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Preliminary Report on Genetic Diversity of Southern Southeast Alaska Chum Salmon Populations

July 1989

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PRELIMINARY REPORT ON GENETIC DIVERSITY OF SOUTHERN SOUTHEAST ALASKA CHUM SALMON POPULATIONS

by

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ABSTRACT

Using protein electrophoresis, genetic data were obtained from adult chum salmon (Oncorhynchus keta) collected in 1986 and 1987 from 32 streams in central and southern Southeast Alaska. Genetic relationships among collections were evaluated by three methods: principal component analysis, maximum-likelihood evolutionary trees, and unweighted pair-group arithmetic average clustering of Rogers' and Nei's genetic distances. All three clustering analyses showed that chum salmon collected from Prince of Wales Island were distinct from fish collected in streams emptying into inside waters which include Portland Canal, Behm Canal, and Revillagigedo Island. Log-likelihood ratios indicated that far more heterogeneity existed between regions than within regions. Comparison of data from this study to results from a previous study of British Columbia chum salmon populations showed significant genetic differences between some chum salmon populations from northern British Columbia and Southeast Alaska. Our results indicate that genetic data will be useful for stock separation problems near the U.S.-Canada border. It is recommended that development of a genetic baseline in Southeast Alaska be continued and that the baseline in northern British Columbia be improved to include an additional seven loci at which substantial genetic variation exists.

CONTENTS

INTRODUCTION

Genetic diversity of chum salmon (Oncorhychus keta) populations in North America has only recently been reported. The genetic structure of western Canadian populations has been described in Beacham et al. (1987), and the Washington Department of Fisheries is presently using starch gel electrophoresis to identify Washington chum stocks. We examined the genetic structure of chum salmon in southern Southeast Alaska to determine if genetic divergence exists among streams in this area or among regions near the northern U.S.-Canada boundary. Prior to our study, little genetic analysis had been done with Southeast Alaska chum salmon.

This project was a feasibility study; we subsampled fish collected from Southeast Alaska streams in 1986 and 1987, and examined them electrophoretically to obtain information about the genetic relationships among these collections. A lack of heterogeneity among collections or a lack of differences between U.S. and Canadian stocks (for which inadequate data presently exists) would indicate that the technique has little promise for stock separation problems in this area. On the other hand, useful differences identified from a preliminary look using subsamples would be amplified when the entire set of samples has been analyzed. In addition, further resolution might also be identified.

Using guidelines for running starch-gel electrophoresis on chum salmon developed by the Washington Department of Fisheries (S. Phelps, personal communication), plus procedures that we

developed, we obtained preliminary data from chum salmon collected from 32 Southeast Alaska streams in 1986 and 1987. Using that preliminary data, we examined the genetic relationships among the populations to test for distinctive stream specific differences or regional differences near the U.S.-Canada boundary that would be useful for multi-stock separation. Here we report those results.

MATERIALS AND METHODS

Samples

Tissues were sampled from approximately 100 adult salmon returning to each of the streams in the study. In 1986, chum salmon tissue samples were collected from 28 streams. Four new streams and 3 of the original 28 streams were sampled in 1987 (Table 1; Fig. 1). Samples were collected from July to October, primarily from streams on Prince of Wales Island and nearby islands to the west, and from streams to the east of Revillagigedo Island and the mainland that drain into Portland Canal, Boca de Quadra, and Behm Canal (Table 1; Fig. 1). Letters in parenthesis after stream names are used throughout this report for ease of reference to Figure 1.

An eye and samples of liver, skeletal muscle, and heart from a single fish were packaged in Whirl-pak[1] bags and put on ice or gel-ice immediately. Subsequently, they were frozen at

[1]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

Table 1.--Group designation (letters correspond to streams listed in Figs. 1-4, 6-8), location, date of collection, and numbers of chum salmon samples used for electrophoretic analysis. Districts are Alaska Department of Fish and Game Statistical Areas. N = number of samples.

Group design.	Location	Date	n
	District 101--Behm Canal-Portland Canal-Boca de Quadra		
A.	Fish Creek	9/05/86	100
		8/26/87	50
B.	Tombstone River	8/10/86	110
C.	Marten River	8/09/86	105
D.	Keta River	7/25/86	103
E.	Blossom River	7/26/86	107
F.	Wilson River	8/08/86	103
G.	Traitor's Creek	8/20/86	101
H.	Carroll River	8/19/86	100
I.	Portage Creek	7/30/86	109
J.	King Creek	7/29/86	100
K.	Klahini River	8/12/86	102
L.	Eulachon Creek	8/13/86	91
M.	Grant Creek	8/14/86	127
N.	Herman River	7/28/86	100
	District 102--East Prince of Wales Island		
O.	Kugel Creek	9/23/86	104
P.	Aiken Creek	9/22/86	100
Q.	Disappearance Creek	9/21/86	100
R.	Lagoon Creek	9/20/86	102
S.	Old Tom Creek	9/24/86	100
T.	Cabin Creek	9/26/86	103
U.	Karta River	9/25/86	100
	District 103--West Prince of Wales Island-western islands		
V.	Coco Harbor	9/24/87	100
W.	Breezy Bay	9/12/86	100
		9/22/87	100
X.	Port Real Marina	9/10/86	100
Y.	Cruz Cove	9/08/86	84
		9/26/87	57
Z.	Tokeen Creek	9/08/86	103
	District 105--West Sumner Strait		
a.	Irish Creek	8/24/86	100

Table 1.--Continued.

Group design.	Location	Date	n
	District 107--Ernest Sound-Bradfield Canal		
b.	Harding River	8/22/86	95
	District 108--Stikine River		
c.	North Arm Creek	8/10/87	81
	District 109--South Chatham Strait		
d.	Lover's Cove Creek	8/19/87	100
	District 110--East Frederick Sound		
e.	Donkey Creek	8/25/86	100
	District 115--Lynn Canal		
f.	Herman Creek	10/17/87	>40

-20°C, and shipped to the Auke Bay Laboratory where they were stored at -85°C until analyzed.

Protein electrophoresis was conducted as described by Aebersold et al. (1987). Buffer systems that were used are listed in Table 2. Specific enzyme activities (Table 3) were stained according to Harris and Hopkinson (1976) and Aebersold et al. (1987). Loci for which data were routinely obtained are listed in Table 4.

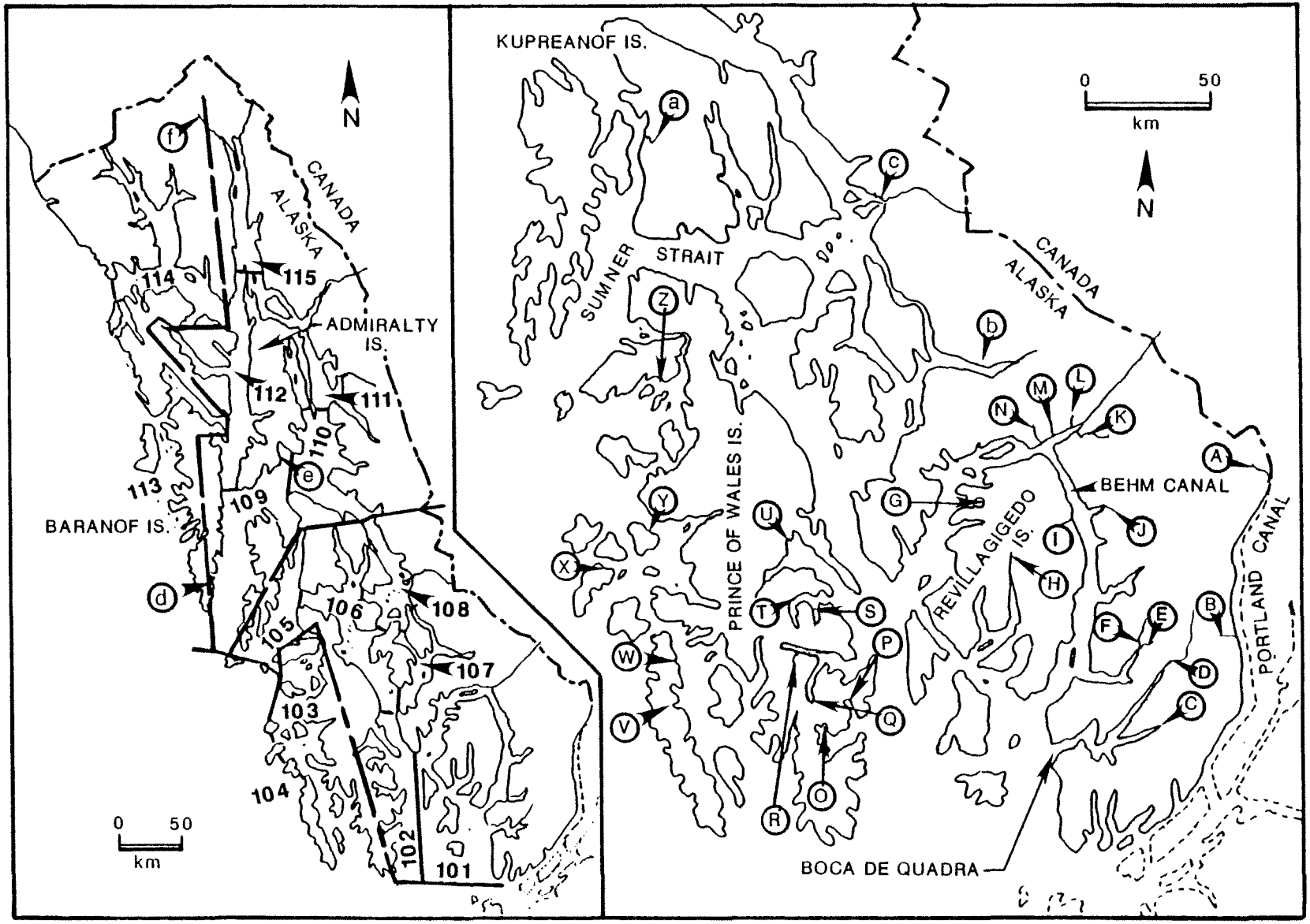

Figure 1.--Sampling sites for chum salmon in Southeast Alaska for 1986 and 1987. Letters correspond to streams listed in Table 1, and Figs. 2, 3, 4, 6, 7, and 8. ADF&G statistical areas are designated by three digit codes.

Table 2.--Buffer systems used for electrophoresis of Southeast Alaska chum salmon samples.

TC-1	electrode buffer pH 7.0 0.135 M tris(hydroxymethyl)amino methane 0.040 M citric acid Gels are made from a 1/20 dilution of electrode buffer. (Shaw and Prasad 1970).
R	gel buffer pH 8.5 0.03 M tris(hydroxymethyl)amino methane 0.005 M citric acid electrode buffer pH 8.1 0.06 M lithium hydroxide 0.3 M boric acid Gels are made using 99% gel buffer and 1% electrode buffer. (Ridgway et al. 1970).
CA6.1 and CA7	electrode buffer pH 6.1 or 7.0 0.04 M citric acid adjusted to desired pH with N-(3-aminopropyl)-morpholine Gels are made from a 1/20 dilution of electrode buffer. (Clayton and Tretiak 1972).
CAME7.2 and CAME6.8	(Modified from CA7 buffer) electrode buffer pH 7.2 or 6.8 0.04 M citric acid 0.01 M disodium ethylenediaminetetraacetate adjusted to desired pH with N-(3-aminopropyl)-morpholine Gels are made from a 1/20 dilution of electrode buffer. (Aebersold et al. 1987).
MF	stock solution pH 8.7 0.9 M tris(hydroxymethyl)amino methane 0.5 M boric acid 0.02 M disodium ethylenediaminetetraacetate (EDTA) Gels are made from a 1/20 dilution of stock. Buffer is a 1/5 dilution of stock. (Markert and Faulhaber 1965).
TC-4	electrode buffer pH 5.8 0.223 M tris(hydroxymethyl)amino methane 0.086 M citric acid titrate with 10 M sodium hydroxide Gels are made from a 1/27.5 dilution of electrode buffer. (buffer "a" of Schaal and Anderson 1974).

Table 3.--Enzymes initially screened, their Enzyme Commission (EC) numbers (International Union of Biochemistry 1984), and abbreviations. Peptidases are designated according to their substrate specificity. Pep(LGG) is peptidase B activity (Frick 1983).

Enzyme	EC Number	Abbreviation
Aconitate hydratase	4.2.1.3	AH
Adenosine deaminase	3.5.4.4	ADA
Alanine aminotransferase	2.6.1.2	ALAT
Aspartate aminotransferase	2.6.1.1	AAT
Creatine kinase	2.7.3.2	CK
Esterase	3.1.1.*	ESTD
N-Acetyl-b-glucosaminidase	3.2.1.30	bGA
Glucosephosphate isomerase	5.3.1.9	GPI
Glycerol-3-phosphate dehydrogenase	1.1.1.8	G3P
Isocitrate dehydrogenase	1.1.1.42	IDH
Lactate dehydrogenase	1.1.1.27	LDH
Malate dehydrogenase	1.1.1.37	MDH
Malic enzyme	1.1.1.40	ME
Mannose-6-phosphate isomerase	5.3.1.8	MPI
Peptidase	3.4.*.*	
glycyl-leucine activity		PEP(GL)
leucyl-glycyl-glycine activity		PEP(LGG)
leucyl-leucine		PEP(LL)
Phosphoglucomutase	5.4.2.2	PGM
6-Phosphogluconate dehydrogenase	1.1.1.44	PGDH
Superoxide dismutase	1.15.1.1	SOD

Table 4.--Protein coding loci (May 1980) for enzymes resolved in this study and the tissues and buffers in which they were resolved. Peptidase loci are designated according to their substrate specificity. The buffers are designated by the acronyms given in Table 1. L = liver, H = heart, M = muscle, E = eye.

Enzyme	Locus	Tissue	Buffer	Level of variability[a]
Aconitate hydratase	mAh-3	L,H	TC-4,CAME7.2	1,4
	Ah-1	L,H	TC-4,CAME7.2	1,3
Adenosine deaminase	Ada-1	L	CA6.1	1,4
	Ada-2	L	CA6.1	1,2
Alanine aminotransferase	Alat	M	MF	4
Aspartate aminotransferase	mAat-1[c]	M,H	CAME6.8,CA7	4
	Aat-1,2[c]	H,M	CA7,CAME6.8	4
	Aat-3[c]	E	R	4
Creatine kinase	Ck-1	M	R	2
	Ck-2	M	R	2
	Ck-5[c]	E	R	2
Esterase	Est-D[c]	M	MF	4
Glucosephosphate isomerase	Gpi-1,2[c]	M,H	R	2
	Gpi-3[c]	M,H	R	3
Glycerol-3-phosphate dehydrogenase	G3p-1[c]	M	TC-4	2
	G3p-2[bc]	H	CA7	4
Isocitrate dehydrogenase	Idh-1[bc]	M	CAME6.8	4
	Idh-2[c]	M	CAME6.8	2
	Idh-3[b]	L	CAME7.2	4
	Idh-4	L	CAME7.2	1,3
Lactate dehydrogenase	Ldh-1[c]	M	R	4
	Ldh-2[c]	M	R	2
	Ldh-3[c]	M,H,E	R	2
	Ldh-4[c]	M,H,E	R	3
	Ldh-5[c]	E	R	3

Table 4.--Continued

Enzyme	Locus	Tissue	Buffer	Level of variability[a]
Malate dehydrogenase	Mdh-1,2[b]	L,M	CAME7.2,CAME6.8	1,4
	Mdh-3,4[b]	M,H	CAME6.8,CA7,TC-4	4
Malic enzyme	Me-1[bc]	M,H	TC-4	4
	Me-2	M,H	TC-4	1,3
Mannose-6-phosphate isomerase	Mpi[bc]	H	CA7	4
Peptidases	Pep(Gl)	H	R	3
	Pep(Lgg-1)[bc]	H,M,E	R	4
Phosphoglucomutase	Pgm-1	H	CA7	4
	Pgm-2[c]	H,M	CA7,R	3
6-Phosphogluconate dehydrogenase	Pgdh[bc]	M	CAME6.8	3
Superoxide dismutase	Sod	L	R	3

[a]1 poor resolution
2 monomorphic
3 variable; most abundant allele > 0.95
4 variable; most abundant allele < 0.95
[b]Reported by Beacham et al. (1987).
[c]Loci used for analysis of all collections and to obtain Figures 2, 3, and 4.

Analysis

Departure from Hardy-Weinberg expectations was examined with chi-square goodness-of-fit tests. Homogeneity of allelic frequencies among collections was examined using log-likelihood ratio analysis (G-test, Sokal and Rohlf 1981). Pooling of genotypic or allelic frequencies, respectively, eliminated classes with expected values less than four. Genetic variation at Pgm-1 involved a "null" allele. Unlike a normal allele, a "null" allele does not produce a gene product that stains; consequently, only two phenotypes (banding patterns) are detectable, a single band that reflects the presence of the normal allele (either as a homozygote or heterozygote) or the absence of a band (a homozygote for the "null" allele). For most loci all genotypes are distinguishable. For the G-test involving Pgm-1, phenotypic frequencies were used rather than allelic frequencies.

Variation at co-migrating duplicated loci (isoloci, Allendorf and Thorgaard 1984) was treated as if one-half of the variation were at each locus.

Relationships among the collections were examined in three ways: 1) principal component analysis of allelic frequencies which were arcsine-square root transformed (Wilkinson 1986), 2) maximum-likelihood evolutionary trees (Felsenstein 1973, 1984), and 3) unweighted pair-group arithmetic average clustering (UPGMA, Sneath and Sokal 1973) of Rogers' (1972) and of Nei's (1972, 1978) genetic distances.

Relationships based on geographical proximity were also examined using hierachical log-likelihood ratio analysis (Sokal

and Rohlf 1981). The first step in the process involved computing heterogeneity among collections within each Alaska Department of Fish and Game statistical area (Fishing District). If there was none, the collections were pooled. Subsequently, geographically adjacent districts were compared. When heterogeneity was observed among collections within a district, the source(s) of the heterogeneity was identified.

RESULTS

Electrophoretic data were obtained for the chum salmon subsamples for 26 loci and 3 isoloci (Appendix Table A). Of these, 7 loci and 1 isolocus were monomorphic for all populations examined. Twelve of the remaining 19 loci and 2 of the isoloci had substantial variability with the common allele present at a frequency of less than 0.95 in at least one population (Table 4). Tests for conformity of phenotypic frequencies to those predicted for Hardy-Weinberg equilibrium failed in only 5 of the 101 possible tests, the rate of failure to expect using a $\underline{P} = 0.05$ test criterion.

Allele frequency data of 23 loci which had been obtained for all collections, were used to examine genetic relationships among the collections. These loci are designated in Table 4. Principal component analysis clearly separated Prince of Wales Island collections from the mainland and Revillagigedo Island collections to the east (Fig. 2). Collections from other Southeast Alaska locations were not as well resolved by principal component analysis. For example, Donkey Creek (e) on Admiralty Island, Herman Creek (f) in the Chilkat River system,

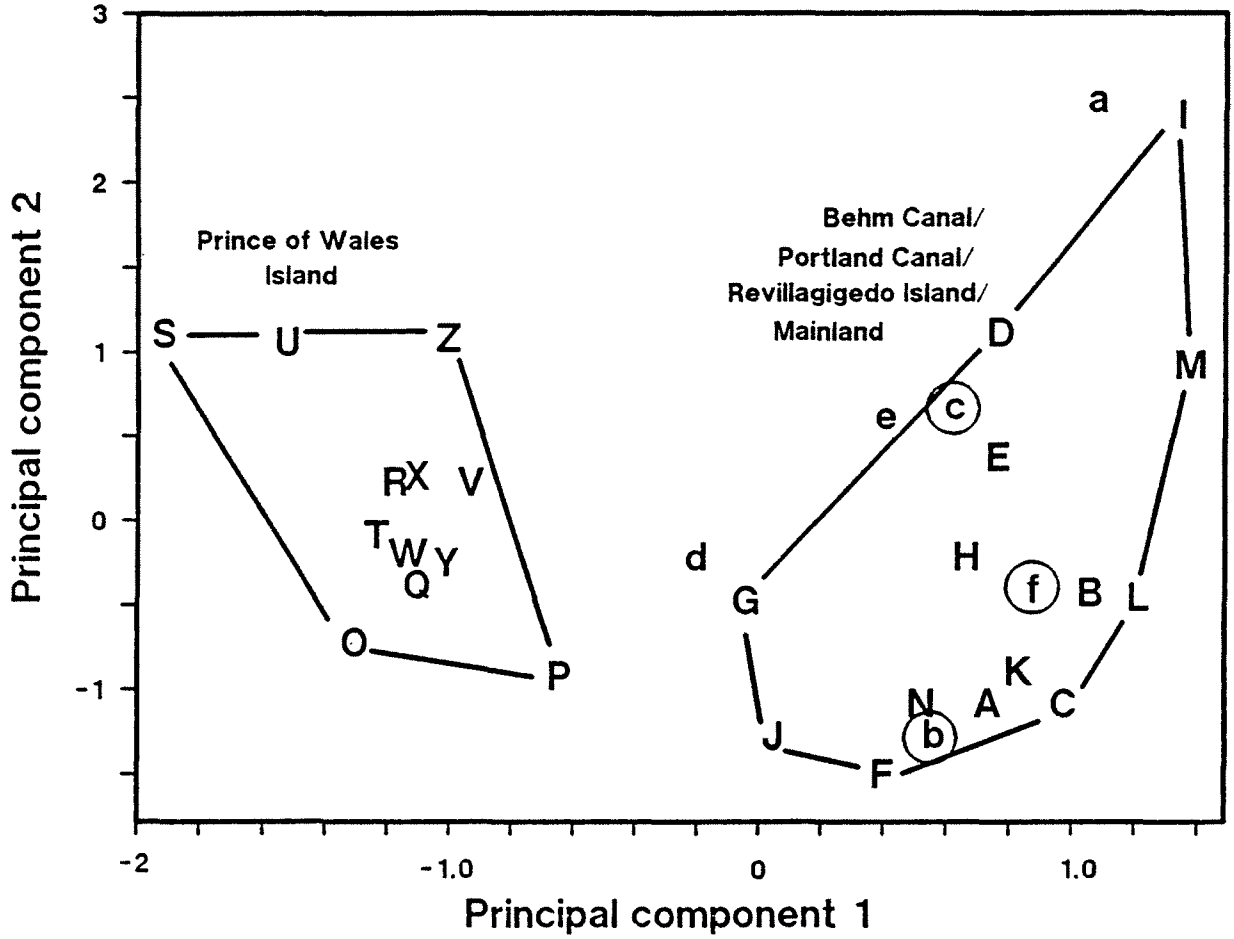

Figure 2.--Principal component analysis of Southeast Alaska chum salmon allelic frequency data. Letters correspond to streams in Fig. 1 and Table 1. The collections had data for 23 loci (see Appendix Table A). Circled letters within aggregations indicate collections not geographically associated with the aggregation.

Irish Creek (a) on Kupreanof Island, and Lover's Cove Creek (d) on south Baranof Island actually clustered near the eastern populations (Fig. 1).

UPGMA clustering of Rogers' genetic distances (Fig. 3) and Nei's distances (Fig. 4) between collections indicated that Prince of Wales collections differed from collections to the east. Both dendrograms showed that the Lover's Cove collection was distinct from all others.

The maximum-likelihood tree (Fig. 5) produced from Felsenstein's (1973, 1984) continuous maximum-likelihood program (CONTML) also shows that the Prince of Wales Island collections are distinct from eastern collections and from the Lover's Cove (d) collection (Fig. 1). Alternative topologies involved rearrangements within local aggregations only.

We also examined the relationships among 19 collections for which data at all 30 loci were present. These loci include all the resolvable loci except Pep(G1) and Sod (Table 4). Results of these analyses were quite similar to results obtained using fewer loci but more populations (Fig. 6, 7, 8, and 9).

All the clustering analyses indicated a geographic component in the genetic relationships among southern Southeast Alaska chum salmon. These geographical relationships were further examined using hierarchical log-likelihood ratio analysis to evaluate heterogeneity within and among regions (Table 5). Twelve loci were sufficiently variable to be useful for this analysis.

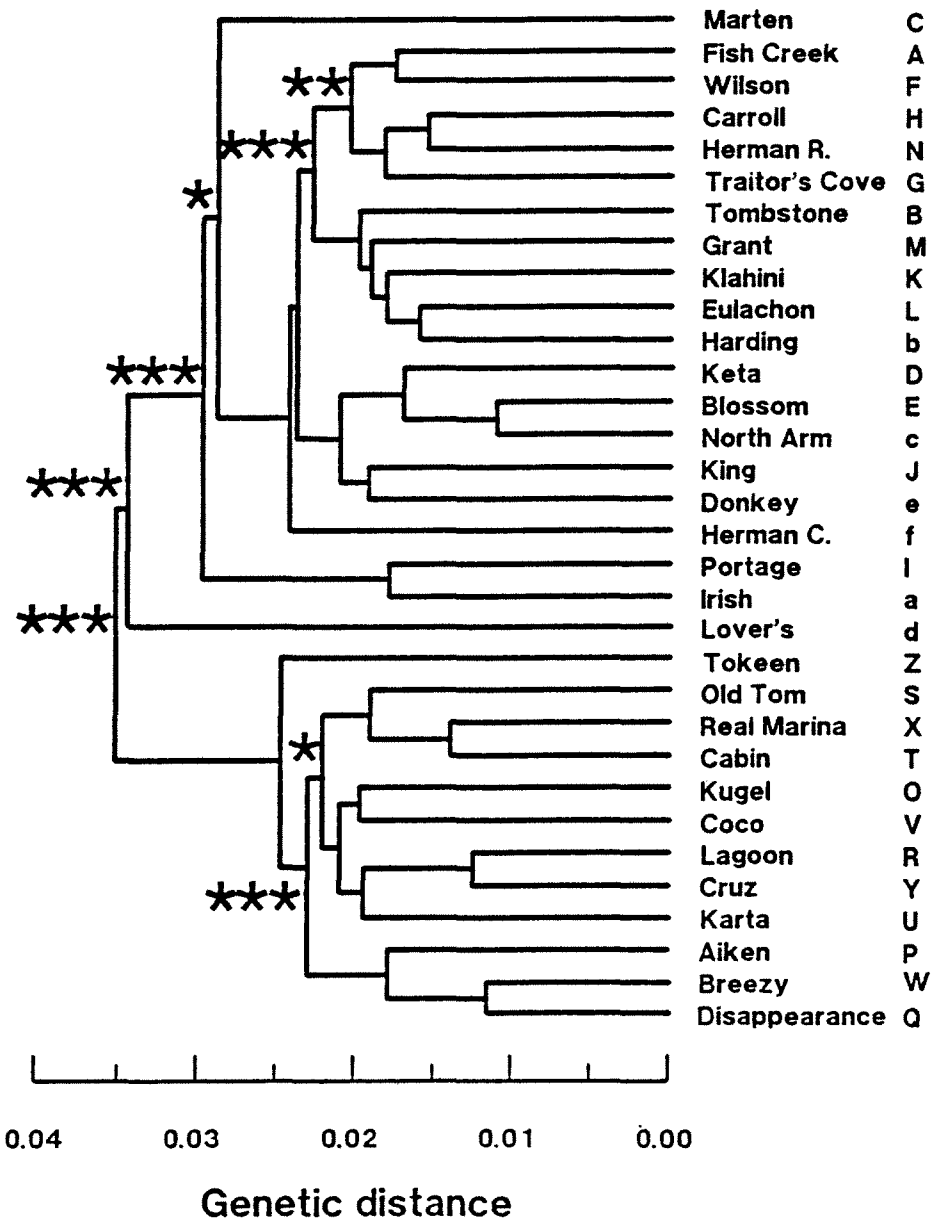

Figure 3.--Dendrogram reflecting genetic relationships using Rogers' (1972) genetic distances. These collections had data for 23 loci (see Appendix Table A). The dendrogram was obtained from UPGMA clustering (Sneath and Sokal 1973). Heterogeneity between the two branches joined at a node was determined by log-likelihood ratios (* $P < 0.05$, ** $P < 0.01$, and *** $P < 0.001$).

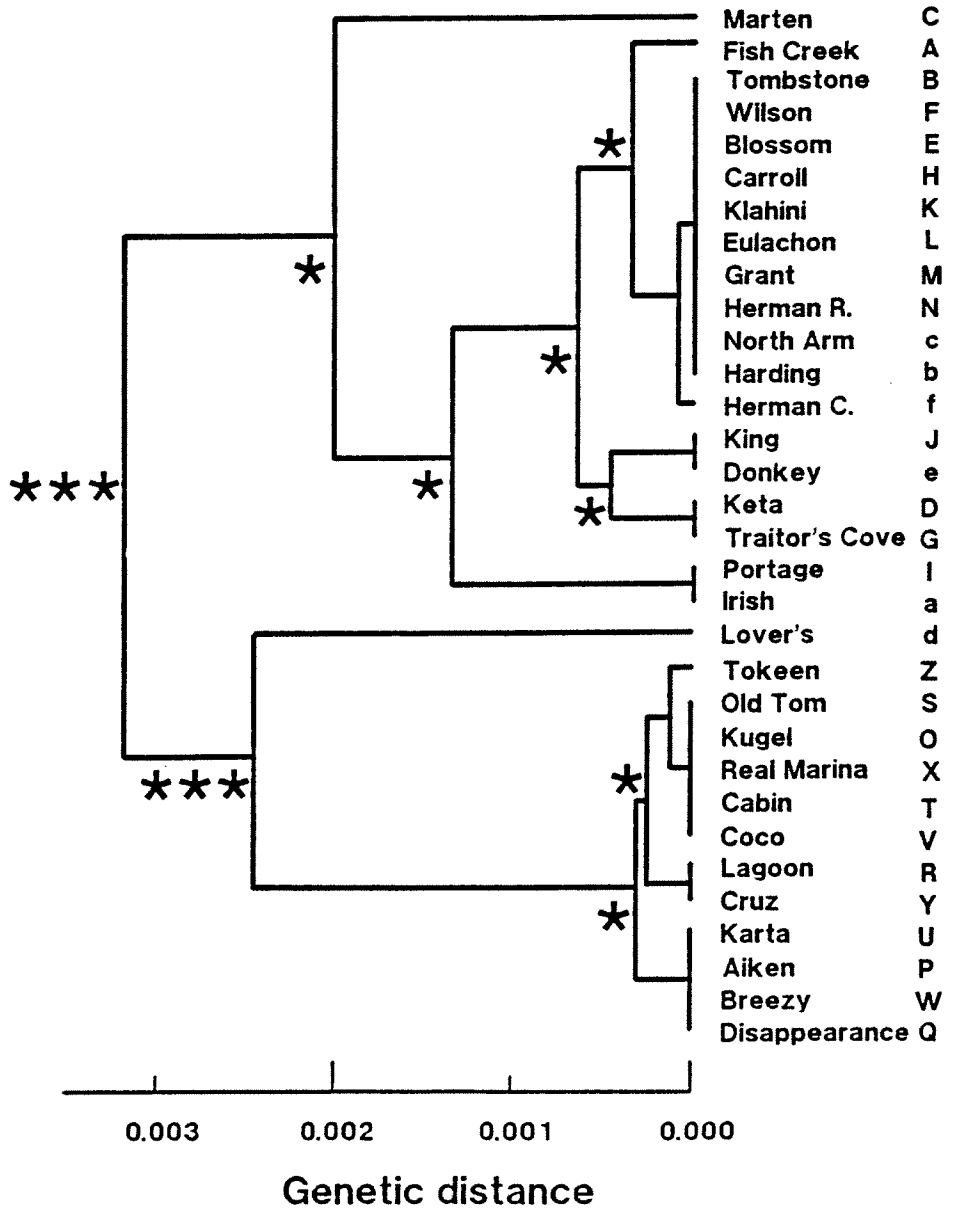

Figure 4.--Dendrogram reflecting genetic relationships using Nei's (1972, 1978) genetic distances. These collections had data for 23 loci (see Appendix Table A). The dendrogram was obtained from UPGMA clustering (Sneath and Sokal 1973). Heterogeneity between the two branches joined at a node was determined by log-likelihood ratios (* $P < 0.05$ and *** $P < 0.001$).

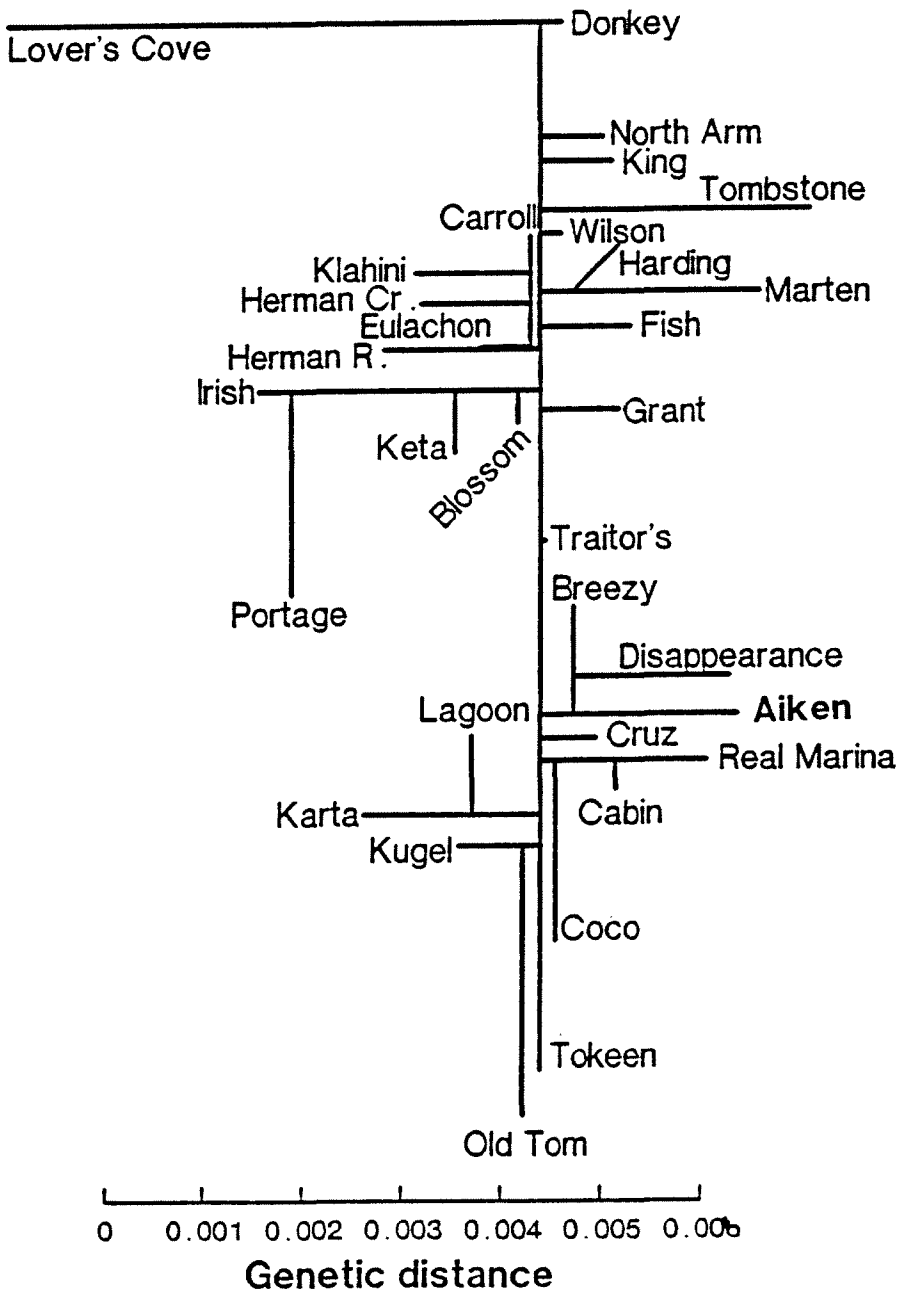

Figure 5.--Maximum-likelihood tree (Felsenstein 1973, 1984) estimate from genetic distances (Cavalli-Sforza and Edwards, 1967). Genetic distance estimates were made from 23 loci (see Appendix Table A).

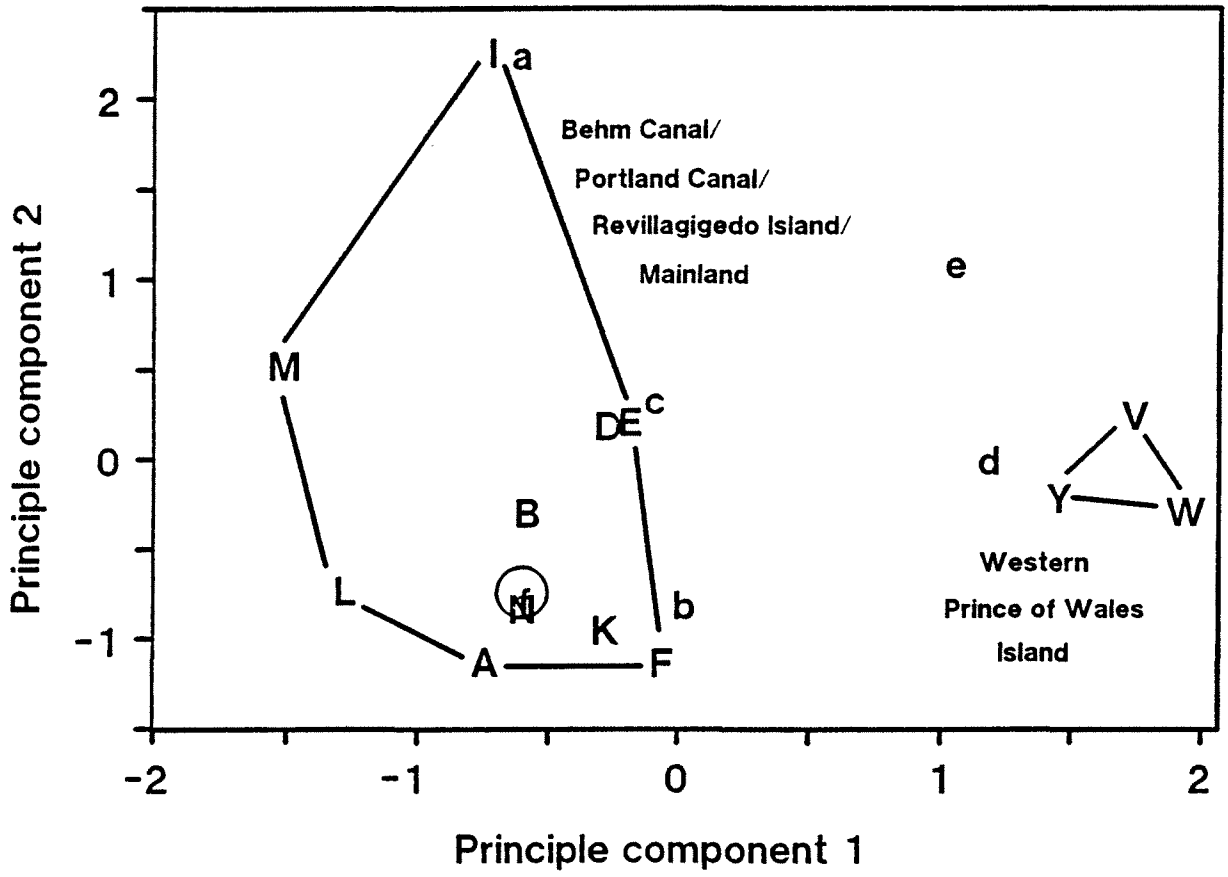

Figure 6.--Principal component analysis of Southeast Alaska chum salmon allelic frequency data. Letters correspond to streams in Fig. 1 and Table 1. This analysis was performed on the 19 collections for which data was obtained for all loci (see Appendix Table A). Circled letters within aggregations indicate collections not geographically associated with the aggregation.

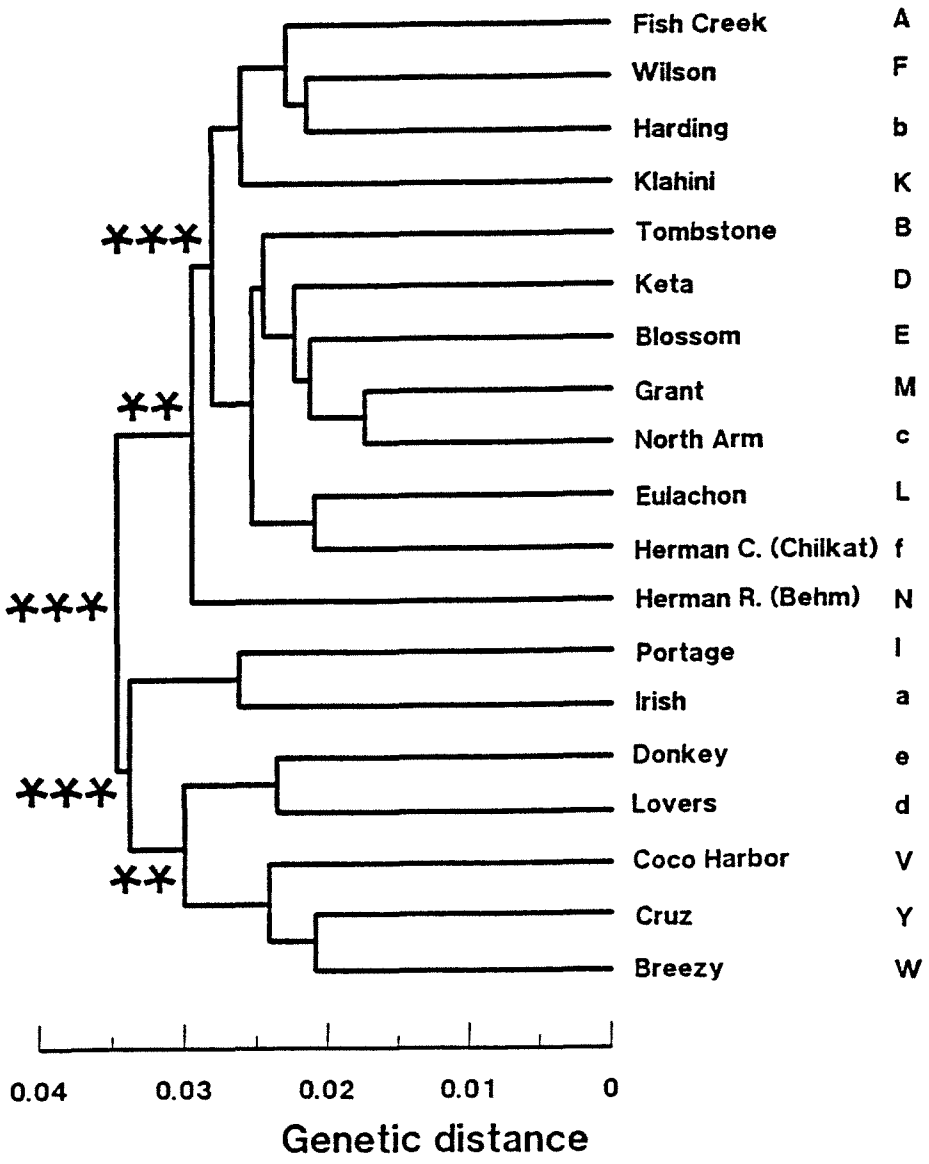

Figure 7.--Dendrogram reflecting genetic relationships using Rogers' (1972) genetic distances. This analysis was performed on the 19 collections for which data was obtained for all loci (see Appendix Table A). The dendrogram was obtained from UPGMA clustering (Sneath and Sokal 1973). Heterogeneity between the two branches joined at a node was determined by log-likelihood ratios (* $\underline{P} < 0.05$, ** $\underline{P} < 0.01$, and *** $\underline{P} < 0.001$).

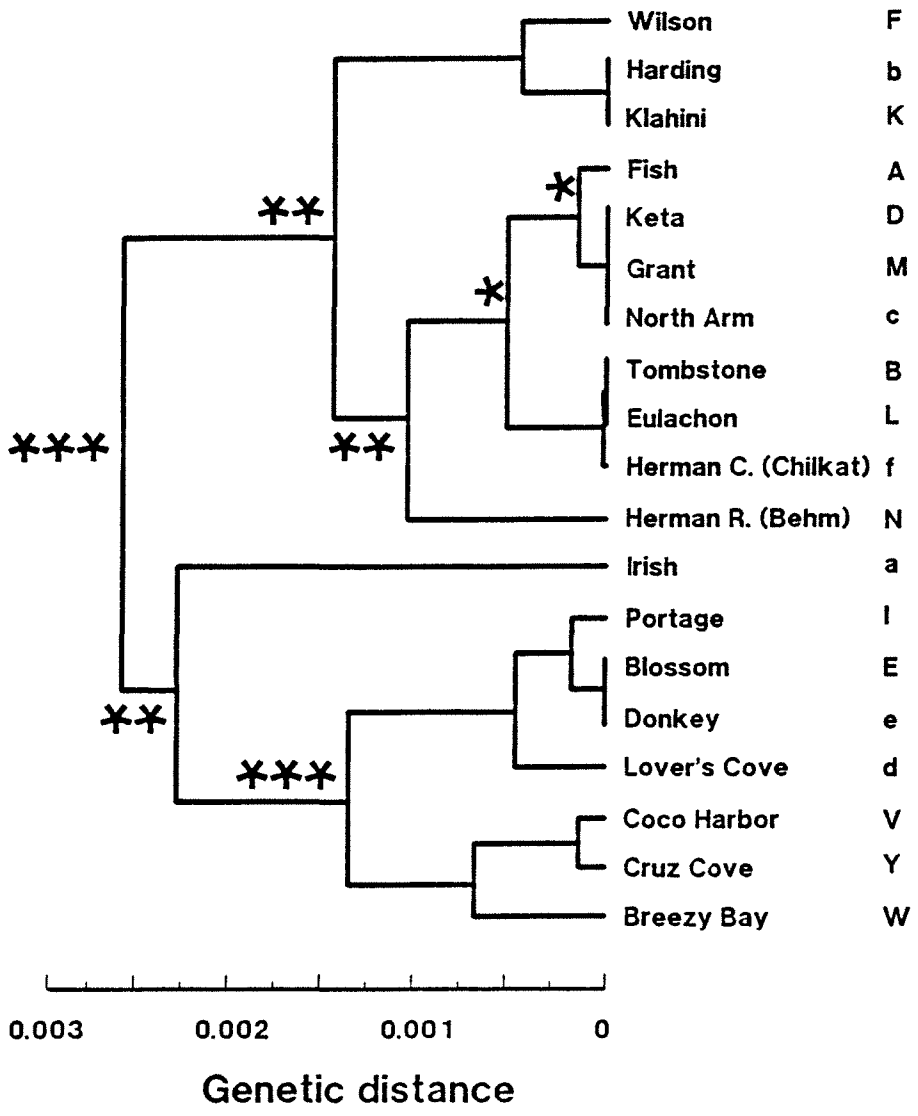

Figure 8.--Dendrogram reflecting genetic relationships using Nei's (1972, 1978) genetic distances. This analysis was performed on the 19 collections for which data was obtained for all loci (see Appendix Table A). The dendrogram was obtained from UPGMA clustering (Sneath and Sokal 1973). Heterogeneity between the two branches joined at a node was determined by log-likelihood ratios (* $\underline{P} < 0.05$ and *** $\underline{P} < 0.001$).

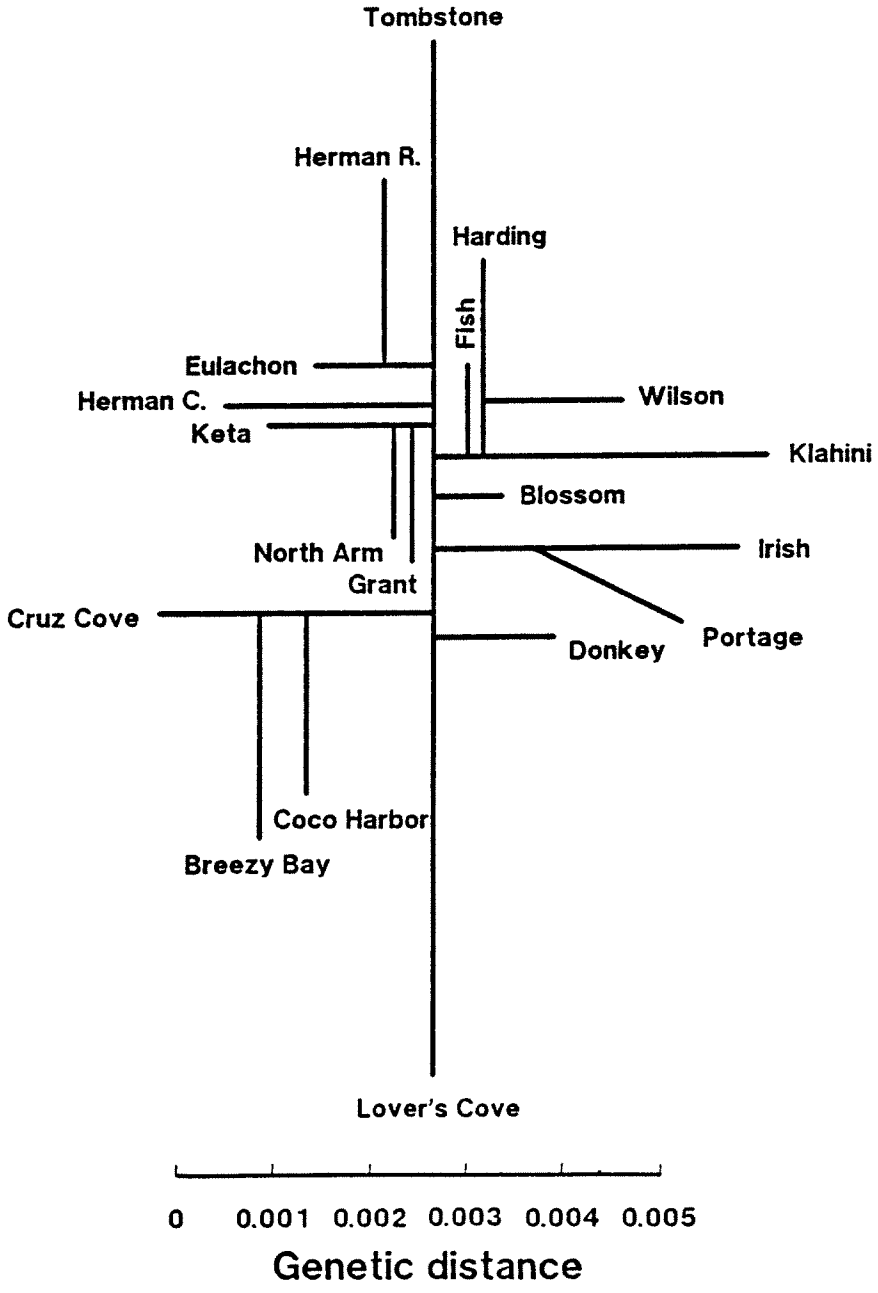

Figure 9.--Maximum-likelihood tree (Felsenstein 1973, 1984) estimate from genetic distances (Cavalli-Sforza and Edwards, 1967). This analysis was performed on the 19 collections for which data was obtained for all loci (see Appendix Table A).

Table 5.--Log-likelihood analysis of electrophoretic data from southeastern Alaskan chum salmon populations. Collections within fishing districts are in Figure 1 and Table 1. The F-ratio which compares among and within heterogeneity is 3.42 (91,276)($P < 10^{-5}$). (*$P < 0.05$, **$P < 0.01$, and ***$P < 0.001$).

	Fishing Districts								Summary G-statistics		
	101										
Locus	Behm Canal[a]	Boca de Quadra	Portland Canal	102-103[b]	105	107-108	109-110	115	Within	Among	Total
Aat-1,2	9.34 9	3.81 1	2.93 1	6.80 11	-- --	1.18 1	2.54 1	-- --	26.60 24	11.94 7	38.54 31
mAat-1	13.11 9	0.40 1	0.53 1	9.67 11	-- --	1.09 1	0.03 1	-- --	24.83 24	96.55*** 7	11.38*** 31
Alat	15.50* 8	2.52 1	0.17 1	13.57 9	-- --	0.20 1	0.00 1	-- --	31.95 21	8.81 7	40.76 28
EstD	12.14 9	0.09 1	0.37 1	24.25** 11	-- --	0.53 1	0.15 1	-- --	37.52* 24	71.98*** 7	109.50 31
Idh-1	13.73 9	2.14 1	2.74 1	26.71** 11	-- --	0.89 1	1.08 1	-- --	47.29** 24	15.96* 7	63.24 31
Pep(Lgg-1)	5.50 9	2.09 1	0.01 1	5.74 11	-- --	0.34 1	3.75 1	-- --	17.42 24	13.18 7	30.59 31
Me-1	8.61 9	0.00 1	1.99 1	18.30 11	-- --	5.85 1	0.59 1	-- --	35.32 24	33.28*** 7	68.60 31
G3p-2	8.66 9	2.09 1	0.15 1	6.38 11	-- --	1.92 1	0.27 1	-- --	19.47 24	25.38*** 7	44.84 31
Mpi	18.16* 9	0.08 1	0.00 1	19.87 11	-- --	0.36 1	0.53 1	-- --	39.00* 24	20.12** 7	59.12 31
Pgm-1	8.91 7	0.74 1	2.08 1	2.76 6	-- --	3.29 1	0.21 1	-- --	17.94 17	18.57** 7	36.51* 24
Idh-3	18.16 12	-- --	5.96 2	3.60 4	-- --	0.63 2	2.64 2	-- --	31.00 22	26.26* 14	57.26 36

Table 5.--Continued.

Locus	Fishing Districts: 101 Behm Canal[a]	101 Boca de Quadra	101 Portland Canal	102-103[b]	105	107-108	109-110	115	Summary G-statistics: Within	Among	Total
Aat-3	12.12	5.68*	4.48*	14.75	--	0.91	0.82	--	38.77*	71.28***	110.05
	9	1	1	11	--	1	1	--	24	7	31
Total	143.91**	19.64	21.39	152.39**	--	17.20	12.61	--	367.11***	413.30***	780.41***
	108	11	13	118	--	13	13	--	276	91	367

[a] Heterogeneity largely attributable to Portage Creek collection; 1 of 10 collections.
[b] Heterogeneity largely attributable to Disappearance and Tokeen Creeks; 2 of 11 collections.

Heterogeneity among streams within District 101 was attributable to small differences between three subareas: Boca de Quadra, Portland Canal, and the collections on Revillagigedo Island and in Behm Canal (Fig. 1). Heterogeneity within the latter subgroup is due largely to Portage Creek (I), 1 of 10 collections in that group. Among Prince of Wales Island collections, Districts 102 and 103, heterogeneity was largely attributable to 2 of the 12 collections, those from Disappearance (Q) and Tokeen (Z) creeks. Data from Portage (I), Disappearance (Q), and Tokeen (Z) Creeks were included in the analysis presented. An approximate F-ratio comparing the among- and within-heterogeneity indicates that far more heterogeneity exists among regions than within the regions ($F = 3.42$ (91,276); $P < 10^{-5}$).

A study of British Columbia stocks, using fewer variable loci than we report herein, indicated a strong geographical structure to western Canadian chum salmon populations (Beacham et al. 1987). Their work reports variability for seven loci and two isoloci. While we observed variability at all the loci reported by Beacham et al. (1987), these loci represent only six of the most variable loci we observed: Idh-1, Idh-3, Me-1, Mpi, G3p-2, Pep(Lgg-1). We observed potentially useful variability at seven additional loci: Alat, mAat-1, Aat-1,2, Aat-3, Est-D, Ldh-1, and Pgm-1 and less substantial variability at another five loci (Appendix Table A).

To get an idea of the increased resolution that could be obtained by using the additional loci, we conducted principal

component and then log-likelihood ratio analyses to examine the divergence between Southeast Alaska regions, between which we had already identified genetic divergence. We had data for all 12 variable loci for 3 collections from islands west of Prince of Wales Island (District 103) and 10 of the collections taken from waters included in District 101 (Table 6).

Table 6.--Relative value of electrophoretic loci for distinguishing between chum salmon from Prince of Wales Island (fall spawning) and from the inside waters of southern Southeast Alaska (summer spawning). F is an approximate statistic, obtained from the ratio of heterogeneity between regions to the heterogeneity within regions $[G_{between}/df_{between}]/[G_{within}/df_{within}]$; df_n and df_d = degrees of freedom in the numerator and denominator, respectively; and P is the probability that the two G-statistics reflect comparable levels of heterogeneity. Relative contribution of each locus to the first two principal components (PC) is indicated by the rank of the loading factor.

Locus	F (df_n, df_d)	P	PC 1	PC 2
mAat-1	61.57 (1,11)	7.9×10^{-6}	2	8
Est-D	13.21 (1,11)	0.004	6	3
Aat-3	10.13 (1,11)	0.009	3	5
Me-1	6.50 (1,11)	0.011	1	11
Idh-1	4.12 (1,11)	0.067	4	9
Mpi	3.07 (1,11)	0.11	11	7
Idh-3	2.32 (2,22)	0.16	5	10
G3p-2	0.79 (1,11)	0.39	7	6
Alat	0.66 (1,11)	0.43	12	12
Pgm-1	0.48 (1,11)	0.50	10	2
Pep(Lgg-1)	0.23 (1,11)	0.64	8	4
Aat-1,2	0.00 (1,11)	1.00	9	1
Total	5.79 (13,143)	$< 10^{-6}$		

The first principal component is the linear combination of data from loci that accounts for the most variance among collections; the second principal component is the axis perpendicular to the first that accounts for the next greatest variance. These components reflect divergence between regions as well as intra-regional variation. The rank order of the absolute value of the contribution by locus is in part an indication of the discrimination value of that locus.

Comparison of heterogeneity within the regions to heterogeneity between regions (an approximate F-ratio) for each locus provides a second indicator of discrimination value. Loci are arranged in Table 6 in descending order of F value.

Statistically, five loci show discrimination ability between eastern and western populations in southern Southeast Alaska: mAat-1, Est-D, Aat-3, Me-1, and Idh-1. Three of these were not included in the survey reported by Beacham et al. (1987). In addition to these loci, Ldh-4 is generally variable (frequency of variant allele approximately 0.03) in collections from Prince of Wales Island, but not from collections from the inside waters. Similarly, Gpi-3 also shows small regional differences in genetic composition. These differences show up in G-tests when regions (pooled collections) are compared and in principal component analysis.

From data common to both studies pooled by region, we determined Felsenstein's (1973, 1984) maximum-likelihood tree (Fig. 10). This tree indicates that Queen Charlotte Island and Fraser River chum salmon differ substantially from other

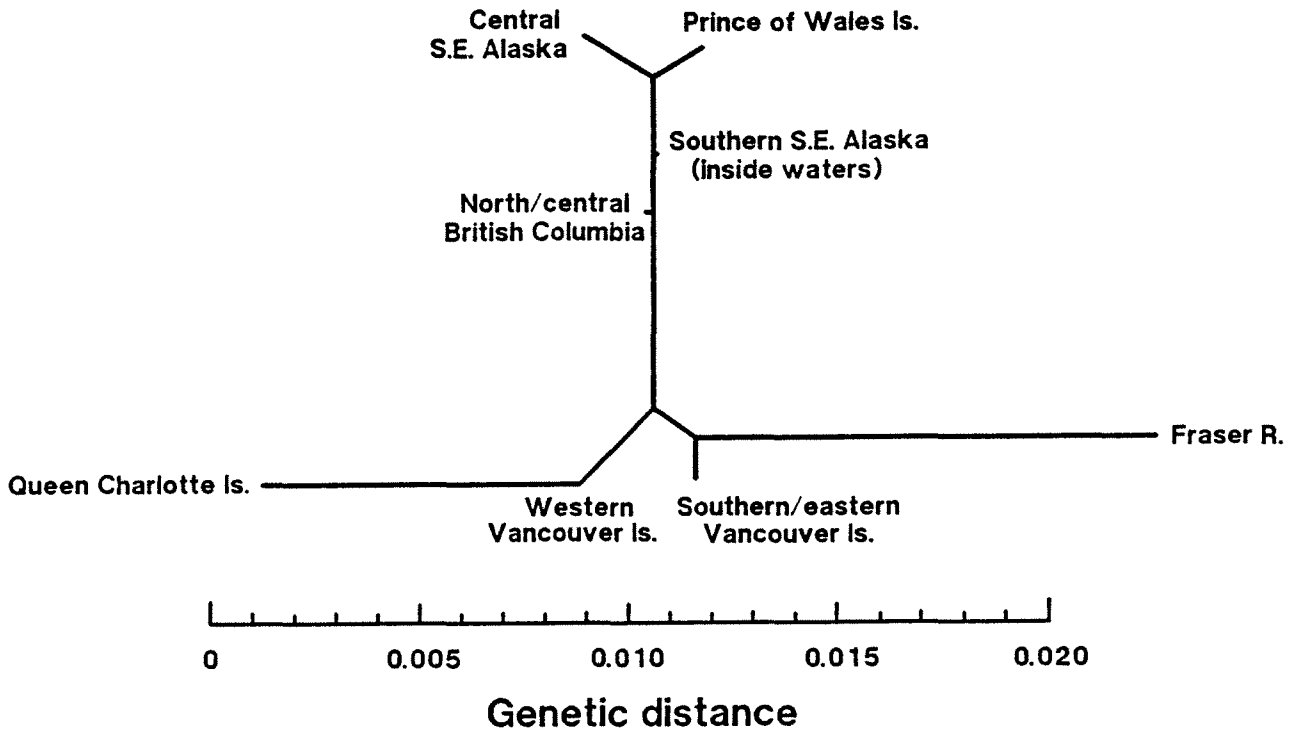

Figure 10.--Maximum-likelihood tree (Felsenstein 1973, 1984) estimate from genetic distances (Cavalli-Sforza and Edwards, 1967) using summary data for western Canadian chum salmon (Beacham et al. 1987) and pooled data from southern southeastern Alaskan collections. This analysis was performed using loci for which Beacham et al. (1987) reported data (see Appendix Table A).

British Columbia and Southeast Alaska populations. The difference between northern British Columbia populations and populations from inside waters of southern Southeast Alaska is not large, but significant.

DISCUSSION

The objective of this work was to examine the potential for starch-gel electrophoresis as a tool to identify or separate stocks of chum salmon originating near the boundary between Southeast Alaska and northern British Columbia. In this preliminary look at subsamples from the collections taken from Southeast Alaska chum salmon populations, it is apparent that genetic differentiation in chum salmon has a geographical basis, and that at least in southern Southeast Alaska, populations within a region are relatively similar. The practical result of the log-likelihood ratio analysis was the realization that far more heterogeneity exists among regions than within the regions. The genetic difference between collections from Prince of Wales Island and collections from inside waters encompassed by District 101, was highly significant statistically (Figs. 3, 4). In addition, it appears from data reported by Beacham et al. (1987), that populations from the Queen Charlotte Islands are distinct from Prince of Wales Island populations. These differences are quite encouraging, especially considering that the data include only a subsample of the fish in each collection. Even more

discrimination may be possible when all the samples have been analyzed.

To date, banding patterns of 12 to 15 loci and isoloci have been resolved in the northern boundary area that have sufficient variability to be useful for stock separation.

These preliminary results are sufficiently encouraging to warrant 1) analysis of the remainder of the tissues and 2) continued development of a genetic baseline for chum salmon, which includes stocks of northern B.C. and uses all the variable loci so far identified. In 1988, samples were collected (but are not yet analyzed) from eight northern British Columbia systems, all representing resamples of populations studied by Beacham and his colleagues (Appendix Table B). With the addition of discriminating loci such as mAat-1, Aat-3, and Est-D, the small difference observed between some Canadian and Southeast Alaska populations may be amplified.

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APPENDIX

Table A.--Biochemical genetic variation in collections of chum salmon from drainages in Southeast Alaska. Allelic frequencies and collection sizes (N) for biochemical genetic loci. Collections are designated as in Fig. 1 and Table 1. Alleles are designated by their mobility relative to the most common allele (100). Data from loci designated with an "a" was used in analyses that included all collections; data from loci designated with a "b" was used in analyses that used data from 19 populations.

		Alat[b]			
Drainage	N	100	95	90	105
District 101--Behm Canal-Portland Canal-Boca de Quadra					
A. Fish Creek					
1986	37	0.85	0.15	0	0
1987	40	0.78	0.21	0	0.01
B. Tombstone River	39	0.83	0.17	0	0
C. Marten River	37	0.89	0.11	0	0
D. Keta River	40	0.80	0.20	0	0
E. Blossom River	39	0.88	0.10	0	0.01
F. Wilson River	35	0.79	0.20	0	0.01
G. Traitor's Creek	38	0.93	0.07	0	0
H. Carroll River	0				
I. Portage Creek	39	0.86	0.14	0	0
J. King Creek	36	0.86	0.14	0	0
K. Klahini River	39	0.74	0.21	0.01	0.04
L. Eulachon Creek	40	0.91	0.09	0	0
M. Grant Creek	38	0.80	0.20	0	0
N. Herman River	41	0.89	0.11	0	0
District 102--East Prince of Wales Island					
O. Kugel Creek	39	0.87	0.13	0	0
P. Aiken Creek	39	0.88	0.12	0	0
Q. Disappearance Creek	38	0.92	0.08	0	0
R. Lagoon Creek	37	0.82	0.18	0	0
S. Old Tom Creek	38	0.80	0.20	0	0
T. Cabin Creek	39	0.83	0.17	0	0
U. Karta River	39	0.73	0.27	0	0

Table A.--Continued.

Drainage	N	Alat[b] 100	95	90	105
District 103--West Prince of Wales Island-western islands					
V. Coco Harbor	41	0.85	0.12	0.02	0
W. Breezy Bay					
1986	31	0.89	0.11	0	0
1987	39	0.83	0.17	0	0
X. Port Real Marina	0				
Y. Cruz Cove					
1986	38	0.91	0.09	0	0
1987	38	0.79	0.21	0	0
Z. Tokeen Creek	0				
District 105--West Sumner Strait					
a. Irish Creek	40	0.84	0.16	0	0
District 107--Ernest Sound-Bradfield Canal					
b. Harding River	37	0.77	0.22	0	0.01
District 108--Stikine River					
c. North Arm Creek	40	0.80	0.20	0	0
District 109--South Chatham Strait					
d. Lover's Cove Creek	40	0.84	0.16	0	0
District 110--East Frederick Sound					
e. Donkey Creek	40	0.84	0.16	0	0
District 115--Lynn Canal					
f. Herman Creek	39	0.91	0.09	0	0

Table A.--Continued.

Drainage	Aat-1,2[ab] N	100	117	57 very slow	mAat-1[ab] N	-100	-115	-80
District 101--Behm Canal-Portland Canal-Boca de Quadra								
A. 1986	40	0.86	0.14	0 0	40	0.69	0.24	0.08
1987	40	0.85	0.15	0 0	40	0.68	0.25	0.08
B.	39	0.91	0.09	0 0	40	0.65	0.29	0.06
C.	39	0.87	0.13	0 0	40	0.76	0.19	0.05
D.	40	0.93	0.07	0 0	40	0.79	0.15	0.06
E.	38	0.91	0.09	0 0	40	0.70	0.24	0.06
F.	40	0.84	0.16	0 0	40	0.64	0.30	0.06
G.	40	0.86	0.14	0 0	40	0.81	0.16	0.03
H.	40	0.88	0.12	0 0	40	0.65	0.34	0.01
I.	38	0.91	0.09	0 0.01	38	0.66	0.30	0.04
J.	40	0.87	0.13	0 0	40	0.70	0.24	0.06
K.	39	0.89	0.11	0 0	40	0.68	0.31	0.01
L.	39	0.88	0.12	0 0	40	0.66	0.29	0.05
M.	40	0.89	0.11	0 0	40	0.69	0.25	0.06
N.	41	0.84	0.16	0 0	39	0.67	0.32	0.01
District 102--East Prince of Wales Island								
O.	40	0.84	0.16	0 0	40	0.85	0.10	0.05
P.	40	0.83	0.17	0 0	40	0.89	0.11	0
Q.	40	0.86	0.14	0 0	40	0.84	0.14	0.02
R.	40	0.89	0.11	0 0	40	0.84	0.11	0.05
S.	41	0.86	0.14	0.01 0	41	0.88	0.07	0.05
T.	41	0.86	0.14	0 0	41	0.88	0.11	0.01
U.	40	0.90	0.10	0 0	39	0.87	0.09	0.04
District 103--West Prince of Wales Island-western islands								
V.	40	0.89	0.11	0 0	41	0.80	0.16	0.04
W. 1986	40	0.89	0.11	0 0	40	0.82	0.15	0.02
1987	40	0.87	0.13	0 0	40	0.89	0.11	0
X.	40	0.88	0.12	0 0	40	0.88	0.11	0.01
Y. 1986	40	0.86	0.14	0 0	40	0.91	0.08	0.01
1987	40	0.90	0.10	0 0	40	0.80	0.19	0.01
Z.	41	0.87	0.13	0 0	41	0.77	0.21	0.02
District 105--West Sumner Strait								
a.	40	0.92	0.08	0 0	40	0.78	0.14	0.09

Table A.--Continued.

Drainage	Aat-1,2[ab] N	100	117	57	very slow	mAat-1[ab] N	-100	-115	-80
District 107--Ernest Sound-Bradfield Canal									
b.	40	0.87	0.13	0	0	39	0.65	0.26	0.09
District 108--Stikine River									
c.	40	0.91	0.09	0	0	39	0.65	0.27	0.08
District 109--South Chatham Strait									
d.	40	0.89	0.05	0	0.06	40	0.71	0.28	0.01
District 110--East Frederick Sound									
e.	40	0.94	0.06	0	0	40	0.70	0.26	0.04
District 115--Lynn Canal									
f.	39	0.89	0.11	0	0	40	0.56	0.38	0.06

Table A.--Continued.

Drainage		Aat-3[ab] N	100	90	107	Est-D[ab] N	100	92	105
District 101--Behm Canal-Portland Canal-Boca de Quadra									
A.	1986	40	0.54	0.46	0	40	0.94	0.06	0
	1987	37	0.55	0.45	0	40	0.95	0.05	0
B.		40	0.40	0.55	0.05	39	0.92	0.08	0
C.		40	0.38	0.62	0	39	0.95	0.05	0
D.		40	0.56	0.44	0	40	0.94	0.06	0
E.		40	0.54	0.46	0	40	0.91	0.08	0.01
F.		40	0.58	0.42	0	40	0.94	0.06	0
G.		40	0.58	0.42	0	40	0.91	0.09	0
H.		37	0.54	0.46	0	40	0.91	0.09	0
I.		38	0.63	0.37	0	39	0.99	0.01	0
J.		40	0.60	0.40	0	40	0.94	0.06	0
K.		37	0.45	0.55	0	40	0.89	0.11	0
L.		40	0.45	0.55	0	40	0.96	0.04	0
M.		40	0.46	0.54	0	39	0.96	0.04	0
N.		40	0.58	0.42	0	40	0.91	0.08	0.01
District 102--East Prince of Wales Island									
O.		40	0.68	0.32	0	40	0.79	0.21	0
P.		39	0.71	0.29	0	40	0.94	0.06	0
Q.		40	0.70	0.30	0	40	0.90	0.10	0
R.		40	0.58	0.42	0	40	0.80	0.20	0
S.		41	0.73	0.27	0	41	0.78	0.22	0
T.		41	0.65	0.35	0	41	0.82	0.18	0
U.		40	0.66	0.34	0	40	0.90	0.10	0
District 103--West Prince of Wales Island-western islands									
V.		40	0.71	0.29	0	41	0.85	0.15	0
W.	1986	40	0.68	0.32	0	40	0.90	0.10	0
	1987	38	0.71	0.29	0	39	0.91	0.09	0
X.		38	0.76	0.24	0	40	0.81	0.19	0
Y.	1986	37	0.59	0.41	0	40	0.84	0.16	0
	1987	40	0.58	0.42	0	40	0.78	0.22	0
Z.		41	0.68	0.32	0	41	0.82	0.18	0
District 105--West Sumner Strait									
a.		36	0.57	0.43	0	40	0.98	0.02	0

Table A.--Continued.

Drainage	Aat-3[ab] N	100	90	107	Est-D[ab] N	100	92	105
District 107--Ernest Sound-Bradfield Canal								
b.	37	0.47	0.53	0	40	0.94	0.06	0
District 108--Stikine River								
c.	40	0.55	0.45	0	40	0.96	0.04	0
District 109--South Chatham Strait								
d.	40	0.72	0.28	0	40	0.95	0.05	0
District 110--East Frederick Sound								
e.	38	0.66	0.34	0	40	0.96	0.04	0
District 115--Lynn Canal								
f.	40	0.50	0.50	0	39	0.94	0.06	0

Table A.--Continued.

Drainage		Gpi-3[ab] N	100	107	slow	G3p-2[ab] N	100	90
District 101--Behn Canal-Portland Canal-Boca de Quadra								
A.	1986	40	1.00	0.00	0	40	0.76	0.24
	1987	40	1.00	0.00	0	39	0.82	0.18
B.		40	1.00	0.00	0	40	0.81	0.19
C.		40	1.00	0.00	0	40	0.91	0.09
D.		40	1.00	0.00	0	40	0.84	0.16
E.		40	1.00	0.00	0	40	0.84	0.16
F.		40	1.00	0.00	0	39	0.83	0.15
G.		40	1.00	0.00	0	40	0.85	0.15
H.		40	1.00	0.00	0	40	0.82	0.18
I.		39	1.00	0.00	0	39	0.73	0.27
J.		40	1.00	0.00	0	40	0.86	0.14
K.		40	1.00	0.00	0	40	0.89	0.10
L.		40	1.00	0.00	0	39	0.86	0.14
M.		40	1.00	0.00	0	39	0.81	0.19
N.		41	1.00	0.00	0	40	0.85	0.15
District 102--East Prince of Wales Island								
O.		40	0.99	0.01	0	40	0.84	0.16
P.		40	1.00	0.00	0	39	0.79	0.21
Q.		40	1.00	0.00	0	40	0.74	0.26
R.		40	0.95	0.04	0.01	40	0.78	0.22
S.		41	0.96	0.04	0	40	0.78	0.22
T.		41	0.99	0.00	0.01	41	0.77	0.23
U.		40	0.95	0.05	0	40	0.76	0.24
District 103--West Prince of Wales Island-western islands								
V.		41	0.99	0.00	0.01	39	0.85	0.15
W.	1986	40	0.98	0.02	0	38	0.79	0.21
	1987	40	1.00	0.00	0	40	0.80	0.20
X.		40	1.00	0.00	0	40	0.75	0.25
Y.	1986	40	1.00	0.00	0	39	0.85	0.15
	1987	40	1.00	0.00	0	40	0.72	0.28
Z.		41	1.00	0.00	0	40	0.74	0.26
District 105--West Sumner Strait								
a.		40	1.00	0.00	0	40	0.69	0.31

Table A.--Continued.

Drainage	Gpi-3[ab] N	100	107	slow	G3p-2[ab] N	100	90
District 107--Ernest Sound-Bradfield Canal							
b.	40	0.99	0.00	0.01	40	0.90	0.10
District 108--Stikine River							
c.	40	1.00	0.00	0	40	0.82	0.18
District 109--South Chatham Strait							
d.	40	1.00	0.00	0	40	0.82	0.18
District 110--East Frederick Sound							
e.	40	0.98	0.00	0.02	38	0.86	0.14
District 115--Lynn Canal							
f.	40	1.00	0.00	0	38	0.84	0.16

Table A.--Continued.

Drainage		Idh-1[ab] N	Idh-1[ab] 100	Idh-1[ab] 30	Idh-3[b] N	Idh-3[b] 100	Idh-3[b] 40	Idh-3[b] 25	Idh-3[b] 85	Idh-3[b] 110
District 101--Behm Canal-Portland Canal-Boca de Quadra										
A.	1986	40	0.86	0.14	39	0.44	0.24	0.20	0.12	0
	1987	40	0.84	0.16	40	0.46	0.40	0.11	0.03	0
B.		39	0.92	0.08	37	0.45	0.27	0.24	0.04	0
C.		40	0.95	0.05	0					
D.		40	0.89	0.11	40	0.48	0.32	0.12	0.08	0
E.		40	0.95	0.05	40	0.44	0.35	0.19	0.02	0
F.		40	0.92	0.08	39	0.52	0.32	0.12	0.04	0
G.		40	0.95	0.05	0					
H.		40	0.89	0.11	0					
I.		38	0.96	0.04	37	0.34	0.35	0.27	0.04	0
J.		39	0.95	0.05	0					
K.		40	0.94	0.06	40	0.42	0.38	0.18	0.02	0
L.		40	0.85	0.15	39	0.49	0.26	0.22	0.04	0
M.		39	0.96	0.04	40	0.48	0.32	0.12	0.08	0
N.		41	0.88	0.12	41	0.38	0.26	0.32	0.05	0
District 102--East Prince of Wales Island										
O.		40	0.98	0.02	0					
P.		40	0.94	0.06	0					
Q.		39	1.00	0.00	0					
R.		37	0.95	0.05	0					
S.		41	0.94	0.06	0					
T.		41	0.89	0.11	0					
U.		39	0.97	0.03	0					
District 103--West Prince of Wales Island-western islands										
V.		41	0.93	0.07	41	0.35	0.37	0.26	0.02	0
W.	1986	40	0.95	0.05	34	0.35	0.40	0.12	0.13	0
	1987	40	0.95	0.05	40	0.40	0.24	0.34	0.02	0
X.		39	0.86	0.14	0					
Y.	1986	39	0.96	0.04	35	0.34	0.40	0.16	0.10	0
	1987	40	0.95	0.05	40	0.40	0.31	0.21	0.08	0
Z.		41	0.98	0.02	0					
District 105--West Sumner Strait										
a.		40	0.92	0.08	39	0.32	0.49	0.13	0.06	0

Table A.--Continued.

Drainage	Idh-1[ab] N	Idh-1[ab] 100	Idh-1[ab] 30	Idh-3[b] N	Idh-3[b] 100	Idh-3[b] 40	Idh-3[b] 25	Idh-3[b] 85	Idh-3[b] 110
District 107--Ernest Sound-Bradfield Canal									
b.	40	0.91	0.09	39	0.38	0.38	0.18	0.05	0
District 108--Stikine River									
c.	40	0.95	0.05	40	0.44	0.38	0.10	0.09	0
District 109--South Chatham Strait									
d.	40	0.92	0.08	40	0.45	0.34	0.20	0.01	0
District 110--East Frederick Sound									
e.	40	0.96	0.04	40	0.33	0.41	0.21	0.05	0
District 115--Lynn Canal									
f.	40	0.90	0.10	40	0.53	0.35	0.10	0.01	0.01

Table A.--Continued.

Drainage	Ldh-1[ab] N	-100	-50	Ldh-4[ab] N	100	110
District 101--Behm Canal-Portland Canal-Boca de Quadra						
A. 1986	40	0.96	0.04	40	1.00	0.00
1987	40	0.96	0.04	40	1.00	0.00
B.	40	0.98	0.02	40	1.00	0.00
C.	40	0.99	0.01	40	1.00	0.00
D.	40	0.99	0.01	40	1.00	0.00
E.	39	0.97	0.03	40	1.00	0.00
F.	40	0.96	0.04	40	1.00	0.00
G.	40	0.95	0.05	40	0.99	0.01
H.	40	0.95	0.05	40	1.00	0.00
I.	39	1.00	0.00	39	1.00	0.00
J.	40	0.91	0.09	40	1.00	0.00
K.	40	0.95	0.05	40	1.00	0.00
L.	40	0.99	0.01	40	1.00	0.00
M.	40	0.96	0.04	40	1.00	0.00
N.	41	0.99	0.01	41	1.00	0.00
District 102--East Prince of Wales Island						
O.	40	0.98	0.02	40	1.00	0.00
P.	40	0.98	0.02	40	1.00	0.00
Q.	39	0.92	0.08	40	0.99	0.01
R.	40	0.92	0.08	40	0.99	0.01
S.	41	1.00	0.00	41	0.99	0.01
T.	41	0.96	0.04	41	0.99	0.01
U.	40	0.96	0.04	40	0.96	0.04
District 103--West Prince of Wales Island-western islands						
V.	41	1.00	0.00	41	0.96	0.04
W. 1986	40	0.90	0.10	40	0.96	0.04
1987	40	0.92	0.08	40	0.99	0.01
X.	40	0.99	0.01	40	0.98	0.02
Y. 1986	40	0.98	0.02	40	1.00	0.00
1987	40	0.94	0.06	40	0.94	0.06
Z.	41	0.98	0.02	41	1.00	0.00
District 105--West Sumner Strait						
a.	40	1.00	0.00	40	1.00	0.00

Table A.--Continued.

Drainage	Ldh-1[ab] N	-100	-50	Ldh-4[ab] N	100	110
District 107--Ernest Sound-Bradfield Canal						
b.	40	0.98	0.02	40	0.99	0.01
District 108--Stikine River						
c.	40	0.98	0.02	40	1.00	0.00
District 109--South Chatham Strait						
d.	40	0.98	0.02	40	0.99	0.01
District 110--East Frederick Sound						
e.	39	0.95	0.05	40	1.00	0.00
District 115--Lynn Canal						
f.	40	0.94	0.06	40	1.00	0.00

Table A.--Continued.

Drainage		Ldh-5[ab] N	Ldh-5[ab] 100	Ldh-5[ab] slow	Mdh-3,4[b] N	Mdh-3,4[b] 100	Mdh-3,4[b] 83	Mdh-3,4[b] 125	Mdh-3,4[b] 92
District 101--Behm Canal-Portland Canal-Boca de Quadra									
A.	1986	40	1.00	0.00	0				
	1987	39	1.00	0.00	40	0.98	0	0	0.02
B.		40	1.00	0.00	40	1.00	0	0	0
C.		40	1.00	0.00	0				
D.		40	1.00	0.00	40	0.98	0	0	0.02
E.		40	1.00	0.00	40	0.96	0	0	0.04
F.		40	1.00	0.00	39	0.97	0	0	0.03
G.		40	1.00	0.00	0				
H.		39	1.00	0.00	0				
I.		39	0.97	0.03	39	0.97	0	0.01	0.01
J.		40	1.00	0.00	0				
K.		40	1.00	0.00	40	0.94	0.04	0	0.02
L.		40	1.00	0.00	40	0.99	0.01	0	0
M.		40	0.99	0.01	40	1.00	0	0	0
N.		41	1.00	0.00	41	0.96	0.01	0	0.02
District 102--East Prince of Wales Island									
O.		40	1.00	0.00	0				
P.		39	1.00	0.00	0				
Q.		40	1.00	0.00	0				
R.		40	1.00	0.00	0				
S.		41	1.00	0.00	0				
T.		41	1.00	0.00	0				
U.		40	1.00	0.00	0				
District 103--West Prince of Wales Island-western islands									
V.		41	1.00	0.00	41	0.95	0	0.01	0.04
W.	1986	40	1.00	0.00	0				
	1987	40	1.00	0.00	40	0.91	0	0	0.09
X.		40	1.00	0.00	0				
Y.	1986	40	1.00	0.00	0				
	1987	40	1.00	0.00	40	0.98	0	0.01	0.01
Z.		41	1.00	0.00	0				
District 105--West Sumner Strait									
a.		38	0.99	0.01	40	0.99	0	0	0.01

Table A.--Continued.

Drainage	Ldh-5[ab] N	100	slow	Mdh-3,4[b] N	100	83	125	92
District 107--Ernest Sound-Bradfield Canal								
b.	40	1.00	0.00	40	1.00	0	0	0
District 108--Stikine River								
c.	40	1.00	0.00	40	0.98	0	0	0.02
District 109--South Chatham Strait								
d.	40	1.00	0.00	40	0.96	0	0	0.04
District 110--East Frederick Sound								
e.	40	1.00	0.00	40	0.99	0	0	0.01
District 115--Lynn Canal								
f.	40	1.00	0.00	40	0.96	0	0	0.04

Table A.--Continued.

Drainage		Me-1[ab] N	Me-1[ab] 100	Me-1[ab] 130	Me-1[ab] 85	Mpi[ab] N	Mpi[ab] 100	Mpi[ab] 90	Mpi[ab] 110	Mpi[ab] 80
District 101--Behm Canal-Portland Canal-Boca de Quadra										
A.	1986	40	0.89	0.11	0	40	0.94	0.06	0	0
	1987	40	0.75	0.25	0	40	0.96	0.04	0	0
B.		40	0.89	0.11	0	40	0.95	0.04	0	0.01
C.		40	0.89	0.11	0	40	0.91	0.08	0	0.01
D.		40	0.89	0.11	0	40	0.92	0.08	0	0
E.		40	0.90	0.10	0	40	0.90	0.10	0	0
F.		40	0.89	0.11	0	40	0.94	0.06	0	0
G.		40	0.86	0.14	0	40	0.84	0.16	0	0
H.		40	0.92	0.08	0	40	0.85	0.14	0	0.01
I.		39	0.90	0.10	0	39	0.85	0.15	0	0
J.		40	0.96	0.04	0	40	0.96	0.04	0	0
K.		40	0.88	0.12	0	39	0.94	0.05	0	0.01
L.		40	0.90	0.10	0	40	0.89	0.11	0	0
M.		40	0.86	0.14	0	40	0.82	0.18	0	0
N.		41	0.87	0.13	0	40	0.85	0.15	0	0
District 102--East Prince of Wales Island										
O.		40	0.96	0.04	0	40	0.94	0.06	0	0
P.		40	0.91	0.09	0	40	0.94	0.06	0	0
Q.		40	0.90	0.10	0	40	0.96	0.04	0	0
R.		40	0.94	0.06	0	40	0.92	0.08	0	0
S.		41	0.98	0.02	0	40	0.85	0.14	0.01	0
T.		41	0.95	0.05	0	41	0.91	0.09	0	0
U.		40	0.98	0.02	0	40	0.91	0.09	0	0
District 103--West Prince of Wales Island-western islands										
V.		41	0.93	0.07	0	41	0.93	0.07	0	0
W.	1986	40	0.86	0.13	0.01	39	0.96	0.04	0	
	1987	39	0.94	0.06	0	40	0.96	0.03		
X.		40	0.91	0.09	0	40	0.92	0.08	0	0
Y.	1986	40	0.91	0.09	0	38	0.89	0.11	0	0
	1987	40	0.96	0.04	0	40	0.98	0.02		
Z.		41	0.99	0.01	0	41	0.83	0.17	0	0
District 105--West Sumner Strait										
a.		40	0.90	0.10	0	40	0.86	0.14	0	0

Table A.--Continued.

Drainage	Me-1[ab] N	100	130	85	Mpi[ab] N	100	90	110	80
District 107--Ernest Sound-Bradfield Canal									
b.	39	0.83	0.15	0.01	40	0.94	0.06	0	0
District 108--Stikine River									
c.	40	0.95	0.05	0	40	0.91	0.09	0	0
District 109--South Chatham Strait									
d.	40	0.96	0.04	0	40	0.96	0.04	0	0
District 110--East Frederick Sound									
e.	39	0.94	0.06	0	40	0.94	0.06	0	0
District 115--Lynn Canal									
f.	40	0.96	0.04	0	39	0.92	0.08	0	0

Table A.--Continued.

Drainage		Pep(Gl) N	Pep(Gl) 100	Pep(Gl) 92	Pep(Lgg)[ab] N	Pep(Lgg)[ab] 100	Pep(Lgg)[ab] 70
District 101--Behm Canal-Portland Canal-Boca de Quadra							
A.	1986	40	1.00	0.00	40	0.81	0.19
	1987	40	0.99	0.01	39	0.79	0.21
B.		40	1.00	0.00	40	0.80	0.20
C.		40	1.00	0.00	40	0.91	0.09
D.		40	1.00	0.00	40	0.84	0.16
E.		40	1.00	0.00	40	0.81	0.19
F.		40	1.00	0.00	40	0.84	0.16
G.		40	1.00	0.00	40	0.80	0.20
H.		0			40	0.80	0.20
I.		39	1.00	0.00	39	0.86	0.14
J.		40	1.00	0.00	40	0.76	0.24
K.		39	1.00	0.00	39	0.76	0.24
L.		40	1.00	0.00	40	0.81	0.19
M.		40	1.00	0.00	40	0.78	0.22
N.		40	1.00	0.00	41	0.76	0.24
District 102--East Prince of Wales Island							
O.		40	1.00	0.00	40	0.76	0.24
P.		0			40	0.79	0.21
Q.		40	1.00	0.00	40	0.85	0.15
R.		38	1.00	0.00	40	0.76	0.24
S.		0			41	0.84	0.16
T.		41	1.00	0.00	41	0.84	0.16
U.		40	1.00	0.00	40	0.79	0.21
District 103--West Prince of Wales Island-western islands							
V.		41	1.00	0.00	41	0.78	0.22
W.	1986	38	1.00	0.00	40	0.84	0.16
	1987	38	1.00	0.00	40	0.80	0.20
X.		40	1.00	0.00	40	0.82	0.18
Y.	1986	30	1.00	0.00	40	0.84	0.16
	1987	40	1.00	0.00	40	0.81	0.19
Z.		41	1.00	0.00	41	0.79	0.21
District 105--West Sumner Strait							
a.		40	1.00	0.00	40	0.81	0.19

Table A.--Continued.

Drainage	Pep(Gl) N	Pep(Gl) 100	Pep(Gl) 92	Pep(Lgg)[ab] N	Pep(Lgg)[ab] 100	Pep(Lgg)[ab] 70
District 107--Ernest Sound-Bradfield Canal						
b.	40	1.00	0.00	40	0.81	0.19
District 108--Stikine River						
c.	40	1.00	0.00	40	0.78	0.22
District 109--South Chatham Strait						
d.	40	1.00	0.00	40	0.92	0.08
District 110--East Frederick Sound						
e.	40	1.00	0.00	40	0.82	0.18
District 115--Lynn Canal						
f.	39	1.00	0.00	40	0.88	0.12

Table A.--Continued.

Drainage		Pgdh[ab] N	100	90	110	Pgm-1[b] N	present	null
District 101--Behm Canal-Portland Canal-Boca de Quadra								
A.	1986	40	1.00	0.00	0	0		
	1987	40	1.00	0.00	0	40	0.65	0.35
B.		40	0.93	0.06	0.01	40	0.50	0.50
C.		40	0.99	0.01	0	40	0.61	0.39
D.		40	1.00	0.00	0	40	0.53	0.47
E.		40	1.00	0.00	0	40	0.73	0.27
F.		40	0.96	0.04	0	40	0.84	0.16
G.		40	1.00	0.00	0	40	0.73	0.27
H.		40	1.00	0.00	0	0		
I.		39	0.99	0.01	0	39	0.64	0.36
J.		40	0.96	0.04	0	0		
K.		40	1.00	0.00	0	39	0.64	0.36
L.		40	1.00	0.00	0	40	0.55	0.45
M.		40	1.00	0.00	0	40	0.61	0.39
N.		41	0.99	0.01	0	40	0.65	0.35
District 102--East Prince of Wales Island								
O.		40	0.99	0.01	0	0		
P.		40	0.98	0.02	0	40	0.73	0.27
Q.		40	0.99	0.01	0	0		
R.		40	1.00	0.00	0	40	0.68	0.32
S.		41	0.99	0.01	0	0		
T.		41	1.00	0.00	0	0		
U.		40	1.00	0.00	0	40	0.68	0.32
District 103--West Prince of Wales Island-western islands								
V.		41	0.98	0.02	0	41	0.78	0.22
W.	1986	40	0.98	0.02	0	39	0.55	0.45
	1987	40	0.99	0.01	0	40	0.20	400.68
X.		40	1.00	0.00	0	0		
Y.	1986	40	0.96	0.04	0	0		
	1987	40	0.99	0.01	0	40	0.19	400.68
Z.		41	1.00	0.00	0	41	0.62	0.38
District 105--West Sumner Strait								
a.		40	1.00	0.00	0	40	0.84	0.16

Table A.--Continued.

Drainage	Pgdh[ab] N	100	90	110	Pgm-1[b] N	present	null
District 107--Ernest Sound-Bradfield Canal							
b.	40	0.99	0.01	0	40	0.78	0.22
District 108--Stikine River							
c.	40	0.98	0.02	0	40	0.58	0.42
District 109--South Chatham Strait							
d.	40	0.96	0.01	0.03	40	0.73	0.27
District 110--East Frederick Sound							
e.	40	0.96	0.04	0	40	0.78	0.22
District 115--Lynn Canal							
f.	40	1.00	0.00	0	40	0.55	0.45

Table A.--Continued.

Drainage		Pqm-2[ab] N	-100	-140	-40	Sod N	100	200
District 101--Behm Canal-Portland-Boca de Quadra								
A.	1986	40	1.00	0.00	0	40	1.00	0.00
	1987	40	1.00	0.00	0	40	1.00	0.00
B.		40	1.00	0.00	0	40	1.00	0.00
C.		40	1.00	0.00	0	40	1.00	0.00
D.		40	0.99	0.01	0	40	1.00	0.00
E.		40	1.00	0.00	0	40	1.00	0.00
F.		40	1.00	0.00	0	40	1.00	0.00
G.		40	1.00	0.00	0	40	1.00	0.00
H.		40	1.00	0.00	0	40	1.00	0.00
I.		39	1.00	0.00	0	39	1.00	0.00
J.		40	1.00	0.00	0	40	1.00	0.00
K.		39	1.00	0.00	0	40	0.99	0.01
L.		40	1.00	0.00	0	40	1.00	0.00
M.		40	1.00	0.00	0	40	1.00	0.00
N.		40	1.00	0.00	0	41	1.00	0.00
District 102--East Prince of Wales Island								
O.		40	1.00	0.00	0	40	1.00	0.00
P.		40	1.00	0.00	0	40	1.00	0.00
Q.		40	1.00	0.00	0	40	1.00	0.00
R.		40	1.00	0.00	0	40	1.00	0.00
S.		41	0.99	0.01	0	41	1.00	0.00
T.		41	1.00	0.00	0	41	1.00	0.00
U.		40	1.00	0.00	0	40	1.00	0.00
District 103--West Prince of Wales Island-western islands								
V.		41	1.00	0.00	0	41	1.00	0.00
W.	1986	40	0.99	0.00	0.01	40	1.00	0.00
	1987	40	1.00	0.00	0	40	1.00	0.00
X.		40	1.00	0.00	0	0		
Y.	1986	40	1.00	0.00	0	40	1.00	0.00
	1987	40	1.00	0.00	0	40	1.00	0.00
Z.		41	0.99	0.00	0.01	41	1.00	0.00
District 105--West Sumner Strait								
a.		40	1.00	0.00	0	40	1.00	0.00

Table A.--Continued.

Drainage	Pgm-2[ab] N	-100	-140	-40	Sod N	100	200
District 107--Ernest Sound-Bradfield Canal							
b.	40	1.00	0.00	0	40	1.00	0.00
District 108--Stikine River							
c.	40	0.99	0.00	0.01	40	1.00	0.00
District 109--South Chatham Strait							
d.	40	1.00	0.00	0	40	1.00	0.00
District 110--East Frederick Sound							
e.	40	1.00	0.00	0	40	1.00	0.00
District 115--Lynn Canal							
f.	39	1.00	0.00	0	40	1.00	0.00

Table A.--Continued.

Drainage	Sample sizes of monomorphic loci			
	Ck-1[b]	Ck-2[b]	Ck-3[ab]	Gpi-1,2[ab]
District 101--Behm Canal-Portland Canal-Boca de Quadra				
A. 1986	39	39	40	40
1987	40	40	39	40
B.	40	40	40	40
C.	40	40	40	40
D.	40	40	40	40
E.	40	40	40	40
F.	40	40	40	40
G.	38	38	40	40
H.	40	40	39	40
I.	39	39	39	39
J.	40	40	40	40
K.	40	40	40	40
L.	40	40	40	40
M.	40	40	40	40
N.	41	41	41	41
District 102--East Prince of Wales Island				
O.	40	40	40	40
P.	0	0	39	40
Q.	40	40	40	40
R.	39	39	40	40
S.	41	41	41	41
T.	41	41	41	41
U.	40	40	40	40
District 103--West Prince of Wales Island-western islands				
V.	41	41	41	41
W. 1986	40	40	40	40
1987	40	40	40	40
X.	40	40	40	38
Y. 1986	40	40	40	40
1987	40	40	40	40
Z.	37	37	41	36
District 105--West Sumner Strait				
a.	40	40	39	40

Table A.--Continued.

Drainage	Sample sizes of monomorphic loci			
	Ck-1[b]	Ck-2[b]	Ck-3[ab]	Gpi-1,2[ab]
District 107--Ernest Sound-Bradfield Canal				
b.	40	40	40	40
District 108--Stikine River				
c.	40	40	40	40
District 109--South Chatham Strait				
d.	40	40	40	40
District 110--East Frederick Sound				
e.	40	40	40	40
District 115--Lynn Canal				
f.	40	40	40	40

Table A.--Continued.

		Sample sizes of monomorphic loci			
		G3p-1[ab]	Idh-2[ab]	Ldh-2[ab]	Ldh-3[ab]
District 101--Behm Canal-Portland Canal-Boca de Quadra					
A.	1986	40	40	40	40
	1987	40	40	40	39
B.		40	39	40	40
C.		40	40	40	40
D.		40	40	40	40
E.		40	40	40	40
F.		40	40	40	40
G.		40	40	40	40
H.		39	40	40	40
I.		39	38	39	39
J.		39	39	40	40
K.		39	40	40	40
L.		40	40	39	40
M.		40	40	40	40
N.		40	41	41	41
District 102--East Prince of Wales Island					
O.		40	40	40	40
P.		40	40	40	40
Q.		40	39	40	40
R.		38	37	40	40
S.		41	41	41	41
T.		41	41	41	41
U.		40	39	40	40
District 103--West Prince of Wales Island-western islands					
V.		41	41	41	41
W.	1986	40	40	40	40
	1987	40	40	40	40
X.		40	39	40	40
Y.	1986	40	40	39	40
	1987	40	40	40	40
Z.		41	41	41	41
District 105--West Sumner Strait					
a.		40	40	40	40

Table A.--Continued.

	Sample sizes of monomorphic loci			
	G3p-1[ab]	Idh-2[ab]	Ldh-2[ab]	Ldh-3[ab]
	District 107--Ernest Sound-Bradfield Canal			
b.	40	40	40	40
	District 108--Stikine River			
c.	40	40	40	40
	District 109--South Chatham Strait			
d.	40	40	40	40
	District 110--East Frederick Sound			
e.	40	40	40	40
	District 115--Lynn Canal			
f.	39	40	40	40

Table B.--Location, date of collection, and numbers of chum salmon sampled in 1988 for electrophoretic analysis. N = number of samples.

Location	Date	N
Northern British Columbia		
Area 2--Queen Charlotte Islands		
Pallant R.	10/09/88	100
Area 3Z--Portland Inlet-Observatory Inlet		
Kitsault R.	8/--/88	100
Kshwan R.	9/13/88	100
Stagoo C.	8/--/88	92
Khutzeymateen R.	9/13/88	100
Toon R.	9/12/88	98
Area 4--Skeena R.		
Ecstall R.	9/12/88	100
Area 6--North Central B.C.-Kitimat Arm		
Kitimat R.	8/--/88	100
Southeastern Alaska		
District 101--Behm Canal-Portland Canal		
Fish C. (early)	8/08/88	100
(late)	9/25/88	52
Traitor's C.	8/22/88	105
King C.	8/20/88	52
Portage C.	8/20/88	63
District 102--East Prince of Wales Island		
Disappearance C.	9/18/88	100
Old Tom C.	9/22/88	53
District 103--West Prince of Wales Island		
Breezy Bay	9/05/88	54
Port Real Marina	9/09/88	50
Cruz Cove	9/03/88	54
District 111--Stephens Passage		
Sheep C. (Hatchery)	8/09/88	51
District 115--Lynn Canal		
Creek 115-10-10420 (Off of St. James Bay)	7/28/88	50