of the climate indices GLB.Ts+dSST on the catch of Asian pink and chum salmon (millions of fish). Data represent the 1925-2010 time period using a 2-point moving average.

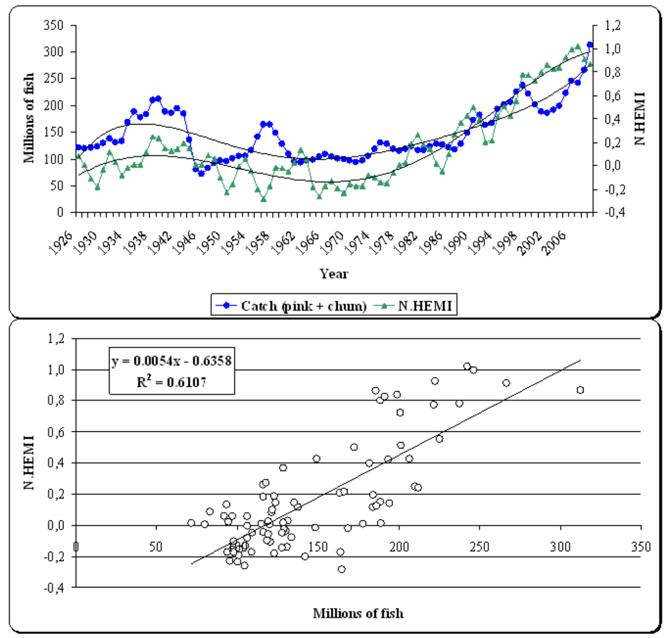

Fig. 5. Diagrams showing the influence of the climate index N.HEMI on the catch of Asian pink and chum salmon (millions of fish). Data represent the 1925-2010 time period using a 2-point moving average.

Table 2. Multiple regression of Asian pink and chum salmon catches and climatic indexes based on a 2-point moving average. $N_{1\ line} = 84$, df = 5.72, $p < 0.001$. R is the coefficient of multiple correlation, b_0 is the estimated intercept, *Beta* is the regression coefficients, SE is the standard error of the estimate, F is the F-statistic, df is the degrees of freedom, P is the probability.

Dependent variable (catches, millions of fish)	Predictors	R	b_0	*Beta*	SE	F
Pink	AFI	**0.61**	96.66	-0.30	24.63	8.40
	ALPI			-0.19		
	GLB.Ts+dSST			-0.46		
	N.HEMI			0.92		
	PDO			0.58		
Chum	AFI	**0.88**	34.45	-0.24	8.35	51.23
	ALPI			-0.17		
	GLB.Ts+dSST			0.59		
	N.HEMI			0.30		
	PDO			0.42		
Pink + Chum	AFI	**0.77**	131.11	-0.32	26.96	20.85
	ALPI			-0.21		
	GLB.Ts+dSST			-0.09		
	N.HEMI			0.80		
	PDO			0.61		

The highest correlation was found between the catches of Asian pink and chum salmon and indices of global air and surface water temperature anomalies (GLB.Ts+dSST and N.HEMI; Table 1; Figs. 4 and 5). This correlation demonstrates a stable character for both pink and chum salmon. The correlation coefficients for five of the nine climate predictors and chum salmon were higher than the coefficient for same climate predictors and pink salmon ($R = 0.82$-0.89 and $R = 0.54$-0.64, respectively). The summary coefficient for the two species combined was also high ($R = 0.74$-0.78). Correlation coefficients of the other four climate predictors and salmon catch were lower ($R = \pm 0.3$). In general, we did not observe strong correlations between Asian pink and chum salmon catch dynamics and the climate indices. In view of the more than 80-year span of the time series, we think the estimations we obtained were statistically real.

We investigated the complex character of the indirect and mutual influence of several climate factors (AFI, ALPI, GLB. Ts+dSST, N.HEMI, PDO) on the catch dynamics of Asian pink and chum salmons using multiple regression (Table 2; Fig. 6). Similar to the correlation analysis described above, the highest correlation ($R = 0.88$) between the climate indices and salmon catch was demonstrated for chum salmon. The correlation for pink salmon and climate indices was not as tight ($R = 0.61$). The coefficient of correlation between both species combined and climate indices was $R = 0.77$.

The data we obtained can be used to further explore the association between climate factors and the abundance of pink and chum salmon. On our view, real progress in this field can be achieved when more thorough analysis of the linkages between climate and aquatic biota focuses on the complex multi-factor ecosystem conditions in the Bering Sea and North Pacific Ocean.

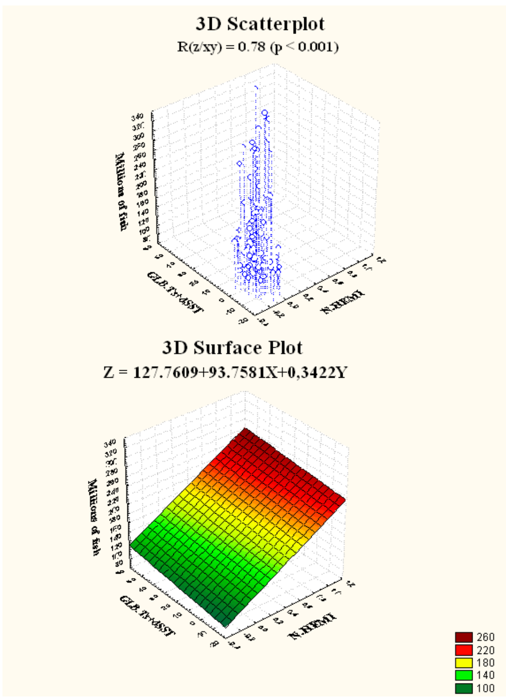

Fig. 6. Three-dimensional diagrams showing the influence of the climate indices GLB.Ts+dSST and N.HEMI on the catch of Asian pink and chum salmon (millions of fish). Data represent the 1925-2010 time period using a 2-point moving average.

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