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To the problem about accuracy using scale pattern analysis for identification of some local stocks of sockeye salmon *Oncorhynchus nerka* from Asia and North America

by

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ABSTRACT

Complex analysis of scale structure for some local sockeye salmon stocks in Asia and North America using various statistical methods has been carried out for 1.3 and 2.3 age groups. The results indicated of the need of more careful approach to the scale criteria application for identification within mixed stocks. In general, direct cluster differentiation has been possible between the complexes of West and East Kamchatka. Bristol Bay group of stocks and Eastern Kamchatka group of stocks have been occurring in total clusters what makes complicated the use of the scale baselines for determination of sockeye salmon continental origin within Russian economic zone. The timing of prespawning migration of principal Asian and American stocks, the ratio between mature and immature individuals in the catches and geographic distance between coastal North America and the area of drifters taken into account make us to suggest that majority of mixed stocks available for identification through the cluster represents the complex of Eastern Kamchatka. Created scale baselines provide identification in mixed stocks with approximate accuracy 94-96% in general. Practical purposes of interpretation of the results, nevertheless, require using the complex approach to provide maximum likelihood on the basis of the tendencies of sockeye salmon local stocks distribution and stock abundance dynamics estimation.

INTRODUCTION

The studies on the Pacific Salmon local stocks identification demonstrate nowadays a number of methods to differentiate certain local stocks and groups of stocks. Mostly popular are the methods: 1) parasitological; 2) phenetical and 3) genetical ones (Margolis, 1963; Anas, Murai, 1969; Konovalov, 1971; Milner et al., 1985; Pella, Milner, 1987; Myers. 1991; Walker, 1991; Taylor et al., 1994; Temnykh et al., 1997; Patton et al., 1998; Urawa et al., 1998; Varnavskaya et al., 1998; Beachem et al., 2000; Gurthrie III et al., 2000, Bugaev, 2003 a, b, c etc.). All the methods mentioned above bear specific limitations and mean accuracy. Till this time reliable data on the origin and distribution could be obtained from tagging only (French et al., 1976; Myers et al., 1996; Atlas distribution…, 2002). Nevertheless, this method is limited due to the impossible mass tagging and tag recovery control restricting the monitoring of local stock areal fluctuations. The most effective direction is hatchery salmon otolith marking (Geiger, Munk, 1998; Carlson et al., 2000). Also that can be used for hatchery populations only. Thus, accuracy level for the studies of interspecies differentiation requires more wide discussion on the options and limitations of the methods used.

In our work we have analyzed some patterns of scale criteria accuracy assess for identification of sockeye salmon stocks from some Asian and North American watersheds. With various methods of statistic analysis the possibility of scale baselines use for practical purposes of interspecies differentiation has been estimated on the example of 2001 scale baselines created.

MATERIAL AND METHODS

As Asian sockeye salmon standard scale samples we had reckoned scale samples collected by the staff of KamchatNIRO and Sevvostrybvod in the off-shore and inshore catches in 2001 (Fig. 1). Scale samples from Bristol Bay have been kindly provided by K. Myers (School of Aquatic and Fishery Science, University of Washington , Seattle). Sampling was carried out for the period from May to August. Sample sizes of standard scale samples are represented in the Table 1. The fishing gears used were gill nets, fixed and thrown nets.

The scales was picked up from the "preferable area", i.e. upward from the lateral line between dorsal and adipose fins (Clutter, Whitesel, 1956; Knudsen, 1985). Age estimation was carried out according to standard method accepted for Pacific Salmon (Mosher, 1969; Bugaev, 1995; Ito, Ishida, 1998 etc.)

Primarily reading of scale parameters was carried out on "BioSonics" OPRS (model OPR-513, OPRS, BioSonics Inc., Seattle, WA, USA) via measuring the scale structural elements within the zones of fresh-water and first marine year growth (FW, O_1, TR_1-TR_6, RTR_1-RTR_6) and the number of sclerites in the first marine year circulus (C_1)(Davis et al., 1990). All measures were carried out along the axis 90? to the line of scale pocket (Figure 2). There have been used 15 criteria in total.

Standard scale samples used in the work was represented by 1.3 and 2.3 age groups which were mostly dominating in adult Asian and North American sockeye salmon (Burgner, 1991; Bugaev, 1995). In the course of standard scale samples selection temporal and spatial population structure of local stocks of every separate river system has been taken into account occasionally. For this purpose the scales of adult sockeye salmon typical for beginning, mediate and finish of the anadromous migration has been used when it was possible. However the latter might take place in the case of rather extensive materials. Small sample sizes were analyzed totally.

Asian standard scale samples consisted of local sockeye salmon stocks, reproducing in the rivers in Kamchatka Region and Koryaksky Autonomous Area. Up to 95% of Asian sockeye salmon stock use to reproduce within the area mentioned (Bugaev, 1995). American standard scale samples have been represented by two variants. The first includes mixed sample from marine catches in the Port Moller control point what American specialists use to analyze the state of and to make instant forecast of run for the complex of Bristol Bay local sockeye salmon stocks (Myers, 1991). The second uses scale samples taken directly in the watersheds throughout Bristol Bay to increase the accuracy of the experiment.

The differentiation is determined by the requirement of checking the level of accuracy for Asian and North American sockeye salmon stocks identification first of all. Appeared contradictions about the competence of the Port Moller test application make us to analyze two probably ways of scale baselines creation. At critical approach we have to suggest the occurrence of partly mixing between Bristol Bay and British Columbia stocks. Nevertheless, despite possible heterogeneous population composition of standard scale samples, averaged test would reprecent the complex of North American stocks only, because Asian sockeye salmon, being the stock 10-15% of international resource of this species, hardly occur within economic zone of USA (Burgner, 1991; Bugaev, 1995). We suggest that it would be more important to demonstrate principal possibility or impossibility of reliable estimation of presence of American sockeye salmon within economic zone of Russia. In applied aspect at setting the work throughout the seas of Far East the most important is differentiation between West Kamchatkan and East Kamchatkan stocks which determine sockeye salmon stock abundance dynamics within economic zone of Russia (Konovalov, 1971; Birman, 1985).

Formation of scale baselines has been carried out on from the results of cluster analysis based on Euclidean distances between scale standards' centers (MathSoft, 1997). Probability level of differences for local stock clusters found has been estimated through Wilcoxon matched pair test (Z)(Borovikov, 2001). The variables used were center variation coefficients (CV) of scale criteria what provided the comparison of variations of complexes where the meaning have different sizes. The level of interrelations of clusters in the simulations obtained were estimated from principal component analysis (MathSoft, 1997). For getting the mean accuracy of the scale baselines created the method of dependent simulations based on the procedure of maximum likelihood estimation (MLE) has been used (Millar, 1987, 1988, 1990).

RESULTS AND DISCUSSION

Hierarchical cluster analysis

Creation of scale baselines required for the first grouping the scale samples which we used by their regional membership. Various statistical methods to provide objectivity for the procedure mentioned have been used. In this work the objects have been grouped with using the cluster analysis (Figures 3 and 4). Characteristics of scale criteria of the clusters obtained in represented in the Table 2.

Obtained results indicated that in both variants for the age groups 1.3 and 2.3 the Eastern and Western stocks have been determined rather well. For practical use it was principal, in general, to have found the difference between two Asian stocks – Kamchatka River stock and Ozernaya River stock, in particular years the contribution of two these stocks being up to 95% of Asian sockeye salmon harvest (Bugaev, 1995). For Asian and North American sockeye salmon stocks the difference like that has not been observed. In all cases the complex of Bristol Bay stocks creates mutual with Severnaya River stock (North-East Kamchatka) cluster. Moreover, this tendency we have observed in our earlier studies. For the period from 1995 to 2000 in dependence of the year-to-year scale criteria variations the Port Moller testsdemonstrate maximum similarity to the samples representing Eastern and North-Eastern Kamchatka: Kamchatka River, Anana River, Ilpyveem River, Severnaya River, Tamanvayam River (Bugaev, 2003a). Unfortunately, annual collecting the materials in the north-east of Kamchatka has not been rather regular yet, therefor we cannot show a complete version of the cluster analysis including all samples mentioned above. Nevertheless, even from the data for 2001 it is clear that the similarity is as stable as in the case of the Port Moller test and as “pure” samples collected in the Bristol Bay watersheds directly.

All of these indicate of polysemantic using the scale criteria for identification of local Asian and North American sockeye salmon stocks in the economic zone of Russia. In this case we mean the use of scale baselines in the area adjacent to Asian coast only which is rather distant from Bristol Bay sockeye salmon migration routs (French et al., 1976; Burgner, 1991; Myers et al., 1996; Atlas distribution…, 2002). Moreover, it should be noted that sockeye salmon catches in Russian 200-miles fishery area consist in 90% of adult fish (Bugaev, Shaporev, 2002; Bugaev, Peshkurova, 2003), i.e. the fish migrating to spawn. Taking into account the facts we cannot neglect that the influence of East Kamchatkan stocks in Russian waters is much more significant being compared to that of hypothetical occurring American stocks. Therefor the part of mixed samples which has been identified by the clusters EKAM+BBAY shoul be reckoned logically to the East Kamchatkan complex (Kamchatka River? 70-90%; minor rivers of the North-East Kamchatka? 10-30%). We emphasize again that this term has been kept within economic zone of Russia only, was the identification made with the scale baselines in central North Pacific of Bering Sea, the fish differentiated by the clusters could be reckoned as belonging to Bristol Bay complex which abundance has been dominating there undoubtedly.

Similar cases take place with Asian stocks. The most demonstrating example has been observed in forming the scale baseline for 2.3 age group. In this case total cluster has been formed of Ozernaya River (West Kamhatka) and Pakhacha River (North-East Kamchatka) stocks. However, as we mean Asian stocks only, the data on the tendencies of their stock abundance dynamics make us to reckon the part of mixed groups differentiated by the WKAM+EKAM cluster as Ozernaya River stock which is largest in Asia, i.e. is dominating in the abundance. Similar situation has been observed for the scale baseline of 1.3 age group. In this case the cluster of East Kamchatkan stocks (Kamchatka River, Khaylula River and Dranka River) includes some West Kamchatkan stocks (Icha River and Krutogorova River). Actually, the approach like we have used for Ozernaya River stock should be accepted because the group of stocks includes the second in Asia sockeye salmon stock – Kamchatka Rover stock. The methodological error can be neglected for practical purposes, because potential part of Icha River and Krutogorova River stocks estimated from the data we have on the abundance of Asian stocks cannot has extensive influence onto interspecies structure of gill-net catches.

The causes of scale criteria similarity between particular local stocks cannot be explained simply despite the fact of remoteness of the areas of reproduction of local stocks from each other. First of all, that might be a consequence of similar ecological terms taking place during freshwater and marine periods of life. Than, if to estimate the situation as maximum real, it should be understood that scale criteria cannot be demonstrative in all cases due to the influence of the factors of environment; as braking as prompting influence of the environment in different ecosystems cause respectively slowing or accelerated growth rate, what, in its turn, has been reflected in the dynamics of forming the sclerites. The factors determining similar reaction can be absolutely different. At last, a methodic error relating to insufficient sample size of particular standard scale samples cannot be excluded. Thus, the level of probability over the identification with scale criteria to be increased needs using the complex approach where, aside from objective probability estimates, well known tendencies of distribution and stock abundance dynamics of local stocks have been used.

Wilcoxon matched pair test

Scale baselines formed as a result of cluster analysis provide identification in mixed marine samples. However, testing the level of probability of the discrimination of the clusters differentiated needs estimating the confidence likelihood of the difference. For this need we used one of non parametrical methods – Wilcoxon's matched pairs test (Table 3, figure 5).

The results indicated that majority of reliable difference means or ones close to the first level of significant difference for scale baselines in the age groups 1.3 and 2.3 is standard for the clusters of East Kamchatkan and West Kamchatkan (EKAM and WKAM) stocks and for the group of North-East Kamchatkan stocks + Bristol Bay and West Kamchatkan (EKAM + BBAY and WKAM) stocks. However, it should be noted that even the clusters mentioned above cannot be differentiated reliably in all cases. The most reliable differences to all clusters have been found for the stock of Bettobu River (Shumshu Island). Hypothetical we can suggest 100 % accuracy in at the identification of this stock in mixed marine samples. Nevertheless, a possibility of methodological error due to the insufficient sample size of standard scale sample itself. Thus, Wilcoxon's test confirms the need of complex approach over the local stocks identification in marine catches because not all the clusters in the standard scale samples demonstrate reliable differences.

Principal component analysis

Analyzing the structure of standard scale samples simulations obtained we have to study especially the interrelations between the clusters. The influence of every particular cluster to the system as a whole estimated can extensively simplify understanding the logical discrepancies might be in the course of identification in mixed marine samples. The example of principal component analysis demonstrates the structure of cluster interrelations within scale baselines (Figures 6 and 7).

Obtained results demonstrate characteristic, rather well expresses instability of components for the both versions of standard scale sample simulation for the age group 1.3. First pair components which of all the comparisons have been made are 88.1 and 87.5 %. Vectorial distribution of clusters, being compared to these components, demonstrates the most influencing the system standards should be KURIL and WKAM1. The least influence is estimated for the cluster EKAM1. Actually, it means that first pair component can include alien part of mixed sample, whereas the cluster EKAM1 is the most probable potential donor. For the standard scale samples of 2.3 age the results of the analysis indicate more stability of the system. In this case first pair components are 88.0 and 89.5 %. The vectors of loading at that are equal approximately what indicates of their equal influence on the structure of standard scale sample structure. Thus, resulting principal component analysis, we can conclude that scale baselines for the age 1.3 are less stable being compared to those for the age 2.3.

Simulation

Mean accuracy of obtained scale baselines has been estimated from the method of dependent simulation. Average accuracy of discrimination of particular clusters in mixed groups imitations has been estimated in both versions for every particular age group (Tables 4-7).

The meanings of mean accuracy for standard scale sample models obtained for the ages 1.3 and 2.3 are quite high. In the first version the mean accuracy is 95.5-95.7 %, in the second case - 93.8-94.3 %. The accuracy of the meanings obtained depends from distribution of variables in criteria examined directly, therefor, when being the sample sizes small the meanings can be distorted. For example, it can be artificial overestimation of mean accuracy of particular elements of scale baselines. Moreover, scale criteria undergo much more variations over identification in mixed samples because population variations in the catches is much more in reality being compared to that in scale baselines limited by the number of standards set. Nevertheless, taking into account the fact that scale samples of largest Asian and North American stocks are representative in this work we can reckon the level of mean accuracy of obtained standard scale sample simulations as quite high. Although it should be emphasized once more that practical use of the simulations should be supported by complex approach implying the use of the tendencies of stock abundance dynamics and potential distribution in the sea by the areas of reproduction.

CONCLUSIONS

Analysis of scale structure of some local Asian and North American sockeye salmon stocks by age groups 1.3 and 2.3 demonstrates the possibility of differentiation no more than up to between the complexes of Western and Eastern Kamchatka. Bristol Bay and Eastern Kamchatka stock groups in both versions have got included in total clusters what complicated significantly the process of identification of these complexes in mixed marine samples within economic zone of

Russia. Prespawning migration dynamics of largest Asian and American stocks, the ratio between mature and immature individuals and geographical distances between the area of gill net fishery and North American Coast taken into account make us to conclude that the part of mixed samples identified with the cluster belongs mostly to the Eastern Kamchatka complex. Actually, the scale baselines formed provide identification of mixed material with the approximate accuracy 94-96 %. However, practical purposes of interpreting the results need using the complex approach based as on the gaining the likelihood esteems, as on knowing the tendencies of distribution and stock abundance dynamics of particular local sockeye salmon stocks.

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Appendix tables and figures

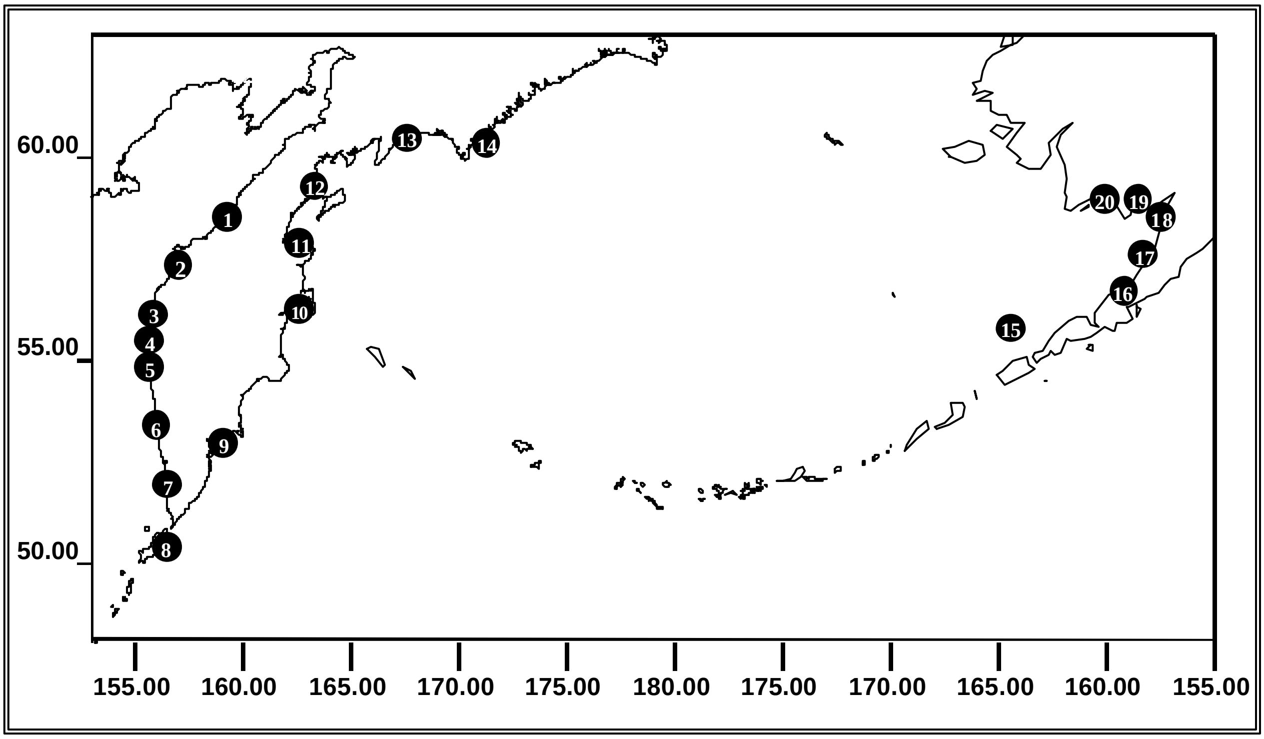

Fig. 1. Scheme areas of collected scale materials for baselines local stocks of sockeye salmon in 2001: 1 – r. Palana; 2 – r. Icha; 3 – r. Krutogorova; 4 – r. Vorovskaya; 5 – r. Kikhchik; 6 – r. Bolshaya; 7 – r. Ozernaya; 8 – r. Bettobu (Sumshu Island); 9 – r. Avacha; 10 – r. Kamchatka; 11 – r. Khailulya; 12 – r. Dranka; 13 – r. Pakhacha; 14 – r. Severnaya; 15 – Port Moller; 16 – r. Ugashik; 17 – r. Egegik; 18 – r. Naknek; 19 – r. Kvichak; 20 – r. Nushagak

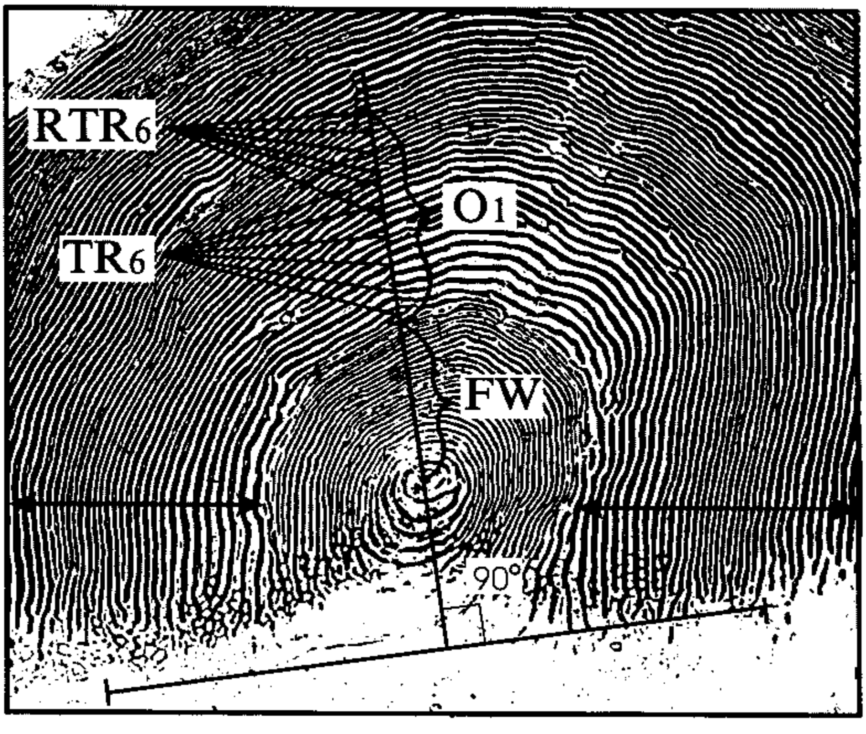

Fig. 2. Scheme of scale image used for identification local stocks of sockeye salmon in economic zone of Russia: FW – total distance in the freshwater growth zone; O_1 – total distance in the first annual ocean growth zone; TR_1-TR_6 – triplets circulus distance from first circuli in the first annual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

Table 1. Total size for scale materials from rivers and coastal catches in 2001, number of fish

Stocks	Age groups	
	1.3	2.3
Eastern Kamchatka		
r. Avacha	-	25
r. Dranka	100	-
r. Kamchatka	100	100
r. Pakhacha	43	-
r. Severnaya	78	100
r. Khailulya	100	-
Western Kamchatka		
r. Bolshaya	100	-
r. Vorovskaya	78	-
r. Icha	81	-
r. Kikhchik	22	-
r. Krutogorova	91	-
r. Ozernaya	-	100
r. Palana	-	100
Kuril Islands		
r. Bettobu (Shumshu Island)	34	-
Bristol Bay		
r. Egegik	100	100
r. Kvichak	100	-
r. Naknek	100	-
r. Nushagak	100	-
r. Ugashik	100	-
Port Moller (complex stocks)	100	100

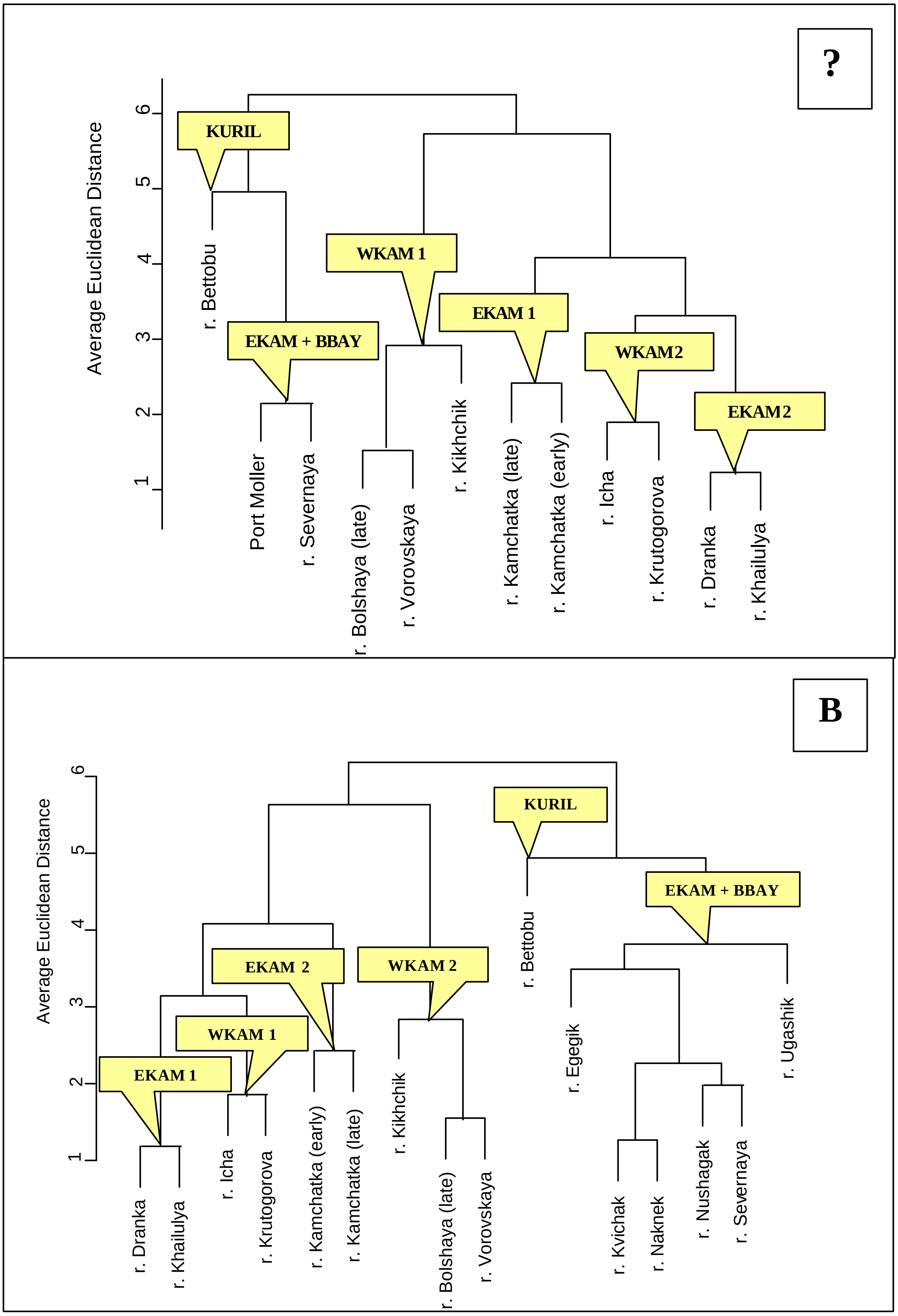

Fig. 3. Hierarchical clustering dendrograms of the stock centroids of sockeye salmon for age 1.3 from scale pattern variables in 2001: A - version 1, B – version 2

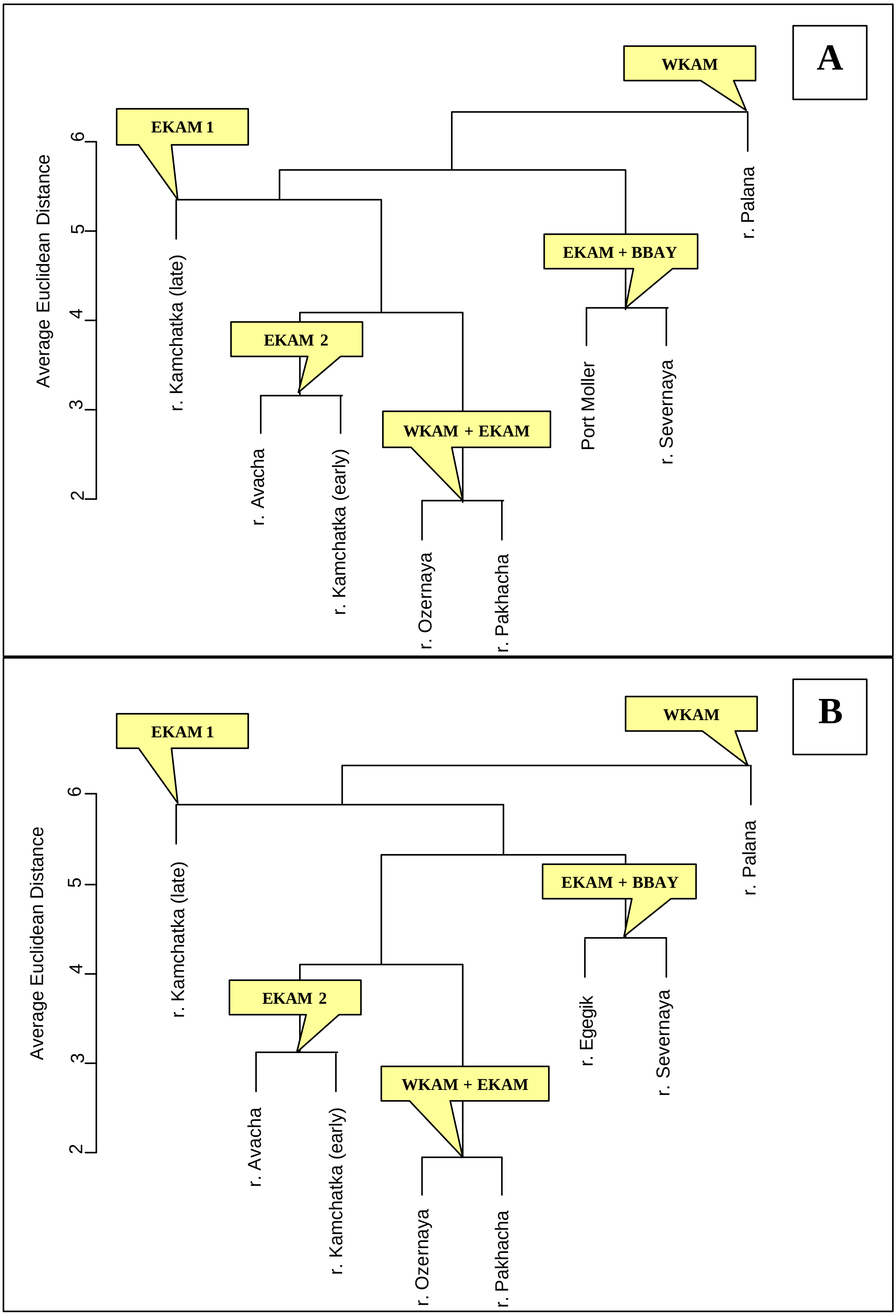

Fig. 4. Hierarchical clustering dendrograms of the stock centroids of sockeye salmon for age 2.3 from scale pattern variables in 2001: A - version 1, B – version 2

Table 2. Characteristics scales criterions of sockeye salmon for baselines by age groups 1.3 and 2.3 in 2001

Age	Cluster	N	Parameter	FW	O_1	C_1	TR_1	TR_2	TR_3	TR_4	TR_5	TR_6	RTR_1	RTR_2	RTR_3	RTR_4	RTR_5	RTR_6
1.3	EKAM 1	100	Min	282.00	643.00	19.00	79.00	73.00	88.00	79.00	74.00	74.00	64.00	69.00	69.00	79.00	83.00	83.00
			Mean	450.80	907.26	24.26	123.73	130.23	124.80	122.43	113.54	102.05	89.92	91.31	103.48	113.28	120.11	121.66
			Max	616.00	1272.00	31.00	163.00	168.00	164.00	159.00	150.00	144.00	125.00	131.00	150.00	154.00	155.00	164.00
			SD	71.76	123.19	2.40	15.13	19.12	16.52	16.63	15.97	15.24	12.12	11.74	15.11	16.88	16.01	16.88
			CV	15.92	13.58	9.88	12.22	14.68	13.24	13.58	14.07	14.94	13.48	12.86	14.61	14.90	13.33	13.87
	EKAM 2	200	Min	252.00	620.00	18.00	74.00	71.00	71.00	91.00	81.00	73.00	53.00	64.00	66.00	76.00	84.00	71.00
			Mean	403.49	928.86	24.44	113.86	124.75	124.80	129.21	127.72	114.71	85.44	90.46	111.07	129.89	128.72	124.62
			Max	574.00	1246.00	32.00	146.00	178.00	174.00	196.00	205.00	173.00	113.00	139.00	173.00	205.00	169.00	196.00
			SD	61.86	137.03	2.56	14.59	18.75	19.86	19.16	21.20	21.78	11.66	14.13	19.51	20.53	19.46	20.00
			CV	15.33	14.75	10.46	12.82	15.03	15.92	14.83	16.60	18.99	13.64	15.62	17.57	15.81	15.12	16.05
	EKAM + BBAY (version 1)	178	Min	329.00	577.00	18.00	87.00	87.00	93.00	92.00	74.00	59.00	64.00	64.00	73.00	92.00	93.00	96.00
			Mean	504.52	889.71	22.11	125.28	143.96	144.34	137.07	114.68	98.03	92.46	92.62	108.31	130.79	141.33	144.38
			Max	739.00	1102.00	27.00	186.00	206.00	196.00	205.00	173.00	154.00	135.00	136.00	178.00	178.00	205.00	201.00
			SD	63.51	112.27	1.93	19.31	23.42	20.00	19.39	19.20	14.67	12.25	13.53	17.50	19.56	20.18	22.44
			CV	12.59	12.62	8.72	15.41	16.27	13.85	14.15	16.74	14.97	13.24	14.61	16.16	14.95	14.28	15.54
	EKAM + BBAY (version 2)	578	Min	367.00	582.00	18.00	83.00	87.00	88.00	79.00	69.00	55.00	59.00	50.00	69.00	74.00	88.00	92.00
			Mean	529.76	917.19	22.19	129.75	152.59	147.29	139.56	119.84	99.39	92.43	95.74	113.88	134.72	145.98	151.09
			Max	772.00	1202.00	30.00	206.00	230.00	215.00	206.00	187.00	154.00	136.00	145.00	173.00	201.00	220.00	230.00
			SD	67.28	109.59	2.02	20.24	23.38	20.90	20.71	19.95	15.07	12.17	14.18	19.66	21.03	21.66	22.99
			CV	12.70	11.95	9.08	15.60	15.32	14.19	14.84	16.64	15.17	13.16	14.81	17.26	15.61	14.84	15.22
	WKAM 1	200	Min	244.00	775.00	21.00	97.00	99.00	100.00	87.00	81.00	84.00	64.00	67.00	71.00	81.00	90.00	87.00
			Mean	409.03	1093.44	25.88	133.12	141.79	137.59	138.42	139.90	137.21	90.21	97.73	130.54	138.90	138.70	135.82
			Max	569.00	1377.00	31.00	182.00	196.00	182.00	187.00	215.00	187.00	136.00	154.00	181.00	215.00	187.00	183.00
			SD	67.71	112.30	1.94	15.93	18.26	17.12	18.96	20.21	18.45	11.89	17.21	20.50	19.13	20.46	17.85
			CV	16.55	10.27	7.51	11.97	12.88	12.44	13.70	14.44	13.44	13.18	17.61	15.71	13.77	14.75	13.14
	WKAM 2	172	Min	221.00	758.00	21.00	88.00	96.00	88.00	83.00	83.00	83.00	59.00	55.00	78.00	79.00	87.00	92.00
			Mean	347.12	1061.94	26.90	125.69	132.44	129.53	130.09	129.50	127.87	85.62	88.48	117.17	127.79	130.48	131.36
			Max	536.00	1383.00	32.00	192.00	191.00	201.00	211.00	182.00	173.00	121.00	131.00	163.00	173.00	211.00	201.00
			SD	61.40	121.33	2.21	16.55	17.52	17.80	19.88	18.08	18.69	11.22	14.28	18.78	18.13	18.43	19.06
			CV	17.69	11.43	8.22	13.16	13.23	13.74	15.28	13.96	14.61	13.10	16.13	16.03	14.19	14.12	14.51
	KURIL	34	Min	301.00	649.00	18.00	93.00	97.00	97.00	111.00	78.00	74.00	69.00	74.00	97.00	97.00	97.00	97.00
			Mean	510.03	856.03	19.85	123.09	147.97	145.38	149.00	122.18	103.27	102.82	105.12	139.71	149.35	144.29	138.03

			Max	682.00	1068.00	24.00	164.00	206.00	210.00	196.00	177.00	149.00	149.00	140.00	196.00	191.00	210.00	187.00
			SD	91.82	127.19	1.69	20.04	23.48	25.43	23.23	25.81	18.72	17.65	17.84	24.29	25.14	25.06	25.11
			CV	18.00	14.86	8.51	16.28	15.87	17.49	15.59	21.13	18.13	17.17	16.97	17.38	16.83	17.37	18.19
2.3	EKAM 1	50	Min	334.00	616.00	20.00	92.00	96.00	96.00	88.00	78.00	79.00	60.00	74.00	83.00	83.00	88.00	88.00
			Mean	474.26	897.46	23.68	123.60	128.68	121.80	122.18	112.68	105.02	94.36	98.02	107.24	115.74	120.20	123.20
			Max	560.00	1323.00	30.00	168.00	191.00	172.00	172.00	149.00	145.00	135.00	141.00	145.00	177.00	154.00	159.00
			SD	51.86	135.82	2.51	15.51	19.85	15.78	17.12	17.82	16.93	13.91	15.13	15.86	17.44	16.73	16.58
			CV	10.94	15.13	10.60	12.54	15.42	12.95	14.01	15.81	16.12	14.74	15.43	14.79	15.07	13.92	13.46
	EKAM 2	75	Min	348.00	738.00	19.00	88.00	93.00	92.00	101.00	83.00	83.00	59.00	69.00	74.00	92.00	83.00	92.00
			Mean	549.95	935.04	23.99	119.03	130.01	130.93	132.49	125.87	109.51	92.35	94.31	113.31	127.73	130.23	130.65
			Max	814.00	1306.00	30.00	169.00	187.00	182.00	173.00	164.00	173.00	121.00	131.00	163.00	173.00	167.00	187.00
			SD	99.45	105.61	2.15	16.74	20.61	18.60	17.53	19.60	17.40	13.69	13.24	19.73	20.44	19.95	18.69
			CV	18.08	11.30	8.98	14.06	15.85	14.20	13.23	15.57	15.88	14.82	14.04	17.41	16.01	15.32	14.31
	EKAM + BBAY (version 1)	200	Min	390.00	623.00	18.00	88.00	102.00	88.00	87.00	74.00	69.00	64.00	59.00	64.00	83.00	87.00	92.00
			Mean	603.45	898.03	21.75	132.43	156.61	148.35	137.17	113.13	96.69	92.20	93.08	110.34	132.71	146.06	151.36
			Max	824.00	1187.00	30.00	206.00	215.00	211.00	196.00	172.00	131.00	130.00	130.00	172.00	220.00	216.00	210.00
			SD	91.65	96.41	2.02	19.99	21.21	19.97	19.80	17.34	13.68	12.97	13.50	18.48	21.65	22.09	23.30
			CV	15.19	10.74	9.30	15.09	13.55	13.46	14.43	15.33	14.15	14.07	14.50	16.75	16.32	15.12	15.39
	EKAM + BBAY (version 2)	200	Min	390.00	623.00	18.00	88.00	102.00	88.00	87.00	79.00	54.00	64.00	54.00	64.00	83.00	87.00	92.00
			Mean	625.72	917.92	22.16	131.13	158.26	150.83	138.45	116.12	97.41	91.77	92.89	110.03	131.75	145.63	152.51
			Max	908.00	1191.00	30.00	206.00	219.00	211.00	191.00	168.00	140.00	130.00	135.00	168.00	220.00	216.00	206.00
			SD	105.28	103.16	2.04	17.97	22.88	22.26	20.21	17.15	14.28	13.92	13.59	18.59	21.90	24.14	23.36
			CV	16.83	11.24	9.21	13.70	14.45	14.76	14.60	14.77	14.66	15.17	14.63	16.89	16.62	16.58	15.32
	WKAM + EKAM	143	Min	230.00	647.00	18.00	84.00	92.00	97.00	106.00	88.00	69.00	67.00	69.00	87.00	93.00	97.00	87.00
			Mean	320.25	820.99	20.54	119.62	126.33	128.37	139.65	125.13	100.62	96.72	104.01	128.37	136.43	129.89	124.82
			Max	431.00	1079.00	25.00	163.00	164.00	186.00	177.00	168.00	144.00	135.00	144.00	177.00	173.00	186.00	164.00
			SD	34.24	90.55	1.60	16.43	16.45	18.07	15.43	18.03	14.63	12.72	16.41	19.36	17.24	17.73	18.49
			CV	10.69	11.03	7.78	13.73	13.02	14.08	11.05	14.41	14.54	13.15	15.78	15.08	12.64	13.65	14.81
	WKAM	100	Min	324.00	749.00	18.00	92.00	96.00	88.00	97.00	83.00	83.00	64.00	64.00	74.00	74.00	88.00	88.00
			Mean	495.00	1032.41	24.80	136.60	146.61	138.51	137.83	134.30	122.90	92.65	94.48	117.09	133.87	137.69	136.93
			Max	631.00	1348.00	30.00	177.00	187.00	191.00	220.00	192.00	182.00	140.00	145.00	172.00	187.00	206.00	182.00
			SD	60.47	108.98	2.00	16.35	18.30	18.58	20.24	18.73	17.73	13.33	14.01	18.32	18.84	19.63	17.91
			CV	12.22	10.56	8.07	11.97	12.48	13.41	14.68	13.95	14.43	14.39	14.83	15.65	14.07	14.26	13.08

Table 3. Wilcoxon matched pairs test for variability scale criterions of sockeye salmon by clusters of stock centroids

Age	Cluster	N	Version 1		Version 2	
			W	P - level	W	P - level
1.3	EKAM 1 EKAM 2	100 200	3.18	< 0.01	3.18	< 0.01
	EKAM 1 EKAM + BBAY	100 178	1.53	0.1252	1.65	0.0995
	EKAM 1 WKAM 1	100 200	0.97	0.3343	0.97	0.3343
	EKAM 1 WKAM 2	100 172	0.74	0.4603	0.74	0.4603
	EKAM 1 KURIL	100 34	3.24	< 0.01	3.24	< 0.01
	EKAM 2 EKAM + BBAY	200 178	2.16	< 0.05	2.21	< 0.05
	EKAM 2 WKAM 1	200 200	2.73	< 0.01	2.73	< 0.01
	EKAM 2 WKAM 2	200 172	2.39	< 0.05	2.39	< 0.05
	EKAM 2 KURIL	200 34	2.50	< 0.05	2.50	< 0.05
	EKAM + BBAY WKAM 1	178 200	1.65	0.0995	1.76	0.0782
	EKAM + BBAY WKAM 2	178 172	1.42	0.1556	1.87	0.0608
	EKAM + BBAY KURIL	178 34	3.24	< 0.01	3.24	< 0.01
	WKAM 1 WKAM 2	200 172	1.93	0.0535	1.93	0.0535
	WKAM 1 KURIL	200 34	3.35	< 0.001	3.35	< 0.001
	WKAM 2 KURIL	172 34	3.41	< 0.001	3.41	< 0.001
2.3	EKAM 1 EKAM 2	50 75	0.85	0.3942	0.85	0.3942
	EKAM 1 EKAM + BBAY	50 200	0.28	0.7764	1.08	0.2805
	EKAM 1 WKAM + EKAM	50 143	1.99	< 0.05	1.99	< 0.05
	EKAM 1 WKAM	50 100	1.70	0.0884	1.70	0.0884

	EKAM 2 EKAM + BBAY	75 200	0.85	0.3942	0.17	0.8647
	EKAM 2 WKAM + EKAM	75 143	2.61	< 0.01	2.61	< 0.01
	EKAM 2 WKAM	75 100	2.78	< 0.01	2.78	< 0.01
	EKAM + BBAY WKAM + EKAM	200 143	2.49	< 0.05	2.95	< 0.01
	EKAM + BBAY WKAM	200 100	2.39	< 0.05	3.24	< 0.01
	WKAM + EKAM WKAM	143 100	0.17	0.8647	0.17	0.8647

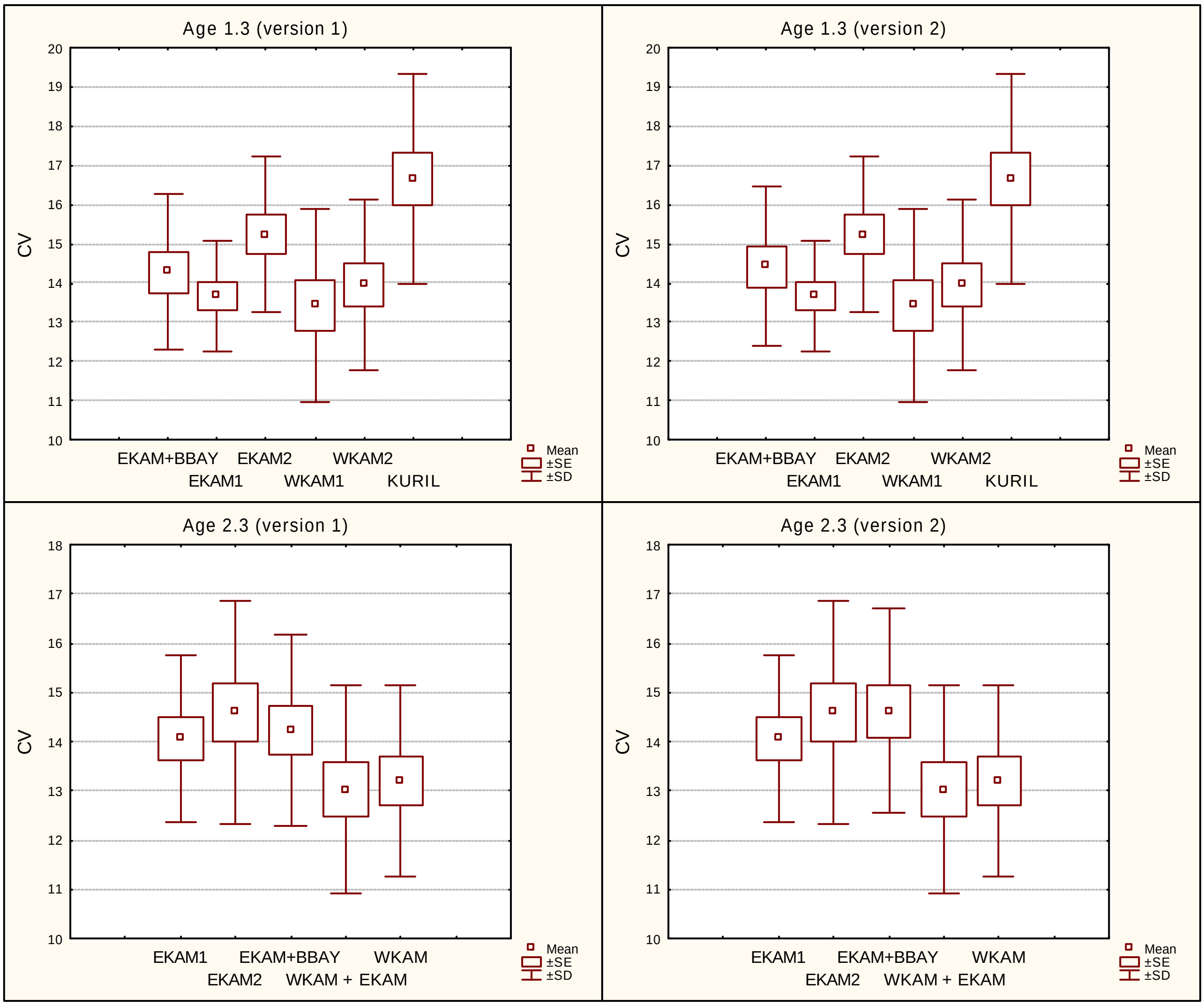

Fig. 5. Box and whisker plot of the clusters stocks of sockeye salmon in the 2001 scale pattern baselines for age 1.3 and 2.3 (two versions)

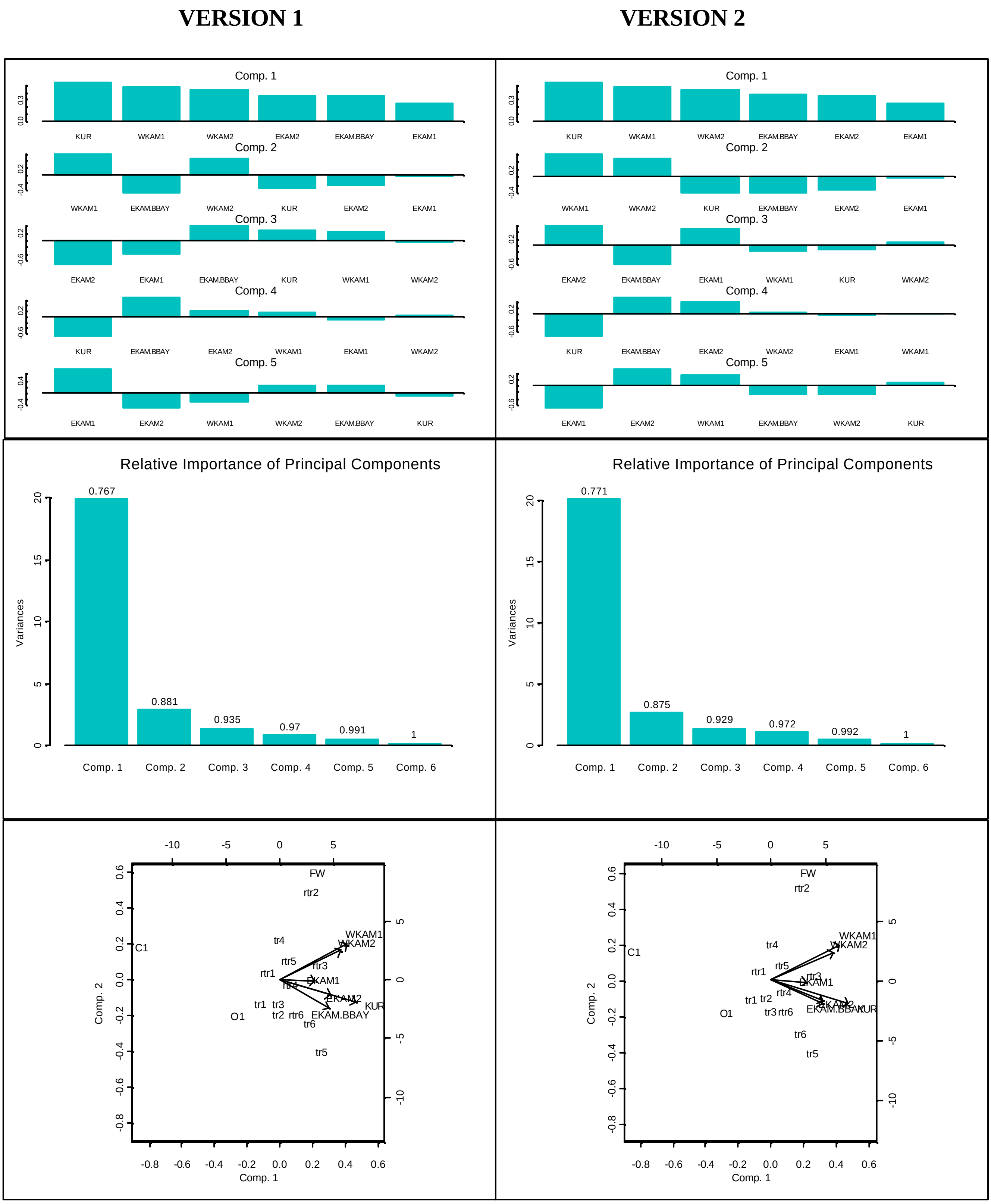

Fig. 6. Principal component analysis for scale baselines of sockeye salmon for age group 1.3 in 2001 (two versions)

VERSION 1 **VERSION 2**

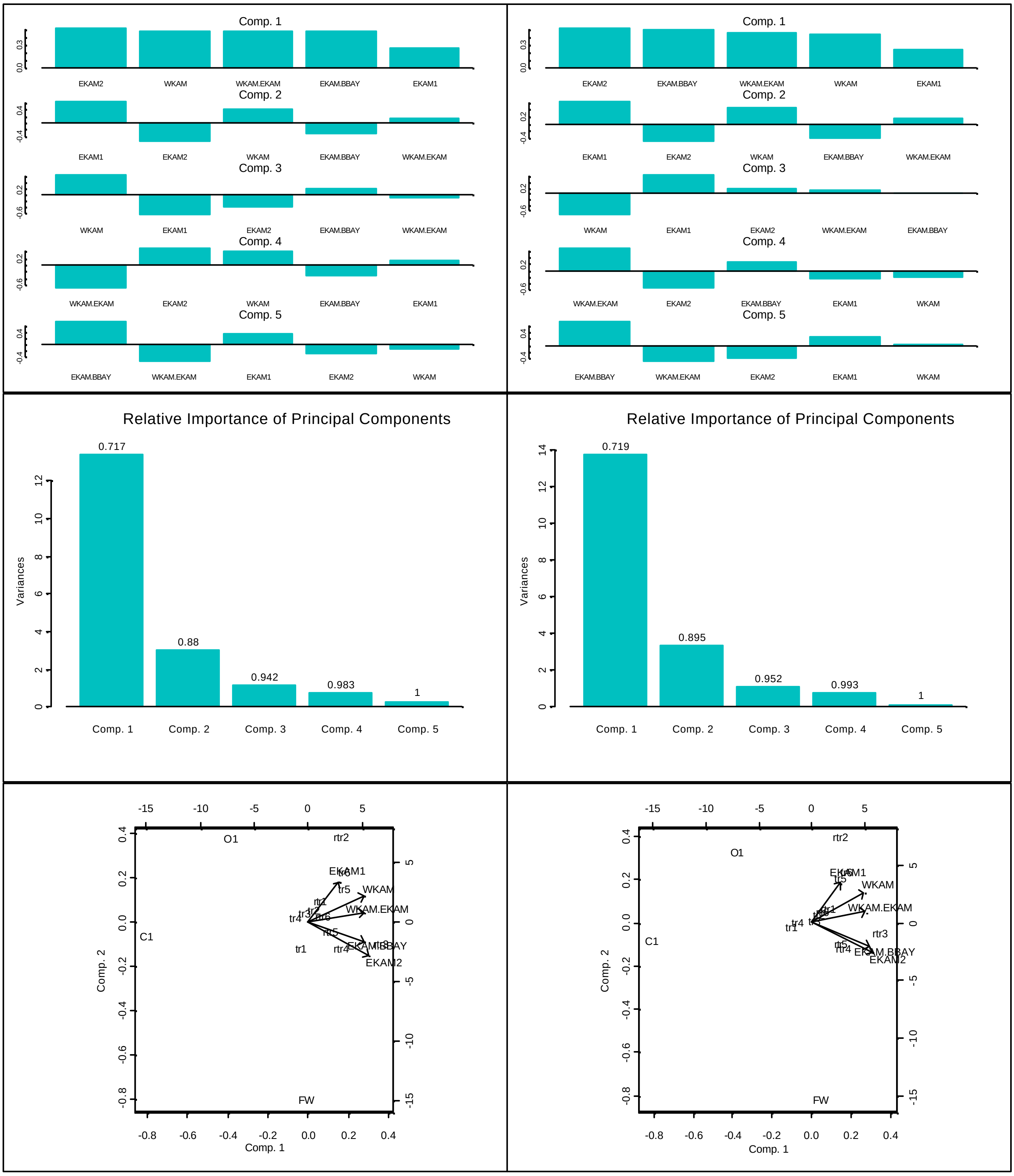

Fig. 7. Principal component analysis for scale baselines of sockeye salmon for age group 2.3 in 2001 (two versions)

Table 4. Baseline-dependent simulation results for the cluster-based of sockeye salmon in 2001 (age 1.3 – version 1), MLE/SE

Cluster	N	1	2	3	4	5	6
KURIL	34	1.0000 0.0273	0.0003 0.0604	0.0045 0.0911	0.0048 0.1077	0.0000 0.0007	0.0179 0.1646
EKAM+BBAY	178	0.0000 0.0019	0.9699 0.2051	0.0007 0.0620	0.0009 0.0727	0.0118 0.1363	0.0115 0.1544
WKAM 1	200	0.0000 0.0000	0.0017 0.0769	0.9346 0.3012	0.0004 0.0610	0.0278 0.2216	0.0308 0.2252
EKAM 1	100	0.0000 0.0000	0.0125 0.1591	0.0007 0.0670	0.9414 0.2627	0.0095 0.1407	0.0028 0.1332
WKAM 2	172	0.0000 0.0000	0.0000 0.0000	0.0539 0.2843	0.0499 0.2451	0.9494 0.2584	0.0026 0.1085
EKAM 2	200	0.0000 0.0313	0.0156 0.1624	0.0056 0.1361	0.0026 0.1204	0.0014 0.0884	0.9343 0.2877
Mean accuracy							95.5 %

Table 5. Baseline-dependent simulation results for the cluster-based of sockeye salmon in 2001 (age 1.3 – version 2), MLE/SE

Cluster	N	1	2	3	4	5	6
KURIL	34	0.9976 0.1030	0.0045 0.0920	0.0049 0.1104	0.0000 0.0005	0.0233 0.1776	0.0022 0.0909
WKAM 1	200	0.0000 0.0000	0.9376 0.2963	0.0005 0.0587	0.0296 0.2251	0.0322 0.2260	0.0028 0.0884
EKAM 1	100	0.0000 0.0000	0.0003 0.0516	0.9445 0.2569	0.0120 0.1492	0.0024 0.1147	0.0024 0.0953
WKAM 1	172	0.0000 0.0000	0.0516 0.2797	0.0479 0.2411	0.9485 0.2608	0.0025 0.1074	0.0000 0.0000
EKAM 2	200	0.0000 0.0031	0.0053 0.1342	0.0015 0.0990	0.0016 0.0900	0.9373 0.2796	0.0162 0.1631
EKAM+BBAY	578	0.0024 0.1031	0.0007 0.0637	0.0007 0.0759	0.0083 0.1197	0.0023 0.0849	0.9764 0.1828
Mean accuracy							95.7 %

Table 6. Baseline-dependent simulation results for the cluster-based of sockeye salmon in 2001 (age 2.3 – version 1), MLE/SE

Cluster	N	1	2	3	4	5
EKAM 1	50	0.9148 0.3143	0.0260 0.1989	0.0694 0.2998	0.0059 0.1427	0.0000 0.0002
EKAM+BBAY	200	0.0000 0.0002	0.9554 0.2362	0.0546 0.2620	0.0000 0.0001	0.0000 0.0000
EKAM 2	75	0.0002 0.0559	0.0012 0.0835	0.8567 0.4002	0.0000 0.0003	0.0000 0.0000
WKAM+EKAM	143	0.0850 0.3137	0.0057 0.1150	0.0193 0.1753	0.9864 0.1593	0.0000 0.0000
WKAM	100	0.0000 0.0000	0.0116 0.1352	0.0000 0.0000	0.0077 0.1101	1.0000 0.0155
Mean accuracy						94.3 %

Table 7. Baseline-dependent simulation results for the cluster-based of sockeye salmon in 2001 (age 2.3 – version 2), MLE/SE

Cluster	N	1	2	3	4	5
EKAM 1	50	0.9168 0.3115	0.0573 0.2836	0.0045 0.1315	0.0000 0.0002	0.0460 0.2486
EKAM 2	75	0.0001 0.0270	0.8531 0.4062	0.0000 0.0003	0.0000 0.0000	0.0003 0.0608
WKAM+EKAM	143	0.0831 0.3113	0.0184 0.1732	0.9883 0.1488	0.0000 0.0001	0.0068 0.1274
WKAM	100	0.0000 0.0000	0.0000 0.0000	0.0072 0.1069	1.0000 0.0155	0.0170 0.1528
EKAM+BBAY	200	0.0000 0.0000	0.0712 0.2907	0.0000 0.0000	0.0000 0.0000	0.9299 0.2862
Mean accuracy						93.8 %