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Experience of the use of complex otolith method for identification stocks of juvenile pink and chum salmon in the offshore waters of the Okhotsk Sea during postcatadromous migrations

No doubts that identification of regional origin of Pacific salmon in ocean feeding aggregations is a challenge, especially on the overlaps of migration routs. No doubts as well, that the challenge should be taken, because the composition of catch, when it is identified correctly, can enhance reliability of salmon stock abundance forecast for certain species. It is also urgent, when estimating juvenile abundance in early marine period, because this period basically forms Pacific salmon production stock. Scientific experience in this field indicates that it is promising to use morphological differences in structure of otolith. The otolith, as it is one of recording structures, is attracting scientific interest in the world long time. The rates of forming the otolith structural elements, influenced within Pacific salmon species by specific environment and genetics, determine microstructural differences between populations. Normally individuals from different populations demonstrate different otolith microstructures and relative sizes (Bugaev et al., 2012; Chistyakova et al., 2012). Examination of the otolith structural variations, provided for juvenile chum and pink salmon of Kamchatka, Sakhalin and the northern coast of the Okhotsk Sea, has demonstrated reliable differences. That says in favor of existing regional population specifics for two mentioned species at the level of otolith microstructural specifics. However, getting an instrument for real identification implies making clarification how far the specifics can be used to answer practical requests.

Moreover, the otolith marking has been used widely in salmon hatcheries of the North Pacific Rim and in the world practice pretty long ago. For today the North Pacific Anadromous Fish Commission (NPAFC) has formed data base of the hatchery marks from all hatcheries in North Pacific, what allows to provide identification of marked hatchery fish in marine catches with almost absolute accuracy.

That provides additional options for identification of salmon origin in mixed marine samples in the way of combining data of otolith structure analysis for wild populations and of results of marking hatchery stocks. We call such approach to exploration of structural diversity of salmon species as a «otolith complex method». The possibility to provide identification of juvenile Pacific salmon in the course of trawl surveys makes this method especially urgent, as internal otoliths can be find anyway, whereas external scales cannot at the risk of loss in the process of fishing.

The purpose of this work was to check how does the otolith complex method work to provide identification in the mixed marine aggregations of juvenile pink and chum salmon during autumn migrations to the Okhotsk Sea.

Materials and methods

The mixed samples for the research work consisted of otoliths of juvenile pink and chum salmon, collected during complex trawl survey, provided by R/V «Professor Kaganovsky» in September-October 2011. The total sample mixed materials consisted 735 specimens of juvenile pink and 819 specimens of juvenile chum salmon.

The otolioth baseline data were collected by scientists from the FSUE «KamchatNIRO», FSUE «SakhNIRO», FSUE «MagadanNIRO» and workers of the Kikhchinsky CSS FSA «Sevvostrybvod». The pool included otoliths of juvenile pink and hum salmon. In some cases, when taking river juvenile fish was hard, we used otoliths of adult individuals. Scheme of sampling the baseline otoliths on West Kamchatka, Sakhalin and north coast of the Okhotsk Sea is provided in Figure 1.

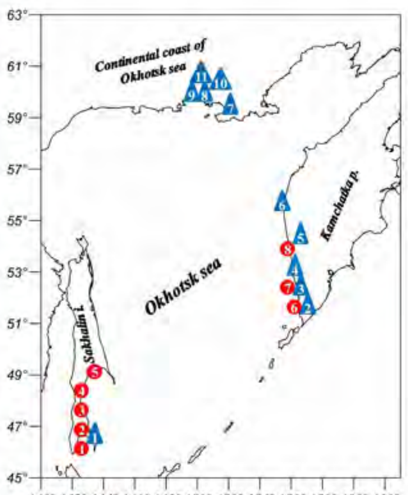

Fig. 1. The scheme of sampling pink and chum salmon otoliths in rivers of Kamchatka, Sakhalin and north coast of the Okhotsk Sea for the baselines. Pink salmon (red color): *Sakhalin* — Kura River (1), Lutoga R. (2), Voznesenka R. (3), Dudinka R. (4), Poronai R. (5); *West Kamchatka* — Opala River (6), Bolshaya R. (7), Kikhhik R. (8). Chum salmon (blue color): *Sakhalin* — Ochepukha River (1); *West Kamchatka* — Opala River (2), Bolshaya R. (3), Kikhchik R. (4), Vorovskaya R. (5), Icha R. (6); the north coast of the Okhotsk Sea «Armansky» Hatchery (7), Tauy R. (8), Kava R. (9), Chelomdzha R. (10), «Tauysky» Hatchery (11)

The total sample of otolith baseline data materials to consisted 735 specimens of pink and 819 specimens of chum salmon.

Processing of the otoliths was provided in laboratory, where the otoliths firstly were set in thermoplastic cement (Buechler, the USA) on the glass slides, and than they were polished on grinding discs with small-sized grains until the central part of the otolith has got visible. Otolith images were scanned in the visual-analytic complex LEICA DM 1000 with resolution 900 pixels/mm.

To figure out the character and the level of otolith structural variety in native stocks of chum salmon we used approach, based on signal wavelet-analysis, what is a version of classical spectral analysis (Astafyeva, 1998; Dobeshi, 2001; Kuznetsova et. al, 2004).

In the course of the analysis of the otolith structural variety in mixed aggregations we examined the otolith for bearing hatchery mark. Later all suggested (potential) marks went identification in the baseline of marks, created by NPAFC (North Pacific Anadromous Fish Commission, NPAFC (http//www.npafc.org)).

Results and discussion

Creating the baselines on the base of otolith structure

The basis of creation of the baselines for analyzing phenotypic variety of recording structures is objective figuring out the principle components to differentiate. In this case the components to differentiate were some regional complexes of pink and chum salmon local stocks, required separation in view of specifics of their otolith structure. Taking into account tight geographical connectivity of examined area with the Okhotsk Sea, we had built the baselines only for the stocks of three principle "hot point" of reproduction of two mentioned species within the Okhotsk Sea basin: West Kamchatka, Sakhalin and northern coast of the Okhotsk Sea. The baseline did no include one more important "hot point" of pink and chum salmon reproduction in Asia — Japan. Some later in the paper we have provided results of otolith marking, helpful to figure out the fish of Japan in the total mixed samples. On our view such approach works well to provide more accurate estimation of juvenile salmon intraspecific composition in the catches from the Okhotsk Sea.

At the current stage of our work we make attempt to figure out the regional complexes of pink and chum salmon, represented either by wild or hatchery populations without marks, exactly on the base of otolith structural specifics. The geographic view of the distribution of centroids of pink and chum salmon otolith baselines in space of multidimensional scaling is demonstrated in figures 2 and 3.

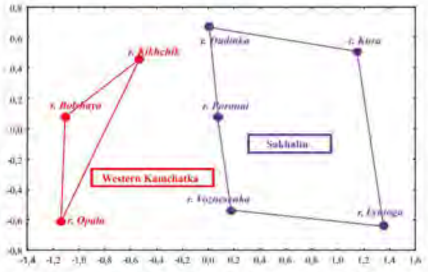

Fig. 2. The diagram of the distribution of the otolith criteria centroids for pink salmon populations of West Kamchatka and Sakhalin (method of multidimensional scaling)

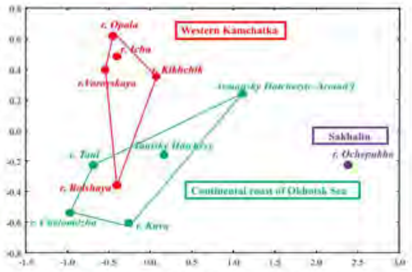

Fig. 3. The diagram of the distribution of the otolith criteria centroids for chum salmon populations of West Kamchatka, Sakhalin and north coast of the Okhotsk Sea (method of multidimensional scaling)

Created pool of the otolith baselines allowed us to figure out 2 regional complexes of the Okhotsk Sea basin pink salmon stocks: of West Kamchatka and of Sakhalin. In similar way there were 3 regional complexes of the Okhotsk Sea basin chum salmon stocks revealed: of West Kamchatka, of Sakhalin and of the north coast of the Okhotsk Sea.

The next step in the identification work was to provide estimation of the resolution ability of the baseline models obtained. For the estimation we used dependent simulation (Tables 1 and 2). The estimated resolution ability was 90.43% for pink salmon and 77.70% for chum salmon.

Table 1

Dependent simulation of the otolith baselines for pink salmon

Region	MLE	SD	CI ±95%	
			Lower	Upper
West Kamchatka	0,9226	0,0577	0,8509	0,9943
Sakhalin	0,8860	0,0706	0,8182	0,9547

Note. The resolution ability is 90,43%.

Table 2

Dependent simulation of the otolith baselines for chum salmon

Region	MLE	SD	CI ±95%	
			Lower	Upper
West Kamchatka	0,7201	0,0874	0,5123	0,7721
Sakhalin	0,9300	0,0648	0,6992	0,9403
North coast of the Okhotsk Sea	0,6810	0,0804	0,5265	0,7930

Note. The resolution ability is 77,70%.

We know of course, that the pool of the baselines demonstrated cannot illustrate completely the phenotypical diversity of the otolith structure of wild pink and chum salmon populations all over the Okhotsk Sea. The main reason is highly difficult sampling the otolith material on the scale of the basin.

Identification of regional complexes of stocks on the otolith structure

Results of identification of principle regional complexes of juvenile pink and chum salmon in the trawl catches, provided by R/V «Professor Kaganovsky» during postcatadromous migrations in the Okhotsk Sea in 2011, on the otolith structure are represented in table 3. It can be seen from the table that in the case of pink salmon the dominance in the catches consisted of stocks of West Kamchatka (72.45%). The contribution of Sakhalin stocks was 27.55%. In the case of chum salmon the principle contribution was also provided by stocks of West Kamchatka (79.83%). Stocks of the north coast of the Okhotsk Sea were next in the contribution (20.02%). The part of Sakhalin chum salmon was identified at the level of statistical error. It is clear that at this stage of research the identification has covered generally wild stocks of the basin.

Table 3

Results of the identification of regional complexes of pink and chum salmon stocks on the base of otolith structure of juvenile individuals in the trawl catches by R/V «Professor Kaganovsky» in the Okhotsk Sea in September-October, 2011

Species	N, spm	Parameter	West Kamchatka	Sakhalin	North coast of the Okhotsk Sea
Pink salmon	735	MLE	*0,7245*	*0,2755*	–
		SD	0,0348	0,0366	–
Chum salmon	861	MLE	*0,7983*	*0,0015*	*0,2002*
		SD	0,0498	0,0000	0,0520

Results of otolith marking

Besides wild populations of pink and chum salmon the Okhotsk Sea provides feeding for juvenile fish released from a number of salmon hatcheries of Far East and Japan. Most hatcheries currently use otolith marking salmons, what creates almost absolute likelihood to identification in mixed catches (Akinicheva, Rogatnykh, 1996; Akinicheva, 2001, 2006; Akinicheva et. al, 2004; Munk et al., 1993; Akinicheva et al., 1998; Munk, Geiger, 1998; Safronenkov et al., 1999).

Juvenile pink and chum salmon with marks of Far East hatcheries (West Kamchatka, Sakhalin, South Kuril Islands, continental coast of the Okhotsk Sea) and Japan (Hokkaido, Honshu) can get feeding in the Okhotsk Sea during postcatadromous migration. This is why the next step in our work was figuring out the hatchery individuals of juvenile pink and chum salmon in the trawl catches with the use of existing international bank of otolith marks (NPAFC).

Analysis of pink and chum salmon otolith structural variety in in September-October mixed aggregations in 2011 has revealed marks from salmon hatcheries of Russian Far East and Japan (chum salmon hatcheries). The part of marked pink salmon individuals was 4.08% and the part of chum salmon individuals – 4.88%. The ratio between marked juvenile pink and chum salmon of different origin in the trawl catches is demonstrated in figures 4 and 5.

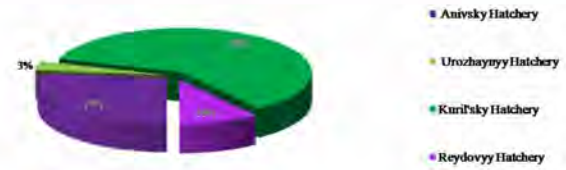

Fig. 4. The ratio between marked juvenile pink
salmon of different origin in the trawl catches by R/V «Professor Kaganovsky» in the Okhotsk Sea in September-October, 2011

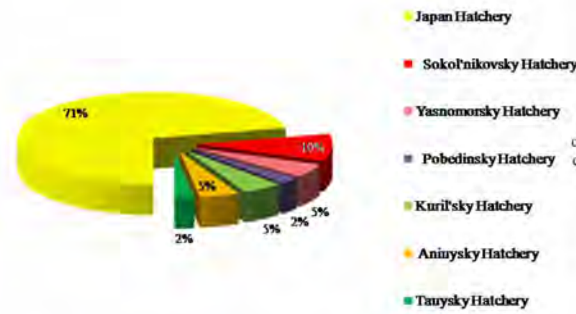

Fig. 5. The ratio between marked juvenile chum salmon of different origin in the trawl catches by R/V «Professor Kaganovsky» in the Okhotsk Sea in September-October, 2011

The results demonstrate dominant position (70%) of pink salmon from Kuril hatcheries among juvenile pink salmon. Pink individuals from Sakhalin hatcheries occupy next position (30%). Among chum salmon individuals the dominant position is occupied by Japan hatchery chum salmon (71%). Russian chum salmon from Far East hatcheries demonstrate the ratio as next: Sakhalin – 17%, Kuril Islands – 5% and continental coast of the Okhotsk Sea – 7%. Taking into account that identification of the marked individuals is very accurate method to figure out hatchery juvenile fish, we decided to use results of theoretical assessment on the base of variety of the otolith structure and results of hatchery marking through consolidation them into one «otolith complex method».

Identification of regional complexes of stocks by the otolith complex method

The results of identification of juvenile pink salmon stocks in the trawl catches, provided by R/V "Professor Kaganovsky" during autumn survey in the Okhotsk Sea in 2011, obtained from the otolith complex method, are demonstrated in figure 6. West Kamchatkan juvenile pink salmon dominated (72,0%) in September and October mixed aggregations in 2011 in the Okhotsk Sea, and the next (24,0%) was Sakhalin juvenile pink salmon stock.

Рис. 6. The ratio in the trawl catches of R/V «Professor Kaganovsky» (September-October, 2011) between juvenile pink salmon of different origin, found by the otolith complex method

The results of identification of juvenile chum salmon stocks in the trawl catches, provided by R/V "Professor Kaganovsky" during autumn survey in the Okhotsk Sea in 2011, obtained from the otolith complex method, are demonstrated in figure 7. West Kamchatkan juvenile chum salmon dominated (75,0%) in the trawl catches like in the case of pink salmon, and the next after them were the stocks of the continental coast of the Okhotsk Sea (20,8%). The part of Japan chum salmon was 3,5%.

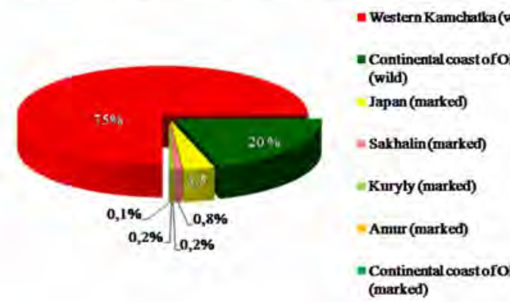

Fig. 7. The ratio in the trawl catches of R/V «Professor Kaganovsky» (September-October, 2011) between juvenile chum salmon of different origin, found by the otolith complex method

In conclusion we can add, that we don't propose using the results of the identification in practice immediately. We have examined just a trial application of the new approach to figuring out intraspecific structure in the Pacific salmon mixed marine catches. Two thoughts seem promising as a result:

1) Using the otolith complex method is quite reasonable, especially in the regions, where effects of hatchery stocks of Pacific salmon in the total structure of stock abundance are significant;

2) Getting true identification results on the base of the otolith complex method can be real only on making standardization and extension of otolith sampling sites to provide sufficient baselines, allowing to grasp all the phenotypic diversity of the otolith structure of Pacific salmon native stocks.