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Differentiation of Local Pink Salmon Stocks on the Basis of Variations in Their Scale Structure

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One of the challenges facing Pacific salmon fisheries management is the differentiation of local populations in mixtures of prespawning or feeding aggregations. The problem of differentiating stocks is especially urgent for pink salmon, the most abundant species of Pacific salmon in Asia. One method for stock identification is based on scale pattern analysis. Investigations in recent decades have demonstrated that pink salmon scales, particularly the first-year zone, can be an informative marker to differentiate populations at the level of major regional groups (e.g., Grachev 1983; Temnykh 1998; Antonov et al. 2005). A general characteristic trait for pink salmon returning to spawn in even- or odd-numbered years is the capacity for significant phenotypic separation using scales collected from local stocks in the southern and northern portions of pink salmon distribution in Asia. The difference in the scale structure has been described by several fish biologists in earlier works. Moreover, some regional complexes can be identified within local stocks in the southern and northern groups.

We expanded the baseline and have improved on procedures of scale pattern analysis since an earlier study by Shaporev et al. (2007). In this project our objective was to use Asian pink salmon scale samples from known populations to explore inter-population differences for fish that returned as adults in 2007-2009. Samples used for this investigation included adult pink salmon scales collected from 34 local areas of Hokkaido, Sakhalin, the Amur River system, continental shore of the Okhotsk Sea, and West and East Kamchatka (Fig. 1). The samples consisted of 8,777 individual adult pink salmon originating from 67 stocks. Scales were scanned at 10-fold magnification and scanned images included the whole scale. From one to five scales were examined from each pink salmon, and the analysis was based on averaged scale variables.

To discover the extent of characteristics differentiating the stocks, we computed the Mahalanobis distance between population centroids using multidimensional scaling. The resolving ability of the data was analyzed using the maximum likelihood estimation procedure available in the computer program SPAM (Statistics Program for Analyzing Mixtures; Masuda et al. 1991; Pella et al. 1996).

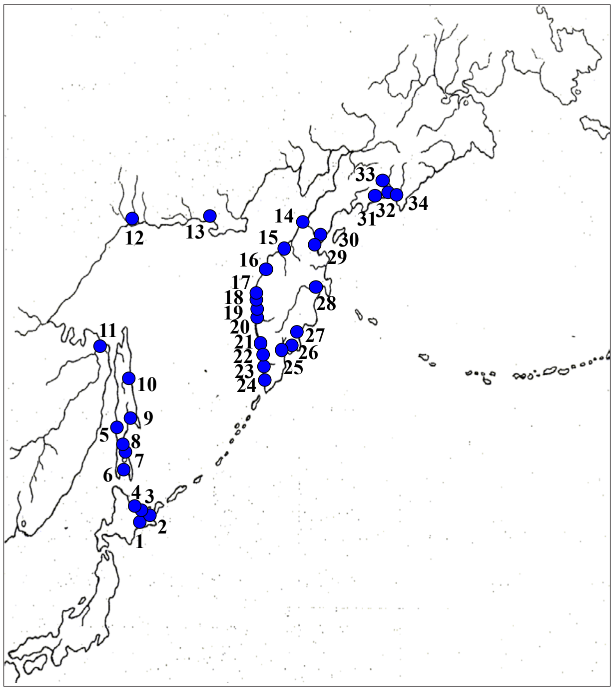

Fig. 1. Location of individual pink salmon populations sampled from adults returning in 2004-2009. Populations were located in the following areas: Hokkaido (1-4), Sakhalin (5-10), Amur River (11), coast of Okhotsk Sea (12-13), Western Kamchatka (14-24), and Eastern Kamchatka (25-34).

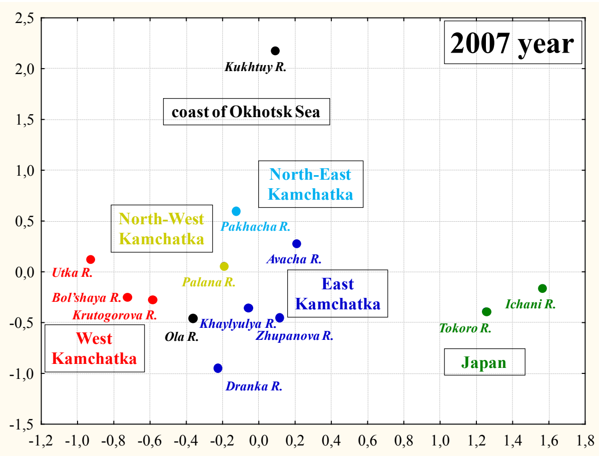

Fig. 2. Separation of populations and regional clusters of Asian pink salmon collected in 2007 based on scale patterns. Multidimensional scaling was used to differentiate among populations.

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Multidimensional scaling of the 2007 samples showed two complexes of pink salmon local stocks, one from the western coast and a second from the eastern coast of Kamchatka (Fig. 2). The scale patterns of pink salmon originating in the Pakhacha (Olutorsky Gulf), Palana (Northwest Kamchatka) and Ola (continental shore of the Okhotsk Sea) Rivers were intermediate between the West and East Kamchatka groups of pink salmon. Pink salmon from the Kukhtuy River on the continental shore of the Okhotsk Sea was widely separated from the other groups.

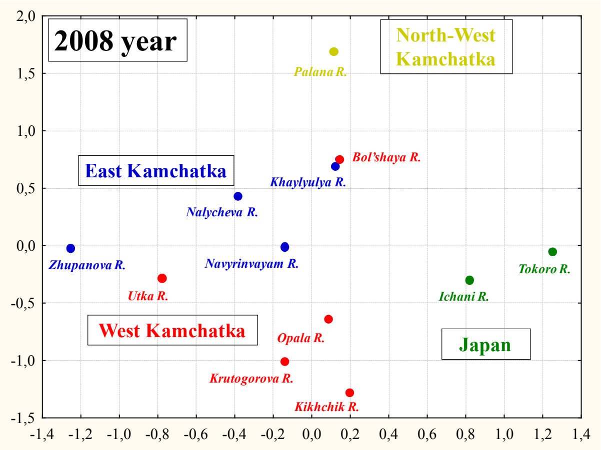

Fig. 3. Separation of populations and regional clusters of Asian pink salmon collected in 2008 based on scale patterns. Multidimensional scaling was used to differentiate among populations.

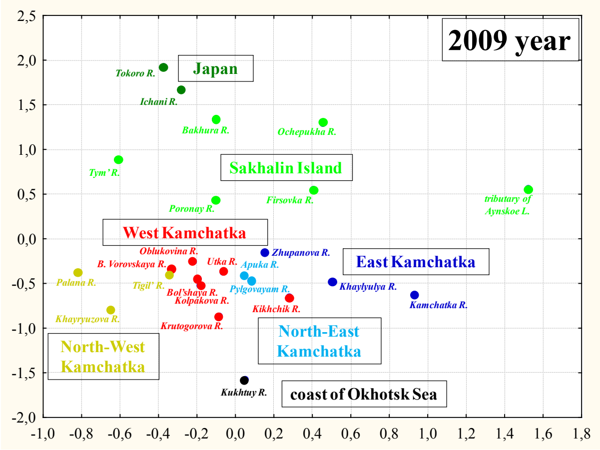

Fig. 4. Separation of populations and regional clusters of Asian pink salmon collected in 2009 based on scale patterns. Multidimensional scaling was used to differentiate among populations.

With the exception of the Bolshaya River, there were no overlapping clusters in the 2008 samples, which indicated that the West and East Kamchatkan regional complexes of pink salmon could be differentiated (Fig. 3). The Palana River (Northwest Kamchatka) sample was widely separated from the other groups.

Analysis of samples collected in 2009 clearly showed that the portion of the scale formed in the estuary can help to characterize stocks originating from Japan and Sakhalin (Fig. 4). Within the northern group, two non-overlapping clusters separated East and Northwest Kamchatka. Scales from the Olutorsky Gulf were similar to the West Kamchatkan populations, and the Kukhtuy River was widely separated from the other samples of the northern group.

Table 1. Maximum likelihood estimates developed from apportionment of scales from a baseline of Asian pink salmon collected from adults returning in 2007. Shaded boxes indicate the correct allocation based on a simulated proportion of 1.00 to the correct region. Misallocations are read across.

Population	Japan	Coast of Okhotsk Sea	West Kamchatka	East Kamchatka	SD	CI ± 90%	
Ichani R.	**0.902**	0.013	0.038	0.048	0.028	0.851	0.943
Tokoro R.	**0.872**	0.018	0.034	0.077	0.032	0.822	0.921
Kukhtuy R.	0.010	**0.791**	0.084	0.115	0.049	0.711	0.874
Ola R.	0.008	**0.614**	0.302	0.076	0.033	0.558	0.669
Palana R.	0.029	0.209	**0.627**	0.136	0.072	0.505	0.747
Krutogorova R.	0.000	0.282	**0.617**	0.101	0.078	0.489	0.743
Utka R.	0.003	0.198	**0.733**	0.066	0.081	0.589	0.867
Bol'shaya R.	0.044	0.222	**0.661**	0.074	0.075	0.533	0.779
Avacha R.	0.042	0.068	0.173	**0.718**	0.074	0.589	0.841
Zhupanova R.	0.124	0.066	0.310	**0.500**	0.075	0.370	0.629
Khaylyulya R.	0.059	0.223	0.240	**0.478**	0.074	0.355	0.601
Dranka R.	0.028	0.193	0.241	**0.539**	0.141	0.301	0.768
Pakhacha R.	0.012	0.108	0.219	**0.661**	0.090	0.508	0.807

Assessment of the likelihood of accurate regional separation of pink salmon varied from year to year. For samples of fish returning in 2007, the estimated correct allocation to groups included Japan 87-90%, continental shore of the Okhotsk Sea 61-79%, West Kamchatka 62-73%, and East Kamchatka 48-72% (Table 1). The maximum likelihood estimates of correct allocation for samples collected in 2008 included Japan 78-84%, West Kamchatka 66-87%, and East Kamchatka 52-91% (Table 2). Estimated correct allocation for samples in the 2009 baseline included Japan 75-76%, Sakhalin 63-91%, continental shore of the Okhotsk Sea 76%, West Kamchatka 53-86%, and East Kamchatka 16-68% (Table 3).

Table 2. Maximum likelihood estimates developed from apportionment of scales from a baseline of Asian pink salmon collected from adults returning in 2008. Shaded boxes indicate the correct allocation based on a simulated proportion of 1.00 to the correct region. Misallocations are read across.

Population	Japan	West Kamchatka	East Kamchatka	SD	CI ± 90%	
Ichani R.	**0.778**	0.089	0.133	0.037	0.715	0.835
Tokoro R.	**0.835**	0.078	0.087	0.036	0.777	0.892
Palana R.	0.008	**0.853**	0.139	0.054	0.761	0.936
Krutogorova R.	0.074	**0.748**	0.178	0.067	0.632	0.846
Kikhchik R.	0.048	**0.782**	0.170	0.058	0.683	0.879
Utka R.	0.014	**0.663**	0.323	0.050	0.582	0.747
Bol'shaya R.	0.007	**0.886**	0.106	0.045	0.807	0.955
Opala R.	0.030	**0.828**	0.143	0.052	0.734	0.907
Nalycheva R.	0.160	0.323	**0.517**	0.067	0.400	0.626
Zhupanova R.	0.034	0.057	**0.908**	0.031	0.853	0.956
Khaylyulya R.	0.011	0.362	**0.628**	0.085	0.493	0.768
Navyrinvayam R.	0.021	0.262	**0.717**	0.056	0.622	0.805

Table 3. Maximum likelihood estimates developed from apportionment of scales from a baseline of Asian pink salmon collected from adults returning in 2009. Shaded boxes indicate the correct allocation based on a simulated proportion of 1.00 to the correct region. Misallocations are read across.

Population	Japan	Sakhalin	Coast of Okhotsk Sea	West Kamchatka	East Kamchatka	SD	CI ± 90%	
Ichani R.	**0.764**	0.194	0.000	0.012	0.031	0.045	0.686	0.840
Tokoro R.	**0.745**	0.225	0.000	0.005	0.025	0.043	0.676	0.817
tributary of Aynskoe L.	0.012	**0.905**	0.010	0.072	0.001	0.046	0.826	0.980
Ochepukha R.	0.089	**0.797**	0.000	0.021	0.094	0.070	0.675	0.912
Bakhura R.	0.156	**0.774**	0.000	0.027	0.043	0.065	0.660	0.874
Firsovka R.	0.024	**0.628**	0.002	0.213	0.134	0.082	0.488	0.759
Poronay R.	0.015	**0.738**	0.000	0.139	0.108	0.073	0.607	0.853
Tym' R.	0.025	**0.878**	0.000	0.097	0.000	0.059	0.775	0.970
Kukhtuy R.	0.000	0.019	**0.756**	0.158	0.067	0.054	0.663	0.846
Palana R.	0.008	0.131	0.073	**0.716**	0.072	0.043	0.644	0.786
Tigil' R.	0.009	0.080	0.112	**0.772**	0.028	0.053	0.683	0.858
Khayryuzova R.	0.029	0.205	0.148	**0.553**	0.065	0.056	0.457	0.645
Oblukovina R.	0.000	0.115	0.004	**0.858**	0.023	0.052	0.775	0.940
Krutogorova R.	0.000	0.029	0.286	**0.654**	0.031	0.060	0.555	0.761
Kolpakova R.	0.000	0.085	0.118	**0.777**	0.019	0.051	0.694	0.857
B. Vorovskaya R.	0.008	0.143	0.097	**0.740**	0.012	0.042	0.667	0.810
Kikhchik R.	0.014	0.136	0.094	**0.655**	0.101	0.048	0.575	0.734
Utka R.	0.033	0.081	0.102	**0.688**	0.096	0.047	0.606	0.771
Bol'shaya R.	0.059	0.205	0.141	**0.529**	0.065	0.051	0.447	0.615
Zhupanova R.	0.017	0.208	0.056	0.414	**0.306**	0.047	0.230	0.387
Kamchatka R.	0.000	0.053	0.089	0.174	**0.684**	0.048	0.612	0.770
Khaylyulya R.	0.020	0.075	0.142	0.269	**0.494**	0.048	0.418	0.574
Pylgovayam R.	0.017	0.105	0.182	0.405	**0.292**	0.071	0.172	0.415
Apuka R.	0.006	0.288	0.111	0.433	**0.162**	0.039	0.096	0.226

One of the problems identified during the course of the investigation was the lack of satisfactory sample size of scales from all principle spawning regions of pink salmon. This was the reason why we were not able to estimate the extent of separation of Amur River pink salmon returns in odd-numbered years, or to separate the local stocks from rivers in Sakhalin and the continental shore of the Okhotsk Sea returning in even-numbered years.

In general the estimated accuracy of the samples suggests to us that the baselines have the capability for rather high resolution. However, in order to test the capability of the baseline and be confident in future scale pattern analyses, we want to examine scale samples from the maximum number of populations available from all principle regions of pink salmon production in Asia.

REFERENCES

Antonov, N.P., Zh.Kh. Zorbidi, and E.S. Baluyeva. 2005. Scale structure comparative analysis of pink salmon *Oncorhynchus gorbuscha* (Walb.) and coho *O. kisutch* (Walb.) intraspecific variations in the north-west part of Pacific Ocean. Popular biology, genetics, and taxonomy of hydrobionts. KamchatNIRO Publishing. Petropavlovsk-Kamchatsky. 1160–1167 pp. (In Russian).

Grachev, L.E. 1983. Differentiation of Asian pink salmon stocks. Biological grounds of salmon fisheries in the watersheds of the USSR. M. Nauka. 84–97 pp. (In Russian).

Pella, J.J., M. Masuda, and S. Nelson. 1996. Search algorithms for computing stock composition of a mixture from traits of individuals by maximum likelihood. NOAA Tech. Memo. NMFS-AFSC-61. 68 pp.

Masuda, M., S. Nelson, and J. Pella. 1991. The computer programs for computing conditional maximum likelihood estimates of stock composition from discrete characters. USA-Doc-NOAA NMFS, Auke Bay Laboratory, Juneau, AK.

Shaporev, R.A., N.V. Varnavskaya, V.A. Savin, V.G. Stepanov, and A.G. Bazhin. 2007. Method of complex analyzing of variations of Pacific salmon's stratified scale structures: Kamchatka River chum salmon example. Investigations of aquatic biological resources of Kamchatka and of the Northwestern Pacific. KamchatNIRO Publishing, Petropavlovsk-Kamchatsky. 9: 131–142. (In Russian).

Temnykh, O.S. 1998. Regional variations of Asian pink salmon scale scleritograms. Izv. TINRO 124: 375–390. (In Russian).