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Scale Pattern Analysis Estimates of 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

by

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ABSTRACT

Scale pattern analysis was used to estimate the age and stock composition of immature sockeye salmon in R/V *TINRO* trawl catches in the western Bering Sea and northwestern North Pacific Ocean in fall (September-October) 2002. Baseline data from adult sockeye salmon in Asia and North America (ages 1.3 and 2.3 in 2001-2002) were used to estimate the stock composition of dominant age groups (1.1, 2.1, 2.1, and 2.2) of immature fish in the R/V *TINRO* samples. Based on similarity in scale patterns the baseline data were grouped into four stock complexes: (1) West Kamchatka, (2) East Kamchatka, (3) Chukotka, and (4) Alaska (Bristol Bay)/Northeast Kamchatka. The mean accuracies of 100% simulations of these baselines ranged from 92.4%-93.5%. The results indicate that Asian stocks dominated R/V *TINRO* catches across the entire region (67-95% of age-.1 fish, 77-89% of age-.2 fish). Alaska /Northeast Kamchatka stocks occurred only in Bering Sea catches, and estimates for these stocks were highest in district 8 (33% of age .1 fish, 23% of age .2 fish), which was the district located closest to the coast of Alaska. East Kamchatka was the dominant Asian stock (44-69% of age-.1 fish, 42-73% of age-.2 fish). West Kamchatka stocks were prevalent only among age-.2 fish (27-42%). Chukotka stocks occurred only in the Bering Sea, and were prevalent only among age-.1 fish (12-21%). In general these results are corroborated by the results of previous studies of the distribution of immature Asian and American sockeye salmon during their fall feeding migrations in the western Bering Sea and northwestern North Pacific Ocean. Nevertheless, the stock composition estimates reported in this document are considered preliminary, as final estimates will be made using brood-year specific scale baselines from adult returns in 2003 and 2004.

INTRODUCTION

Previous studies of Pacific Salmon populations in the seas of the Russian Far East and adjacent waters of the North Pacific Ocean have usually focused only on maturing salmon during their prespawning migrations (Konovalov 1971; Temnykh 1996; Temnykh et al. 1994, 1997; Varnavskaya 2001; Bugaev 2003a,b,c). This is understandable given the practical interest of the fishing industry in Pacific Salmon at this life history stage. Aside from problems of inseason regulation of fisheries and estimation of the harvest of separate complexes of local salmon populations, the issue of greatest importance that has not been addressed concerns the population structure of immature salmon. Without assessments of the population composition of mixed-stock marine catches of immature salmon during the period of ocean feeding, we cannot use the results of trawl surveys to make reliable forecasts of the abundance of regional stock groups. This issue has usually been addressed by analysis of data on the distribution of Pacific Salmon during their feeding migrations in waters adjacent to the area of reproduction of certain regional stock groups (e.g., Shuntov et al. 1989a,b; Yerokhin 2002). Nevertheless, this method seems to lead to frequent errors in run forecasting. Of course the issue of population structure is just one component of a complex set of problems concerning estimation of the abundance of salmon returns. Among these problems the most important is variation in natural mortality level with respect to the influence of the environment and the inevitable methodological errors that occur during the collection of field data. This document addresses some aspects of problems concerning identification of the population structure of immature sockeye salmon in mixed-stock trawl catches in the southwestern Bering Sea and adjacent waters of the northwestern North Pacific Ocean in fall.

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 sockeye 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 June to August 2001-2002. Mixed-stock ocean samples were collected by TINRO-Center scientists aboard the R/V *TINRO* during trawl catches in September and October 2002.

Baseline scale samples were collected according to well-accepted methods for Pacific salmon scale pattern analysis , i.e., from the “preferred” body area (Fig. 1, area A; 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.

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., Mosher 1972; Bugaev 1995; 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. 2). Fifteen scale measurement variables 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 sockeye salmon likely to be present in the mixed ocean samples. The second stage was to identify the stock composition of salmon in the trawl harvests and to evaluate trends in the distribution of local stock complexes in the southwest Bering Sea and adjacent waters of the northwest Pacific Ocean.

The baselines included samples from local sockeye salmon stocks reproducing in rivers of the Kamchatka Region, Koryaksky and Chukotsky Autonomic Districts, and Alaska (Fig. 3). For the Alaska baseline, I used scale samples from the Port Moller test fishery, which is used by experts in the USA for estimating age and stock composition and making inseason forecasts of the abundance of runs of Bristol Bay sockeye salmon (e.g., Myers 1991; Flynn and Hilborn 2004). Our studies have indicated as well that the composition of the test fishery samples is representative of the entire group of stocks returning to Bristol Bay (Bugaev 2003d). 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 spawning ground samples of sockeye salmon, scales that characterized the start, the main body, and the end of the run were used. 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 two age groups, 1.3 and 2.3, which were the dominant age groups of adult sockeye salmon in the majority of samples from local stocks of Asian and American fish (Bugaev 1995; Burgner 1991). The differences in age structure of fish between the baseline data (ocean age-.3 –harvested in 2001-2002) and the trawl catches (dominant ocean ages-.1 and -.2 – harvested in 2002) may cause some error in the results due to interannual variations in sockeye salmon scale growth patterns (Bugaev 2003a). Nevertheless, the general structure of scale growth patterns and age composition seem to be relatively consistent for particular local stocks or complexes of stocks over long periods of time (Bugaev, 1995), as assumed in this analysis.

Mixed-stock oceanic samples were composed of scale materials collected during the complex trawl surveys by TINRO-Center in the south-west part of the Bering Sea and adjacent waters of the Pacific Ocean (Fig. 4). The mixed-stock samples were stratified using the same system of districts used for biocenological studies in the Russian fishery zone (Shuntov, 1986; Volvenko, 2003). The sample size and the composition of the material has been represented in the Table 2.

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). In some cases the abundance dynamics of Asian sockeye salmon stocks had to be considered when interpreting the results of cluster analysis and forming the regional baselines (Table 3). When a cluster included a principal stock and a minor stock, the baseline was named after the principal stock.

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. 5). Descriptive statistics for 15 scale pattern variables used in the analysis are shown for each baseline stock cluster in Table 4. In both cases (1.3 and 2.3 age groups), North American baseline data (BBAY) and northeast Kamchatka baseline data (Olyutorsky Bay, NEKAM2, and Navarinsky district, NEKAM3) were included in the same cluster. A similar result was observed in previous studies (Bugaev 2003a, d). The similarity in scale growth patterns of Bristol Bay and northeast Kamchatka fish may be related to similarity in feeding conditions experienced by these local stocks. In this case, identification of the individual stocks forming this cluster in mixed-stock samples was not possible. To reduce error in the analysis, therefore, Bristol Bay and northeast Kamchatka stocks were grouped into one baseline. Nevertheless the assumption that a significant part of estimates for this baseline group in the R/V TINRO samples may belong to the Bristol Bay complex of stocks, which are much more abundant than northeast Kamchatka stocks, seems reasonable (Table 3). The geographic distribution of stocks is not always a useful criterion for evaluating the appropriateness of the results of mixture analyses of immature ocean age-.1 and -.2 sockeye salmon, because their ocean feeding migrations are known to extend for long distances away from their coastal areas of reproduction (Burgner 1991).

Concerning the Asian baselines it should be noted that the most distinct stocks are those from Chukotka (CHUKOTKA). The complexes of stocks from West Kamchatka and East Kamchatka have similar scale structures. For age-1.3 sockeye salmon these two geographic complexes can be separated only poorly, which increases the likelihood of error in the analysis. The stocks of the Kamchatka River (EKAM) and Karaginsky Bay (NEKAM1) form one cluster, but considering their relative abundances we can assume that 80-90% of the fish in estimates for this cluster are Kamchatka River stocks (Table 3). For age 2.3 sockeye salmon, the chance for correct identification seems to be higher. Despite the fact that one cluster includes both stocks (Kamchatka River, EKAM, and Palana River, NWKAM), Kamchatka River stocks were accurately estimated in 100%-mixture simulations (Table 5). The similarity in scale patterns of East and West Kamchatka sockeye salmon may also be due to similar freshwater and early marine feeding ecology. Nevertheless, the differences between baseline scale data for Kamchatka River and Ozernaya River (SWKAM) stocks, which amount to about 80-90% of the total population of Asian sockeye salmon (Bugaev and Bugaev 2003), are substantial enough to permit reliable identification.

The results of computer dependent simulations demonstrate a fairly high accuracy for the baseline data models (Table 5). Mean accuracies were 93.5% for age 1.3 fish and 92.4% for age 2.3 fish. For age 1.3 fish, the Chukotka baseline had the highest accuracy (98.9%), and the East Kamchatka baseline had the lowest accuracy (83.4%). Almost 10% of the relatively minor West Kamchatka stocks were estimated to be of Kamchatka River origin, which indicates that West Kamchatka fish may be overestimated to some extent in the mixture sample. For age 2.3 fish, the West Kamchatka (Ozernaya River) baseline had the highest accuracy (97.5 %), and the Chukotka baseline had the lowest accuracy (89.1%) with 6.9% estimated to be Bristol Bay fish and 0.3% East Kamchatka fish.

Age composition of sockeye salmon from trawl catches

Sockeye salmon in the R/V *TINRO* trawl catches in fall 2002 were dominated by four age groups 1.1, 1.2, 2.1 and 2.2 (Table 7, Fig. 6). This age structure is typical for immature sockeye salmon feeding in the open waters of Bering Sea and northern North Pacific Ocean (Burgner, 1991). The percentage of age-.0 fish increased coastward from the open ocean, which corresponds well to previous information on the distribution of juvenile salmon in the coastal zone (Karpenko, 1998). However, the percentages of age-.0 fish in the catches are low compared to age-.1 and age-.2 fish, because most of the trawl operations occurred in open ocean areas.

Sockeye salmon in the northwestern North Pacific Ocean (district 6 + 5) were dominated by age-.2 fish (87.4%), whereas the percentages of this age group were somewhat lower in the southwestern Bering Sea (38.4% in district 12 + 9 and 51.5% in district 8 + 7; Table 6; Fig. 6). The percentages of age-.1 sockeye salmon were high only in the Bering Sea (45.4% in district 12 and 36.9% in district 8). Samples of yearlings (age-.0) fish in all districts were insufficient for further assessment. The stock origins of age-.0 sockeye salmon in the western Bering Sea, however, are relatively well known from previously published information on the distributions of juvenile salmon stocks in offshore areas during their September and October feeding migrations (Karpenko, 1998). The dominant age groups of sockeye salmon in the trawl catches (1.1, 1.2, 2.1 and 2.2) accounted for 75-84% of the total catch, and were sufficiently representative of the mixture sample to proceed with stock identification analysis. Age groups not included in the stock composition analysis amounted were ≤25.0% of the samples stratified by district (Table 7).

Identification local stocks

Stock identification results for the dominant age groups of sockeye in the trawl catches by the R/V *TINRO* are presented in Table 8. For age-.1 (1.1 + 2.1) fish, East Kamchatka was the dominant stock in the southwestern Bering Sea (districts 12 + 9; 69%; Fig. 7), and the East Kamchatka fish are likely 80-90% Kamchatka River stocks (Fig. 7). In the northwestern Bering Sea (districts 8 + 7), the contribution of East Kamchatka stocks decreased (44%; Fig. 7). The highest estimate for West Kamchatka stocks was in district 12 (14%), whereas in district 8 the average contribution of this stock complex was only 3%. The West Kamchatka baseline included only the primary stock from this region (Ozernaya River), which means that this estimate may be relatively precise for Ozernaya River sockeye salmon. The percentages of

Chukotka sockeye salmon in the catches were relatively high (12% in district 12 and 21% in district 8; Fig. 7). The percentages of the Alaska/Northeast Kamchatka sockeye salmon were also relatively high in district 8 (33%), although the percentage to the south in district 12 (+9) was much lower (5 %; Fig. 7).

For age-.2 (1.2 + 2.2) fish the patterns of distribution are somewhat different (Table 8; Fig. 8), although East Kamchatka was also the dominant stock for this age group (Fig. 8). The contribution of East Kamchatka stocks in the northwestern North Pacific Ocean (district 6 + 5) was highest (73%), and percentages were lower in the western Bering Sea (42% and 46%). In contrast to estimates for age-.1 fish, the estimated percentages of West Kamchatka stocks were relatively high among age-.2 fish (Fig. 8; Table 8). Moreover, the percentages of West Kamchatka stocks in the southwestern Bering Sea (district 12) were higher (42%) than adjacent districts in the North Pacific Ocean (27%) and northwestern Bering Sea (29%). Concerning the other regional groups in the Bering Sea, the contribution of Chukotka stocks was low (2-5%), whereas the contribution of Alaska (Bristol Bay)/Northeast Kamchatka sockeye salmon was relatively high (11% and 23%; Fig. 8). In principal stock composition estimates for North American stocks can be expected to be highest in regions closer to the coast of Alaska. The results for both ocean age groups indicate that the percentages of Bristol Bay sockeye salmon are highest in district 8, which is closest to the coast of North America (Table 8; Figs. 7 and 8). Assuming that stock proportions of unallocated and allocated age groups in the 2002 R/V TINRO samples are similar, Asian stocks composed 100% of the total catch in the northwestern North Pacific Ocean (district 6+5), 92% of the total in the southwestern Bering Sea (district 12+9), and 73% of the total in the northwestern Bering Sea (district 8+7; Table 9; Fig. 9).

As noted earlier the contributions of East Kamchatka stocks in the mixed sample may have been underestimated, particularly in the case where high estimates were obtained for minor West Kamchatka stocks in the age 1.2 group (Table 8). Considering the results of baseline simulations (Table 5) and Asian stock abundance dynamics, the contribution of the West Kamchatka complex may have been overestimated. Although the scale variables most responsible for the similarity in scale patterns of several sockeye salmon stocks from the east and west coasts of Kamchatka in 2001-2002 were not determined, similar ecological conditions in the freshwater and early marine periods could have influenced the results.

In general, however, the relatively high estimates for West Kamchatka stocks in the Bering Sea mixture samples are corroborated by information from other studies. For example, the estimate for age 2.2 West Kamchatka (Ozernaya River) sockeye salmon in district 12 was higher (51%) than the estimate for age 2.1 fish (28%, Table 8), and it is well known that immature age 2.2 Ozernaya River sockeye salmon feed in the southwestern Bering Sea (Konovalov 1971; Birman 1985; Selifonov 1989). In general, the scale pattern analysis results also agree with conceptual models of the migration patterns of immature sockeye salmon in the southwestern Bering Sea and adjacent waters of the northwestern Pacific Ocean (French et al. 1976; Burgner 1991). However, global climate changes may have affected salmon migration patterns in the North Pacific Ocean since these models were developed, and migration models need to be updated with more recent information on distribution of local stocks in the western Bering Sea. Much of the historical information on high seas migrations of Asian and American sockeye salmon is of a very general nature, and cannot be used to address many issues of concern raised by current research.

CONCLUSIONS

The results of stock identification indicated the dominance of Asian sockeye salmon stocks in the southwestern Bering Sea (district 12; 92% of allocated samples) and adjacent waters of the northwestern Pacific Ocean (district 6; 100% of allocated samples) in all the districts studied in September-October 2002 (67% and 95% age-.1; 77% and 89% age-.2). The contribution of North American (Bristol Bay) sockeye salmon was highest in the northwestern Bering Sea (district 8, 27% of allocated samples; 33% age-.1 ; 23% age-.2), which is the district located closest to the coast of Alaska. Among Asian stocks East Kamchatka sockeye salmon dominated (44% and 69% age-.1, 42% and 73% age-.2 sockeye) (72% of allocated samples in northwestern Pacific Ocean; 56% in southwestern Bering Sea; 45% in northwestern Bering Sea). The percentages of West Kamchatka stocks were relatively high only in the age-.2 group– 27% and 42% (28% of allocated samples in northwestern Pacific Ocean; 27% in southwestern Bering Sea; 18% in northwestern Bering Sea), and those of the Chukotka stocks only in the age-.1 group – 12% and 21% (0% of allocated samples in northwestern Pacific Ocean; 8% in southwestern Bering Sea; 10% in northwestern Bering Sea). In general, the estimated percentages of local stocks in the R/V TINRO trawl catches is corroborated by historical information on the known distribution immature age-.1 and age-.2 Asian and American sockeye salmon during their fall feeding in their fall feeding migrations. The stock composition estimates reported in this document are considered preliminary, as final estimates will be made using brood-year specific scale baselines from adult returns in 2003 and 2004.

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Appendix figures and Tables

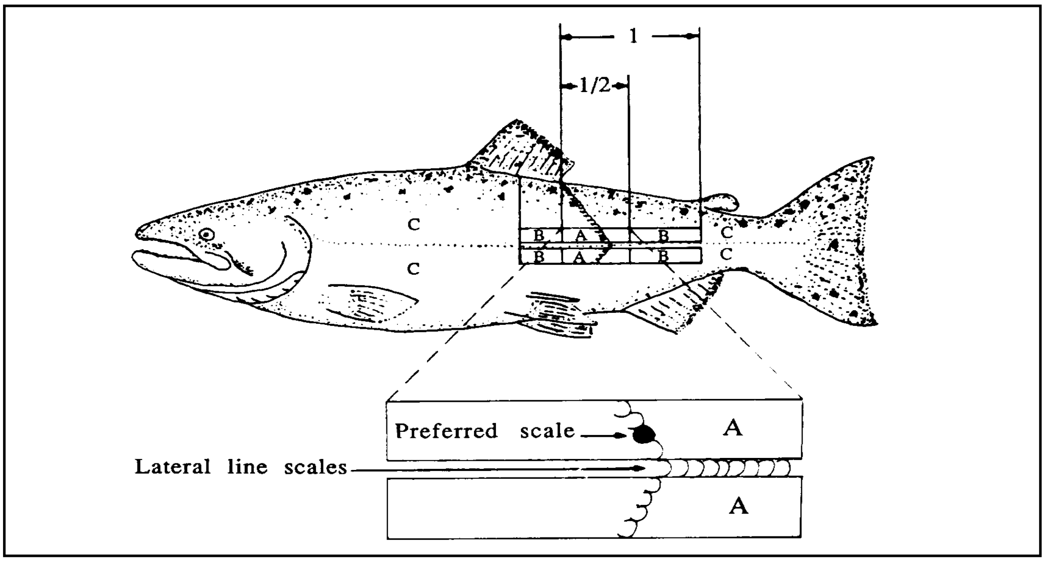

Fig. 1. The area of a salmonid's body designated as preferred for scale collection (area A) by the International North Pacific Fisheries Commission (from Knudsen 1985).

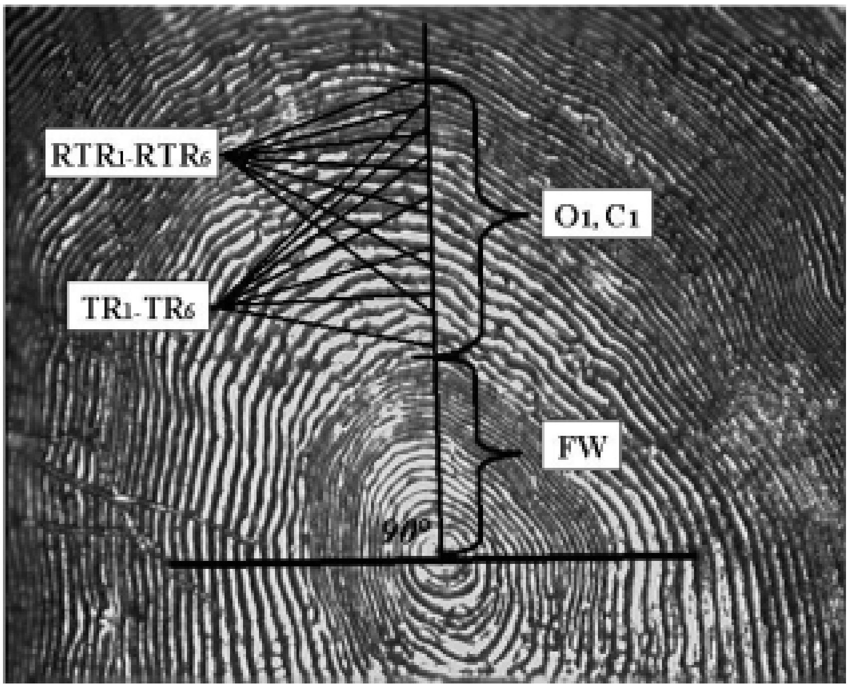

Fig. 2. Scheme of scale image used for identification local stocks of sockeye salmon in economic zone of Russia: FW – total distance in the freshwater growth zone; O_1 – total distance in the first annual ocean growth zone; C1 – number sclerites in the first annual ocean growth zone; TR_1-TR_6 – triplets circulus distance from first circuli in the first annual ocean growth zone (sixth triplets); RTR_1-RTR_6 – reverse-triplets circulus distance from last circuli in the first annual ocean growth zone (sixth reverse-triplet).

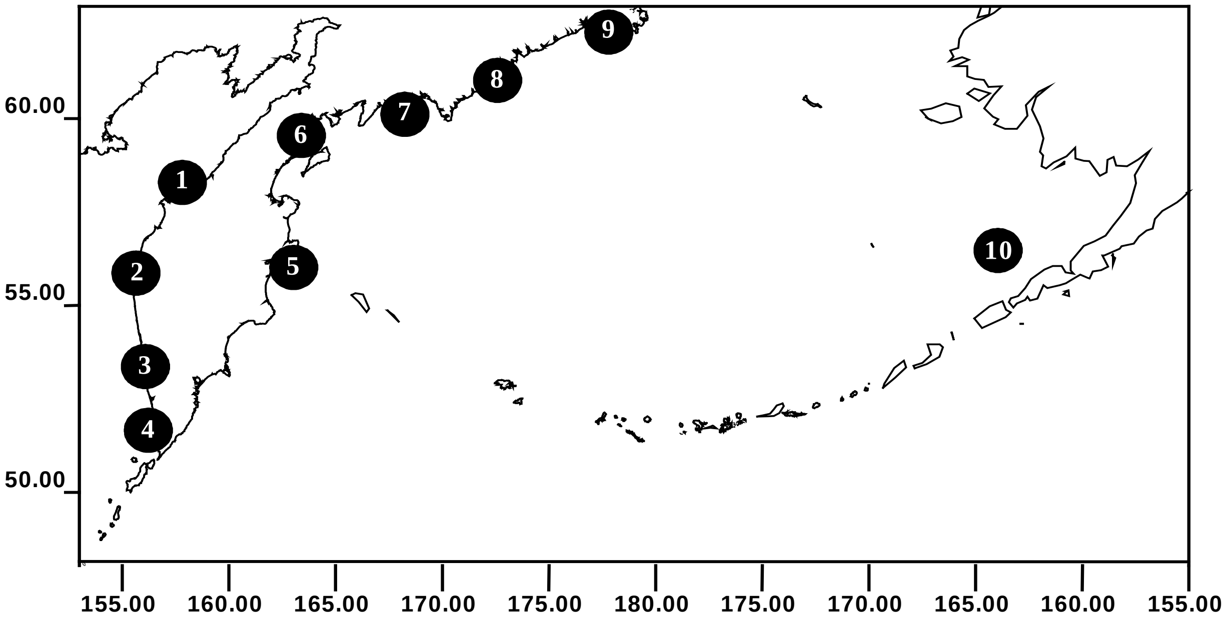

Fig. 3. The geographic locations and stocks of sockeye salmon in 2001-2002 scale samples used for baseline data: 1 – Northwest Kamchatka (Palana River); 2, 3 – West Kamchatka (Sobolevsky district – Icha River, Krutogorova R., Vorovskaya R.; Bolsheretsky district – Bolshaya River, Kikhchik R.); 4 – Southwest Kamchatka (Ozernaya R.); 5 – East Kamchatka (Kamchatka R.); 6, 7, 8 – Northeast Kamchatka (Karaginsky Bay – Khaylula R., Dranka R.; Olutorsky B. – Anna R.; Navarinsky B. – Severnaya R.); 9 – Chukotka (Meynypilgyn R., Nyghcheckviem R.); 10 – Alaska (Bristol Bay – Port Moller test fishery).

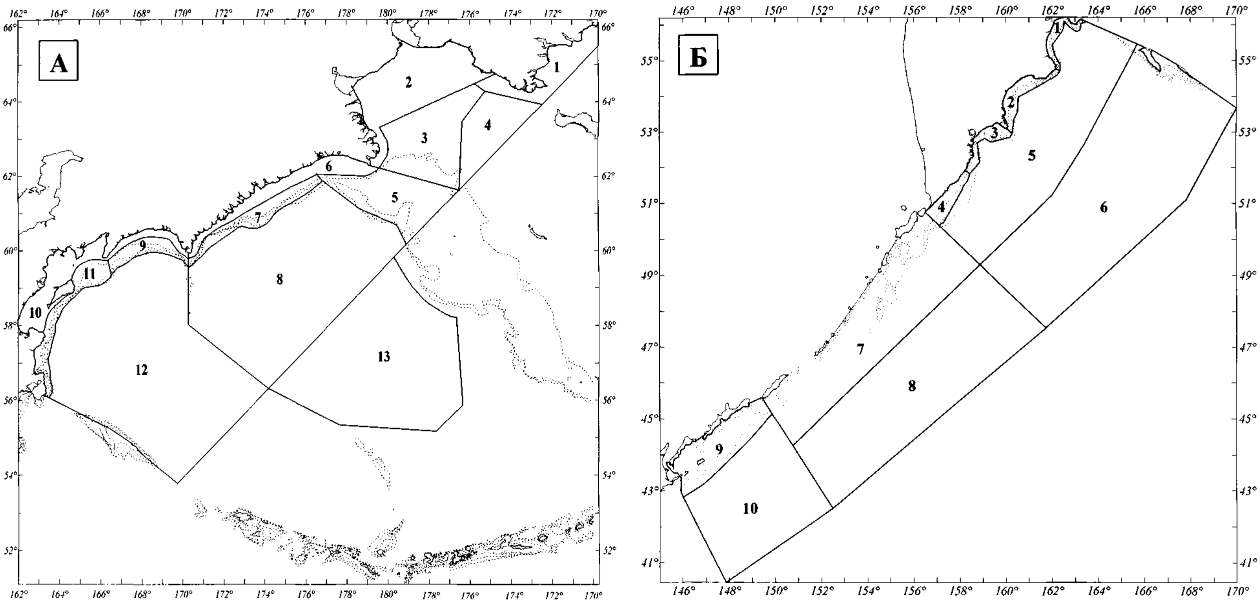

Fig. 4. The biostatistical districts used by TINRO-Center for biocenological studies in the western Bering Sea (A) and adjacent waters of the northwestern North Pacific Ocean (B) (From Volvenko 2003).

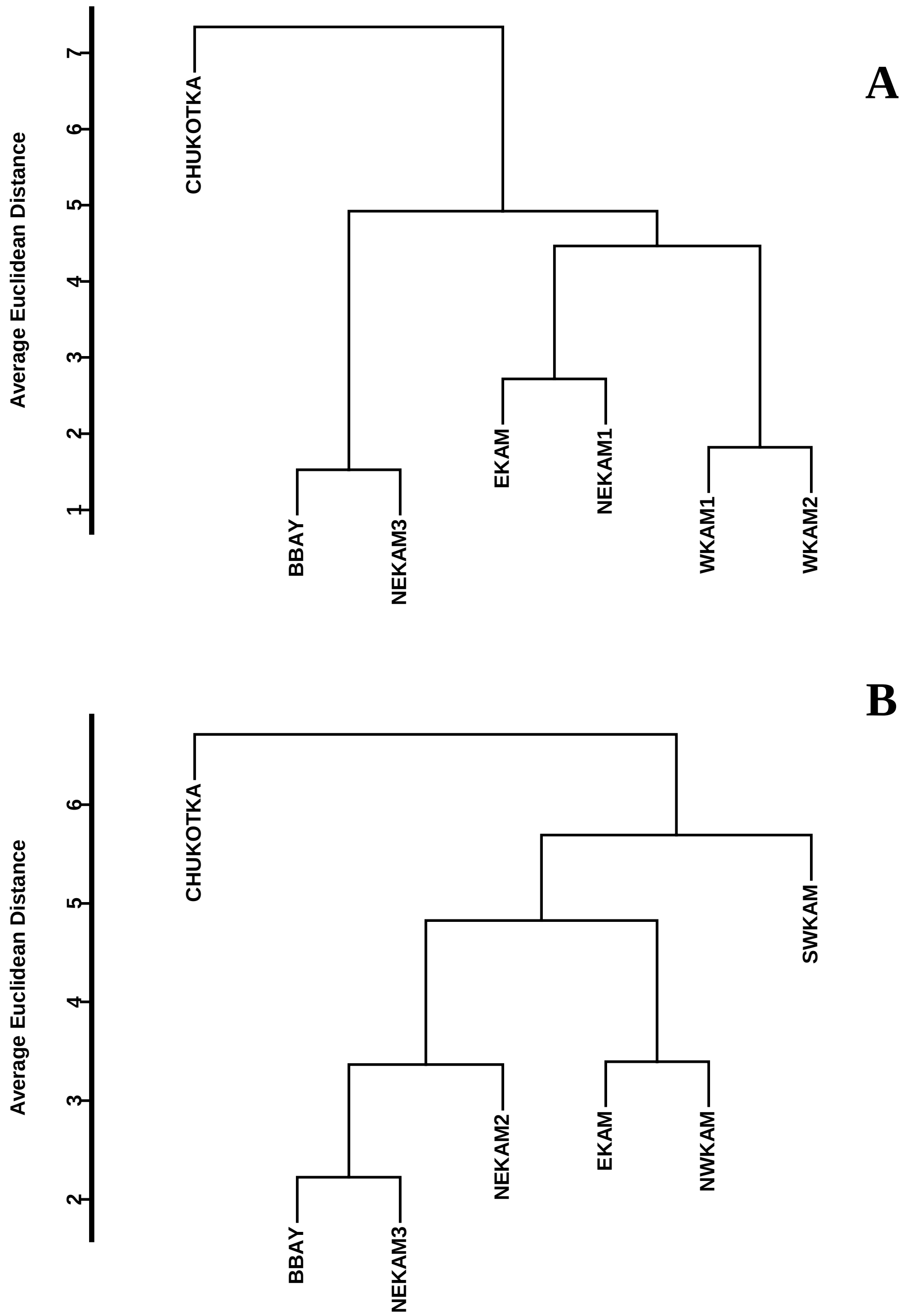

Fig. 5. Hierarchical clustering dendrograms of the scale pattern baselines of sockeye salmon for age groups 1.3 (A) and 2.3 (B). The stocks included in each cluster are listed in Table 1.

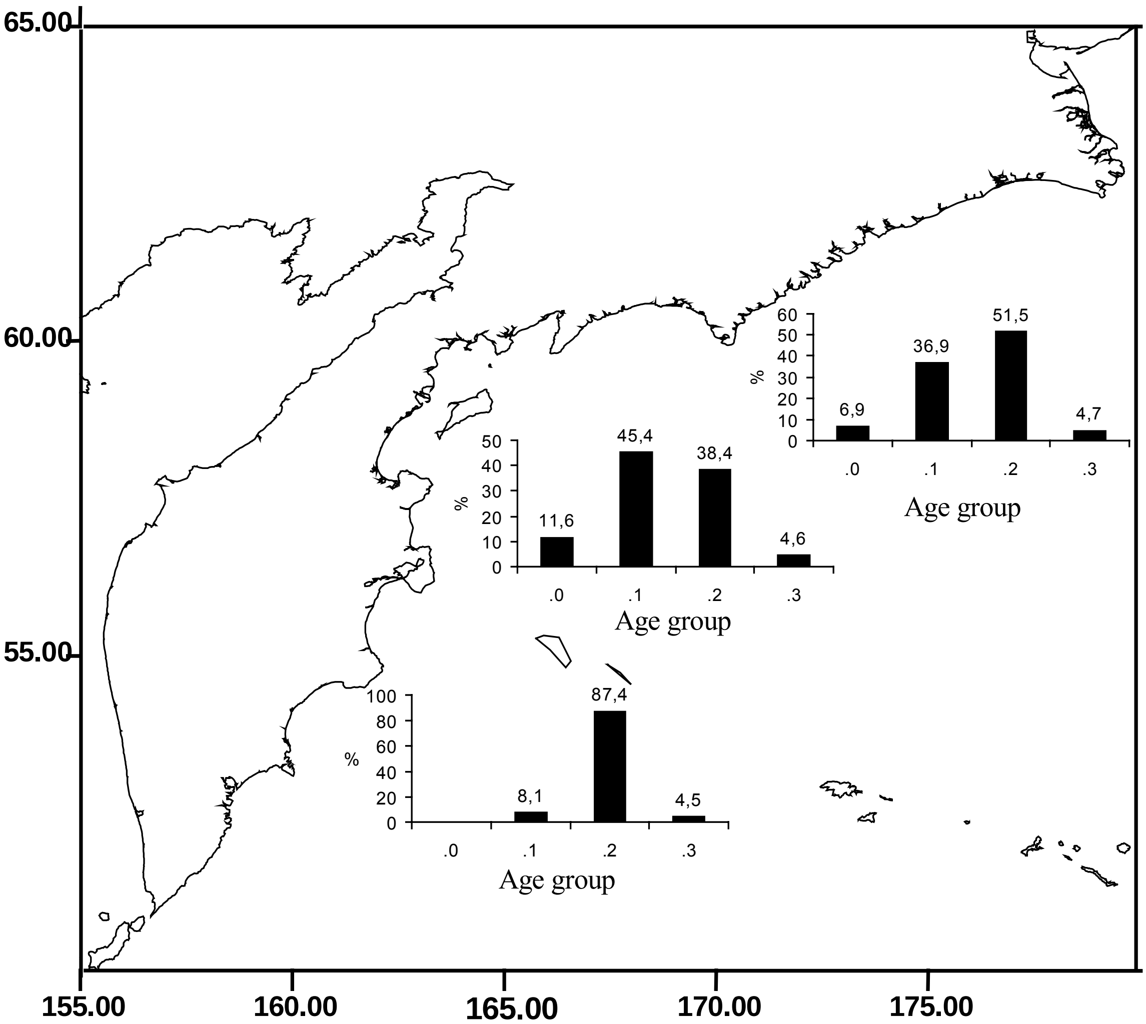

Fig. 6. Distribution of immature sockeye salmon age groups in the western Bering Sea and adjacent waters of the northwestern North Pacific Ocean based on the data from R/V TINRO trawl catches in September and October 2002.

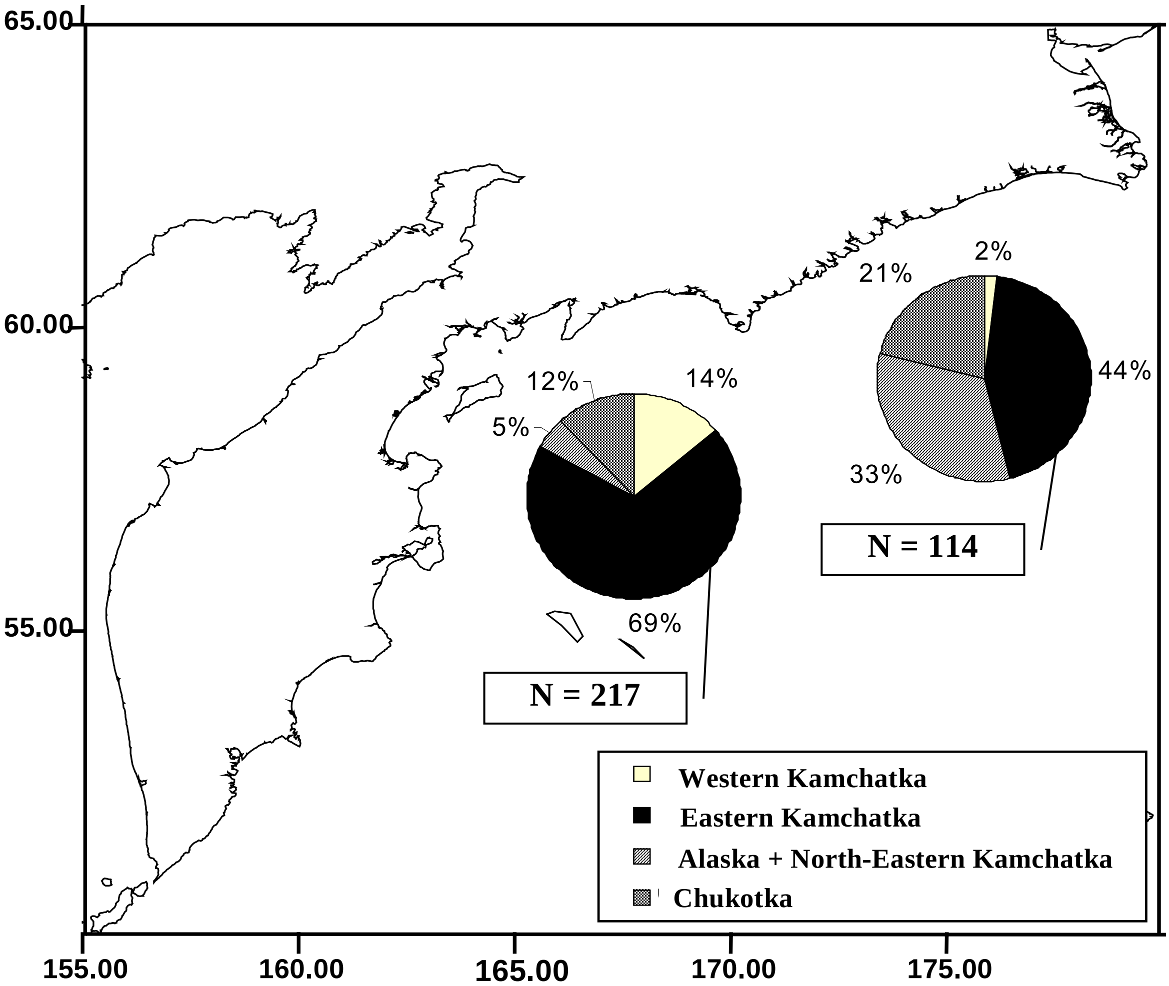

Fig. 7. The distribution of principal stock complexes of age 1.1 and 2.1 immature sockeye salmon in trawl catches by the R/V *TINRO* in the western Bering Sea in September-October 2002. The percentages shown are the unweighted averages of maximum likelihood estimates for ages 1.1 and 2.1 fish in each district (Table 8).

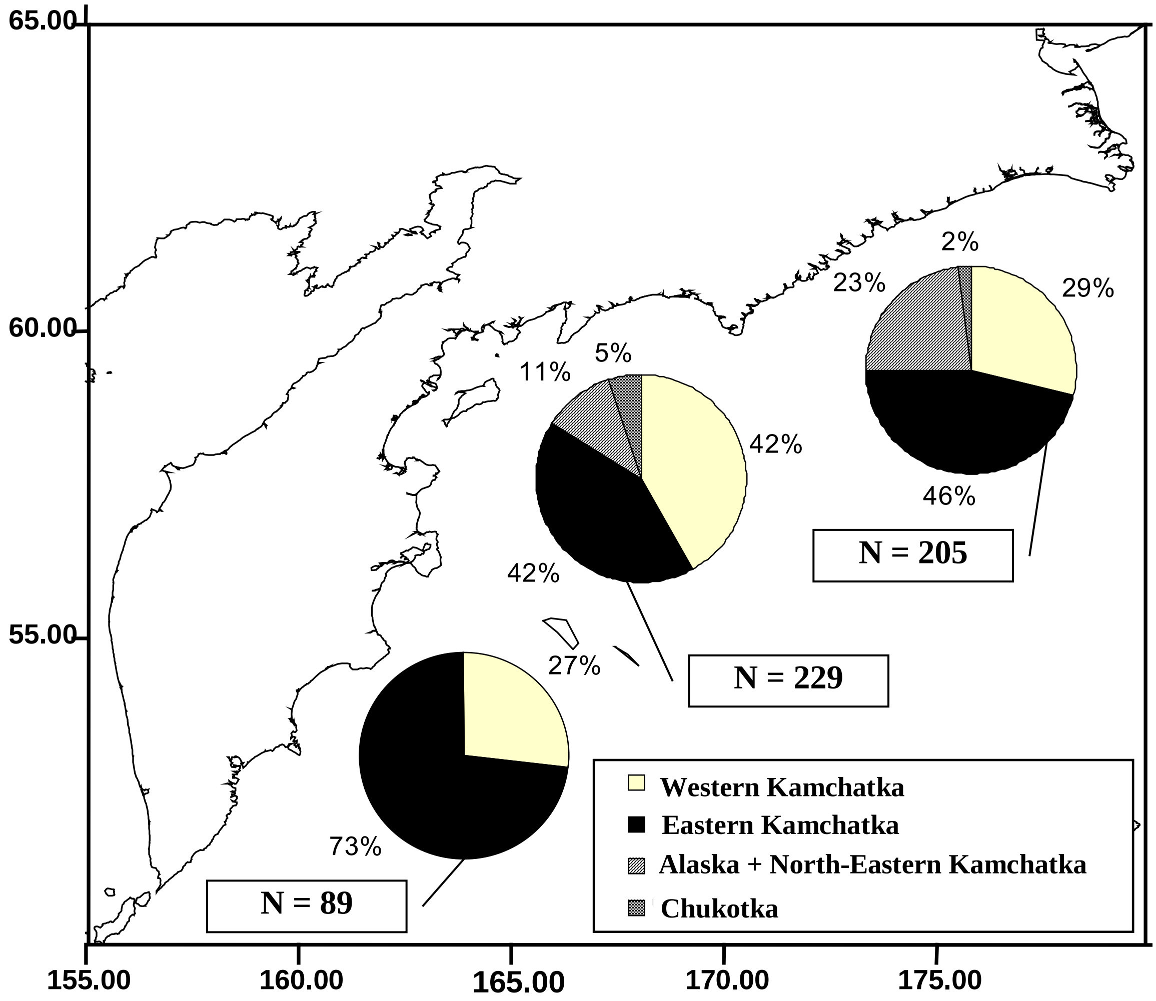

Fig. 8. The distribution of principal stock complexes of age 1.2 and 2.2 immature sockeye salmon in trawl catches by the R/V *TINRO* in the southwest Bering Sea and adjacent waters of the northwest Pacific Ocean in September-October 2002. The percentages shown are the unweighted averages of maximum likelihood estimates for ages 1.2 and 2.2 fish in each district (Table 8).

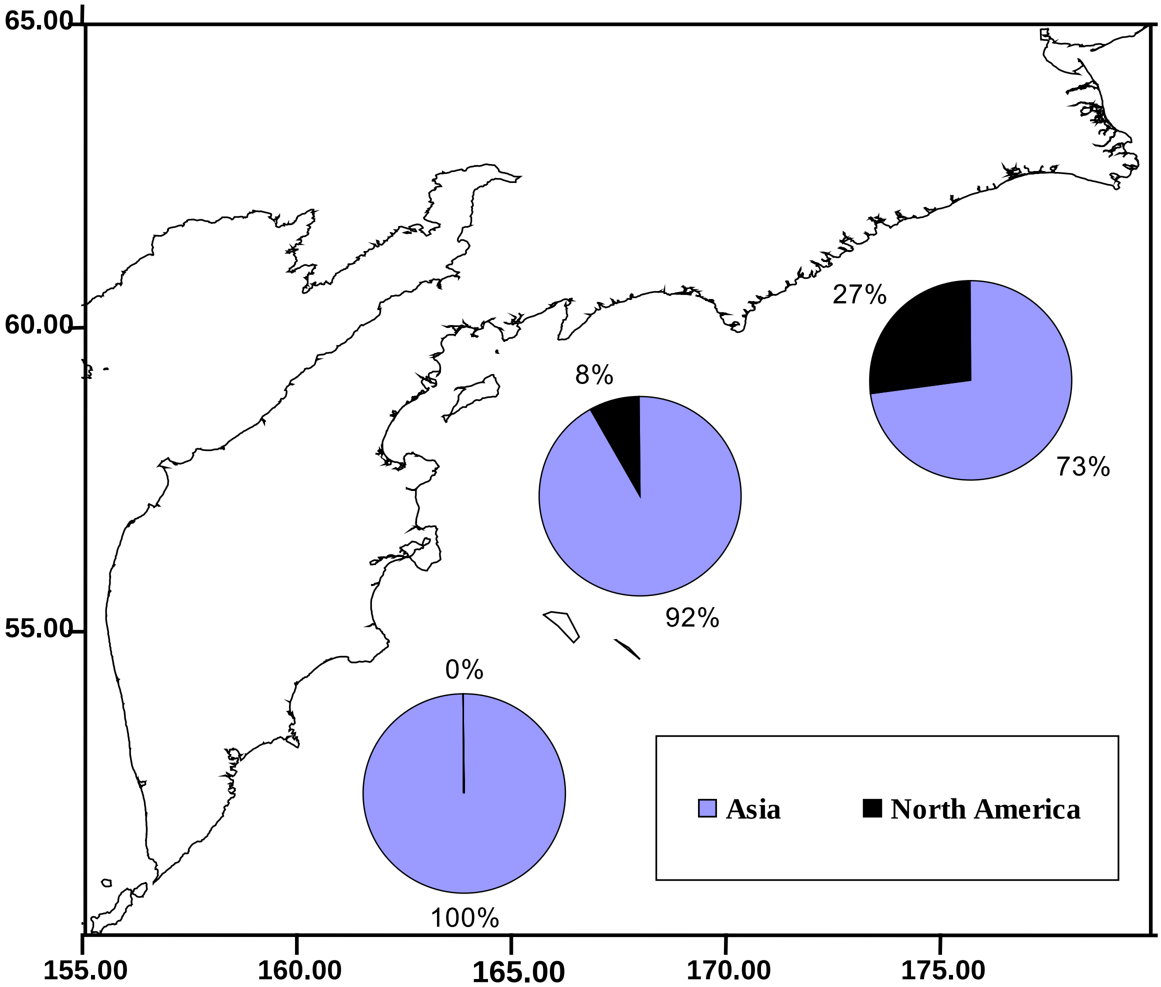

Fig. 9. The distribution of Asian and North American stock complexes of immature sockeye salmon in trawl catches by the R/V *TINRO* in the southwest Bering Sea and adjacent waters of the northwestern North Pacific Ocean in September-October 2002. The percentages shown are the unweighted averages for all age groups in each district (Table 9).

Table 1. Stock composition and sample size of sockeye salmon scale baselines for 2001-2002.

Region	Stock/river	Code	Number fish
North-West Kamchatka	Palana River	NWKAM	200
West Kamchatka	Sobolevsky district	WKAM1	
	Icha R.		123
	Krutogorova R.		101
	Vorovskaya R.		91
	Bolsheretsky district	WKAM2	
	Bolshaya R.		200
	Kikhchik R.		42
South-West Kamchatka	Ozernaya R.	SWKAM	200
East Kamchatka	Kamchatka R.	EKAM	200
North-East Kamchatka	Karaginsky Bay	NEKAM1	
	Khaylula R.		121
	Dranka R.		100
	Olyutorsky Bay	NEKAM2	
	Anana R.		71
	Navarinsky District	NEKAM3	
	Severnaya R.		122
Chukotka	Meynypilgyn R. Nygchekveem R.	CHUKOTKA	183
Alaska	Bristol Bay Port Moller	BBAY	200
Total			1,954

Table 2. The district, month, trawl coordinates, number (N) of trawl stations, and sample sizes used to estimate age and stock composition of immature sockeye salmon in R/V TINRO samples in 2002. The samples from district 12 included scale samples obtained during operations to calibrate trawls. Districts are shown in Fig. 4.

District	Month	R/V *TINRO* trawl coordinates	N trawl stations	Sample size	
				Age	Stock ID
6 (+ 5)	September	54°01'-55°11' N 162°19'-170°05' E	7	111	89
12 (+ 9)	September-October	53°28'-59°57' N 164°00'-175°04' E	37	726	446
8 (+ 7)	September	56°36'-61°01' N 170°58'-179°49' E	20	470	319

Table 3. Total inshore run size (catch and escapement, thousands of fish) of Asian and North American sockeye salmon stock groups used in the stock identification analyses, 1990-2002.

Year	West Kamchatka[1]		East Kamchatka[1]		Chukotka[2]	Bristol Bay[3]	Percentage of Asian stocks, %
	Principal stock (Ozernaya R.)	All secondary stocks	Principal stock (Kamchatka R.)	All secondary stocks	Principal stock (Meynypilgyn R.)	All stocks	
1990	10 583	878	594	1 314	400	48 118	22
1991	6 679	1 134	626	722	290	41 909	18
1992	4 883	1 005	1 616	355	200	45 131	15
1993	4 005	706	2 117	550	140	51 841	13
1994	4 818	474	1 788	890	210	50 469	14
1995	3 648	543	3 305	704	410	60 730	12
1996	4 728	854	2 885	1 455	230	36 955	22
1997	1 870	384	2 504	392	40	18 968	21
1998	2 842	849	2 231	891	105	18 449	27
1999	3 136	454	3 082	644	250	39 834	16
2000	4 450	677	2 287	734	330	28 184	23
2001	6 421	544	1 881	1 103	400	22 026	32
2002	9 650	569	1 225	473	240	16 817	42
Average	5 209	698	2 011	787	250	36 879	20

1. Source: Bugaev, A.V., and V.F. Bugaev. 2003. Long-term tendencies of fishery and abundance dynamic of Asian stocks of sockeye salmon *Oncorhynchus nerka*. Izv. TINRO. V. 134: 101-119. (In Russian).

2. Source: Golub E.V. 2003. Few data on biology and number dynamics of sockeye salmon of Meynypilgyn lake-river system (Chukotka). Problems of fisheries. Vol. 4. N 4(16): 638-660. (In Russian).

3. Source: Alaska Department of Fish and Game, Commercial Fisheries Division, Regional Information Report 2A0318.

Table 4. The sample size (N), mean (m), standard deviation (SD), minimum value (Min), maximum value (Max), and coefficient of variation (CV) of 15 scale pattern variables for each stock cluster in the baseline data by age group (1.3 and 2.3).

Age	Stock cluster	N	Parameter	*FW*	*O1*	*C1*	*TR1*	*TR2*	*TR3*	*TR4*	*TR5*	*TR6*	*RTR1*	*RTR2*	*RTR3*	*RTR4*	*RTR5*	*RTR6*
1.3	Bristol Bay + North-East Kamchatka	322	M	516.35	869.28	21.42	129.29	145.07	143.89	135.06	112.74	97.73	93.89	94.25	111.80	134.10	141.80	144.86
	(BBAY + NEKAM3)		SD	65.49	104.16	2.07	20.83	23.33	20.28	19.93	19.53	14.31	12.90	14.02	19.99	21.05	20.32	22.94
			Min	324.00	577.00	18.00	87.00	87.00	93.00	73.00	55.00	59.00	64.00	64.00	55.00	73.00	93.00	88.00
			Max	739.00	1136.00	27.00	186.00	206.00	197.00	205.00	173.00	154.00	135.00	140.00	186.00	192.00	205.00	201.00
			CV	12.68	11.98	9.65	16.11	16.08	14.09	14.76	17.32	14.64	13.74	14.87	17.88	15.70	14.33	15.84
	West Kamchatka	557	M	381.80	1064.19	26.10	127.81	137.39	136.69	135.99	135.13	129.79	87.46	92.21	121.24	132.76	135.74	136.15
	(WKAM1 + WKAM2)		SD	70.71	118.44	2.18	17.57	19.13	19.09	20.03	19.21	19.74	12.12	15.99	21.06	19.48	20.24	19.40
			Min	211.00	711.00	18.00	74.00	92.00	88.00	79.00	81.00	64.00	59.00	45.00	71.00	64.00	87.00	79.00
			Max	612.00	1383.00	32.00	192.00	196.00	215.00	211.00	215.00	187.00	136.00	154.00	181.00	215.00	211.00	201.00
			CV	18.52	11.13	8.36	13.75	13.92	13.96	14.73	14.22	15.21	13.86	17.34	17.37	14.68	14.91	14.25
	East + North-East Kamchatka	421	M	423.68	882.01	23.30	118.67	127.21	127.10	127.16	118.44	104.44	86.53	90.02	109.05	126.00	128.00	124.55
	(EKAM + NEKAM1)		SD	70.65	144.58	2.94	16.20	19.06	20.31	20.06	22.48	21.96	12.42	13.34	19.19	21.22	20.25	18.78
			Min	252.00	575.00	18.00	74.00	71.00	71.00	69.00	68.00	54.00	50.00	64.00	66.00	68.00	79.00	71.00
			Max	645.00	1272.00	32.00	168.00	182.00	197.00	196.00	205.00	173.00	135.00	139.00	173.00	205.00	197.00	196.00
			CV	16.68	16.39	12.60	13.65	14.98	15.98	15.78	18.98	21.02	14.35	14.82	17.60	16.84	15.82	15.08
	Chukotka	36	M	496.78	1041.22	22.83	145.67	157.94	157.69	158.44	144.28	117.19	100.08	102.25	127.94	153.56	159.75	156.31
	(CHUKOTKA)		SD	54.87	100.78	1.68	15.99	16.17	18.11	19.56	18.90	17.73	17.74	15.31	23.10	17.64	18.79	18.44
			Min	372.00	838.00	18.00	111.00	121.00	116.00	111.00	106.00	83.00	55.00	69.00	82.00	116.00	121.00	116.00
			Max	626.00	1212.00	27.00	178.00	192.00	196.00	201.00	182.00	159.00	135.00	135.00	182.00	196.00	196.00	197.00
			CV	11.05	9.68	7.37	10.98	10.23	11.48	12.35	13.10	15.13	17.72	14.97	18.05	11.49	11.76	11.79
2.3	Bristol Bay + North-East Kamchatka	410	M	628.53	883.50	21.16	135.41	156.90	149.04	136.45	111.70	96.65	93.94	94.85	112.98	136.03	148.96	151.51
	BBAY + NEKAM2 + NEKAM3		SD	88.28	94.97	1.97	19.61	21.42	20.56	20.27	18.17	14.06	13.31	14.31	20.14	21.79	22.83	22.73
			Min	381.00	602.00	18.00	88.00	102.00	83.00	78.00	64.00	64.00	64.00	59.00	64.00	83.00	87.00	92.00
			Max	904.00	1187.00	30.00	206.00	234.00	243.00	196.00	177.00	140.00	154.00	154.00	187.00	220.00	243.00	215.00
			CV	14.05	10.75	9.33	14.49	13.65	13.80	14.85	16.27	14.55	14.16	15.09	17.82	16.02	15.32	15.00
	East Kamchatka	400	M	454.18	844.30	21.60	122.66	132.87	131.77	130.42	116.61	98.51	92.26	95.35	115.64	129.84	130.91	130.16
	EKAM + NWKAM		SD	107.66	120.91	2.46	17.15	20.48	19.29	19.00	20.61	17.39	13.51	16.15	20.22	19.58	20.16	20.27
			Min	230.00	561.00	18.00	83.00	84.00	92.00	79.00	69.00	59.00	60.00	59.00	69.00	79.00	83.00	87.00
			Max	814.00	1323.00	30.00	173.00	216.00	196.00	191.00	168.00	173.00	136.00	144.00	177.00	191.00	210.00	201.00
			CV	23.71	14.32	11.38	13.98	15.41	14.64	14.57	17.67	17.65	14.65	16.94	17.48	15.08	15.40	15.57
	West Kamchatka	200	M	471.68	1012.64	24.13	139.25	145.87	140.65	138.29	136.32	121.29	92.38	94.01	121.46	135.48	138.27	140.51

Age	Stock cluster	N	Parameter	*FW*	*O1*	*C1*	*TR1*	*TR2*	*TR3*	*TR4*	*TR5*	*TR6*	*RTR1*	*RTR2*	*RTR3*	*RTR4*	*RTR5*	*RTR6*
	SWKAM		SD	68.03	101.14	1.77	16.24	18.46	18.81	18.60	18.06	15.34	13.10	12.91	18.14	17.97	19.43	18.28
			Min	287.00	711.00	20.00	97.00	92.00	83.00	92.00	88.00	87.00	55.00	60.00	78.00	88.00	69.00	88.00
			Max	631.00	1293.00	30.00	177.00	187.00	201.00	201.00	182.00	164.00	121.00	135.00	172.00	187.00	192.00	201.00
			CV	14.42	9.99	7.33	11.66	12.66	13.38	13.45	13.25	12.64	14.18	13.74	14.94	13.27	14.05	13.01
	Chukotka	147	M	641.40	924.93	20.45	142.39	168.29	160.23	144.63	120.29	107.42	101.42	105.36	125.97	151.76	164.12	157.20
	(CHUKOTKA)		SD	87.27	120.82	2.20	21.04	22.01	21.18	23.84	20.73	14.53	13.42	15.41	20.42	22.87	22.49	25.81
			Min	419.00	634.00	18.00	92.00	111.00	92.00	92.00	83.00	78.00	74.00	69.00	88.00	101.00	112.00	92.00
			Max	843.00	1255.00	29.00	192.00	229.00	206.00	210.00	177.00	145.00	136.00	145.00	177.00	206.00	220.00	262.00
			CV	13.61	13.06	10.74	14.78	13.08	13.22	16.49	17.23	13.52	13.23	14.62	16.21	15.07	13.70	16.42

Table 5. The results of computer dependent simulations of scale baselines for age groups 1.3 and 2.3, 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.

Age	Stock cluster	N, spm.	1	2	3	4
1.3	1. Bristol Bay + Northeast Kamchatka	322	**0.9622**	0.0023	0.0634	0.0057
			0.0396	0.0064	0.0442	0.0144
	2. West Kamchatka	557	0.0004	**0.9538**	0.0994	0.0000
			0.0017	**0.0349**	0.0459	0.0000
	3. East + Northeast Kamchatka	421	0.0360	0.0127	**0.8340**	0.0056
			0.0393	0.0227	**0.0637**	0.0126
	4. Chukotka	36	0.0014	0.0312	0.0032	**0.9887**
			0.0061	0.0300	0.0090	**0.0191**
Total			1.0000	1.0000	1.0000	1.0000
Mean accuracy, %						**93.5**
2.3	1. Bristol Bay + Northeast Kamchatka	410	**0.9170**	0.0323	0.0015	0.0809
			0.0630	0.0331	0.0050	0.0718
	2. East Kamchatka	400	0.0140	**0.9147**	0.0235	0.0002
			0.0194	**0.0431**	0.0285	0.0013
	3. West Kamchatka	200	0.0002	0.0503	**0.9750**	0.0278
			0.0016	0.0305	**0.0291**	0.0240
	4. Chukotka	147	0.0688	0.0027	0.0000	**0.8911**
			0.0590	0.0086	0.0000	**0.0740**
Total			1.0000	1.0000	1.0000	1.0000
Mean accuracy, %						**92.4**

Table 6. Age composition of immature sockeye salmon in trawl catches of the R/V *TINRO* in September-October 2002. N, spm = number of specimens. Locations of districts are shown in Fig. 4.

District	N, spm	Age															
		0.0	0.1	0.2	0.3	1.0	1.1	1.2	1.3	2.0	2.1	2.2	2.3	3.0	3.1	3.2	4.0
6 (+ 5)	111	-	-	3.6	0.9	-	6.3	46.9	0.9	-	1.8	36.9	2.7	-	-	-	-
12 (+ 9)	726	0.6	2.5	2.6	0.1	6.2	20.0	18.2	1.9	3.3	20.0	16.8	2.6	1.4	2.9	0.8	0.1
8 (+ 7)	470	-	1.3	1.9	-	2.3	21.5	28.3	3.0	4.0	13.2	18.3	1.7	0.4	0.9	3.0	0.2

Table 7. Proportions of unallocated age groups in stock compositon analysis of 2002 R/V TINRO catches of immature sockeye salmon by district (Fig. 4).

District	Principal age groups				Total	Unallocated
	1.1	1.2	2.1	2.2		
6 (+5)	-	0.469	-	0.369	0.838	0.162
12 (+9)	0.200	0.182	0.200	0.168	0.750	0.250
8 (+7)	0.215	0.283	0.132	0.183	0.813	0.187

Table 8. Maximum likelihood estimates (MLE) of the stock compositon of immature sockeye salmon by dominant age groups in trawl catches of R/V *TINRO* in September-October 2002. N = sample size, SD = standard deviation, CI = bootstrap confidence interval. The locations of districts are shown in Fig. 4.

District	Age	N	Stock Cluster	MLE	SD	CI - 95%
6 (+ 5)	1.2	49	Bristol Bay + North-East Kamchatka	-	-	-
			West Kamchatka	0.1812	0.0897	0.0000 - 0.3069
			East + North-East Kamchatka	0.8188	0.0897	0.6828 - 0.9999
			Chukotka	-	-	-
	2.2	40	Bristol Bay + North-East Kamchatka	-	-	-
			East Kamchatka	0.6003	0.0933	0.3928 - 0.8171
			West Kamchatka	0.3997	0.0933	0.1766 - 0.5920
			Chukotka	-	-	-
12 (+ 9)	1.1	97	Bristol Bay + North-East Kamchatka	0.1035	0.0578	0.0000 - 0.2242
			West Kamchatka	-	-	-
			East + North-East Kamchatka	0.8038	0.0643	0.6264 - 0.8979
			Chukotka	0.0927	0.0556	0.0002 - 0.2400
	2.1	120	Bristol Bay + North-East Kamchatka	-	-	-
			East Kamchatka	0.5677	0.0603	0.4389 - 0.6905
			West Kamchatka	0.2819	0.0518	0.1619 - 0.3897
			Chukotka	0.1504	0.0434	0.0637 - 0.2510
	1.2	117	Bristol Bay + North-East Kamchatka	0.1009	0.0408	0.0063 - 0.1737
			West Kamchatka	0.3482	0.0644	0.1495 - 0.4163
			East + North-East Kamchatka	0.4660	0.0734	0.3534 - 0.6454
			Chukotka	0.0849	0.0464	0.0240 - 0.2332
	2.2	112	Bristol Bay + North-East Kamchatka	0.1261	0.0421	0.0326 - 0.2047
			East Kamchatka	0.3657	0.0618	0.2427 - 0.4895
			West Kamchatka	0.5082	0.0560	0.3910 - 0.6165
			Chukotka	-	-	-
8 (+ 7)	1.1	66	Bristol Bay + North-East Kamchatka	0.4123	0.0915	0.1997 - 0.5713
			West Kamchatka	-	-	-
			East + North-East Kamchatka	0.4160	0.0905	0.2727 - 0.6191
			Chukotka	0.1717	0.0700	0.0420 - 0.3273
	2.1	48	Bristol Bay + North-East Kamchatka	0.1969	0.1148	0.0000 - 0.4042
			East Kamchatka	0.4668	0.1014	0.2731 - 0.6908
			West Kamchatka	0.0680	0.0488	0.0000 - 0.1704
			Chukotka	0.2683	0.1114	0.0673 - 0.5406
	1.2	120	Bristol Bay + North-East Kamchatka	0.2427	0.0466	0.1485 - 0.3379
			West Kamchatka	0.2536	0.0545	0.1133 - 0.3396
			East + North-East Kamchatka	0.5037	0.0660	0.3966 - 0.6693
			Chukotka	-	-	-
	2.2	85	Bristol Bay + North-East Kamchatka	0.2136	0.0719	0.0448 - 0.3612
			East Kamchatka	0.3876	0.0699	0.2494 - 0.5307
			West Kamchatka	0.3542	0.0592	0.2198 - 0.4759
			Chukotka	0.0446	0.0434	0.0000 - 0.1576

Table 9. Stock proportion estimates of immature sockeye salmon in the 2002 R/V TINRO catches weighted by age group.

District	Stock Cluster	Principal age groups				Unallocated	Total	Sum of Allocated	% of Allocated	% Asian	% N. American
		1.1	1.2	2.1	2.2						
6 (+5)	BBAY										
	EKAM		0.3840		0.2215		0.6055		72.3		
	WKAM		0.0850		0.1475		0.2325		27.7		
	CHUK										
	Unallocated					0.1620	0.1620				
	Total						1.0000	0.8380	100.0	100.0	0.0
12 (+9)	BBAY	0.0207	0.0184		0.0212		0.0602		8.0		
	EKAM	0.1608	0.0848	0.1135	0.0614		0.4205		56.1		
	WKAM		0.0634	0.0564	0.0854		0.2051		27.4		
	CHUK	0.0185	0.0155	0.0301			0.0641		8.5		
	Unallocated					0.2500	0.2500				
	Total						1.0000	0.7500	100.0	92.0	8.0
8 (+7)	BBAY	0.0886	0.0687	0.0260	0.0391		0.2224		27.4		
	EKAM	0.0894	0.1425	0.0616	0.0709		0.3645		44.8		
	WKAM		0.0718	0.0090	0.0648		0.1456		17.9		
	CHUK	0.0369		0.0354	0.0082		0.0805		9.9		
	Unallocated					0.1870	0.1870				
	Total						1.0000	0.8130	100.0	73.0	27.0