NPAFC
Doc. 946
Rev. 1
Rev Date 2006 May 31

Identification local stocks of sockeye salmon *Oncorhynchus nerka* by scale pattern analysis in the western part of Bering Sea from trawl catches R/V "TINRO" in September-October 2004

by

Alexander V. Bugaev

KamchatNIRO, Kamchatka Fisheries & Oceanography Inst., Fisheries State Committee of Russia, Petropavlovsk-Kamchatski, Naberezhnaja st. 18, Russia.

Submitted to the
NORTH PACIFIC ANADROMOUS FISH COMMISSION
by the
RUSSIAN NATIONAL SECTION

May 2006

THIS PAPER MAY BE CITED IN THE FOLLOWING MANNER:

Bugaev, A.V. 2006. Identification local stocks of sockeye salmon *Oncorhynchus nerka* by scale pattern analysis in the western part of Bering Sea from trawl catches R/V "TINRO" in September-October 2004. (NPAFC Doc. 946 Rev. 1) 22 p. KamchatNIRO, Kamchatka Fisheries & Oceanography Inst., Fisheries State Commit. of Russia, Petropavlovsk-Kamchatski, Naberezhnaja street 18, Russia.

ABSTRACT

The work has represented the results of the identification of the complexes of local stocks of immature sockeye salmon from the data of the trawl survey by RV «TINRO» on the program Bering-Aleutian Salmon International Survey (BASIS) in the Western Bering Sea in September-October 2004. The research was carried out according to the system of districts, accepted in TINRO-center for biocenological researches. The differential used was the scale structure. In the total the age composition of mixed ocean samples was assessed for 898 sockeye salmons, including directly identified 596 individuals. In the analysis there were used only the dominant age groups 1.1, 1.2, 2.1 and 2.2, summary taking over 90% of immature sockeye salmon in the trawl catches. The scale baselines consisted of 2926 sockeye salmon individuals of the ages 1.2, 1.3, 2.2 and 2.3.

The basis data lines were formed with using the cluster and discriminate analysis. Four complexes of sockeye salmon stocks were figured out: Eastern and North-Eastern Kamchatka + Chukotka, Western Kamchatka, Central (Bristol Bay) and South-Western Alaska and Kodiak Island. The resolution of the basis data lines was 87.42% (the age 1.) and 90.35% (the age 2.).

Preliminary results of the identification of the local stock complexes have indicated the dominance of Asian stocks – 85 % (the district 12) and 65% (the districts 3-8) - in the Western Bering Sea in September-October in feeding aggregations. Among these stocks the share of the Eastern and North-Eastern Kamchatka and Chukotka took 44% (the district 12) and 56% (the districts 3-8). The share of the Western Kamchatka stocks was in these districts 41 and 9%, respectively. The Western Kamchatka complex was mainly represented with the Ozernaya River stock – 88% (the district12) and 100% (the districts 3-8). North American sockeye salmon was in a great number only in the districts 3-8, the share being up to 35%. That was the group of stocks of Central (Bristol Bay) and South-Western Alaska. To the south in the district 12 the share of this complex was not over 13%. There was also revealed the feeding aggregation (2%) of sockeye salmon from Kodiak Island there. On the base of the assessments of sockeye salmon abundance distribution, obtained by TINRO-center, and also of the represented results of the identification there was estimated the relative abundance of the figured out stock complexes during the fall feeding in the Western Bering Sea.

INTRODUCTION

This our work continues the identification monitoring of Pacific Salmon resources in the Western Bering Sea on the base of trawl surveys by RV «TINRO» on the program Bering-Aleutian Salmon International Survey (BASIS). The target species was sockeye salmon. Identification of sockeye salmon stock complexes was accomplished with using scale structure. Some of results from studying this species we already demonstrated in 2002 and 2003 (Bugaev, 2004a, 2005). The new data obtained concern the fall period and are to illustrate infraspecific structure of sockeye salmon feeding aggregations. In the analysis we used the scale of immature fishes only. The work, similar to the work done in 2002-2003, was just an intermediate step in the basis research direction. Preliminary generalization of results of identification of sockeye salmon local stocks in the Western Bering Sea is expected to be accomplished on finishing the first block of five years of studies on the program BASIS.

The results of previous studies have indicated, that the Western Bering Sea in the summer-fall period is the area of intense feeding of almost all Asian and partly North American sockeye salmon stocks. Therefore the ratio (between the stocks) can vary substantially from year to year. It is especially important, as the fishes emerged from different continents.

In 2004 we used first time for the identification of the complexes of sockeye salmon local stocks the extended data base lines, which included not only traditional samples of Asian (Kamchatka and Chukotka) and American (Bristol Bay) stocks, but also additional scale samples from the south-west part of Alaska and Kodiak Island. That provided a more accurate assessment of the frequency ratio between Asian and North American sockeye salmon in the trawl catches.

The purpose of this work was to make identification of the largest complexes of Asian and American immature sockeye salmon stocks on the base of scale structure analysis of samples from the principle biostatistical districts of the Economic Zone of Russia in the Bering Sea part in the fall 2004.

MATERIALS AND METHODS

The mixed materials consisted of sockeye salmon scale samples collected by the staff of TINRO-center in trawl catches by RV «TINRO» in the Western Bering Sea for the fall period 2004 (fig. 1). In the work we used the system of districts accepted for the purposes of biocenological researches in commercial fishery zone of Russia in the Far East (Shuntov, 1986; Volvenko, 2003). Basing on the volume of mixed samples collected the samples were organized into two groups. The first group was to characterize sockeye salmon from the district 12 and the second group – sockeye salmon from the districts 3-8. The amount of mixed scale samples is demonstrated in table 1. Totally for the assessment of age composition there were used 898 individuals, including 596 them identified as sockeye salmon of the age classes 1.1, 1.2, 2.1 and 2.2.

The basis scale lines were collected by the staff of KamchatNIRO, ChukotNIRO, Sevvostrybvod and Department of Fish and Game (Anchorage, Alaska) from stream and coastal catches on Asian and American coasts of North Pacific in June-August 2004 (fig. 2). The composition and the sample size of the basis scale lines is demonstrated in table 2. In the total in this work the basis scale lines used consisted of 2926 specimens of sockeye salmon of the age classes 1.2, 1.3, 2.2 and 2.3. The differences between the ages in mixed sockeye salmon samples and the basis lines can influence the final result to some extent due to the factor of interannual variations in the growth rate of fish. However the differences are in general insufficient, we

noted many times that the level of differentiation of regional sockeye salmon stock complexes is rather stable in time, i.e. the problems of similarity or difference between scale criteria are stable for certain stocks (Bugaev, 2004b). In the essence the error is permanent. It is important in this situation to have the error standardized to judge objectively about the interannual variations of distribution of different groups of stocks. Nevertheless, the results of these studies formally should be reckoned as preliminary, because additional calculating is required to take into account the growth rate of fish from the basis lines and mixed samples by generations.

This work does not bear the detail description of the methods of sampling and processing the scale criteria data, because the procedures are standard in all similar studies and were described earlier (many times). The methods use the approaches, accepted in international practice (Davis et al., 1990). The basis data lines were formed on the base of results of cluster and discriminant analysis (MathSoft, 1997). The assessment of the resolution ability (simulation) of formed basis data lines and the identification of mixed ocean samples was made on the base of the maximum likelihood estimation (MLE) (Millar, 1987, 1990). The critical interval of the obtained likelihood estimations with given accuracy of 95 % (CI – 95 %) was assessed with the method of boot-stripe (500 repetitions) (Efron, Tibshirani, 1986).

RESULTS AND DISCUSSION

Scale baselines

In the work we used the regional principle of grouping the complexes of sockeye salmon local stocks. Similar approach was also used earlier in the works on the program Bering-Aleutian Salmon International Survey in 2002 and 2003. In 2004 the basis data line was extended at the expense of North American stocks from South-West Alaska and Kodiak Island. Moreover, the analysis additionally embraced the fishes of the age classes 1.2 and 2.2. This extension was used mainly because the part of these age classes increased among Asian spawners in recent years and also because of the dominant state of the stocks of Alaska mentioned. The results of the cluster and discriminative analysis of the basis data lines are demonstrated in figures 3 and 4.

It can be seen from the data demonstrated that for sockeye salmon of the age classes 1.2 and 1.3 the complexes of West Kamchatka stocks (WKAM and NWKAM) and Kodiak Island stock (KODIAK) can be identified very well. The rest stocks make up the family (nest) clusters. The scale criteria of East (EKAM) and North-East (NEKAM) Kamchatka stocks and of Chukotka (CHUKOTKA) and South-West Alaska stocks (AK PENS) are the closest to each other. Bristol Bay sockeye salmon (BBAY) can be identified better to some extent. However, as

the most principle for us was to get identification of American and Asian stocks, the complexes of stocks of South-West Alaska (AK PENS) and of North-East Kamchatka (NEKAM) have been analyzed especially. The stocks of East Kamchatka and Chukotka were united into a separate cluster (EKAM + CHUKOTKA) because scale criteria are very similar. Same situation of having very similar scale criteria was also for the stocks of West and North-West Kamchatka, which we have reckoned as one united cluster (WKAM + NWKAM) too.

Among the fishes of the ages 2.2 and 2.3 all principle groups of stocks can be identified rather well. The complex of stocks of Alaska sockeye salmon makes up a united cluster, where the most close stocks are the stock of Bristol Bay and the stock of Southwestern Alaska (BBAY + AK PENS). Kodiak Island sockeye salmon is derived into an independent cluster (KODIAK). East Kamchatkan group, similar to that as it was in the age class 1., forms a united cluster jointly with Chukotkan stocks (EKAM + CHUKOTKA). The basis line to characterize South-East Kamchatka (SEKAM) has been analyzed separately, although, judging by discriminate analysis, its' closeness to the stocks of East Kamchatka and Chukotka appears to be obvious. The West Kamchatkan stocks are derived traditionally authentic from the total group. In this case such authentic stock was Ozernaya River stock (SWKAM).

In principle, four main stock complexes can be identified with a minimal errors: 1) Western Kamchatka; 2) Eastern Kamchatka and Chukotka; 3) Central and Southwestern Alaska; 4) Kadiak Island. The stock complexes of Western and Eastern Kamchatka include sockeye salmon as from Kamchatka Region, as from Koryakski Autonomic Okrug. Nevertheless, inside the Western Kamchatka complex there can be also derived authentically the stock of the Ozernaya River. That can provide a real practical benefit in view of commercial fishery importance of this river for Kamchatka Region (in the whole).

Simulation

The mean accuracy of the scale baselines has been assessed with the method of dependent simulation (table 3 and 4). The average from the sum of assessments obtained for every complex of stocks is that same resolution ability of the simulation. The final results are represented as a percentage. For the basis data line of sockeye salmon of the age classes 1.2 and 1.3 the identification accuracy assessed was 87.42 %, and of fish of the age classes 2.2 and 2.3 – 90.35 %. In the first case the highest levels were for the stock complex of Kodiak Island (KODIAK) – 95.23 %, and the lowest levels for the stocks of Central Alaska (Bristol Bay) (BBAY) – 74.93 %. In the second case the most certain identification was for the stock of the Ozernaya River (SWKAM) – 98.04 %, and the least certain one – for the complex of stocks of Southwestern

and Central (Bristol Bay) Alaska (AK PENS + BBAY) – 77.49 %. In both cases the worst identified were obviously the stocks of Central and Southwestern Alaska.

Distribution and assessment of relative abundance

In September-October 2004 in the Western Bering Sea there was accomplished a trawl survey, the results of which have been a basis for making an assessment of the character of distribution of aggregations and relative abundance of immature sockeye salmon either in this region (fig. 3). It can be seen from the figure represented that in the biostatistical district 12 the highest catches were observed close to the coastal waters of the north-east coast of Kamchatka. In the direction toward the high seas the catches were visibly lower. The local abundance of immature sockeye salmon assessed was 48.15 mln. fishes (NPAFC, 2005). Judging by the character of the distribution it can be suggested that most sockeye salmon feeding in the district 12 is of Asian origin.

In the districts 3-8 the catches were higher in the direction toward high seas. The summary relative abundance of immature sockeye salmon in this region took 73.80 mln. fishes (NPAFC, 2005). Similar high abundance and the character of distribution allows to make a suggestion about the occurrence of a part of Alaskan sockeye salmon stocks there, which visibly predominate in the abundance in North Pacific.

Thus, the abundance of feeding sockeye salmon assessed in the fall 2004 according to the data of trawl survey by R/V «TINRO» was at a rather high level. In principle, current state of stock abundance of Alaskan and Kamchatkan stocks allows to confirm the possibility of such high levels despite the mortality in the period of ocean feeding. However, taking into account the fact that we are discussing the Economic Zone of Russia, i.e. potential zone of mass feeding of Asian stocks exactly, we have remember, that currently the highest abundance of sockeye salmon is on the Ozernaya River stock (West Kamchatka), and also in resent years it has been clearly seen the growth of stock abundance of the stocks of North-East Kamchatka and Chukotka.

Age structure

The total age structure of sockeye salmon from the trawl catches by R/V «TINRO» in the fall 2004 is demonstrated in Table 5 and Fig. 6. It can be seen from the data demonstrated that the part of postcatadromous juveniles in the district 12 took 12.9%, and in the districts 3-8 – 18.7%. The basis of the catch consisted of immature individuals of the age class .1 – 73.2 and

62.8% respectively. The part of fishes of the age class .2 was substantially less. In the district 12 it took 13.5 %, and in the districts 3-8 – 18.5%. The age class .3 was almost absent in the catches, what is characteristic for feeding sockeye salmon. Thus, as in this work our attention was paid to immature sockeye salmon directly, we have analyzed separately the age composition of the immature sockeye salmon (table 6).

In our analysis we used only allocate age groups (AAG) – 1.1, 1.2, 2.1 and 2.2, in the other words the classes, which are comparable to the bench mark data bases in the time of freshwater period of life. Accomplishing the tasks of the identification of sockeye salmon local stocks requires the summary part of age classes mentioned to be 70-80% at least. That can allow getting a quite authentic result. In our case the part of AAG in the district 12 was 90.2%, and in the districts 3-8 – 94.6%. This percent is pretty high, what allows to make an objective assessment of infraspecific structure of trawl catches of sockeye salmon from scale criteria. The part of unallocated age groups (UAG) in both cases has not been over 10%, what implies to be probable error insufficient.

Identification of local stocks

Detail results of identification of principle complexes of local stocks of immature sockeye salmon by age classes are demonstrated in Tables 7 and 8 and also in Fig. 7. From the data obtained one can see the predominance of Asian stocks in the fall 2004 in trawl catches. This appropriateness was same for all age classes.

In the whole for the united data pool of sockeye salmon of the ages .1 and .2 in the trawl catches predominated the stocks of East Kamchatka and Chukotka – 44% in the district 12 and 56% in the districts 3-8 (fig. 8). Moreover, the complex of East Kamchatka stocks included not only Kamchatka River sockeye salmon stock and Southeastern coast stocks, but the stocks of the Northeastern region either. Unfortunately, in this year there was a deficiency of bench marks from the rivers of Koriakski Autonomic district, therefore we did not succeed to frame out them into a separate complex.

The part of stocks of West Kamchatka was also rather high, especially in the district 12, where these stocks took 41%. Moreover, approximately 88% of this complex of stocks were Ozernaya river sockeye salmons. In the districts 3-8 the contribution of this stock was not over 9%. In principle, it can evidence of a high modern abundance of the Ozernaya River stock, because just the northern boundary of distribution of this stock is situated in the Western Bering Sea (Selifonov, 1989). Highly abundant runs can be expected in 2005 (the catch over 15 thousand tons is already recorded) and in 2006.

The part of American stocks in the district 12 was not over 15%. In the districts 3-8 the percent of these stocks increased to 35%. Judging by the data for previous years, the percent of American stocks in the district 12 varied in average as 10-20%, and in the districts 3-8 – as 20-40% (Bugaev, 2004a, 2005). In 2004 the tendency was same, what evidences of a stable run of Alaskan complex of stocks to the Western Bering Sea.

On the base of the data from the identification there was estimated the relative abundance of local stock complexes identified (table 9). It is seen from the table that the highest summary abundance by the districts is in the group of stocks of East Kamchatka and Chukotka – 58.20 mln. fishes. Taking into account that the Western Bering Sea is a traditional feeding location of this complex of stocks, that seems to be logical. Nevertheless, the abundance obtained is too high, being compared to the average number of spawners observed (catch + escapement) in this area for many years (resent 10-15 years). Though, most spawners of East Kamchatka and Chukotka have the age at maturation .3. Therefore, perhaps it is the factor of ocean mortality to play an important role. The abundance of West Kamchatkan stocks was 24.09 mln. fishes and of Alaska stocks – 30.95 mln. fishes. These volumes are quite correspondent to the abundance levels of the complexes mentioned. If we take into account that the Western Bering Sea is only a part of feeding area we also can get the level of relatively high abundance like in the case of stocks of East Kamchatka. In principle that indicates a high level of mortality of Pacific Salmon, sockeye salmon in particular, during their ocean life. Unfortunately, for nowadays yet there are no empirical data obtained on the assessment of the level of salmon ocean mortality. Therefore the references in the literature mostly mention only theoretical assumptions about this problem.

ACKNOWLEDGEMENTS

I thank E.V. Golub' (ChukotNIRO), J. Seeb and M. Foster (Department of Fish and Game, Alaska State, the USA) for help in this work.

REFERENCES

Bugaev, A.V. 2004a. Some methodical aspects for identification of local stocks of pacific salmon by scale pattern analysis. Thesis of NPAFC International Workshop. BASIS-2004: salmon and marine ecosystems in the Bering Sea and adjacent waters. Technical report 6. Sapporo, Hokkaido, Japan, October 30-31. P. 109-111.

Bugaev, A.V. 2004b. Scale pattern analysis estimates of the age and stock composition of sockeye salmon *Oncorhynchus nerka* in R/V *TINRO* trawl catches in the western Bering Sea and northwestern Pacific ocean in September-October 2002 (NPAFC Doc. 763) 26 p. KamchatNIRO, Kamchatka Fisheries & Oceanography Inst., Fisheries State Commit. of Russia, Naberezhnaja Street 18, Petropavlovsk-Kamchatski, Russia.

Bugaev, A.V. 2005. Scale pattern analysis estimates of the age and stock composition of sockeye salmon *Oncorhynchus nerka* in R/V *TINRO* trawl catches in the western Bering Sea and northwestern Pacific ocean in summer-autumn 2003. (NPAFC Doc. 866) 25 p. KamchatNIRO, Kamchatka Fisheries & Oceanography Inst., Fisheries State Commit. of Russia, Naberezhnaja Street 18, Petropavlovsk-Kamchatski, Russia.

Davis, N.D., K.W. Myers, R.V. Walker, and C.K. Harris. 1990. The Fisheries Research Institute's high-seas salmonid tagging program and methodology for scale pattern analysis. Amer. Fish. Soc. Symp. 7: 863–879.

Efron, B., Tibshirani R. 1986. Bootstrap methods for standard errors, confidence interval, and other measures of statistical accuracy. Statistical Science 1 (1): 54-77.

MathSoft. 1997. S-PLUS Guide to Statistics. Data Analysis Products Division. MathSoft Inc., Seattle. 877 p.

Millar, R.M. 1987. Maximum likelihood estimation of mixed stock fishery composition. Can. J. Fish. Aquat. Sci. 44: 583-590.

Millar, R.M. 1990. Comparison of methods for estimating mixed stock fishery composition // Can. J. Fish. Aquat. Sci. 47: 2235-2241.

North Pacific Anadromous Fish Commission. 2004. Annual report of the Bering-Aleutian Salmon International Survey (BASIS), 2004. (NPAFC Doc. 857) 105 p. BASIS Working Group. North Pacific Anadromous Fish Commission. Vancouver, B.C. Canada.

Selifonov, M.M. 1989. Contributions of Ozernaya River sockeye salmon (*Oncorhynchus nerka*) to ocean catch with special reference to their distribution in time and space. *In* R.J. Beamish and G.A. McFarlane (ed.). Effect of ocean variability on recruitment and

evaluation of parameters used in stock assessment models. Can. Spec. Publ. Fish. Aquat. Sci. 108: 341-352.

Shuntov,V.P. 1986. State of studies of many-years cyclic dynamics of fish stocks abundance in the Far East Seas. Biol. Morya 3: 3-14. (In Russian)

Volvenko, I.V. 2003. Morphometric characteristics of standard biostatistic districts for biological studies of fishery zone of Russia in the Far East. Izv. TINRO 132: 27-42. (In Russian)

Appendix figures and tables

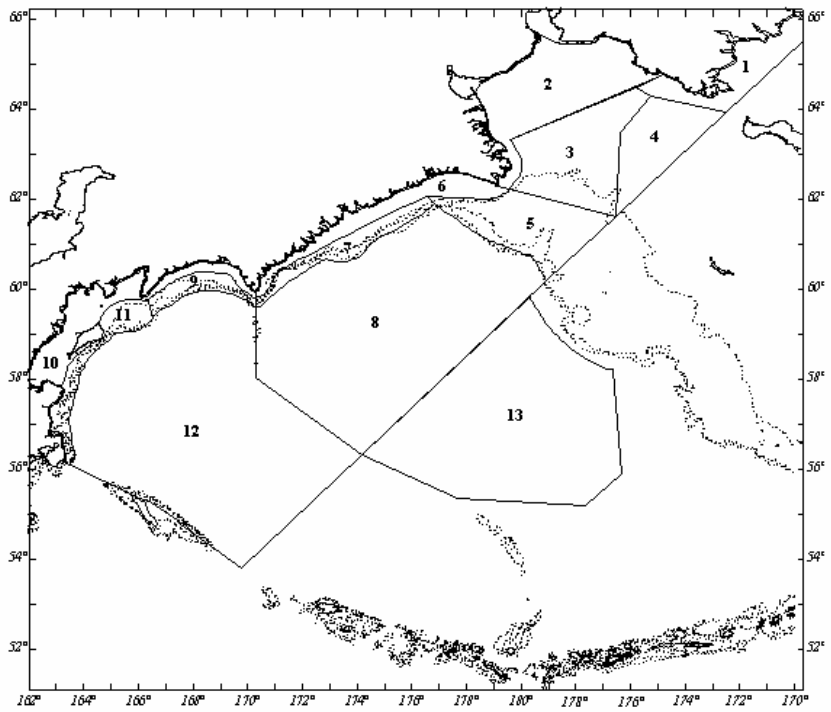


Fig. 1. Scheme of biostatistical districts in the western part of Bering sea used TINRO-center for ecosystems researches (Shuntov, 1986; Volvenko, 2003)

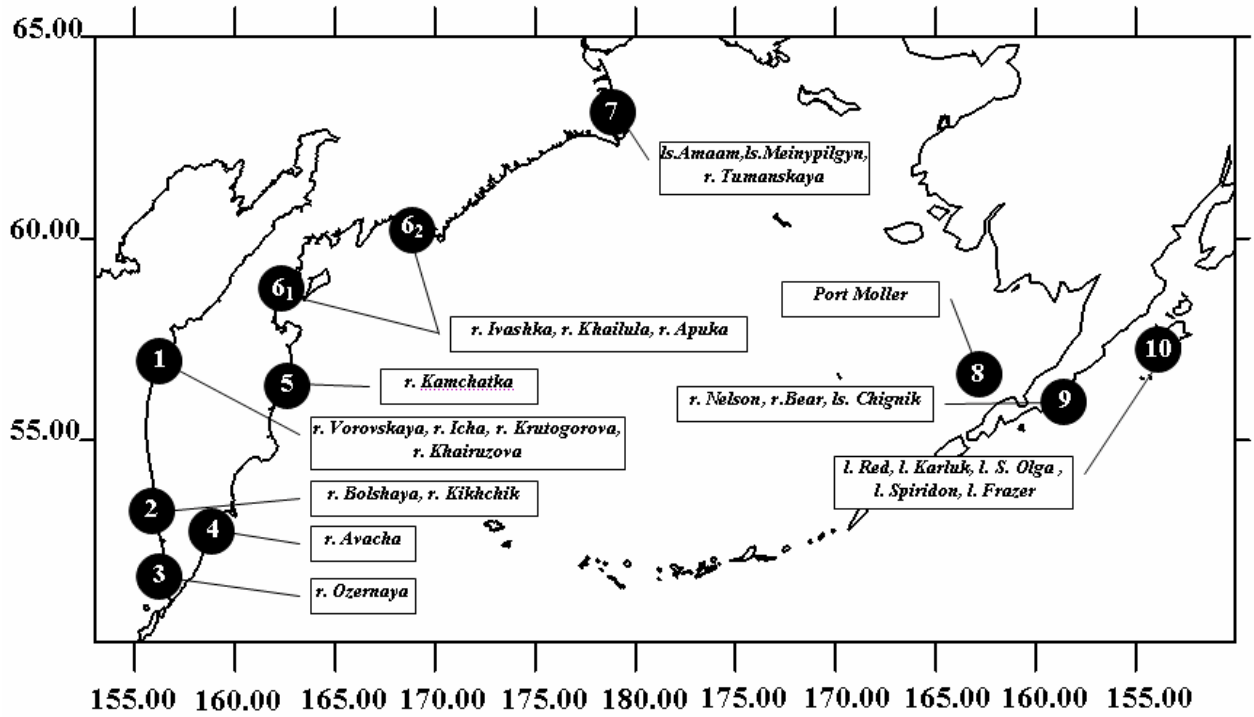


Fig. 2. Areas collected scale samples of sockeye salmon used for baselines in 2004: 1 – north-west Kamchatka (NWKAM); 2 – west Kamchatka (WKAM); 3 – south-west Kamchatka (SWKAM); 4 – south-east Kamchatka (SEKAM); 5 – east Kamchatka (EKAM); 6_1, 6_2 – north-east Kamchatka (NEKAM); 7 – Chukotka (CHUKOTKA); 8 – centralAlaska (BBAY – Bristol bay); 9 – south-western Alaska (AK PENS); 10 – Kodiak island (KODIAK)

Table 1. Size used of mixed scale materials from trawl catches R/V “TINRO” in the western part of Bering sea

Biostatistical districts	Period	Coordinates	Size scale materials, inds.	
			Age	Identification
3-8	5.10-23.10	56°59' - 63°03' N 171°02' - 179°35' E	363	278
12	26.09-11.10	53°52' - 59°58' N 163°56' - 172°59' E	535	318
Total	26.09-23.10		898	596

Table 2. Size and composition of scale standards used in this work, inds.

Region	Stock/river	Code	Age				Total
			1.2	1.3	2.2	2.3	
Asian stocks							
North-West Kamchatka	r. Vorovskaya	NWKAM	-	37	-	-	37
	r. Icha		-	100	-	-	100
	r. Krutogorova		-	57	-	-	57
	r. Khairuzova		-	100	-	-	100
West Kamchatka	r. Bolshaya	WKAM	-	100	-	-	100
	r. Kikhchik		-	55	-	-	55
South-West Kamchatka	r. Ozernaya	SWKAM	-	-	100	102	202
South-East Kamchatka	r. Avacha	SEKAM	-	-	-	32	32
East Kamchatka	r. Kamchatka	EKAM	-	100	100	100	300
North-East Kamchatka	r. Apuka	NEKAM	-	100	-	-	100
	r. Ivashka		-	100	-	-	100
	r. Khailula		-	100	-	-	100
Chukotka	ls. Amaam	CHUKOTKA	-	42	36	-	78
	ls. Meinypilgyn		-	100	64	-	164
	r. Tumanskaya		-	53	25	-	78
American stocks							
Central Alaska (Bristol Bay)	Port Moller	BBAY	100 -	95 -	100 -	43 -	338
South-West Alaska (Alaska Peninsula)	r. Nelson	AK PENS	-	45	100	30	175
	r. Bear		-	-	50	50	100
	ls. Chignik		38	49	-	50	137
Kodiak island	l. Karluk	KODIAK	-	-	50	44	94
	l. Red		50	-	50	-	100
	l. S. Olga		100	-	99	-	199
	l. Spiridon		50	50	-	-	100
	l. Frazer		30	-	50	-	80
Total			368	1283	824	451	2926

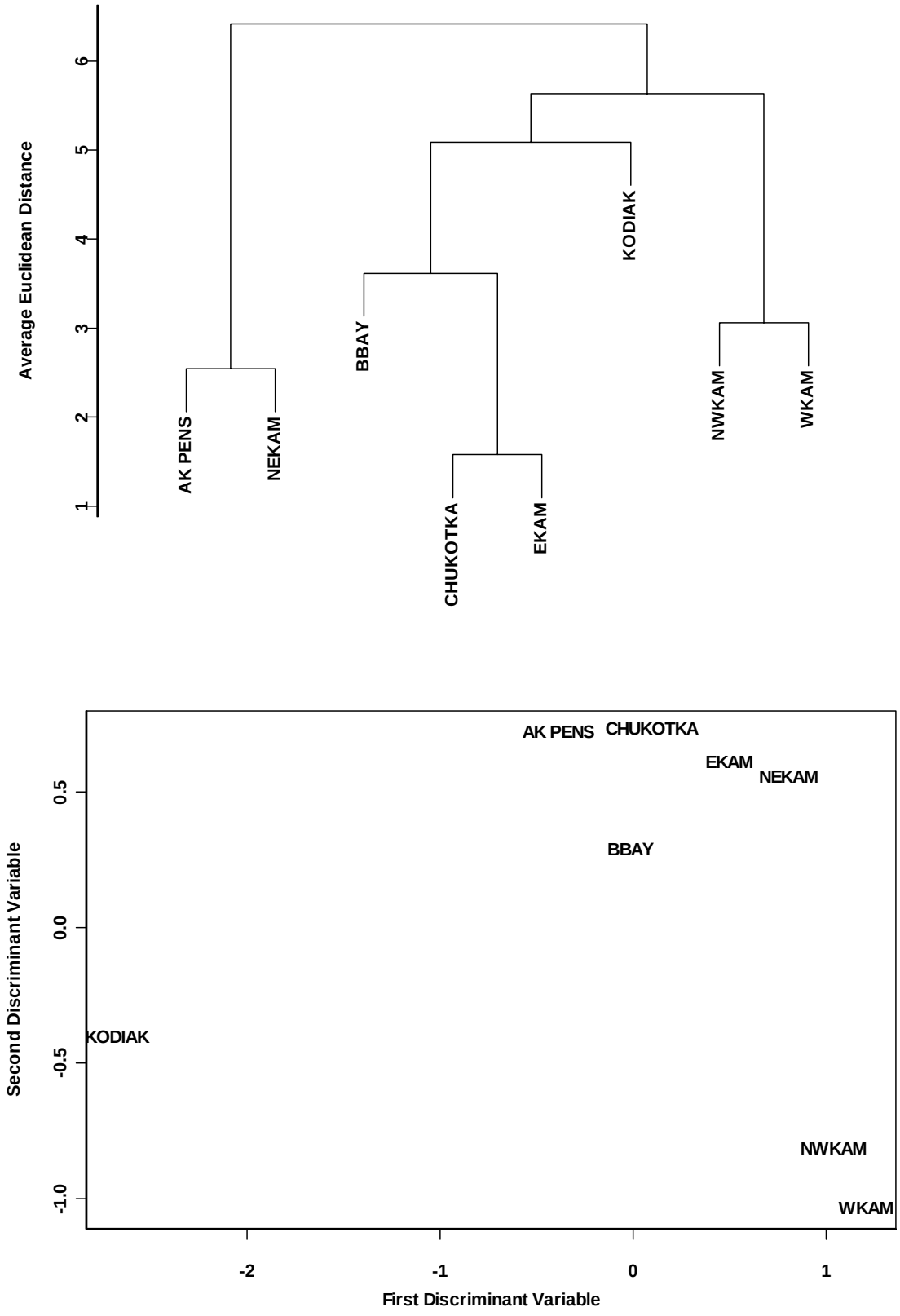


Fig. 3. Hierarchical clustering dendrogram and multivariate distribution of complexes stock centroids plotted against the first and second canonical discriminate variables for the scale baselines of sockeye salmon in age 1.2 + 1.3

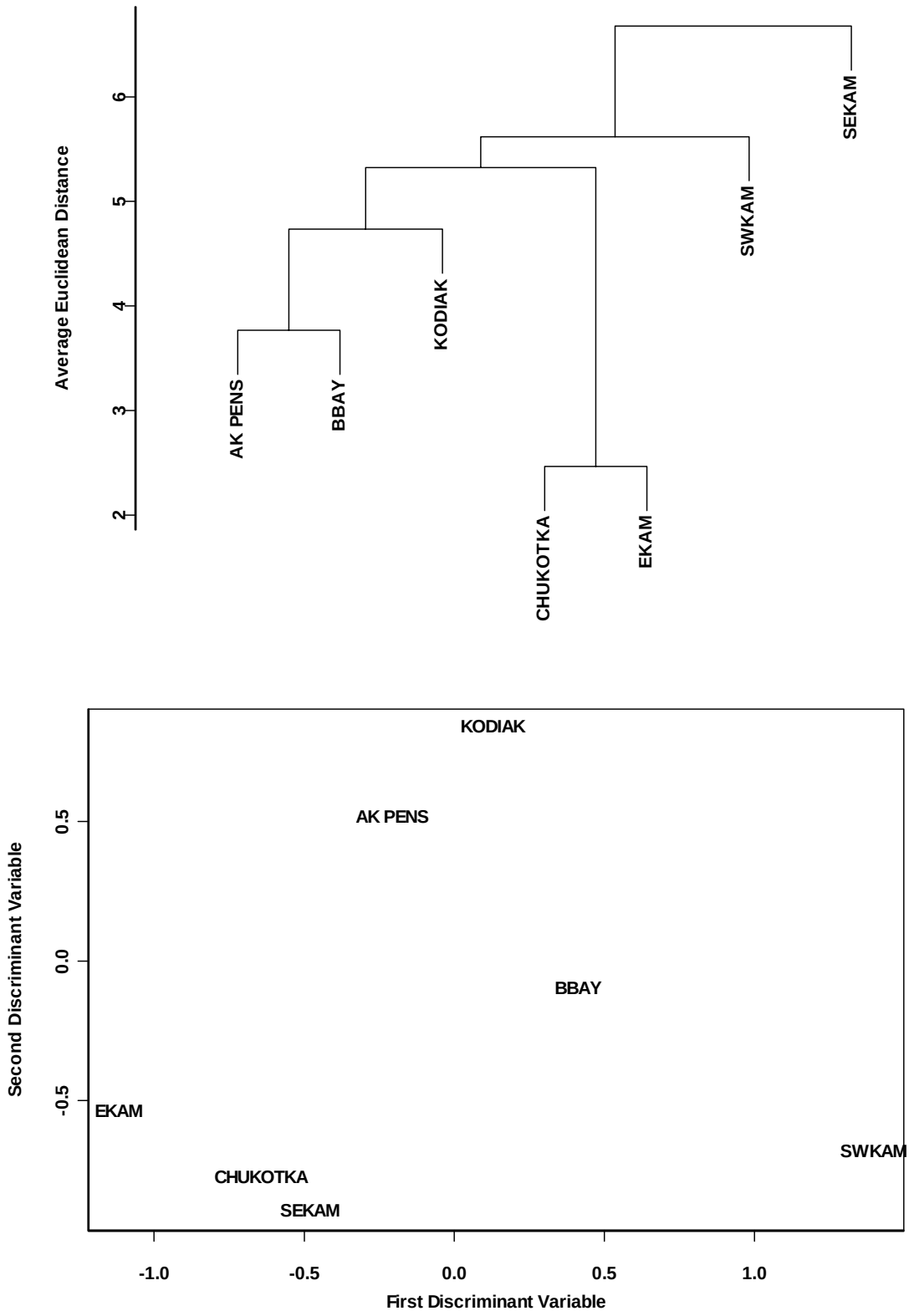


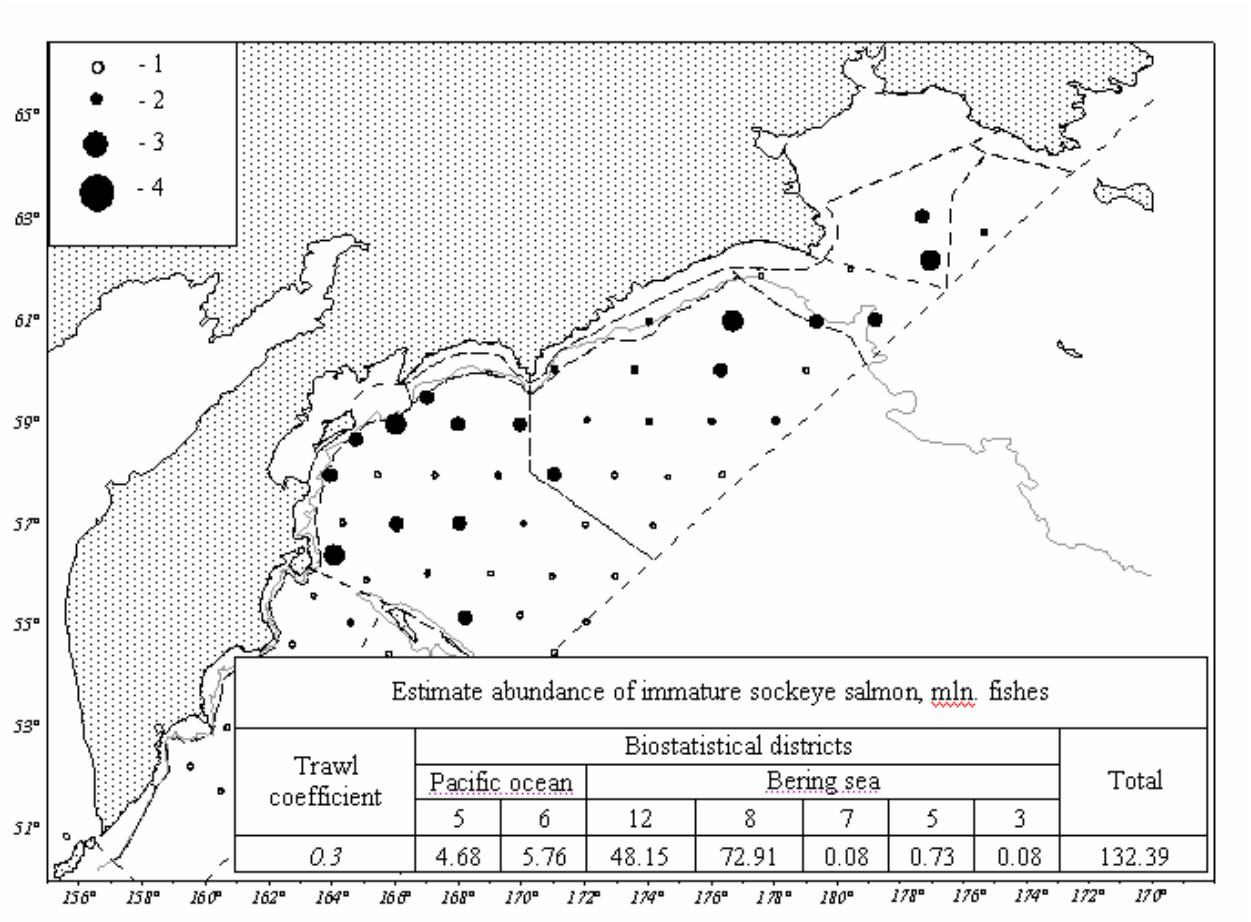
Fig. 4. Hierarchical clustering dendrogram and multivariate distribution of complexes stock centroids plotted against the first and second canonical discriminate variables for the scale baselines of sockeye salmon in age 2.2 + 2.3

Table 3. Homogenous-mixture baseline-dependent simulation results for the cluster-based of sockeye salmon by age groups 1.2 and 1.3, MLE/SD

Complex stocks	N	1.	2.	3.	4.	5.	6.
1. AK PENS	133	**0.9013** **0.0908**	0.0174 0.0308	0.1304 0.0998	0.0235 0.0387	0.0049 0.0149	0.0012 0.0060
2. NEKAM	300	0.0167 0.0442	**0.8778** **0.0886**	0.0131 0.0329	0.0616 0.0770	0.0001 0.0013	0.0414 0.0554
3. BBAY	195	0.0463 0.0759	0.0218 0.0353	**0.7493** **0.1169**	0.0339 0.0480	0.0323 0.0336	0.0124 0.0264
4. EKAM + CHUKOTKA	295	0.0340 0.0493	0.0486 0.0649	0.0681 0.0609	**0.8644** **0.0924**	0.0008 0.0052	0.0427 0.0380
5. KODIAK	279	0.0017 0.0076	0.0005 0.0022	0.0034 0.0078	0.0108 0.0145	**0.9523** **0.0363**	0.0021 0.0050
6. WKAM + NWKAM	449	0.0000 0.0000	0.0339 0.0392	0.0357 0.0395	0.0058 0.0144	0.0096 0.0132	**0.9002** **0.0622**
Mean accuracy, %							**87.42**

Table 4. Homogenous-mixture baseline-dependent simulation results for the cluster-based of sockeye salmon by age groups 2.2 and 2.3, MLE/SD

Complex stocks	N	1.	2.	3.	4.	5.
1. AK PENS + BBAY	423	**0.7749** **0.0963**	0.0279 0.0532	0.0169 0.0325	0.0105 0.0248	0.0100 0.0287
2. KODIAK	293	0.0969 0.0767	**0.8975** **0.0707**	0.0379 0.0431	0.0042 0.0127	0.0035 0.0128
3. EKAM + CHUKOTKA	325	0.0948 0.0637	0.0611 0.0523	**0.9226** **0.0609**	0.0042 0.0094	0.0441 0.0567
4. SWKAM	202	0.0192 0.0280	0.0123 0.0200	0.0044 0.0095	**0.9804** **0.0285**	0.0003 0.0038
5. SEKAM	32	0.0142 0.0254	0.0012 0.0054	0.0182 0.0326	0.0007 0.0034	**0.9421** **0.0628**
Mean accuracy, %						**90.35**



Estimate abundance of immature sockeye salmon, mln. fishes

Trawl coefficient	Biostatistical districts							Total
	Pacific ocean		Bering sea					
	5	6	12	8	7	5	3	
0.3	4.68	5.76	48.15	72.91	0.08	0.73	0.08	132.39

Fig. 5. Spatial distribution (inds./km^2) and estimates of relative abundance (mln. inds.) of immature sockeye salmon in the western Bering sea in september–october 2004. Designations: 1 – no catch; 2 - 2 – 1-11; 3 – 11-101; 4 – 101-501 inds./km^2 (TINRO Center, Vladivostok, Russia)

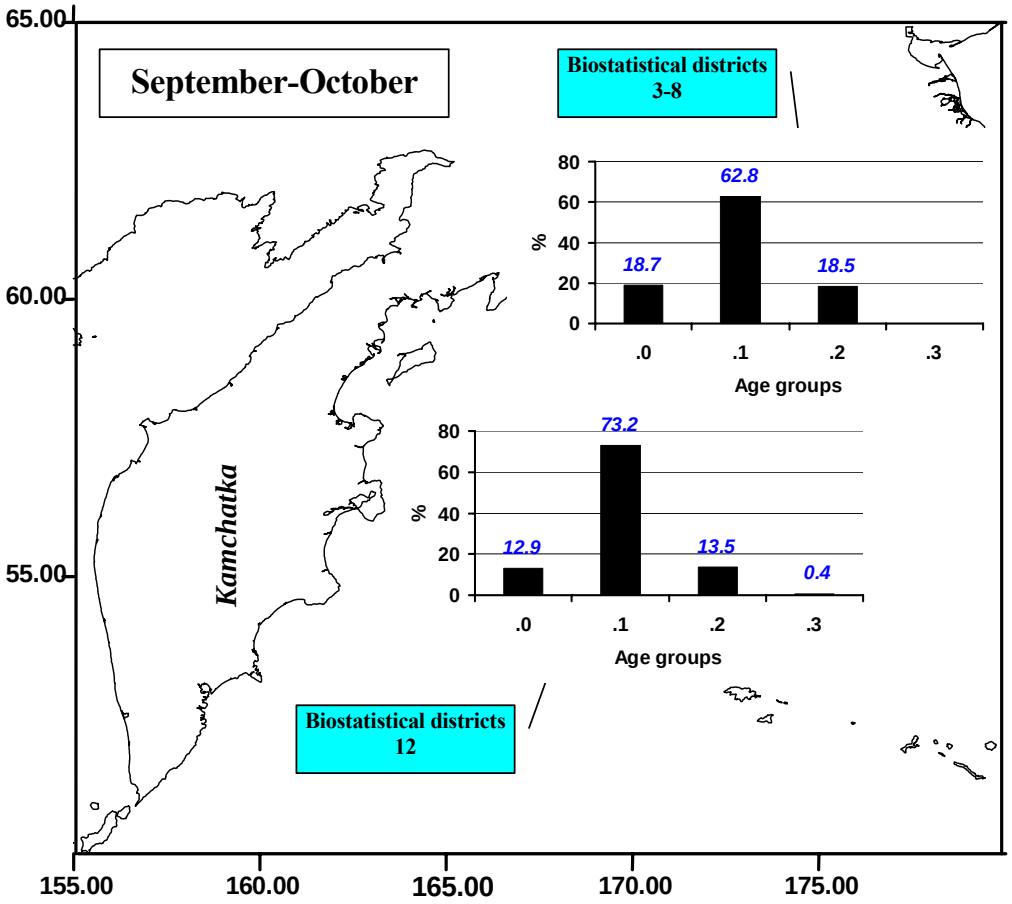


Fig. 6. Distribution age groups of immature sockeye salmon in the western part of Bering sea by data from trawl catches R/V "TINRO" in autumn 2004

Table 5. Total age composition of sockeye salmon from trawl catches R/V "TINRO" in autumn 2004

Biostatistical districts	Period	N	Age, %													
			0.0	0.1	0.2	0.3	1.0	1.1	1.2	2.0	2.1	2.2	3.0	3.1	3.2	4.1
3-8	5.10-22.10	363	1.4	1.4	0.6	-	6.9	34.7	12.7	9.9	24.2	5.2	0.5	2.2	-	0.3
12	16.09-9.10	535	0.9	5.6	1.1	0.4	10.5	32.1	9.2	1.5	34.4	2.8	-	1.1	0.4	-

Table 6. Age composition of immature sockeye salmon from trawl catches R/V "TINRO" in autumn 2004

Biostatistical districts	Period	N	Age, %									AAG, %
			0.1	0.2	0.3	1.1	1.2	2.1	2.2	3.1	3.2	4.1	
3-8	5.10-22.10	295	1.7	0.7	-	42.7	15.6	29.9	6.4	2.7	-	0.3	94.6
12	16.09-9.10	466	6.4	1.3	0.4	36.9	10.5	39.6	3.2	1.3	0.4	-	90.2

Note. AAG – allocated age groups.

Table 7. Maximum likelihood estimates (MLE), standard deviations (SD) and confidence intervals (CI – 95 %) derived for results of identification local stocks of immature sockeye salmon from trawl catches R/V "TINRO" in the western part of Bering sea in autumn 2004 (age .1)

Biostatistical districts	Period	Age	N	Complex stocks	MLE	SD	CI - 95 %
3-8	5.10-22.10	1.1	120	AK PENS	0.5387	0.0855	0.3298-0.6665
				NEKAM	0.0374	0.0813	0.0000-0.2451
				BBAY	-	-	-
				EKAM + CHUKOTKA	0.4239	0.0896	0.2391-0.6105
				KODIAK	-	-	-
				WKAM + NWKAM	-	-	-
		2.1	96	AK PENS + BBAY	0.1059	0.0866	0.0000-0.2021
				KODIAK	-	-	-
				EKAM + CHUKOTKA	0.7044	0.0874	0.5633-0.8745
				SWKAM	0.1897	0.0604	0.0801-0.3359
				SEKAM	-	-	-
12	16.09-9.10	1.1	107	AK PENS	0.1287	0.0976	0.0427-0.2701
				NEKAM	0.1091	0.0995	0.0000-0.2203
				BBAY	0.1772	0.1139	0.0000-0.3733
				EKAM + CHUKOTKA	0.4167	0.0983	0.3362-0.5912
				KODIAK	0.0471	0.0265	0.0146-0.0824
				WKAM + NWKAM	0.1212	0.0626	0.0837-0.2415
		2.1	150	AK PENS + BBAY	-	-	-
				KODIAK	-	-	-
				EKAM + CHUKOTKA	0.2774	0.0516	0.1585-0.4010
				SWKAM	0.7226	0.0516	0.5968-0.8348
				SEKAM	-	-	-

Table 8. Maximum likelihood estimates (MLE), standard deviations (SD) and confidence intervals (CI – 95 %) derived for results of identification local stocks of immature sockeye salmon from trawl catches R/V "TINRO" in the western part of Bering sea in autumn 2004 (age .2)

Biostatistical districts	Period	Age	N	Complexes stocks	MLE	SD	CI - 95 %
3-8	5.10-22.10	1.2	43	AK PENS	0.3568	0.1397	0.0603-0.6039
				NEKAM	-	-	-
				BBAY	0.1329	0.132	0.0000-0.4471
				EKAM + CHUKOTKA	0.5103	0.1178	0.2870-0.7576
				KODIAK	-	-	-
				WKAM + NWKAM	-	-	-
		2.2	19	AK PENS + BBAY	-	-	-
				KODIAK	-	-	-
				EKAM + CHUKOTKA	0.6539	0.1388	0.3380-0.9044
				SWKAM	0.3461	0.1388	0.0541-0.6405
				SEKAM	-	-	-
12	16.09-9.10	1.2	48	AK PENS	0.1496	0.1007	0.0000-0.3314
				NEKAM	-	-	-
				BBAY	-	-	-
				EKAM + CHUKOTKA	0.7458	0.116	0.5252-0.9487
				KODIAK	0.0618	0.0502	0.0000-0.1727
				WKAM + NWKAM	0.0428	0.0547	0.0000-0.1886
		2.2	13	AK PENS + BBAY	-	-	-
				KODIAK	-	-	-
				EKAM + CHUKOTKA	0.5313	0.1767	0.1704-0.8854
				SWKAM	0.4687	0.1767	0.0457-0.8087
				SEKAM	-	-	-

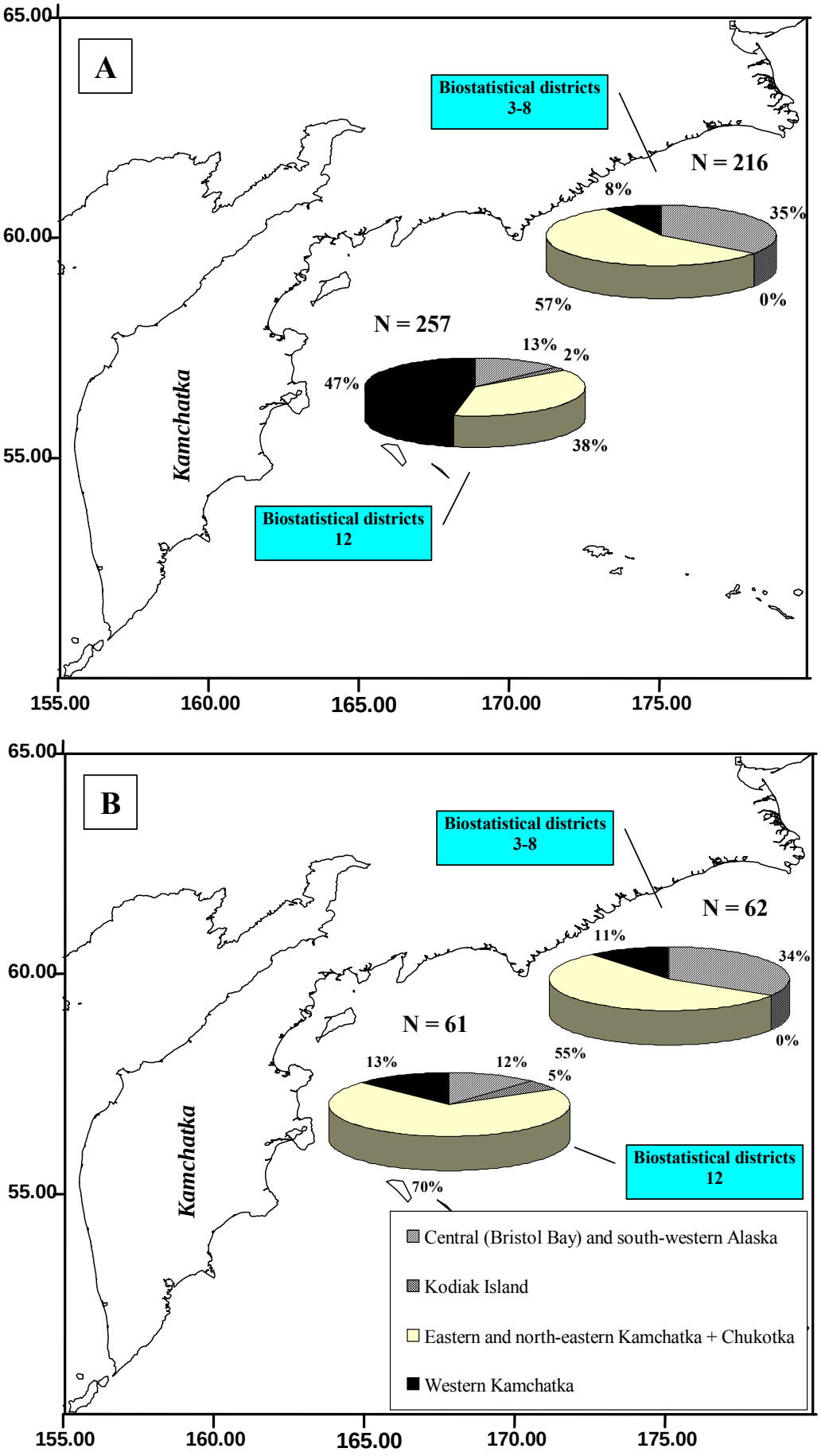


Fig. 7. Distribution complexes local stocks of immature sockeye salmon for age group .1 (A) and .2 (B) in the western part of Bering sea by data from trawl catches R/V "TINRO" in the september-october 2004

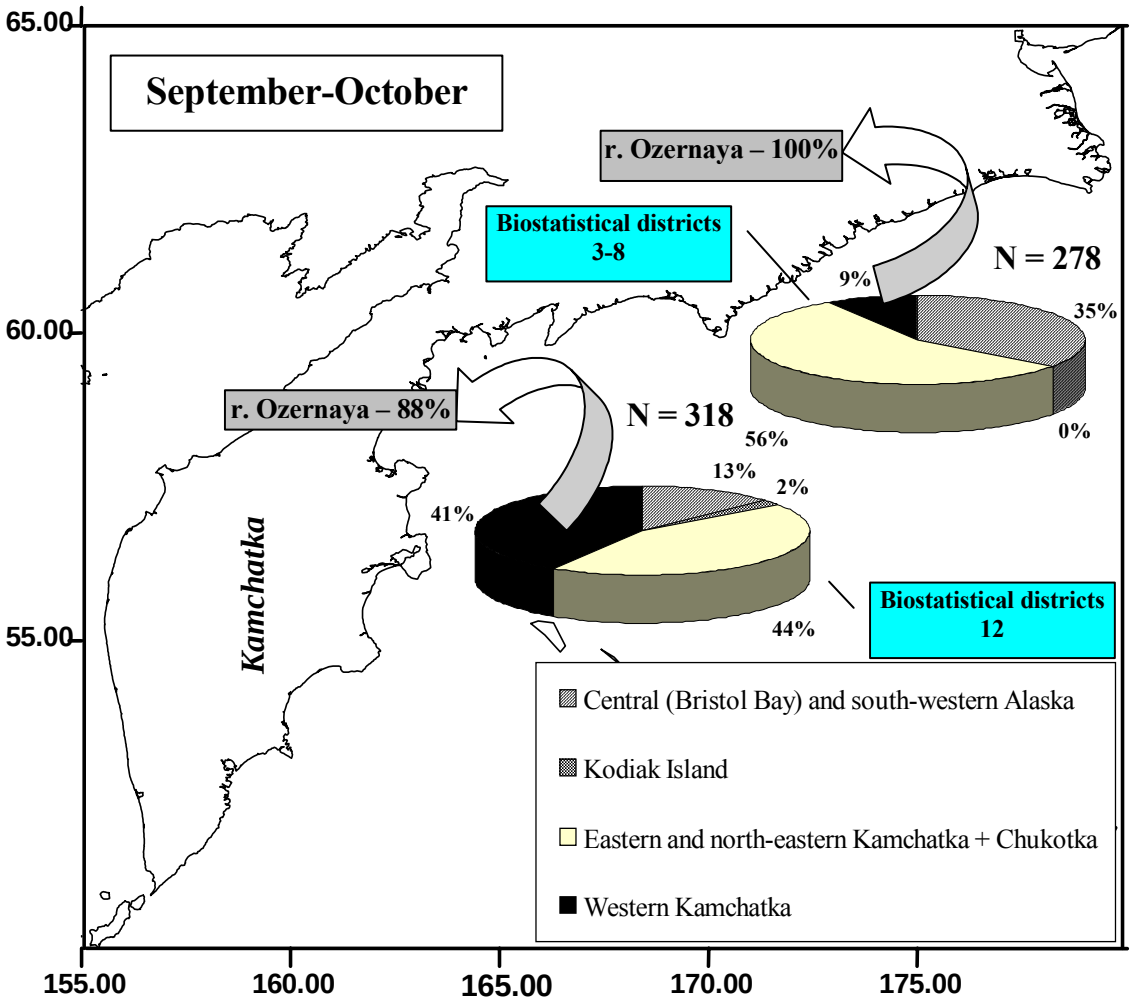


Fig. 8. Distribution complexes local stocks of immature sockeye salmon (age .1 + .2) in the western part of Bering sea by data from trawl catches R/V "TINRO" in autumn 2004

Table 9. Estimate of abundance complexes stocks of immature sockeye salmon from Asia and North America in the western Bering sea from data trawl catches R/V "TINRO" in autumn 2004

Biostatistical districts	Age groups	%	Mln. fishes	Complexes stocks					
				Western Kamchatka		Eastern Kamchatka + Chukotka		Alaska	
				%	mln. fishes	%	mln. fishes	%	mln. fishes
3-8	AAG	94.6	69.81	9	6.28	56	39.09	35	24.44
	UAG	5.4	3.99						
Total		100	73.80						
12	AAG	90.2	43.43	41	17.81	44	19.11	15	6.51
	UAG	9.8	4.72						
Total		100	48.15						
All districts	AAG	92.9	113.24	21	24.09	51	58.20	28	30.95
	UAG	7.1	8.71						
		100	121.95						

Note. AAG – allocated age groups, UAG – unallocated age groups.