FRI-UW-9119
October 1991

ESTIMATES OF ORIGIN OF COHO SALMON CAUGHT IN THE JAPANESE HIGH SEAS SQUID DRIFTNET FISHERY IN 1990

by

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Submitted to
International North Pacific Fisheries Commission
by the
United States National Section

THIS PAPER MAY BE CITED IN THE FOLLOWING MANNER:

Walker, R.V. 1991. Estimates of origin of coho salmon caught in the Japanese high seas squid driftnet fishery in 1990. (INPFC Doc.) FRI-UW-9119. Fish. Res. Inst., Univ. Washington, Seattle. 14 pp.

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ABSTRACT

The continent of origin of coho salmon caught in the Japanese high seas squid driftnet fishery in 1990 was determined by scale pattern analysis. Scales collected by U.S., Japanese, and Canadian observers on board commercial squid fishing vessels provided a direct sample of the coho by-catch of the fishery. These samples were compared to four groupings (standards) of inshore scale samples: Bolshaya River (western Kamchatka Peninsula); Kamchatka River (eastern Kamchatka); northern western Alaska (Norton Sound to central Bristol Bay); and southern western Alaska (southern Bristol Bay and north coast of the Alaska Peninsula). A maximum likelihood method was employed to calculate mixing proportion estimates of age 2.1 U.S.S.R. and western Alaska fish, and samples were bootstrapped to derive estimates of variance. In 1990 western Alaskan fish appeared to predominate in the fishery. Estimates of age 2.1 western Alaskan fish in the fishery were 74% overall (73.7% northern western Alaska, 0.9% southern western Alaska). The estimates obtained were higher than those of previous scale pattern studies of coho salmon origins in the Japanese traditional landbased driftnet salmon fishery, and are higher than the proportion of western Alaskan fish in the small number of recoveries of tags from the area of the squid fishery. Applying the estimated proportions of age 2.1 fish to all ages and using an estimate of total coho by-catch by the fishery yields estimated by-catches of 17,900 for U.S.S.R. coho and 52,500 for western Alaska fish.

INTRODUCTION

Most of the species caught in high seas squid driftnet fisheries are not under the jurisdiction of any single state. Salmonid species are an exception. The primary responsibility for these species is recognized under article 66 of the Convention on the Law of the Sea as belonging to the states where the individual stocks spawn. Because of this sense of ownership, it is important to determine the origins of salmonids caught in the high seas squid driftnet fisheries. In 1990 Canadian, Japanese, and U.S. observers on board Japanese commercial squid fishing vessels collected scales from salmonids incidentally taken (Int. N. Pac. Fish. Comm. 1991, Myers and Bernard 1991). These scales provide an adequate sample to estimate the origins of coho salmon in that fishery by means of scale pattern analysis.

Previous scale pattern studies have addressed the origin of coho salmon in and near the area of the Japanese traditional landbased driftnet salmon fishery, southwest of 46°N, 175°W (Myers et al. 1981; Walker and Harris 1982; Walker and Davis 1983; Kato and Ishida 1985, 1986, 1988, 1989; Walker 1990, 1991). In general most studies estimated that Asian coho predominate in that area, but that North American fish are present to some extent. Early summaries of oceanic distribution and origin of coho relied solely on tagging data, and no recoveries had been reported from in or near the area of the future squid driftnet fishery at that time (Godfrey 1965, Godfrey et al. 1975). The recent scale pattern studies cited above have usually reported updated tag recovery data. The majority of the few recoveries of fish tagged in or near the squid fishery area have come from the U.S.S.R., although some recoveries have been reported from western Alaska. No studies of origin using genetic stock identification, parasites, or morphometric techniques have been conducted on coho from the squid fishery area.

METHODS

SCALE SAMPLES

All scale samples measured were in the form of acetate impressions. Samples from U.S. fishery observers were provided by the U.S. observer program and were processed at the Fisheries Research Institute (FRI), School of Fisheries, University of Washington. Acetate impressions of Canadian and Japanese observer samples were provided to FRI by the U.S. National Marine Fisheries Service (NMFS). (See Myers and Bernard 1991 for details.) Impressions for Alaska stocks were provided by the Alaska Department of Fish and Game (ADF&G). Scale impressions from the Kamchatka and Bolshaya Rivers were provided by the Fisheries Agency of Japan (FAJ) and the U.S.S.R.'s Pacific Research Institute of Fisheries and Oceanography (TINRO).

AGE DETERMINATION

Ages were determined by the number of checks (decrease in spacing and thickness of circuli, and breakage, interbraiding, and cutting over of circuli) which were considered annuli (checks formed annually in the winter or spring). Age designation was by the European method, in which the number of freshwater annuli is separated from the number of ocean annuli by a period (Koo 1962). For example, an age 2.1 fish spent two winters in freshwater after emergence and one winter in the ocean. Since there were no samples of known-age coho from Alaskan or Asian streams to validate ages, any strong checks in the freshwater zone were considered annuli. Emphasis was placed less on the 'correctness' of the age than on consistency, that is that fish from Asia, North America, and high seas fishery samples having similar patterns of checks would be considered as the same age and would be analyzed together. Age determination of Alaskan and Asian samples was made as scales were measured, in part guided by ages determined by the agency that provided the scales. Scales from the fishery observer samples were aged earlier, as part of a separate study (Myers and Bernard 1991).

Age determination was in general agreement with ages listed on data sheets by ADF&G, but there was less agreement with ages of Bolshaya River fish on data sheets from TINRO. TINRO scientists tended to regard fewer freshwater checks as annuli, leading to a higher estimated proportion of age 1.1 fish. This is a similar circumstance to that encountered in earlier analyses of coho scales (Myers et al. 1981, Walker 1990). It is not considered a problem in this analysis, as all scales in both the standards and fishery samples were aged by one person and all scales with similar patterns of freshwater checks were analyzed together.

SCALE MEASUREMENT

Scales were measured using an image analysis system, the Optical Pattern Recognition System (OPRS, BioSonics, Inc., Seattle, WA; Walker 1987). A reference line was chosen which connected the posterior ends of the ocean annulus, and measurements were made on an axis 90° to this line. Distances were measured from the center of the focus of the scale. Because of resolution difficulties, measurements were not made of most freshwater circuli. The first measurement was at the outer edge of the last freshwater annulus, and subsequent measurements were made at the outer edge of each circulus thereafter, including circuli of freshwater plus growth if present, to the outer edge of the ocean annulus. A marker consisting of two very closely placed measurements (one OPRS sampling unit apart) was made to denote the beginning of the ocean annulus and separate the summer and winter growth of the first ocean year.

SAMPLE SIZES

For most of the samples from the 13 rivers used in this analysis, 60 scales of age 2.1 fish were measured (Table 1). For Asian stocks as many age 2.1 scales as possible were measured (Bolshaya: n=84; Kamchatka: n=141). For Yukon River fish, 30 scales were measured from each of three fisheries samples. All samples came from commercial or test fisheries near river mouths.

All measurable scales of age 2.1 fish (n=378) from observer samples were measured. Samples were collected from June through September, with the majority collected in July (298). The area where usable age 2.1 coho scales were collected was from 168°E to 158°W, and from 39°N to 46°N, with the majority collected between 170°E and 170°W and between 40°N and 42°N (218). See Myers and Bernard (1991) for maps of detailed locations of samples.

SCALE CHARACTERS

Measurement data were exported from OPRS internal files as ASCII files, which were in turn reformatted by a FORTRAN program. Reformatted data included biological and collection information on each scale and 20 measurement variables. All reformatted measurements are expressed in microns.

Individual circulus measurements were grouped in threes (triplets) up to a maximum of 45 circuli (15 triplets). As most scales did not contain this many circuli in the first ocean year, only those triplets for which all scales had a value were used. Under this criterion only the first through the seventh triplets were used (Table 2). Distance along the measurement axis of the freshwater zone through the end of the last freshwater annulus and of the first ocean summer growth were also used, as was the circulus count of the first ocean summer. Basic statistics for these ten variables were calculated for each stock; outliers were identified and those greater than four standard deviations from the mean were removed.

CONSTRUCTION OF STANDARDS

In line with recommendations from the International North Pacific Fisheries Commission (INPFC) Scale Pattern Analysis Workshop (Int. N. Pac. Fish. Comm. 1987) groupings based on similarity were attempted in forming standard samples composed of several stocks. The linear discriminant function analysis (LDA) program, 7M, of BMDP (Dixon 1988) was used to evaluate the similarity of individual stocks. LDA was used rather than a clustering approach because it was felt that the LDA algorithm was closer than clustering algorithms to the actual method used in allocating scales. Although the use of a large number of groups in LDA is not a valid approach when actually classifying groups, the method was used because it tries to discriminate or separate groups. Those samples that are difficult to separate can be considered as a natural grouping. An indication of the distance between groups can be seen in a two-dimensional plot of the first two canonical variables (which account for over 80% of the dispersion in this case) evaluated at the mean of each group. This plot is provided in output from BMDP 7M. BMDP 7M output also provides a table of the values of all canonical variables evaluated at group means. These values can be used as coordinates in a space of dimension n, where n is the number of canonical variables. Euclidean distances can be calculated between the groups using these coordinate values. A table of these distances can then be examined for stocks or groupings of stocks which are relatively closer together or further apart, and composite standards can be decided on. Canonical variable plots and tables of distance measures from the analysis of 1990 age 2.1 coho are provided as an example of the method (Fig. 1; Table 3).

Coho stocks from southeastern Alaska, British Columbia, Washington, Oregon, and California were not included in the analysis, as they were considered less likely to be present in the area of the fishery sampled by observers. All tag recoveries from these areas have come from east of 158°W (854 external tags, 144 coded-wire tags; Myers et al. 1990). Stocks from south central Alaska were also excluded. Nearly all tag returns (43 of 44; Myers et al. 1990) from these stocks have come from fish tagged in the Gulf of Alaska, east of 161°W, and in earlier analyses (Walker 1990) scales from this area were often confused in allocation models with scales from Asian stocks.

When all individual stocks were considered together, values of canonical variables from western Kamchatka Peninsula (Bolshaya River) and from eastern Kamchatka Peninsula (Kamchatka River) scales were each distinctive from other stocks (Fig. 1; Table 3). Kamchatka River scales may have been distinctive in part because they were of slightly poorer quality than other samples. Values from Norton Sound, Yukon River, and Kuskokwim River samples formed a cluster with samples from northern and central Bristol Bay (Togiak, Nushagak, and Naknek-Kvichak). This grouping was used as a northern western Alaska standard. Values from southern Bristol Bay (Egegik and Ugashik) and three stocks from the northern coast of the Alaska Peninsula formed a separate cluster, which was considered as a southern western Alaska standard. In summary four standard groupings from 13 stocks were used: Bolshaya R.; Kamchatka R.; northern and southern western Alaska. Means and standard deviations for variables used in this analysis for each standard grouping are presented in Table 4.

TEST OF THE MODEL

There are no accepted methods for estimating the accuracy of the maximum likelihood model. However, the maximum likelihood estimator uses the same likelihood values that are used by classification models. The jackknifed classification matrix from the BMDP 7M LDA model is presented as a crude indicator of the probable general accuracy of the maximum likelihood model, and to indicate directions of misclassification among the standards (Table 5). The overall unweighted accuracy of the four standard model was 78.1%. When misclassifications within continental groups are taken into account, overall North American accuracy was 91.3% and overall Asian accuracy was 85.3%.

CALCULATION OF MIXING PROPORTIONS OF UNKNOWNS

Estimates of proportions of fish from each of the standard groupings present in the fishery samples (unknowns) were obtained by a maximum likelihood method (Millar 1987, 1990) using a FORTRAN program written by R. Millar (Millar 1988). Ten variables were used; there was no selection of variables, following Davis's (1987) finding that inclusion of nondiscriminating variables had only a slight effect on classification accuracy. Confidence intervals (95%) were derived from ranked results of bootstrap runs (500 iterations) of the same program.

INTERCEPTION ESTIMATES

Interception estimates were calculated by applying estimated proportions for all observer samples to the total estimated decked coho by-catch by the Japanese high seas squid driftnet fishery (Pella et al. 1991). The estimate of Pella et al. was used as it included the estimated fraction of coho included in the unidentified salmonid by-catch. Pella et al. (1991) calculated estimates for decked (i.e., landed on the vessel) and total (including an estimated proportion from observed net dropouts) salmonid catch by species. The decked by-catch was used for this analysis. Proportions for the two North American standards were pooled, as were those from the two Asian standards. Pooled variances were also calculated, and were used to calculate 95% confidence intervals for the catch estimates. The variance for the decked coho by-catch is from Pella et al. (1991). The variance was large because of large variability in coho by-catch between squid vessels.

RESULTS

MIXING PROPORTION ESTIMATES OF UNKNOWN (FISHERY AREA) SAMPLES

As sample sizes for smaller strata were generally less than the recommended level of 100, mixing proportions were estimated for all observer samples combined (Table 6). Maximum likelihood estimates show northern western Alaskan fish predominating (74%), with Bolshaya fish the major secondary stock (18%). Kamchatka River fish were estimated to be present in lesser abundance (8%). Southern western Alaska estimates were very low (1%). The combined estimate for North American fish is 74.6%.

INTERCEPTION ESTIMATES

Provisional estimates of decked by-catches and 95% confidence intervals of age 2.1 North American- and Asian-origin coho salmon in the Japanese high seas squid driftnet fishery in 1990 are presented in Table 7. By-catches of North American age 2.1 fish in the fishery total 45,166, and those of Asia total 15,378. An estimate for the entire decked coho by-catch, including other age classes, can be calculated on the assumption that age 1.1 and 3.1 fish are from the same stocks in the same proportions as the age 2.1 fish. This assumption may not be entirely accurate, as in North America age 1.1 fish are more common in more southern stocks which were not included in the model. The total decked by-catch of North American coho by the fishery in 1990 would then be 52,518 (Table 8).

DISCUSSION

Results of this study indicate a high proportion of North American coho in the area sampled by observers. Other studies have found that U.S.S.R. streams are the predominant producers of fish in the Japanese traditional landbased driftnet salmon fishery area (Myers et al. 1981; Kato and Ishida 1985, 1986, 1988, 1989; Walker 1990). In some of these studies, estimates of North American coho were higher in eastern areas of high seas samples, closer to the location of squid fishery samples used in this study, but this pattern is not consistent.

There are many possible reasons for the difference between this study and those of the traditional landbased fishery. The squid fishery operates much further to the east than the landbased fishery does. Most (66%) of the observer samples are from east of 175°E, outside of the landbased salmon fishery area. In 1990 the abundance of North American coho may have been higher than that of Asian coho, or relative distribution of coho from the two continents may have shifted. The squid fishery vessels with observers on board may have been fishing in areas that happened to have higher concentrations of North American fish. The scale patterns of western Alaska fish in 1990 may have resembled those of some Asian stocks, such as North Okhotsk coast stocks, which were not in the model. The scales from Kamchatka River fish may not have been collected from the preferred body area and were of slightly poorer quality than other standards. The estimates do indicate that western Alaska coho are probably present in appreciable numbers in the squid fishery by-catch.

In 35 years of high seas salmon tagging experiments, there have been only 50 tag returns reported through 1990 from coho in the area represented by observer samples, 47 from the U.S.S.R. and three from western Alaska. In the area containing 78% of the samples, south of 42°N, there have been only two tag returns, both Asian. Although tag returns indicate predominance of Asian stocks in the northern squid fishery area, the small number of returns does not permit any firm conclusions to be drawn. In an earlier analysis (Walker 1990) I have discussed the difficulties, including possible differences in exploitation and reporting rates between the Soviet Far East and western Alaska, of using the small number of high seas coho tag returns in a quantitative manner.

The total by-catch of coho by the Japanese fishery seems to have been on the order of 70,000 fish in 1990, of which an appreciable proportion may be of western Alaskan origin. This does not include coho by-catch by Taiwanese and Korean squid fisheries, nor the coho caught by squid fishermen illegally targetting salmon, nor the dropouts from the net. Estimated interceptions of coho of western Alaskan origin are not large when compared to the 1990 inshore catches in that area of 777,000 (Geiger and Savikko 1991), but are not insignificant.

ACKNOWLEDGEMENTS

I would like to thank the observers and observer programs of Canada, Japan, and the United States for obtaining and providing scales from the squid driftnet fishery. I thank scientists of ADF&G, TINRO, and FAJ for collecting and providing scales used for the standard samples in this study. Several people have given welcome advice and reviewed this document: my colleagues at FRI, Kate Myers, Nancy Davis, and Dr. Robert Burgner. Information provided Dr. Michael Dahlberg and Dr. Jerome Pella of the National Marine Fisheries Service (NMFS) Auke Bay Laboratory was much appreciated. Funding for this work was provided through contract No. 50ABNF100027 of the Alaska Fisheries Science Center of the NMFS.

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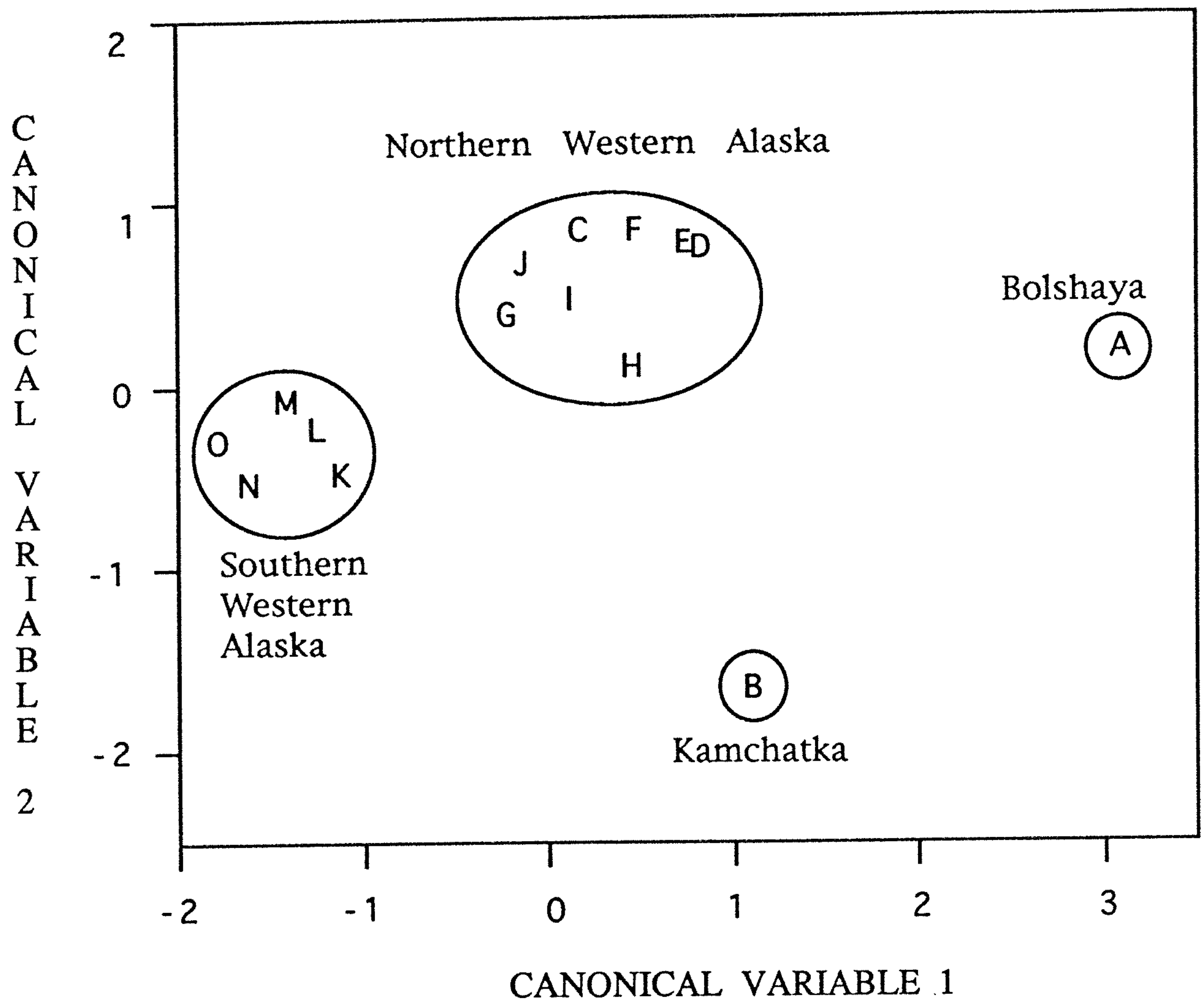

A = Bolshaya
B = Kamchatka
C = Unalakleet
D = Yukon Middlemouth
E = Yukon Big Eddy
F = Yukon Emmonak
G = Kuskokwim

H = Nushagak
I = Togiak
J = Naknek/Kvichak
K = Egegik
L = Ugashik
M = Nelson Lagoon
N = Ilnik Lagoon
O = Bear River

Figure 1. Plot of first two canonical variables from BMDP 7M linear discriminant function analyzed at the mean of each of 15 samples from Asia and western Alaska used in construction of four composite standards for analysis of 1990 age 2.1 coho scales. Note relatively good separation between four groupings.

Table 1. Number of scales measured from samples used in 1990 age 2.1 coho analysis.

Standard grouping	Region	Stock or Sample	N
Bolshaya R.	Western Kamchatka	Bolshaya R.	84
Kamchatka R.	Eastern Kamchatka	Kamchatka R.	141
Northern Western Alaska	Norton Sound	Unalakleet	60
	Yukon	Yukon River:	
		Middlemouth	30
		Emmonak	30
		Big Eddy	30
	Kuskokwim	Bethel	60
	Bristol Bay	Nushagak	60
		Togiak	60
		Naknek/Kvichak	60
Southern Western Alaska	Bristol Bay	Egegik	60
		Ugashik	60
	North Peninsula	Nelson Lagoon	60
		Ilnik Lagoon	60
		Bear R.	60

Table 2. Scale characters used in 1990 age 2.1 coho analysis. All distances measured along an axis 90° to a reference line connecting the posterior ends of the ocean annulus.

Name of Scale Character	Description
Freshwater size	Distance in the freshwater zone from the center of the focus to the outer edge of the last circulus in the last freshwater annulus
Ocean summer size	Distance in the first year of ocean growth from the edge of the last freshwater annulus to the edge of the first circulus in the ocean annulus; may include freshwater plus-growth after the last freshwater annulus
Ocean summer circulus count	Number of circuli in the first summer of ocean growth; may include circuli of freshwater plus-growth
Triplet 1	Distance from the edge of the last circulus in the last freshwater annulus to the edge of the third circulus in the first year of ocean growth; may include plus-growth
Triplet 2	Distance from the third to the sixth circulus in the first year of ocean growth
Triplet 3	Distance from the sixth to the ninth circulus in the first year of ocean growth
Triplet 4	Distance from the ninth to the twelfth circulus in the first year of ocean growth
Triplet 5	Distance from the twelfth to the fifteenth circulus in the first year of ocean growth
Triplet 6	Distance from the fifteenth to the eighteenth circulus in the first year of ocean growth
Triplet 7	Distance from the eighteenth to the twenty-first circulus in the first year of ocean growth

Table 3. Euclidean distances calculated from values of canonical variables analyzed at the mean of each of 14 samples from Asia and western Alaska used in construction of four composite standards for analysis of 1990 age 2.1 coho scales. Samples closer together than two measurement units were generally grouped together. See Table 1 for names of samples.

Stock	BOLS	KAM	UNAL	YUKM	YUKB	YUKE	KUSK	NUSH	TOG	NAKV	EGE	UGAS	NELS	ILNK	BEAR
BOLS	0.000														
KAM	3.027	0.000													
UNAL	3.351	2.766	0.000												
YUKM	2.848	2.481	1.058	0.000											
YUKB	2.761	2.527	0.879	0.580	0.000										
YUKE	3.059	2.638	0.720	0.650	0.391	0.000									
KUSK	3.538	2.522	0.911	1.359	1.197	1.002	0.000								
NUSH	3.063	2.130	1.819	1.473	1.461	1.541	1.634	0.000							
TOG	3.261	2.472	1.455	1.342	1.420	1.345	1.135	1.016	0.000						
NAKV	3.564	2.869	1.722	1.764	1.680	1.704	1.709	1.055	1.189	0.000					
EGE	4.378	2.606	2.240	2.539	2.424	2.341	1.613	1.803	1.748	1.726	0.000				
UGAS	4.427	2.836	2.176	2.525	2.403	2.326	1.596	1.900	1.767	1.665	0.397	0.000			
NELS	4.632	3.139	2.124	2.733	2.514	2.377	1.485	2.440	2.108	2.260	1.152	1.119	0.000		
ILNK	4.902	3.268	2.635	3.147	2.908	2.820	2.095	2.894	2.781	2.712	1.467	1.371	1.394	0.000	
BEAR	5.000	3.300	2.594	3.147	2.992	2.849	2.027	2.510	2.253	2.208	0.991	1.036	0.960	1.716	0.000

Table 4. Means and standard deviations of scale variables used in 1990 age 2.1 coho analysis, by standard grouping. All measurements are expressed in microns.

Standard	N	Size of Freshwater	Ocean Summer Circuli	Size of Ocean Summer	Triplet 1	Triplet 2	Triplet 3	Triplet 4	Triplet 5	Triplet 6	Triplet 7
Bolshaya	84	376.4 (58.5)	24.1 (2.7)	1105.2 (172.2)	110.5 (18.4)	140.5 (24.8)	161.2 (19.1)	161.1 (26.6)	138.9 (28.7)	124.8 (21.5)	129.4 (19.2)
Kamchatka	141	497.3 (92.9)	26.7 (5.1)	1182.1 (264.9)	96.0 (19.4)	109.5 (25.2)	132.0 (23.9)	146.1 (23.1)	150.0 (23.3)	149.6 (23.6)	141.8 (23.7)
N. Western Alaska	390	497.8 (82.5)	26.9 (2.6)	1396.6 (136.1)	111.6 (21.3)	138.4 (26.5)	161.2 (23.3)	170.9 (21.2)	176.4 (22.0)	177.3 (19.4)	171.8 (19.5)
S. Western Alaska	300	605.2 (104.1)	26.3 (2.6)	1424.0 (126.1)	105.6 (17.9)	124.7 (30.0)	157.7 (33.0)	181.2 (29.3)	192.0 (26.8)	191.8 (22.6)	186.9 (19.5)

Table 5. Jackknifed classification matrix for 1990 age 2.1 coho model from BMDP 7M. Information provided as crude index of accuracy of the maximum likelihood models and is not intended to represent the true accuracy of the models.

Overall accuracy: 78.1%

		Calculated Decision			
Correct Decision	N	Bolshaya	Kamchatka	N. Western Alaska	S. Western Alaska
Bolshaya	84	75 (89.3)	2	7	0
Kamchatka	141	11	104 (73.8)	12	14
N. Western Alaska	390	11	34	286 (73.3)	59
S. Western Alaska	300	0	15	57	228 (76.0)

Table 6. Provisional maximum likelihood mixing proportion estimates for 1990 age 2.1 coho. Estimates utilize Millar's (1988) method with confidence intervals derived from bootstrapping (500 runs).

	Bolshaya		Kamchatka		N. Western Alaska		S. Western Alaska	
N	Est.	95% CI	Est.	95% CI	Est.	95% CI	Est.	95% CI
378	.175	(.101-.253)	.079	(.035-.136)	.737	(.637-.816)	.009	(.000-.038)

Table 7. Provisional estimated decked by-catch of age 2.1 coho of Asian and western Alaskan origin in the Japanese high seas squid driftnet fishery areas in 1990. Total decked coho by-catch estimate from Pella et al. (1991). Confidence intervals calculated using bootstrap-derived variances for by-catch estimate and pooled variances from bootstrap-derived individual variances for two Asian (Bolshaya and Kamchatka) and two Alaskan standard groupings (northern and southern western Alaska).

	Total Est.	Age 2.1		Asian origin 2.1		Western Alaskan origin 2.1	
	By-catch	Prop.	By-catch	Prop.	By-catch	Prop.	By-catch
	70,400	.86	60,544	.254	15,378	.746	45,166
95% CI	(3,564-137,236)				(0-30,880)		(1,971-88,361)

Table 8. Provisional estimated decked by-catch of coho of Asian and western Alaskan origin in the Japanese high seas squid driftnet fishery in 1990. Estimates made by extending estimated proportions of age 2.1 fish to all ages.

Total Est.	Asian origin		Western Alaskan origin	
By-catch	Prop.	Catch	Prop.	Catch
70,400	.254	17,882	.746	52,518