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Assessing the Use of Otolith Microstructure for Identification of Regional Stock Complexes of Juvenile Chum Salmon

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The ability to differentiate the stocks of juvenile salmon that are in mixed aggregations at sea is vital for forecasting salmon returns. Research in this field indicates that stock differentiation based on morphological variability of otolith structure is promising. Otoliths have been of great interest to fish biologists as structures that record physiological and ontogenetic transformations of fish, and environmental changes of fish habitat. Otolith microstructure of populations should reflect the genetic specifics of the population and environmental conditions of juvenile development. As a rule, individuals from different populations demonstrate differences in otolith microstructure and in the relative size of otoliths. Variability in otolith microstructure has been used to differentiate populations of White Sea and Barents Sea herring (Svetocheva and Stasenkova 2003), Asian and American populations of Dolly Varden (Radtke et al. 1996) Norwegian coastal cod populations (Otterlei et al. 2000), and summer/winter and wild/hatchery stocks of steelhead (McKern et al. 1974). Different chum salmon temporal groups and the varied hydrological conditions on the spawning grounds can be fixed in the otolith microstructure of ecological morphs (Akinicheva and Izergin 2004). As a rule, morphological classification of the otoliths is subjective and can be used only for identification of certain ecological morphs within a single watershed. The question of how to characterize and estimate differences between chum salmon at a regional or population level based on otolith microstructure was the problem we sought to answer.

The purpose of this our work was to estimate intra- and inter-population variation in otolith microstructure of juvenile chum salmon as a possible tool to differentiate populations in mixed-stock aggregations during the first year of ocean residence. Otolith samples of juveniles from eight rivers in Kamchatka and five rivers from the northern coast of the Okhotsk Sea were collected in May and June 2008-2009. In addition, chum salmon were collected from hatcheries in the Magadan region (Armansky, Tauysky and Yansky hatcheries) and in Kamchatka (Paratunsky and Ketkinsky hatcheries). To estimate the character and degree of microstructure variability, we used wavelet analysis, which is a modification of classical spectral analysis. Readings from the wavelet transformation scalegram (Morlet wavelet transform) were used as criteria for differentiation (Fig 1). We used scalegrams of the diapason with scaling coefficients from 1 to 7 and a 0.3 step. Statistical processing was made using STATISTICA 6.0 and Microsoft Excel. To estimate the resolution of the method, we used the maximum likelihood estimation (MLE) procedure available in the computer program SPAM.

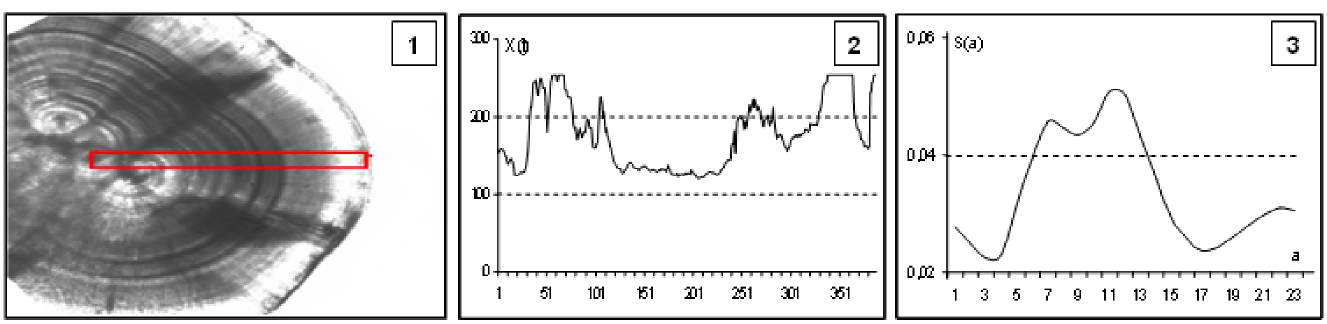

Fig. 1. Photo of a juvenile chum salmon otolith and the portion in the red box that was analyzed by wavelet spectral analysis (1, left panel); example of the signal values of the otolith scan (2, center panel); scheme of the wavelet transformation of the signal (3, right panel).

Discriminate analysis of intra-population variability of juvenile chum salmon within populations of the Bolshaya River did not reveal any differences between temporally distant samples ($p > 0.05$). Similarly, examination of the otolith microstructure of juvenile chum salmon from the Palana River did not show differences between samples collected from different periods of downstream migration ($p > 0.05$).

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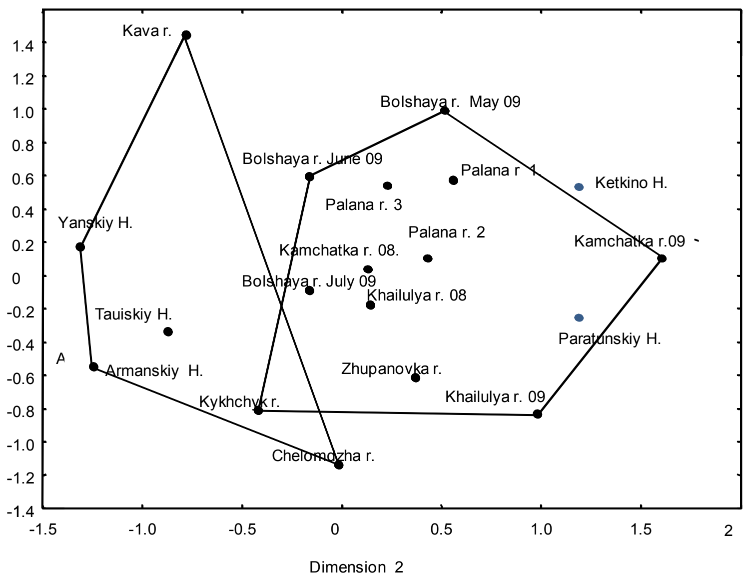

Fig. 2. Diagram of similarities using multidimensional scaling of samples from populations of juvenile chum salmon collected from rivers in Kamchatka and the northern coast of the Sea of Okhotsk.

Discriminate analysis of inter-population variability indicated the Mahalanobis distance between the centroids of the northern Okhotsk Sea and Kamchatkan regional groups of chum salmon was highly significant (2.79, $p < 0.001$; Fig. 2). The high heterogeneity within the hatchery samples from the Magadan hatcheries (Arman, Tauy and Yana) produced a non-significance result ($p > 0.05$). However, these samples were highly significantly different from the groups of Kamchatka populations (3.86, $p < 0.001$) and from the Chelomdzha River (wild population on the north shore of the Okhotsk Sea; 3.58, $p < 0.001$). An explanation may be that when hatchery chum salmon alevins shift to exogenous feeding the regular feeding schedule produces stable daily growth on the otoliths that is different from the pattern on wild fish otoliths (Zhang and Beamish 1994). Otoliths of hatchery-raised Pacific salmon record hatchery “release marks” depicting wide uniform increments when the fish rears in the hatchery and then showing irregular and narrow increments after the fish is released from the hatchery (Brothers 1981; Zhang et al 1995; Fukuwaka 1998).

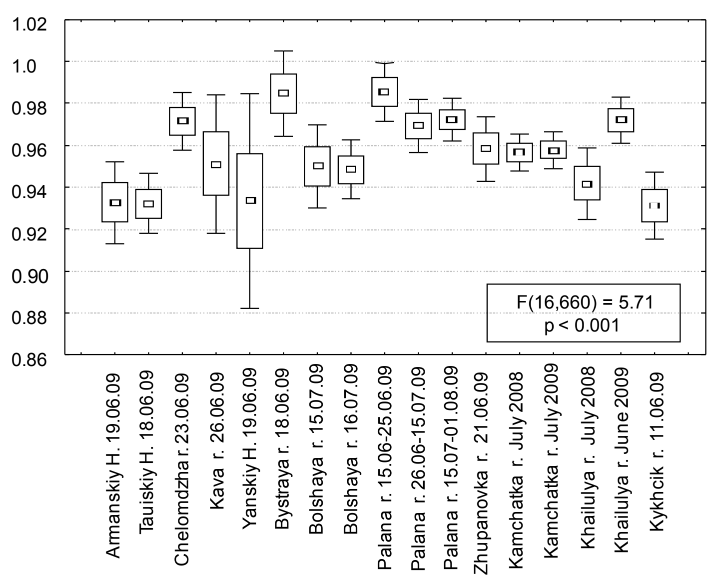

Fig. 3. Group statistical indicators of the first scaling coefficient that characterizes otolith microstructure of juvenile chum salmon collected from rivers in Kamchatka and the northern coast of the Sea of Okhotsk.

Statistical characteristics of the populations based on the first scaling coefficient are shown in Fig. 3. Minimal differentiating characteristics were demonstrated by Arman, Tauy and Yana hatchery fish and Kikhchik River chum salmon. This may result from minimal or complete lack of daily temperature fluctuations, which causes the formation of evenly-spaced growth increments on the otoliths. Assessment of the baseline resolution by MLE indicated the level of accuracy in differentiating regions ranged from 62% to 93%.

We conclude there is likely to be enough variability in otolith microstructure in these regional stock complexes to differentiate mixed-stock samples of chum salmon at the regional level.

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