NPAFC
Doc. No. 764

Rev. No.

Scale Pattern Analysis Estimates of Age and Stock Composition of Chinook Salmon *Oncorhynchus tshawytscha* in R/V *TINRO* Trawl Catches in the Western Bering Sea in September-October 2002

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

October 2004

THIS PAPER MAY BE CITED IN THE FOLLOWING MANNER:

Bugaev A.V. 2004. Scale pattern analysis estimates of the age and stock composition of chinook salmon *Oncorhynchus tshawytscha* in R/V *TINRO* trawl catches in the western Bering Sea in September-October 2002 (NPAFC Doc. 764) 15 p. KamchatNIRO, Kamchatka Fisheries & Oceanography Inst., Fisheries State Commit. of Russia, Naberezhnaja Street 18, Petropavlovsk-Kamchatski, Russia.

ABSTRACT

An integral part of Bering-Aleutian Salmon International Survey (BASIS) research is to estimate the age and stock composition of salmon migrating in the Bering Sea and adjacent waters of the North Pacific Ocean. In this document, scale pattern analysis was used to estimate the age and stock composition of immature chinook salmon caught during the R/V *TINRO*/BASIS survey in the western Bering Sea in fall 2002. The R/V *TINRO* sample was composed of three dominant age groups (41% age-1.0, 44% age-1.1, 11% age 1.2, and 4% other age groups; n=229 fish). All juvenile (age 1.0) chinook salmon were assumed to be of Asian (Kamchatka) origin. The mean accuracy of a maximum likelihood estimation model developed to identify complexes of local stocks of immature age 1.1 and 1.2 chinook salmon was about 85%. For immature age 1.1 chinook salmon (n=69 fish), the estimated stock composition was 59% East Kamchatka, 20% West Kamchatka, and 21% Western Alaska. For immature age 1.2 chinook salmon (n=22 fish), the estimated stock composition was 67% East Kamchatka, 10% West Kamchatka, and 23% Western Alaska, although none of the estimates were statistically significant (95% CIs included zero). The sample sizes were not large enough to evaluate spatial or temporal trends in chinook salmon distribution in the western Bering Sea. In conclusion, the results indicate that Asian stocks dominated catches of chinook salmon in the western Bering Sea in fall 2002, but because of insufficient sample sizes these results are considered to be preliminary.

INTRODUCTION

An integral part of Bering-Aleutian Salmon International Survey (BASIS) research is to estimate the age and stock composition of salmon migrating in the Bering Sea and adjacent waters of the North Pacific Ocean (NPAFC 2001). In this document, scale pattern analysis is used to estimate of the age and stock composition of immature chinook salmon caught during the R/V *TINRO*/BASIS survey in the western Bering Sea in fall 2002 (Temnykh et al. 2003).

MATERIALS AND METHODS

Analysis of scale patterns has been used since the 1950s to estimate the regional stock composition of salmon caught in mixed-stock fisheries on the high seas, and Major et al. (1972) outlined the basic principles and procedures of scale pattern analysis. For high seas applications, scale pattern analysis methods involve the collection and measurement of representative scales from major regional stocks of Asian and North American salmon (baseline samples) and from salmon of unknown stock origins in the ocean (mixed-stock samples). In this study, baseline samples of chinook salmon scales were collected by scientists from KamchatNIRO, Sevvostrybvod, and the Alaska Department of Fish and Game from streams or terminal area fisheries in marine waters from May to August 2002. Mixed-stock ocean samples were collected by TINRO-Center scientists aboard the R/V *TINRO* during trawl catches in the western Bering Sea in September and October 2002 (Temnykh et al. 2003).

Baseline scale samples were collected according to well-accepted methods for Pacific salmon scale pattern analysis , i.e., from the “preferred” body area (Clutter and Whitesel 1956; Knudsen 1985; Davis et al. 1990). Because immature salmon loose many scales when they are caught in trawls, the marine mixture samples included scales taken from non-preferred body areas. All scale samples were used to estimate age composition, however, only scales collected from the preferred body area were used to estimate stock composition. This approach was necessary because different rates of scale growth on different parts of the fish's body can influence the results of scale pattern analysis. A similar approach has been used by foreign scientists for stock identification of Pacific salmon in incidental catches by commercial trawl fisheries in the eastern Bering Sea (Patton et al. 1998; Myers et al. 2003).

Age was estimated by counting the number of freshwater and marine annuli on scales, which is the standard method accepted for Pacific Salmon (e.g., Ito and Ishida 1998). In some cases scales taken from non-preferred body areas, e.g., the caudal peduncle or the pectoral fins, were very deformed, and in these cases length-weight parameters of individual fish were used to estimate age.

Scale structural elements in the freshwater and first year of marine growth were measured with a BioSonics Optical Pattern Recognition System (OPR-513 and OPRS models, BioSonics Inc., Seattle, WA, USA). The structure of these scale growth zones has been used for many years to differentiate local stocks of Pacific salmon in mixed-stock catches in the North Pacific Ocean (e.g., Davis et al. 1990). All measurements were made along a standard axis that crossed the line of the scale pocket at an angle of 90° (Fig. 1). Thirteen scale measurement variables in the first ocean year zone (C1) were used in the analysis.

Intraspecific differentiation of stocks in the catches was carried out in two stages. The first stage involved formation of scale data baselines representative of major stocks of chinook salmon likely to be present in the mixed ocean samples. The second stage was to estimate the stock composition of salmon in the mixed-stock trawl catches in the western Bering Sea.

The baselines included samples from the most important and abundant local stocks of chinook salmon reproducing in rivers of Kamchatka and western Alaska (Fig. 2). To form the baselines, a stratified random sample of scales, which accounted for spatial and temporal population structures of each river system in the baseline, was selected. For large stocks, scales that characterized early, middle, and late periods of the run were selected. This method, however, varied depending on sample sizes, and when sample size was small the entire sample was used in the analysis. Sample size and composition of the baselines are shown in Table 1.

The baseline data included scales from three age groups, 1.2, 1.3, and 1.4, which are the dominant age groups of adult Asian and North American chinook salmon (Healey 1991). Because the abundance of Asian chinook salmon is low, sufficient samples for baselines were obtained only by pooling samples over ocean age group. This increased the variance of scale pattern variables of populations included in the baselines. Moreover, brood-year specific baselines could not be created for each age group because of insufficient samples. Differences between the age and brood year of chinook salmon in the baselines and in the trawl catches probably reduced the accuracy of the stock composition estimates. However, previous studies have indicated that scale patterns are relatively consistent for particular local stocks or complexes of stocks over long periods of time (e.g., Major et al. 1972).

Mixed-stock oceanic samples were composed of scales collected by TINRO-Centre scientists during trawl surveys in the western Bering Sea (Fig. 3). The mixed-stock samples were stratified by the same system of districts used by TINRO-Centre for biocenological studies in the Russian fishery zone (Shuntov, 1986; Volvenko, 2003). More than 90% of samples were collected in districts 8 and 12. Nevertheless, when samples were stratified by district the number of scales was not sufficient to obtain statistically reliable results. Therefore, the mixture samples were pooled over all districts. Samples from a total of 229 chinook salmon were used for age composition estimates, and only 91 fish were used for stock composition estimates..

The results of cluster analysis (hierarchical agglomeration by average Euclidean distance) were used to group baseline data from individual stocks and age groups into a few baselines that included all fish with similar scale patterns (MathSoft, 1997).. Millar's software (Millar 1987, 1990) was used to evaluate the accuracy of the regional baseline models. This method involved baseline-dependent simulations of mixed-stock samples of fish, randomly sampled with replacement from within each regional baseline. The percent composition of each baseline within the mixture was set before the start of the simulation, which calculates maximum likelihood estimates (MLE) of stock composition for each simulation run. The averages of the estimates from 500 simulation runs were used as measures of the accuracy of the baseline models.

Millar's software was also used to calculate MLE estimates of the proportions of the regional stocks in the 2002 R/V TINRO samples (Millar 1987, 1990). The standard deviation and 90% confidence intervals of the MLEs were calculated from 500 bootstrap runs, which included resampling of both the baseline and mixture samples and calculation of the stock composition estimates for each run.

RESULTS AND DISCUSSION

Scale baselines

Tree-diagrams of the results of cluster analysis characterize both the similarities and differences in the scale baselines used in the analysis (Fig. 4). A clear division between stocks of Eastern and Western Kamchatka can be seen from the data represented in all levels. The results show maximum similarity between stocks of Eastern and South-Eastern Kamchatka (EKAM and SEKAM) and between stocks of Western and South-Western Kamchatka (WKAM and SWKAM). These homogenous divisions can be explained by similar feeding conditions in freshwater and the early marine period of life. Western Alaskan stocks demonstrated a slight similarity to the East Kamchatkan stock complex. Similar relations among these regional stocks were observed in an earlier study of sockeye salmon scale patterns (Bugaev 2003). Nevertheless, the levels of difference are quite high, and are sufficient to identify these complexes in mixed-stock samples.

The mean accuracies of estimating particular baseline groups in the six stock-cluster MLE model varied from 75.6 to 95.1% (Table 2). The accuracies were lowest for the western Kamchatka baselines, with the highest errors occurring among neighboring baselines. Thus, the estimates for these baselines might be combined into a common complex of West Kamchatkan stocks. The mean accuracies of the two East Kamchatkan baselines were relatively high. Nevertheless, Kamchatka River stocks are much more abundant than Avacha River chinook salmon, and it seems likely that the model will tend to underestimate Kamchatka River fis. The errors in the estimates for the Western Alaska baseline were highest (>17%) for East Kamchatka. Although these simulation results do not provide exact estimates of the probabilities of error in the model, they should be considered when interpretating the results. The mean accuracy for all baseline simulations was 84.4%, which is relatively high for stock identification studies using scale pattern variables.

Age structure

Ages 1.0 and 1.1 fish dominated trawl catches of chinook salmon in the western Bering Sea in fall 2002 (84% of the total; n=229; Table 3, Fig. 5). This age structure is typical for juveniles (age 1.0) migrating from rivers and immature fish (age 1.1) feeding in the open waters of the Bering Sea and in the northern North Pacific Ocean (Healey 1991). About 88% of the juveniles were caught in district 12. In contrast, the majority (about 86%) of the immature (age 1.1) fish were caught in district 8. The low spatial overlap between the two dominant age groups can be explained by differences in feeding behavior of chinook salmon during early and later stages of their marine life (Birman 1985; Karpenko 1998). Given that district 12 is a part of the feeding area of the largest Asian chinook salmon stock (Kamchatka River), it is reasonable to assume that all juveniles (age 1.0) in the trawl catches are of Asian origin and that the majority are Kamchatka River fish. Certainly, the catches of juveniles may also include some fish from northeastern Kamchatka stocks, e.g., Apuka and Pakhacha rivers. However, Kamchatka River fish accounted for more than 95% of the total regional harvest of chinook salmon in 1990-2000 , and are most likely to dominate catches of juvenile chinook salmon in district 12. Older age groups of immature fish (1.1 and 1.2) are most likely composed of a mixture of stocks, especially if we take into account the duration of ocean migrations of chinook salmon. The percentages of these age groups were lower in district 12 than in district 8, which is closer to of the U.S. EEZ. This suggests that there may be mixture of Asian and North American chinook salmon in the district 12 catches. The identification of local stocks of ages 1.1 and 1.2 fish in the R/V TINRO samples, therefore, was of the most interest in this study.

Identification local stocks

The stock composition estimates indicate that a relatively high percentage of age 1.1 and 1.2 fish (59 and 67%, respectively) in the R/V *TINRO* catches were East Kamchatka stocks (Table 4, Fig. 6). As noted above, the dominant part of this complex is Kamchatka River fish. West Kamchatkan stocks contributed approximately 10-20% to the mixtures, and the majority were Bolshaya River fish. This result is in close agreement to known population dynamics because Bolshaya River is the second most abundant chinook salmon stock in Asia. The estimated contribution of western Alaska chinook salmon stocks was approximately the same for both age groups – 21-23%.

In principle, my stock composition estimates seem reasonable. Historical scale pattern studies (June-July 1966-1970) indicated that western Alaska stocks accounted for 20-90% of the chinook salmon in the western Bering Sea (Major et al. 1978). Stock composition estimates for five brood-years (1991-1995) of chinook salmon in samples from walleye pollock trawl fishery bycatches in the eastern Bering Sea averaged 56% Western Alaska, 31% Cook Inlet, 8% Southeast Alaska-British Columbia, and 5% Kamchatka chinook salmon (Myers et al. 2003). Nevertheless, the results of my computer simulations indicated a tendency for Western Alaska stocks to be estimated as East Kamchatka stocks. Moreover, estimates of the biomass of chinook salmon in the 2002 R/V *TINRO* trawl catches were higher than would be expected given the potential abundance of the chinook salmon resource in Asia (Temnykh et al. 2003). In this case, it may be best to supplement information from my stock composition estimates with expert opinion, especially because the an adequate number of samples were not available for analysis .

In conclusion, the results of this analysis indicate that Asian stocks dominated catches of chinook salmon in the western Bering Sea in fall 2002, but because of insufficient sample sizes these results are considered to be preliminary.

REFERENCES

Birman, I.B. 1985. Marine period of life and questions of Pacific salmon stock dynamics. M. Agropromizdat. 208 p. (In Russian)

Bugaev, A.V. 2003. To the problem about accuracy using scale pattern analysis for identification of some local stocks of sockeye salmon from Asia and North America (NPAFC Doc. 699) 26 p. KamchatNIRO, Kamchatka Fisheries & Oceanography Inst., Fisheries State Commit. of Russia, Petropavlovsk-Kamchatski, Naberezhnaja street 18, Russia.

Clutter, R.I., and L.E. Whitesel. 1956. Collection and interpretation of sockeye salmon scales. INPFC Bull. 9. 159 p.

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.

Healey, M.C. 1991. Life history of chinook salmon. *In* C. Groot and L. Margolis (ed.). Pacific salmon life histories. Canada, Vancouver, UBC press. pp. 311-393.

Ito, S., and Y. Ishida. 1998. Species Identification and Age Determination of Pacific Salmon (*Oncorhynchus spp.*) by Scale Patterns. Bull. of the National Res. Inst. of Far Seas Fisheries. 35: 131-153.

Karpenko, V.I. 1998. Early marine period of life in the Pacific salmon. M. Izd. VNIRO: 166 p.

Knudsen, C.M. 1985. Chinook salmon scale character variability due to body area sampled and possible effects on stock separation studies. Master's thesis. Univ.of Washington, Seattle, USA. 141 p.

Major, R.L., K.H. Mosher, and J.E. Mason. 1972. Identification of stocks of Pacific salmon by means of their scale features. Pages 209-231 *in* R.C. Simon and P.A. Larkin, editors. The stock concept in pacific salmon. H.R. MacMillan lectures in Fisheries, University of British Columbia, Vancouver.

Major, R.L., Ito J., Ito S., Godfrey H. 1978. Distribution and origin of chinook salmon (*Oncorhynchus tshawytscha*) in offshore waters of the north Pacific ocean. INPFC Bull. 38. 54 p.

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.

Myers, K.W., R.V. Walker, J.L. Armstrong, and N.D. Davis. 2003. Estimates of the bycatch of Yukon River chinook salmon in U.S. Groundfish Fisheries in the Eastern Bering Sea, 1997-1999. Final Report to the Yukon River Drainage Fisheries Association, Contr. No. 04-001. SAFS-UW-0312, School of Aquatic and Fishery Sciences, University of Washington, Seattle. 59 p.

North Pacific Anadromous Fish Commission (NPAFC). 2001. Draft plan for NPAFC Bering Aleutian Salmon International Survey (BASIS). NPAFC Doc. 579. Vancouver, B.C., Canada. 27 p.

Patton, W.S., Myers K.W. and R.V. Walker. 1998. Origins of chum salmon caught incidentally in the eastern Bering Sea walleye pollock trawl fishery as estimated from scale pattern analysis. N. Am. J. Fish. Res. Bull. 9: 53-64.

Shuntov, V.P. 1986. Long-term studies cyclical changes for fish abundance in the Far East Seas. Biol. Sea. 3: 3-14. (In Russian)

Temnykh, O.S., Starovoytov A.N., Glebov I.I., Khen G.V., Efimkin A.Ya., Slabinsky A.M. and V.V. Sviridov. 2003. The results of trawling survey in the epipelagic layer of the Russian economic zone in the Bering Sea during September-October, 2002. (NPAFC Doc. 682, Rev. 1). 39 p. TINRO-Center, Vladivostok, Russia. 39 p.

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

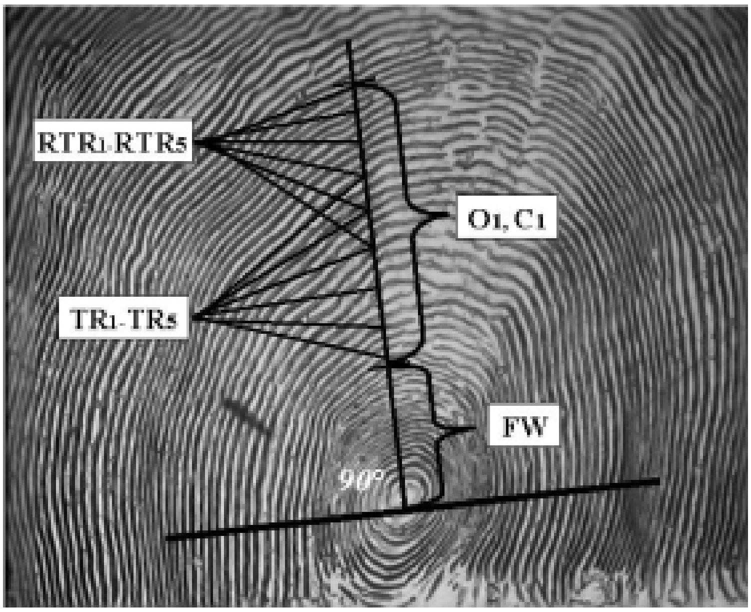

Fig. 1. Scheme of scale image used for identification local stocks of chinook salmon in the economic zone of Russia: FW – total distance in the freshwater growth zone; O_1 – total distance in the first annual ocean growth zone; C1 – number sclerites in the first annual ocean growth zone; TR_1-TR_5 – triplets circulus distance from first circuli in the first annual ocean growth zone (sixth triplets); RTR_1-RTR_5 – reverse-triplets circulus distance from last circuli in the first annual ocean growth zone (sixth reverse-triplets).

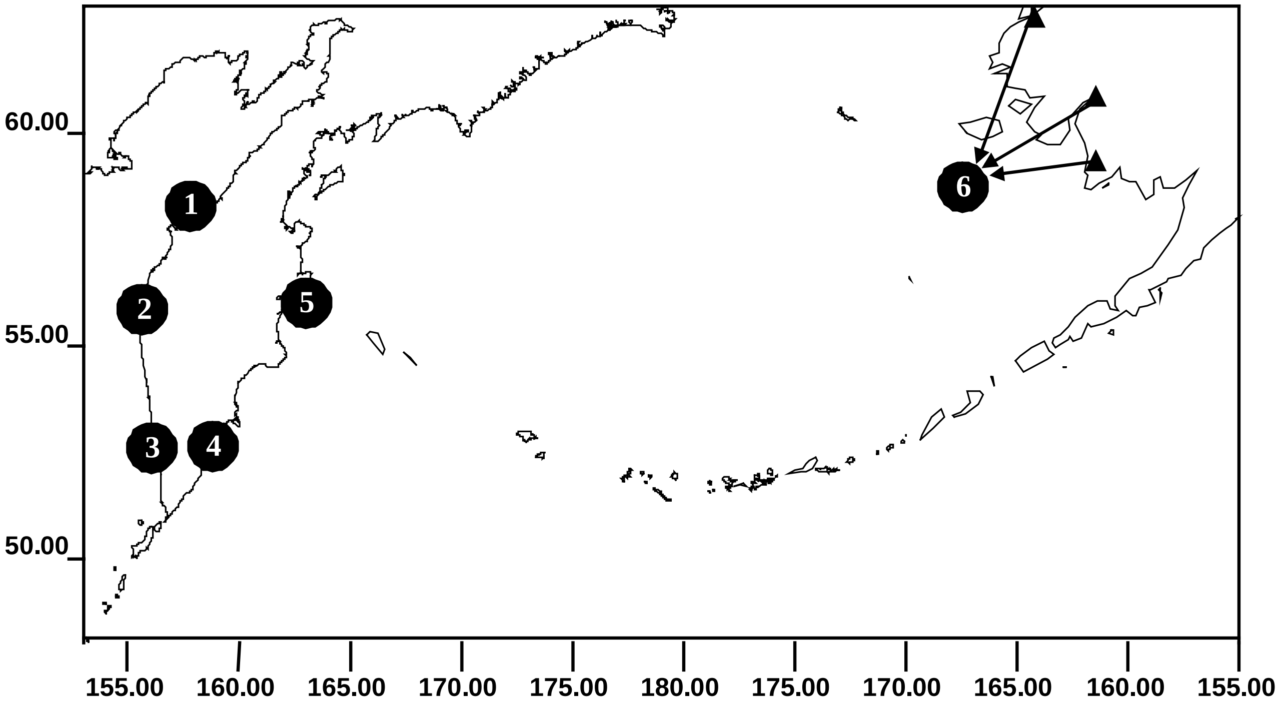

Fig. 2. The geographic locations and stocks of chinook salmon in 2002 scale samples used for baseline data: 1 – Northwest Kamchatka (Palana River); 2 – West Kamchatka (Pymta R., Vorovskaya); 3 – Southwest Kamchatka (Bolshaya R., Kikhchik R., Utka R.); 4 – Southeast Kamchatka (Avacha R.); 5 – East Kamchatka (Kamchatka R.); 6 –Alaska (Yukon R., Kuskokwim R., Nushagak R.).

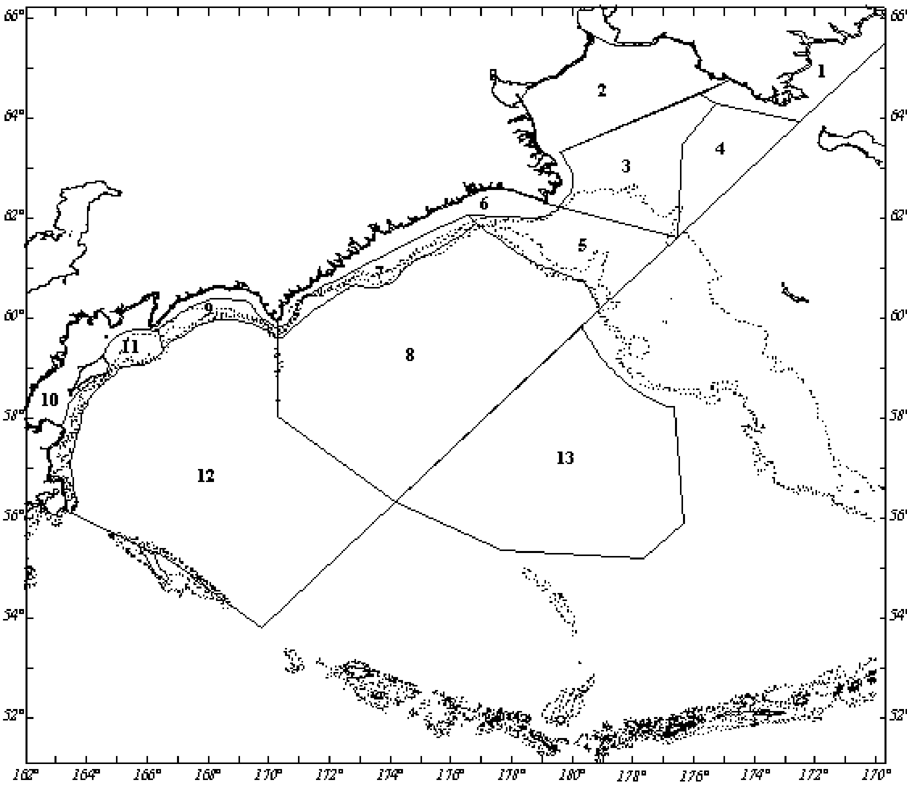

Fig. 3. The biostatistical districts used by TINRO-Center for biocenological studies in the western Bering Sea (From Volvenko 2003).

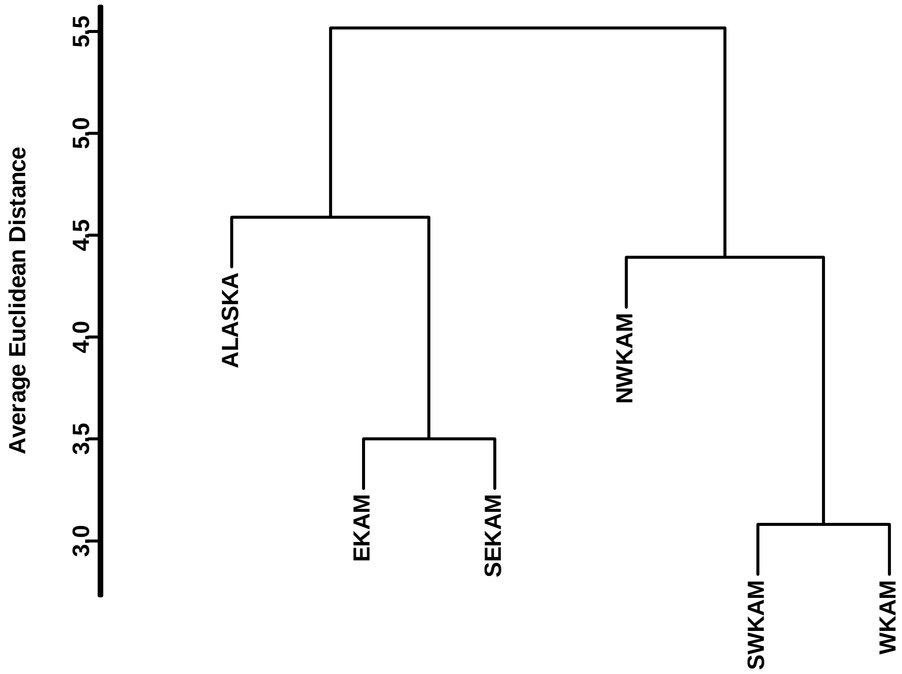

Fig. 4. Hierarchical clustering dendrograms of the scale pattern baselines of chinook salmon for combined age groups (1.2, 1.3 and 1.4) in 2002. The stocks included in each cluster are listed in Table 1.

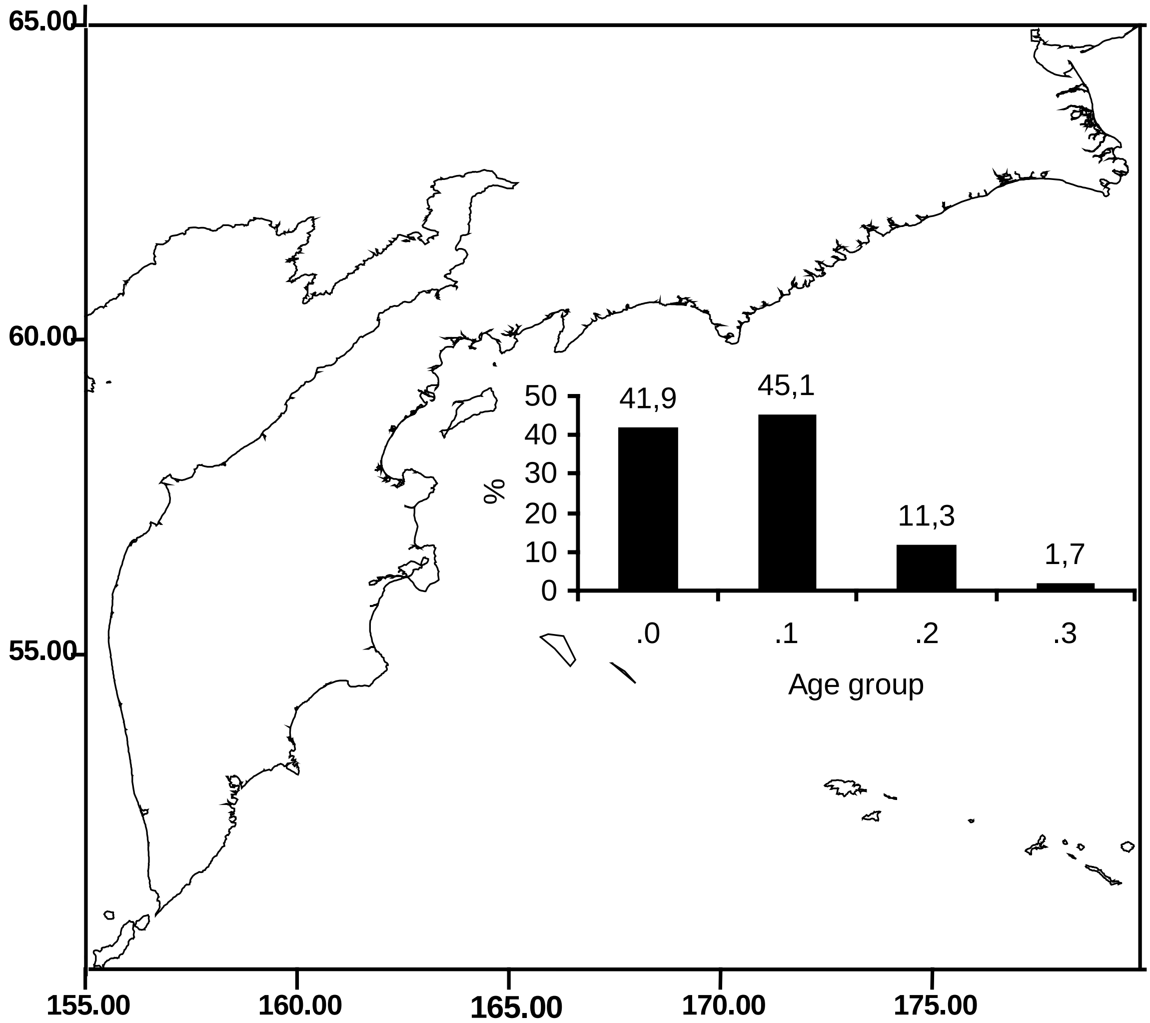

Fig. 5. Distribution of immature chinook salmon age groups in the western Bering Sea based on the data from R/V *TINRO* trawl catches in September and October 2002.

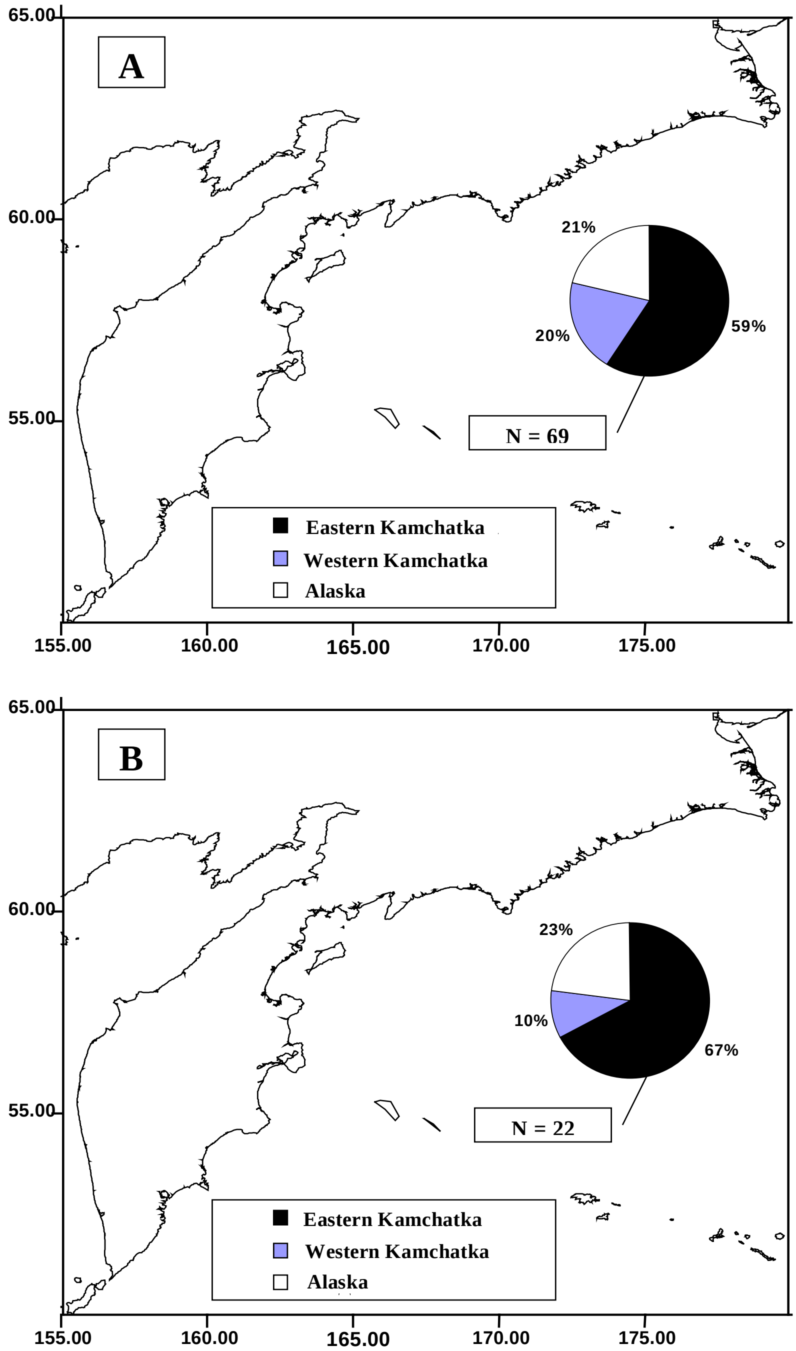

Fig. 6. The distribution of principal stock complexes of age 1.2 and 2.2 immature chinook salmon in trawl catches by the R/V *TINRO* in the west Bering Sea in September-October 2002. The percentages shown are of maximum likelihood estimates for ages 1.1 (A) and 1.2 (B) fish in district 8 + 12 (Table 4).

Table 1. Stock composition and sample size of chinook salmon scale baselines for combined age groups (1.2, 1.3 and 1.4) in 2002.

Region	Stock/river	Code	Number fish
Northwest Kamchatka	Palana R.	NWKAM	42
West Kamchatka	Pymta R.	WKAM	156
	Vorovskaya R.		13
Southwest Kamchatka	Bolshaya R.	SWKAM	249
	Kikhchik R.		24
	Utka R.		43
Southeast Kamchatka	Avacha R.	SEKAM	29
East Kamchatka	Kamchatka R.	EKAM	331
Alaska	Yukon R.	ALASKA	169
	Kuskokwim R.		221
	Nushagak R.		251
Total			1528

Table 2. The results of baseline-dependent computer simulations of the six stock cluster model for combined age groups (1.2, 1.3 and 1.4) in 2002. The results shown are the maximum likelihood estimate (MLE)/standard deviation (SD). Simulations are from 500 iterations of randomly sampled scales in the model (with replacement) with 100% representation by one stock cluster only. Bold font indicates correct stock cluster for 100% simulations. N, Spm. = number of specimens.

Stock Cluster	N	SEKAM	EKAM	SWKAM	WKAM	NWKAM	ALASKA
SEKAM	29	**0.9410** **0.0536**	0.0328 0.0389	0.0235 0.0255	0.0458 0.0331	0.0000 0.0000	0.0724 0.0502
EKAM	331	0.0348 0.0429	**0.8818** **0.0691**	0.0286 0.0392	0.0003 0.0027	0.0032 0.0093	0.0997 0.0589
SWKAM	316	0.0010 0.0073	0.0598 0.0586	**0.7561** **0.1296**	0.0344 0.0705	0.0394 0.0701	0.0105 0.0232
WKAM	169	0.0161 0.0271	0.0046 0.0127	0.0829 0.0999	**0.7592** **0.1244**	0.0061 0.0242	0.0026 0.0097
NWKAM	42	0.0023 0.0115	0.0033 0.0109	0.0955 0.0873	0.1215 0.1050	**0.9507** **0.0735**	0.0162 0.0226
ALASKA	641	0.0048 0.0123	0.0177 0.0267	0.0134 0.0249	0.0388 0.0329	0.0006 0.0044	**0.7986** **0.0726**
Total		1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Mean accuracy, %							**84.8**

Table 3. Age composition of immature chinook salmon in trawl catches of the R/V *TINRO* in the western Bering Sea in September-October 2002. N, spm = number of specimens. Locations of districts are shown in Fig. 3.

District	N, spm.	Age						
		0.2	1.0	1.1	1.2	1.3	2.0	2.1
8 + 12	229	0.4	40.6	44.2	10.9	1.7	1.3	0.9
Allocated age groups (1.1 and 1.2) – 55.1%								
Unallocated age groups – 44.9%								

Note: Potential stock origin of all juvenile (age1.0) chinook salmon is 100% Asia.

Table 4. Maximum likelihood estimates (MLE) of the stock composition of immature chinook salmon by age group (1.1 and 1.2) in trawl catches of R/V *TINRO* in the western Bering Sea in September-October 2002. N, spm. = sample size, SD = standard deviation, CI = bootstrap confidence interval. The locations of districts are shown in Fig. 3.

District	Age	N, spm.	Stock Cluster	MLE	SD	CI - 95 %
8 + 12	1.1	69	SEKAM	0.0462	0.0778	0.0000-0.2399
			EKAM	0.5435	0.1290	0.2503-0.7460
			SWKAM	0.1820	0.1526	0.0000-0.4116
			WKAM	0.0150	0.1090	0.0000-0.1160
			NWKAM	-	-	-
			ALASKA	0.2133	0.0944	0.0780-0.4102
8 + 12	1.2	22	SEKAM	0.2558	0.1810	0.0000-0.7248
			EKAM	0.4161	0.3105	0.0000-0.6231
			SWKAM	0.0985	0.2577	0.0000-0.6644
			WKAM	-	-	-
			NWKAM	-	-	-
			ALASKA	0.2296	0.1642	0.0000-0.5367