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NWAFC PROCESSED REPORT 90-03

Preliminary Report on Genetic Diversity of Southern Southeast Alaskan Pink Salmon Populations

March 1990

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PRELIMINARY REPORT ON GENETIC DIVERSITY OF SOUTHERN SOUTHEAST ALASKAN PINK SALMON POPULATIONS

by

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March 1990

ABSTRACT

Using protein electrophoresis, genetic data were obtained from pink salmon (Oncorhynchus gorbuscha) collected from 19 streams in southern Southeast Alaska in 1987. Genetic relationships among the collections were examined from dendrograms and trees constructed from genetic distances between collections, from principal component analysis of allelic frequencies, and from log-likelihood ratio analysis. These techniques showed that the populations were genetically quite similar, but that there was a geographic component underlying the genetic differences. In particular, western Prince of Wales collections tended to cluster together, and as a group were statistically distinct from collections from inside waters. Comparisons of these findings to results from a previous study of British Columbia and Puget Sound pink salmon showed that although there are many genetic differences between pink salmon stocks from the northern and southern ends of this range, stocks near the Alaska/British Columbia border are quite similar. Genetic data presently available will be useful for separating northern and southern pink salmon stocks; however, more information is needed to determine whether or not it is possible to distinguish among stocks near the border.

CONTENTS

INTRODUCTION

Pink salmon (Oncorhynchus gorbuscha) fisheries in southeastern Alaska and northern British Columbia intercept complex mixtures of fish populations which originate in different countries. Separating the stocks of these fisheries is important both for management and for allocation under the terms of the Pacific Salmon Treaty between the United States and Canada.

If genetic differences occur among populations (defined here as an interbreeding group of fish), those differences often can be used to separate or identify populations of Pacific salmon, and to estimate the contribution of each population to a mixture (Pella and Milner 1987). In order to use genetic information for separating or identifying stocks, each population that is to be identified must possess distinct genetic characteristics. Either baseline genetic information must be available for all populations that potentially contribute to the mixture, or there must be a geographic basis for the genetic variation.

The first step in applying genetic information to stock separation is to obtain and analyze baseline information from pertinent populations. A sufficient number must be sampled to verify that the pattern of genetic variation among populations is related to their geographic distribution.

Little genetic work has been done on Southeast Alaskan pink salmon. Aspinwall (1974) examined only two loci and

McGregor (1982) focused primarily on northern Southeast Alaskan populations. Both observed large differences between even-year spawning and odd-year spawning populations. In fact, the genetic differences between pink salmon spawning in consecutive years in the same stream are far more pronounced than differences between spatially separated populations spawning in the same year. This has also been reported by Johnson (1979) and Beacham et al. (1988). Genetic differences between even- and odd-year fish are a result of the rigid two-year life cycle (Gilbert 1913; Davidson 1934; Rounsefell 1958; Anas 1959; Bilton and Ricker 1965; Turner and Bilton 1968) which reproductively isolates the two groups. The genetic differences between even- and odd-year pink salmon necessitate development of two separate baselines.

Using starch gel protein electrophoresis, we have conducted a preliminary investigation of the genetic composition of southern Southeast Alaskan pink salmon. We improved upon and added to techniques originally reported by McGregor (1982) and Lane (1984) and incorporated suggestions made by J. Shaklee of the Washington Department of Fisheries. In this paper we report preliminary results from a genetic study of subsamples of collections from 19 populations of odd-year pink salmon. Our primary objective is to determine whether or not the genetic structure of pink salmon populations can be used for stock separation and identification and, if so, on what geographical scale this can be applied.

MATERIALS AND METHODS

Samples

In August and September 1987, we collected tissue samples of approximately 100 adult salmon returning to streams on Prince of Wales Island and Revillagigedo Island and from streams on the mainland that drain into Portland Canal, Boca de Quadra, Behm Canal, Ernest Sound, and East Frederick Sound (Fig. 1; Table 1). Letters preceding stream names are used throughout this report for ease of reference to Figure 1.

An eye, the heart, and samples of skeletal muscle and liver from each fish were packaged in Whirl-pak[1] bags and put on ice or gel-ice immediately. They were subsequently frozen at -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). As of the writing of this paper, 50-100 of the samples collected for each population have been analyzed (Table 1). Buffer systems that were used are listed in Table 2. Specific enzyme activities (Table 3) were stained according to Harris and Hopkinson (1976) and by Aebersold et al. (1987). Loci for which data were routinely obtained are listed in Table 4.

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

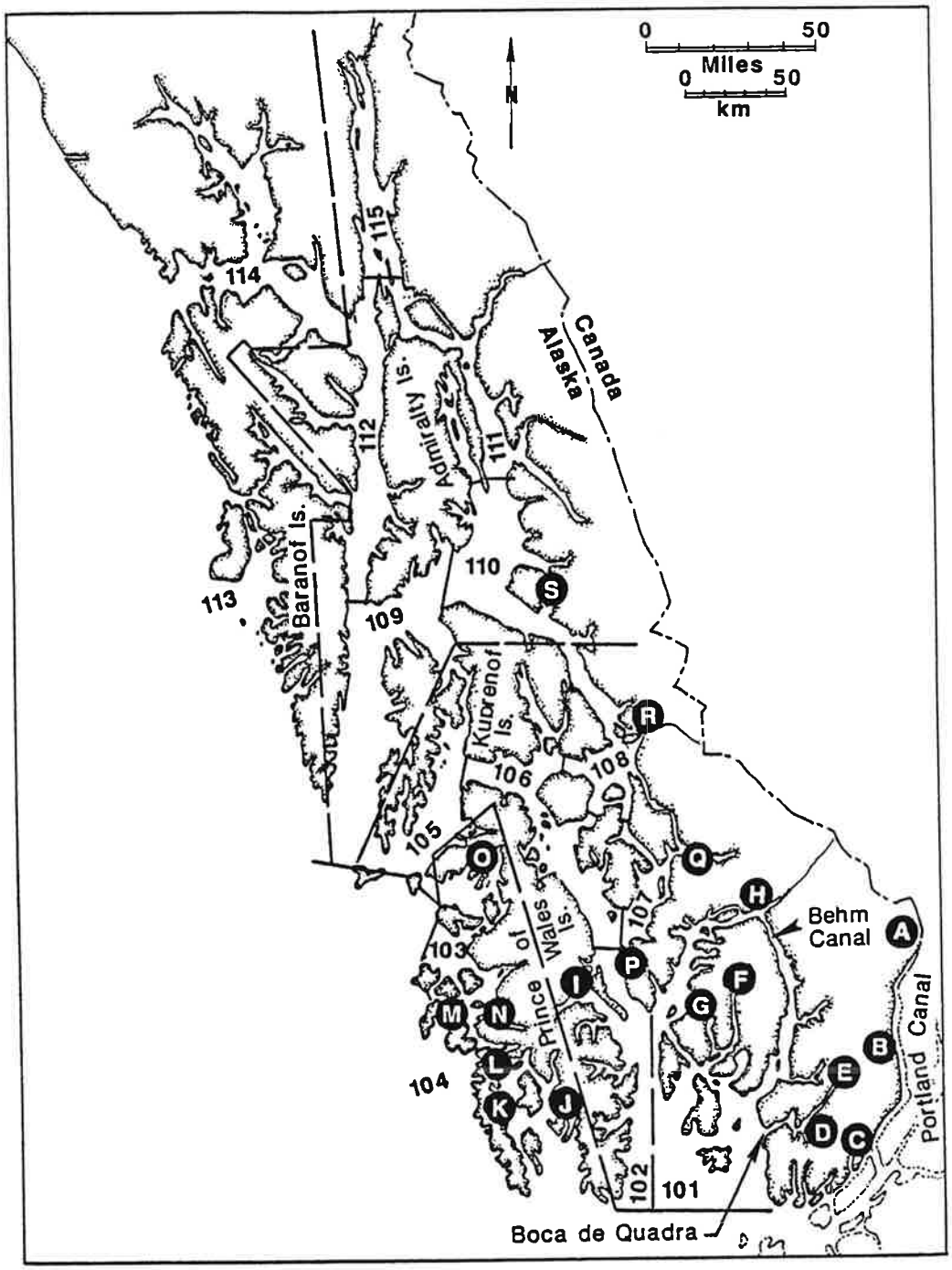

Figure 1.--Sampling sites for pink salmon in Southeast Alaska for 1987. Letters correspond to streams listed in Table 1 and Figures 2, 3, 4 and 5. Alaska Department of Fish and Game statistical areas are designated by three-digit codes.

Table 1.--Group designation (letters correspond to streams listed in Figs. 1-5), location, date of collection, and sizes of pink salmon samples used for electrophoretic analysis. Districts are Alaska Department of Fish and Game Statistical Areas. N = sample size.

Group design.	Location	Date	N
	District 101--Behm Canal-Portland Canal-Boca de Quadra		
A.	Fish C.	8/26/87	50
B.	Tombstone R.	8/13/87	100
C.	Hidden Inlet C.	8/15/87	100
D.	Hugh Smith R.	9/06/87	51
E.	Wilson R.	8/14/87	100
F.	Naha R.	8/14/87	50
G.	Carroll R.	8/16/87	100
H.	Herman C.	8/17/87	100
	District 102--East Prince of Wales Island		
I.	Karta R.	8/14/87	100
	District 103--West Prince of Wales Island-western islands		
J.	Keete Inlet	9/23/87	100
K.	Coco Harbor	9/24/87	100
L.	Breezy Bay	9/22/87	100
M.	Port Dolores	9/25/87	100
N.	Port Caldera	9/24/87	50
O.	Tokeen C.	9/27/87	100
	District 107--Ernest Sound-Bradfield Canal		
P.	Black Bear C.	8/28/87	100
Q.	Anan C.	8/11/87	100
	District 108--Stikine River		
R.	North Arm C.	8/10/87	100
	District 110--East Frederick Sound		
S.	Sandborn C.	8/09/87	100

Table 2.--Buffer systems used for electrophoresis of Southeast Alaskan pink salmon samples.

TC-1	electrode buffer pH 7.0 0.135 M tris(hydroxymethyl)amino methane 0.040 M citric acid Gel buffer is a 1/20 dilution of electrode buffer. (Shaw and Prasad 1970).
R	gel buffer stock 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 Gel buffer is 99% gel buffer stock and 1% electrode buffer. (Ridgway et al. 1970).
CA6.1 and CA6.8	electrode buffer pH 6.1 or 6.8 0.04 M citric acid pH is adjusted with N-(3-aminopropyl)-morpholine Gel buffer is a 1/20 dilution of electrode buffer. (Clayton and Tretiak 1972).
CAME7.2	electrode buffer pH 7.2 (modified from CA buffers) 0.04 M citric acid 0.01 M disodium ethylenediaminetetraacetate pH is adjusted with N-(3-aminopropyl)-morpholine Gel buffer is 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 Gel buffer is a 1/20 dilution of stock. Electrode 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 Gel buffer is a 1/27.5 dilution of electrode buffer. (buffer "a" of Schaal and Anderson 1974).
TG	gel and electrode buffer pH 8.5 (used undiluted) 0.248 M tris(hydroxymethyl)amino methane 0.192 M glycine (Holmes and Masters 1970).

Table 3.--Enzymes initially screened, their Enzyme Commission (E.C.) numbers (IUBNC 1984), and abbreviations. Peptidases are designated by substrate.

Enzyme	E.C. Number	Abbreviation
b-N-Acetylgalactoseaminidase	3.2.1.53	bGALA
N-Acetyl-b-glucosaminidase	3.2.1.30	bGA
Acid phosphatase	3.1.3.2	ACP
Aconitate hydratase	4.2.1.3	AH
Adenosine deaminase	3.5.4.4	ADA
Adenylate kinase	2.7.4.3	AK
Alanine aminotransferase	2.6.1.2	ALAT
Aspartate aminotransferase	2.6.1.1	AAT
Creatine kinase	2.7.3.2	CK
Cytachrome B_5 reductase	1.6.2.2	CYBR
Esterase, Esterase-D	3.1.1.*	EST, EST-D
Fructose-biphosphate aldolase	4.1.1.13	FBALD
Fumarate hydratase	4.2.1.2	FH
Galactose-1-phosphate uridyl transferase	2.7.7.12	GALT
Glucosephosphate isomerase	5.3.1.9	GPI
b-Glucuronidase	3.2.1.31	bGUS
Glyceraldehyde-3-phosphate dehydrogenase	1.2.1.12	GAP
Glycerol-3-phosphate dehydrogenase	1.1.1.8	G3P
Glutathione reductase	1.6.4.2	GR
Guanine deaminase	3.5.4.3	GDA
Hexokinase	2.7.1.1	HEX
Hydroxyacylglutathione hydrolase	3.1.2.6	HAGH
Isocitrate dehydrogenase	1.1.1.42	IDH
Lactate dehydrogenase	1.1.1.27	LDH
Lactoyl-glutathione lyase	4.4.1.5	LGL
Malate dehydrogenase	1.1.1.37	MDH
Malic enzyme	1.1.1.40	ME
a-Mannosidase	3.2.1.24	MAN
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 activity		PEP(LL)
phenylalanyl-proline activity		PEP(PP)
Phosphoglucomutase	5.4.2.2	PGM
6-Phosphogluconate dehydrogenase	1.1.1.44	PGDH
Phosphoglycerate kinase	2.7.2.3	PGK
Purine nucleoside phosphorylase	2.4.2.1	PNP
Pyruvate kinase	2.7.1.40	PK
Sorbitol dehydrogenase	1.1.1.14	SDH
Superoxide dismutase	1.15.1.1	SOD
Triose phosphate isomerase	5.3.1.1	TPI

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 2. L = liver, H = heart, M = muscle, E = eye.

Enzyme	Locus	Tissue	Buffer	Level of variability[a]
Aconitate hydratase	Ah-1[cd]	L	CA6.8,TC4	3
	mAh-3[cd]	H,M	TC,TC4	3
	mAh-4[cd]	H,M	TC,TC4	1,4
Adenosine deaminase	Ada-1[cd]	M,E,H	CA6.1	3
	Ada-2[bcd]	M,E,H	CA6.1	4
Alanine aminotransferase	Alat[cd]	M	MF	4
Aspartate aminotransferase	mAat-1[cd]	M,H	TC,CAME7.2	3
	mAat-2[cd]	L	TC,CAME7.2	3
	Aat-1,2[cd]	H,M	TC	3
	Aat-3[bcd]	E	R	4
	Aat-4[cd]	L,H	CAME7.2,TC	4
Creatine kinase	Ck-1[cd]	M	R	3
	Ck-2[cd]	M	R	3
	Ck-5[c]	E	R	2
Cytachrome B reductase	Cybr[cd]	E	TC4,TC,CAME7.2	3
Fumarate hydratase	Fh	H,M	TC4	3
Glucosephosphate isomerase	Gpi-1[bc]	M,E	R	2
	Gpi-2[bcd]	H,M,E	R	3
	Gpi-3[bcd]	M,H	R	3
Glycerol-3-phosphate dehydrogenase	G3p-1[bcd]	M,H	CA6.1,CAME7.2,MF	4

Table 4.--Continued

Enzyme	Locus	Tissue	Buffer	Level of variability[a]
Glutathione reductase	Gr[cd]	E,H	R,TC4,TC	3
Guanine deaminase	Gda[cd]	L	TG,CA6.8	1,4
Hydroxyacylglutathione hydrolase	Hagh[cd]	L,M,E	CAME7.2,TG	4
Isocitrate dehydrogenase	Idh-1[bcd]	H,M	TC,TC4	3
	Idh-2[c]	H,M	TC,TC4	2
	Idh-3[cd]	L	CAME7.2,CA6.8,TC4	4
Lactate dehydrogenase	Ldh-1[cd]	M	R	3
	Ldh-2[c]	M	R	2
	Ldh-3[bcd]	H,E,M	R	3
	Ldh-4[cd]	L,E	R	3
	Ldh-5[bc]	E	R	2
Malate dehydrogenase	Mdh-1,2[bcd]	L,H,E	CAME7.2,CA6.1,TC4	3
	Mdh-3,4[bcd]	M,H,E	CA6.1,MF	4
Malic enzyme	Me-1[bcd]	M,H	CA6.1,TC	3
Mannose-6-phosphate isomerase	Mpi[cd]	H	MF	3
Peptidases	Pep(Gl)	M	MF	2
	Pep(Lgg-1)[bcd]	M,H,E	R,MF	3
	Pep(Ll-)[cd]	M,E	TC,MF	4
	Pep(Pp-1)[cd]	M,H	MF,R	3
	Pep(Pp-2)[bcd]	M,H	MF,CAME7.2,R,TC	4
Phosphoglucomutase	Pgm-2[bcd]	M,H	R	4

Table 4.--Continued

Enzyme	Locus	Tissue	Buffer	Level of variability[a]
6-Phosphogluconate dehydrogenase	Pgdh[bcd]	E,M,H,L	CAME7.2,CA6.8,TC4	4
Sorbitol dehydrogenase	Sdh[c]	L	TG,R	2
Superoxide dismutase	Sod	L	R	3
	mSod	H	R	3
Triose phosphate isomerase	Tpi-1[cd]	E,M,L,H	R	3
	Tpi-2[cd]	E,M,L,H	R	3
	Tpi-3[c]	E,M,L,H		2
	Tpi-4[c]	E,M,L,H	R	2

[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. (1988).
[c]Loci used to obtain Figures 2, 3, 4, and 5.
[d]Loci used in principal component analysis.

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 eliminated classes with expected values less than four.

Variation at co-migrating duplicated loci (termed isoloci by Allendorf and Thorgaard 1984) was treated as if all the variability appeared at one locus and the other was monomorphic (Gharrett and Thomason 1987).

Relationships among collections were examined in three ways: 1) unweighted pair-group arithmetic average clustering (UPGMA, Sneath and Sokal 1973) of Rogers' unmodified (1972) and modified (Wright 1978) genetic distances and of Nei's (1972, 1978) genetic distance, 2) principal component analysis of the arcsine-square root transformed frequencies of the alleles that were most common at each locus (Wilkinson 1986), and 3) maximum-likelihood evolutionary trees (Felsenstein 1973, 1984). Relationships based on geographical proximity were also examined using hierarchical log-likelihood ratio analysis (Sokal and Rohlf 1981).

RESULTS

Initially, stains for 41 different enzymatic activities were tested (Table 3). Interpretable banding patterns were resolved, with 26 of the stains and 52 putative biochemical loci and isoloci (Allendorf and Thorgaard 1984) identified (Table 4). Data were routinely obtained for 42 loci and three pairs of isoloci (Appendix Table A). Of these loci, 8 were monomorphic in all populations examined. Rare variants at seventeen other loci and two pair of isoloci were seen in only a few of the collections. Thirteen loci and one pair of isoloci had substantial variability with the common allele present at a frequency of less than 0.95. The four remaining loci, mAh4, Gpi-2, Pep(Lgg-1), and Me-1 had relatively low levels of variability (frequency of common allele generally > 0.95), but in most collections were either variable or displayed some regionality in the variation. Tests for conformity of phenotypic frequencies to Hardy-Weinberg expectations did not fail in 64 possible tests.

Guanine deaminase (Gda) was variable in all collections and had 5 or more alleles. Unfortunately, it was quite diffi-cult to reliably distinguish among the relatively infrequent, fast alleles. Therefore, analyses presented herein use only the three most common alleles: Gda^{100}, Gda^{117}, and Gda^{126}; the faster alleles were pooled with Gda^{126}.

Allelic frequency data for 48 loci were used to examine genetic relationships among the collections. UPGMA clustering of Nei's unbiased genetic distances (1978) shows that many of the collections are essentially indistinguishable (Fig. 2). Some of the genetic differences observed, however, seem to have a geographic basis. With the exception of the collection from Breezy Bay, the collections from western Prince of Wales Island (District 103) cluster together. The collections from Herman Creek on Behm Canal and from Hidden Inlet on Portland Canal cluster with Prince of Wales Island collections rather than with other inland waters ones. However, divergences among most of these collections are small.

Two collections, Black Bear Creek in Ernest Sound and Anan Creek in Bradfield Canal (District 107), differed somewhat from all other collections. The difference in the collection from Black Bear Creek is attributable primarily to high variation at Ldh-1. Greater variation at Ada-2 and Gpi-2 account for much of the difference in the Anan Creek collection.

Dendrograms produced from UPGMA clustering of Rogers' genetic distance (1972) and Wright's (1978) modification of Rogers' distance were similar to the one constructed from Nei's distances (Fig. 3). The similarity among western Prince of Wales Island collections and the apparent difference between the Anan Creek and Black Bear Creek collections and the others are shown. It is interesting

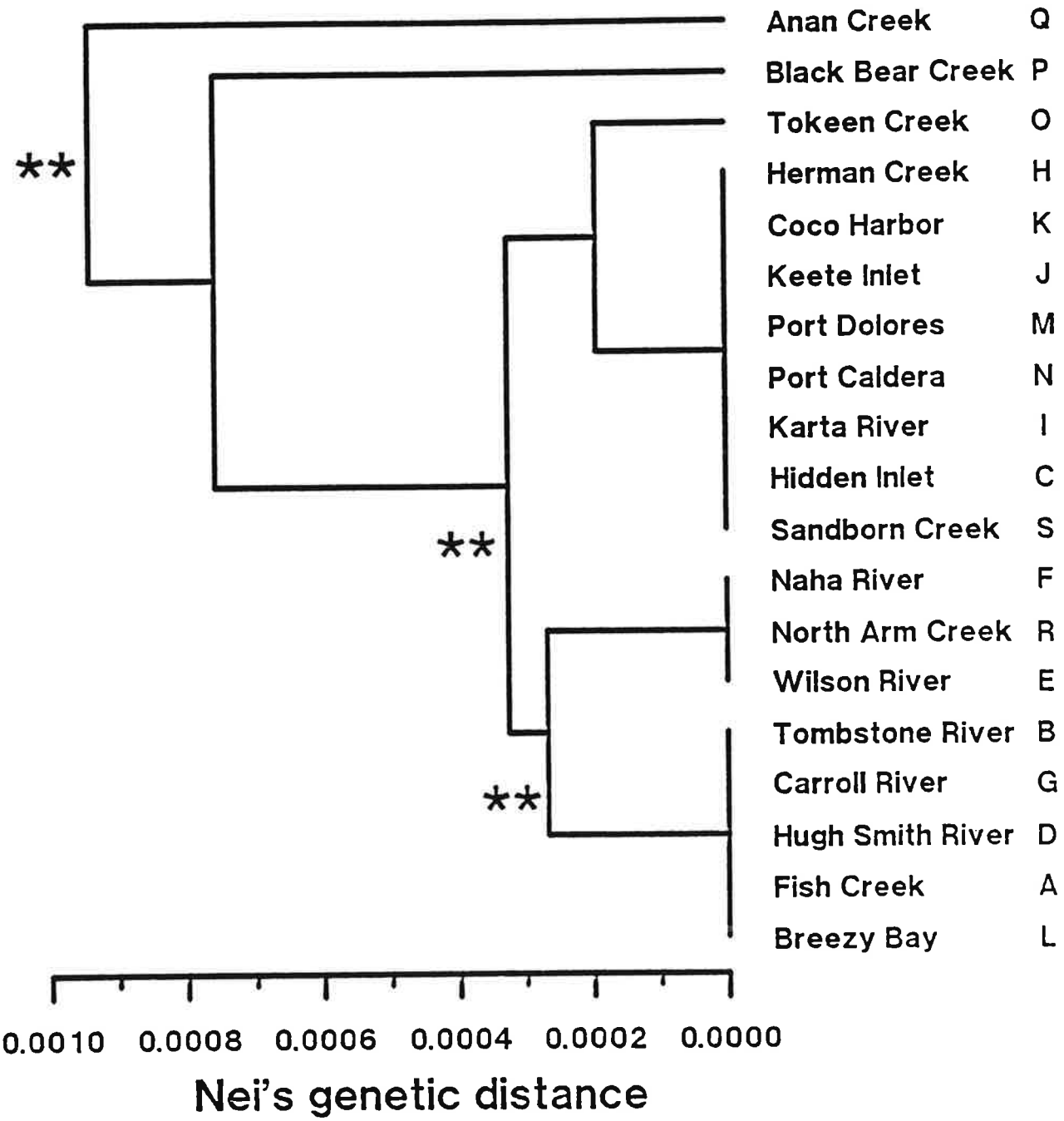

Figure 2.--Dendrogram constructed from Nei's (1972, 1978) unbiased genetic distances for data from 48 loci. The UPGMA algorithm (Sneath and Sokal 1973) was used to obtain the dendrogram. Heterogeneity between two branches joined at a node was determined by log-likelihood ratios (** $\underline{P} > 0.01$).

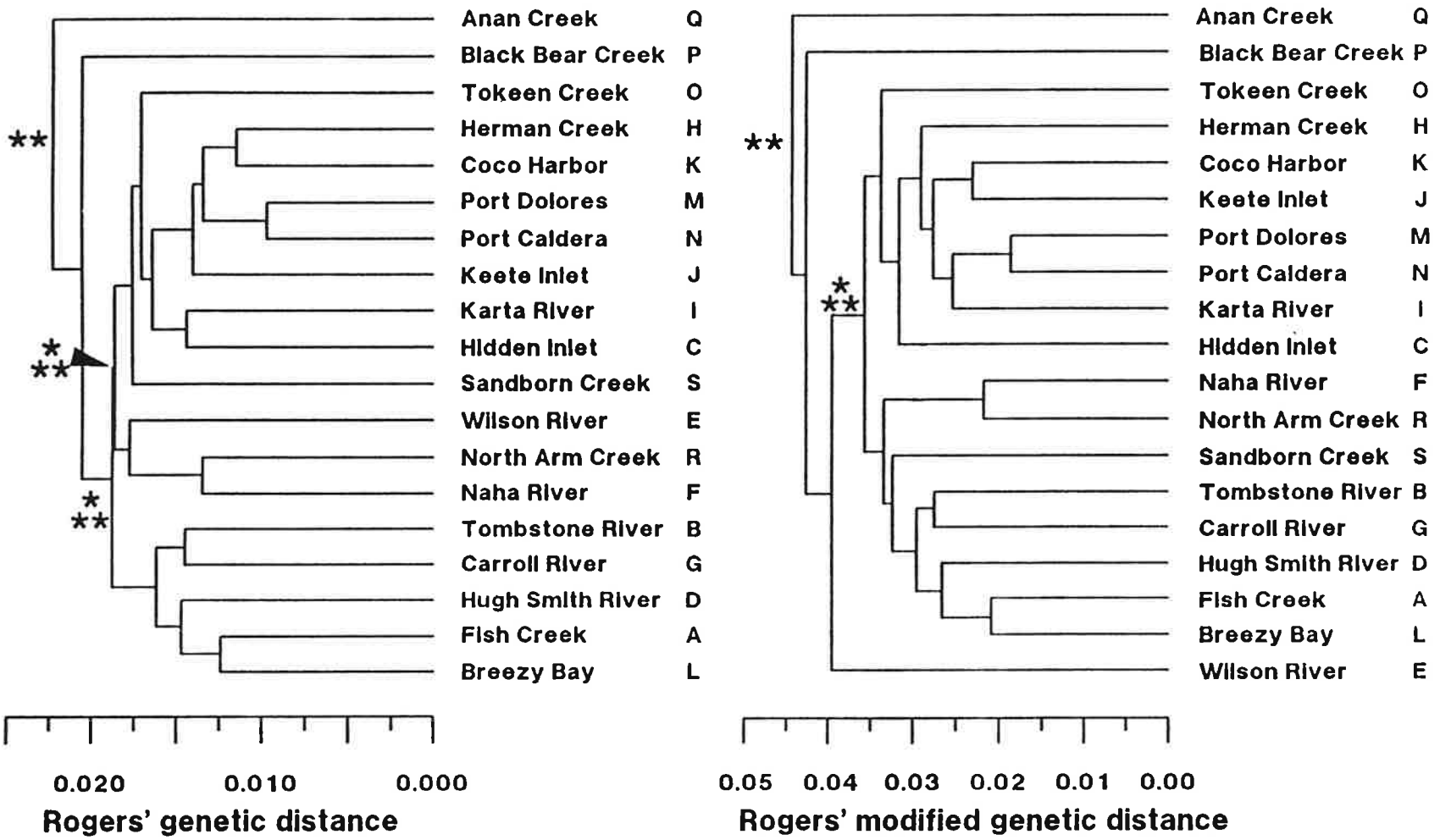

Figure 3.--Dendrograms constructed from Rogers' (1972) genetic distance (left) and from modified (Wright 1978) Rogers' distances (right) for data from 48 loci. The UPGMA algorithm (Sneath and Sokal 1973) was used to obtain the dendrogram. Heterogeneity between two branches joined at a node was determined by log-likelihood ratios (** $P < 0.01$ and *** $P < 0.001$).

that the dendrograms produced from the different genetic distances differ in detail, but are generally similar. It should be reiterated that the overall differences among collections is small.

The maximum-likelihood tree (Felsenstein 1973, 1984) produced from Cavalli-Sforza and Edwards' (1967) chord distances shows some of the clustering of western Prince of Wales Island populations, but it does not clearly show genetic relationships that indicate a geographic basis (Fig. 4). Alternative topologies produced by Felsenstein's algorithm differed in minor rearrangements of branches or limbs, but were quite similar to the one shown.

Principal component analysis was also used to examine the genetic variability among collections. Only loci at which variability exists are useful for this analysis; 37 of the 48 loci studied were used. The proportions of the total variability accounted for by the first six principal components were 0.135, 0.124, 0.102, 0.095, 0.083, and 0.076, respectively. These results indicate that the variability is not attributable to only one or a few loci, but that many of the loci contribute. Of these first six principal components, only the first and the fourth separated the collections according to geographic relationships (Fig. 5). The fourth principal component had the strongest relationship to geographic distribution. The loci contributing most strongly to the fourth principal component were Gpi-3, Gpi-2 and

Pgm- 2. None of these loci has a large amount of genetic variability, but little of the variability observed in the GPI loci was seen in the western Prince of Wales Island collections. In addition, the Pgm-2 variability is somewhat lower in the western Prince of Wales Island populations. The first principal component does not have as strong a geographic relationship as the fourth. The loci weighted most heavily in the first principal component were (in descending order) mAh-3, Aat-1,2, Aat-4, Pep(Ll-1), and Cybr-1. The first two of these loci have little variability, and that appears equally distributed among the geographic areas. Aat-4 appears to be somewhat less variable in Prince of Wales Island populations, and the variation of the other loci is not remarkably different between coastal and inside water stream systems.

The small geographic component that appears to underlie the genetic variability was further examined using log-likelihood ratio analysis (Table 5). Because Alaska Department of Fish and Game statistical areas (Fishing Districts) have a geographic basis, heterogeneity within and among Fishing Districts was analyzed. Only the collections from District 107 (Anan and Black Bear Creeks) showed heterogeneity ($P < 0.01$) within an area. This heterogeneity was due largely to Gda, Pep(Ll-1), and Ada-2.

Karta River on the east side of Prince of Wales Island (District 102) could be included with collections from either

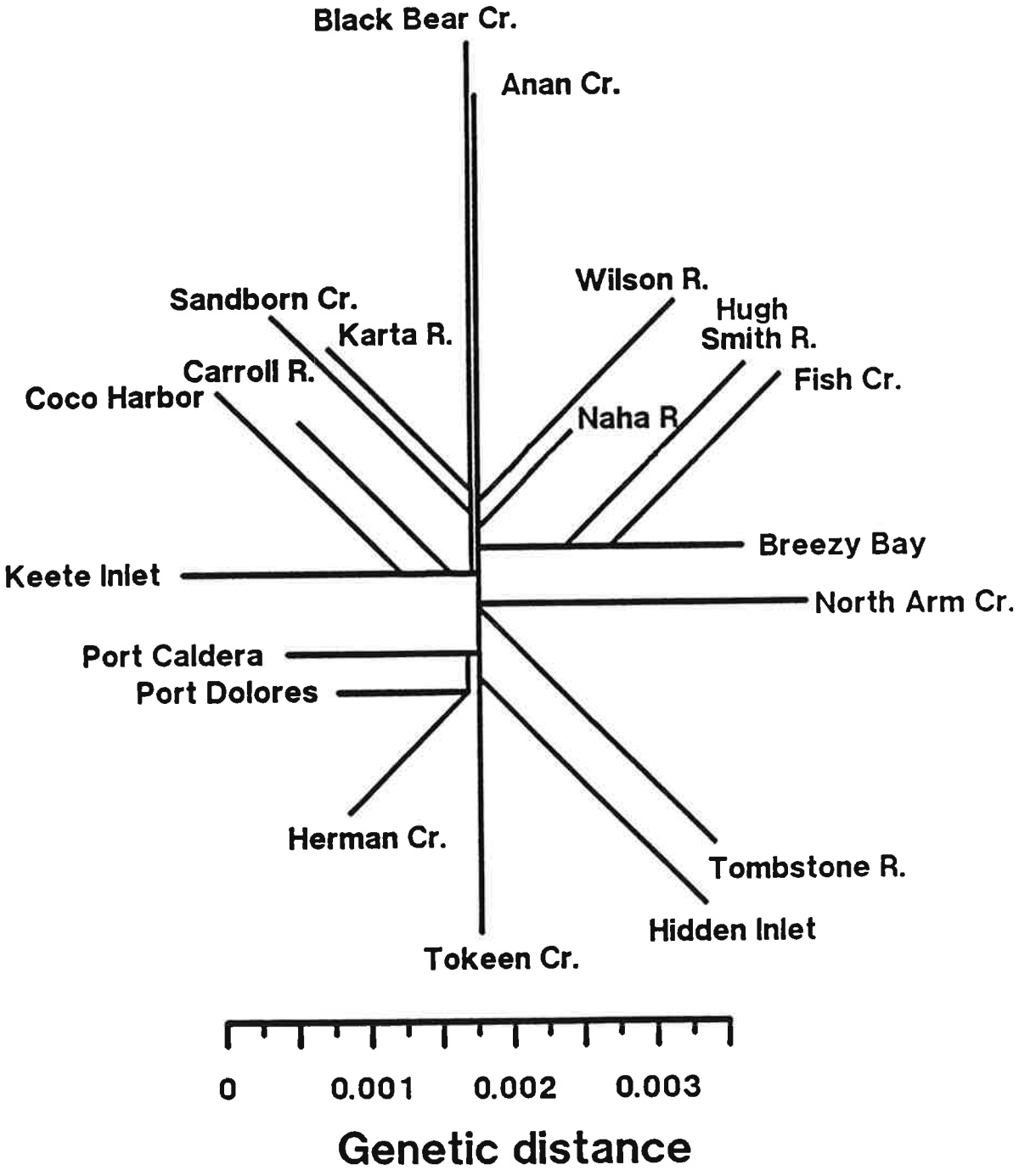

Figure 4.--Maximum-likelihood tree (Felsenstein 1973, 1984) estimated from genetic distances (Cavalli-Sforza and Edwards 1967).

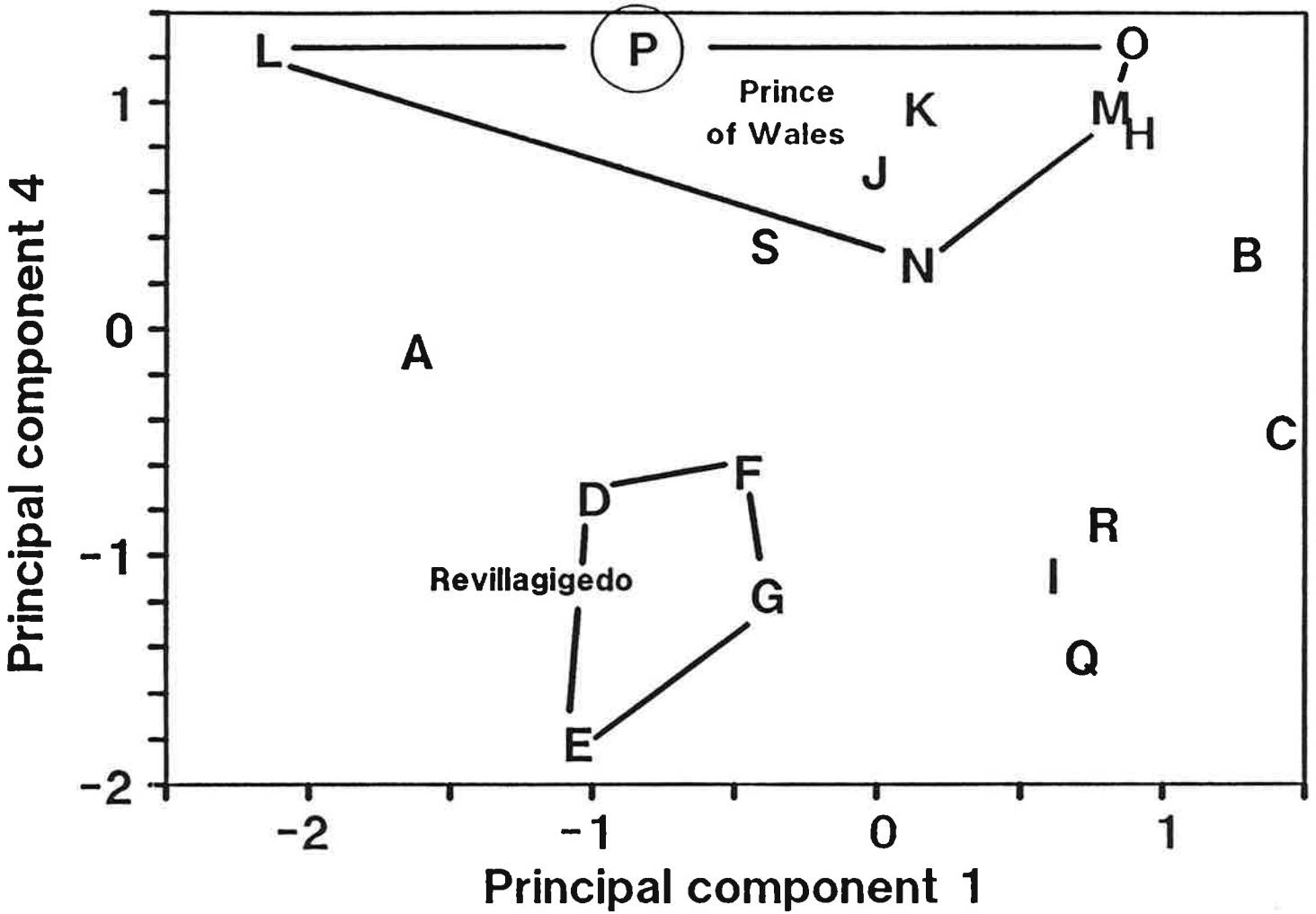

Figure 5.--Principal component analysis of Southeast Alaskan pink salmon allelic frequency data. Letters correspond to streams in Table 1 and Fig. 1. Circled letters within aggregations indicate collections not geographically associated with the aggregation.

Table 5.--Log-likelihood analysis of electrophoretic data from Southeast Alaskan pink salmon populations. Collections within fishing districts are in Fig. 1 and Table 1. ($^{a}P < 0.05$ and $^{b}P < 0.01$).

	Fishing Districts				Summary G-statistics		
Locus	101-102	103	107	108-110	Within	Among	Total
Aat-4	11.51	3.46	2.48	0.03	17.90	2.60	20.51
	8	5	1	1	15	3	18
Gda	20.66	9.94	8.77[a]	1.40	39.37	10.79	50.17
	16	10	2	2	30	6	36
Idh-3	13.28	14.31	2.11	3.77	33.72	7.15	40.87
	16	10	2	2	30	6	36
Aat-3	8.17	3.36	0.04	0.88	14.11	2.02	16.14
	8	5	1	1	15	3	18
Cybr-1	10.01	3.64	1.08	2.34	17.94	5.48	23.42
	8	5	1	1	15	3	18
Pgdh	10.78	3.90	1.74	0.46	16.78	3.18	19.96
	8	5	1	1	15	3	18
G3pdh-1	9.20	9.55	1.19	0.23	18.70	7.37	26.07
	8	5	1	1	15	3	18
Pep(Ll-1)	13.80	8.49	6.60[a]	0.21	28.64[a]	2.75	31.39[a]
	8	5	1	1	15	3	18
Pep(Pp-2)	13.56	6.88	0.81	2.16	22.00	8.38	30.38
	16	10	2	2	30	6	36
Pgm-2	5.01	5.34	0.92	0.76	14.52	3.01	17.52
	8	5	1	1	15	3	18
Ada-2	8.40	3.81	6.95[a]	0.67	19.18	10.81[a]	29.99[a]
	8	5	1	1	15	3	18
Mdh-3,4	3.93	2.15	0.28	0.07	7.30	1.07	8.36
	8	5	1	1	15	3	18
Total	128.29	74.85	32.97[b]	12.96	250.14	64.63[a]	314.77[a]
	120	75	15	15	225	45	270

western Prince of Wales (District 103) or southern inside waters (District 101) without producing heterogeneity. However, District 103 collections were significantly different from District 101 collections [G = 36.61 (18 df); P = 0.006]. Since Karta River is geographically closest to District 101, they were pooled together for subsequent analysis. Heterogeneity among geographical areas (Fishing Districts) was primarily due to Ada-2, but the heterogeneity was not strong ($P < 0.05$).

The genetic composition of collections from inland waters of southern Southeast Alaska (Districts 101 and 102) and from western Prince of Wales Island (District 103) were compared to compositions of aggregations of pink salmon populations from British Columbia and Puget Sound (Beacham et al. 1988). Felsenstein's (1973, 1984) maximum-likelihood tree was constructed using the 17 loci for which data was reported in all Canadian and Washington regions: Me-1, Mdh-1,2, Mdh-3,4, Pgdh, Gpi-1, Gpi-2, Gpi-3, Ldh-5, Idh-1, Aat-3, G3pdh-1, Ada-2, Pep(Pp-2), Pep(Lgg-1), and Pgm-2 (Fig. 6). The tree indicates that genetic similarities among the different regions examined are strongly influenced by the geographic distributions of the regions. Aggregations of pink salmon collections from the northern boundary areas (southern Southeast Alaska, Skeena River, and northern and central British Columbia) cluster together closely, as do Fraser River and Puget Sound aggregations from the southern

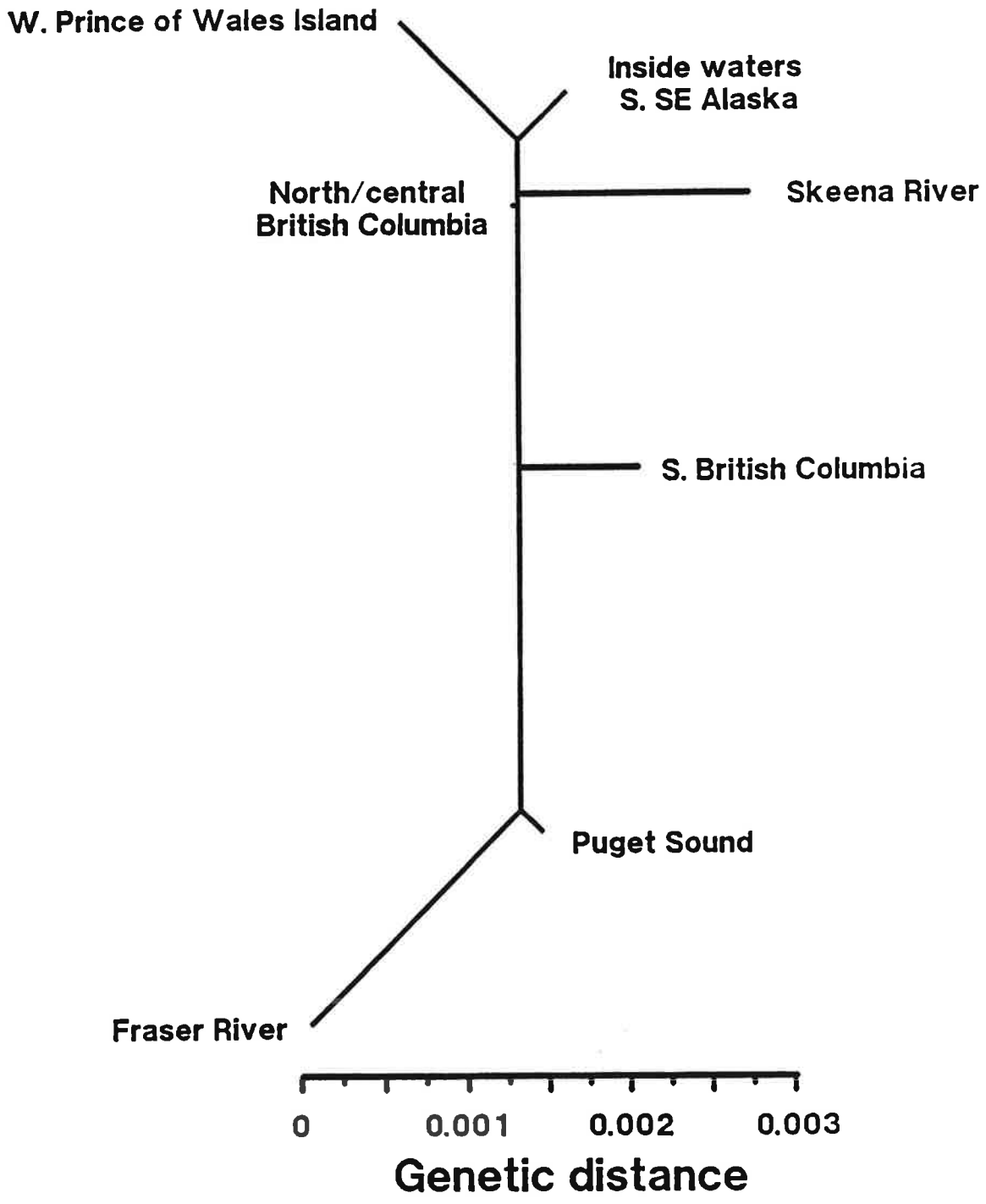

Figure 6.--Maximum-likelihood tree (Felsenstein 1973, 1984) estimated from genetic distances (Cavalli-Sforza and Edwards 1967) using summary data for British Columbia and Puget Sound pink salmon (Beacham et al. 1988) and from southern Southeast Alaska pink salmon.

end of the range. The northern and southern ends are quite distinct from each other. The aggregation of collections from southern British Columbia falls between the two, but is somewhat closer to the Fraser River and Puget Sound aggregations. Differences among northern aggregations are not large but are statistically significant.

DISCUSSION

Clearly, extreme northern and southern pink salmon stocks can be distinguished by their genetic differences (Fig. 6). This concept was applied by the Pacific Salmon Commission in 1989. The Commission used our data reported here along with data obtained from a parallel, unpublished study of southern stocks by the Washington Department of Fisheries to estimate interception of Fraser River pink salmon in northern and southern fisheries.

On a finer scale, a means for discriminating between stocks near the northern British Columbia and southern Southeast Alaska border is still needed. Although statistically significant differences were observed among geographical areas near the border, the actual genetic differences were small. Three explanations could account for the similarities among stocks in that area: 1) the populations were established relatively recently from common ancestors, 2) substantial gene flow (straying) occurs among pink salmon populations, or 3) convergent selection has occurred.

We are presently trying to achieve additional resolution of pink salmon stocks near the border by: obtaining data from additional loci; increasing the number of populations sampled; completing analysis of samples already collected; and collecting even-year stocks. We now routinely obtain data from 6 additional loci (Aat-4, Cybr-1, Hagh, Idh-3, Pep(Ll-1), and Gda) which are quite variable. (Aat-4 and Cybr-1 are both heavily weighted in the first principal component, which was one of the two components that indicated a geographic basis for genetic differences among southern Southeast Alaska collections.) Additional populations were sampled in 1989 to extend the geographical range for which we have genetic information to central Southeast Alaska and Northern British Columbia, and to increase the number of loci for which we have data in Canadian stocks. Analysis of the remaning samples in each collection will increase the power of statistical analysis. Also, analysis of even-year (1988) samples of pink salmon stocks collected near the Alaskan/ Canadian border will allow us to examine possible genetic differences between the reproductively isolated even- and odd-year pink salmon.

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APPENDIX

Table A.--Biochemical genetic variation in collections of pink salmon sampled from drainages in Southeast Alaska in 1987. Allelic frequencies and collection sizes (N) for biochemical genetic loci. Alleles are designated by their mobility relative to the most common allele (100).

	Aat-1,2			Aat-3		
Drainage	N	100	89	N	100	85
District 101--Behm Canal-Portland Canal-Boca de Quadra						
A. Fish C.	50	0.99	0.01	49	0.81	0.19
B. Tombstone R.	40	1.00	0	38	0.74	0.26
C. Hidden Inlet	40	1.00	0	40	0.71	0.29
D. Hugh Smith	51	0.99	0.01	50	0.76	0.24
E. Wilson R	40	1.00	0	40	0.82	0.18
F. Naha R.	51	0.99	0.01	51	0.76	0.24
G. Carroll R.	40	0.99	0.01	40	0.70	0.30
H. Herman Cr.	39	1.00	0	40	0.84	0.16
District 102--East Prince of Wales Island						
I. Karta R.	40	1.00	0	40	0.74	0.26
District 103--West Prince of Wales Island-western islands						
J. Keete Inlet	37	1.00	0	36	0.78	0.22
K. Coco Harbor	38	1.00	0	38	0.83	0.17
L. Breezy Bay	48	0.99	0.01	58	0.84	0.16
M. Port Dolores	39	1.00	0	39	0.81	0.19
N. Port Caldera	48	0.99	0.01	49	0.82	0.18
O. Tokeen C.	40	1.00	0	40	0.75	0.25
District 107--Ernest Sound-Bradfield Canal						
P. Black Bear C.	36	1.00	0	39	0.78	0.22
Q. Anan C.	40	1.00	0	39	0.79	0.21
District 108--Stikine River						
R. North Arm C.	39	1.00	0	40	0.80	0.20
District 110--East Frederick Sound						
S. Sandborn C.	40	1.00	0	40	0.74	0.26

Table A.--Continued

Drainage	Aat-4 N	Aat-4 100	Aat-4 slow	mAat-1 N	mAat-1 -100	mAat-1 -80	mAat-2 N	mAat-2 -100	mAat-2 -200
District 101--Behm Canal-Portland Canal-Boca de Quadra									
A.	49	0.56	0.44	50	1.00	0	50	0.99	0.01
B.	40	0.65	0.35	40	1.00	0	40	0.99	0.01
C.	39	0.59	0.41	40	1.00	0	40	0.98	0.02
D.	49	0.52	0.48	52	1.00	0	52	1.00	0
E.	40	0.58	0.42	40	1.00	0	40	1.00	0
F.	48	0.49	0.51	51	1.00	0	51	1.00	0
G.	40	0.51	0.49	40	1.00	0	40	1.00	0
H.	40	0.69	0.31	40	1.00	0	40	1.00	0
District 102--East Prince of Wales Island									
I.	38	0.57	0.43	40	1.00	0	40	1.00	0
District 103--West Prince of Wales Island-western islands									
J.	40	0.60	0.40	40	1.00	0	40	0.99	0.01
K.	40	0.66	0.34	40	1.00	0	40	1.00	0
L.	54	0.54	0.46	59	1.00	0	60	1.00	0
M.	40	0.62	0.38	40	1.00	0	40	0.99	0.01
N.	47	0.61	0.39	48	1.00	0	50	1.00	0
O.	40	0.62	0.38	40	1.00	0	40	0.99	0.01
District 107--Ernest Sound-Bradfield Canal									
P.	38	0.57	0.43	40	1.00	0	40	1.00	0
Q.	40	0.69	0.31	40	1.00	0	40	1.00	0
District 108--Stikine River									
R.	40	0.56	0.44	40	0.99	0.01	40	0.98	0.02
District 110--East Frederick Sound									
S.	40	0.58	0.42	40	0.99	0.01	40	1.00	0

Table A.--Continued

	Ada-1			Ah-1				mAh-3		
Drainage	N	100	slow	N	100	115	87	N	100	75
District 101--Behm Canal-Portland Canal-Boca de Quadra										
A.	50	1.00	0	50	1.00	0	0	50	1.00	0
B.	40	0.99	0.01	39	0.99	0	0.01	40	0.99	0.01
C.	40	1.00	0	39	0.99	0.01	0	40	1.00	0
D.	52	1.00	0	52	0.99	0	0.01	52	0.99	0.01
E.	40	1.00	0	40	1.00	0	0	40	1.00	0
F.	47	1.00	0	51	1.00	0	0	49	0.99	0.01
G.	40	1.00	0	40	1.00	0	0	40	1.00	0
H.	40	1.00	0	40	1.00	0	0	40	1.00	0
District 102--East Prince of Wales Island										
I.	40	1.00	0	40	1.00	0	0	40	1.00	0
District 103--West Prince of Wales Island-western islands										
J.	40	1.00	0	40	1.00	0	0	40	1.00	0
K.	40	0.99	0.01	40	1.00	0	0	40	1.00	0
L.	60	1.00	0	58	1.00	0	0	57	0.99	0.01
M.	40	1.00	0	39	1.00	0	0	40	0.99	0.01
N.	50	1.00	0	50	1.00	0	0	50	0.99	0.01
O.	40	1.00	0	40	1.00	0	0	40	0.99	0.01
District 107--Ernest Sound-Bradfield Canal										
P.	40	1.00	0	40	1.00	0	0	40	1.00	0
Q.	40	1.00	0	40	1.00	0	0	40	1.00	0
District 108--Stikine River										
R.	40	1.00	0	40	0.98	0.01	0.01	39	0.96	0.04
District 110--East Frederick Sound										
S.	40	1.00	0	40	1.00	0	0	40	0.98	0.02

Table A.--Continued

Drainage	Ada-2 N	100	87	113	G3pdh-1 N	100	200	175	120
District 101--Behm Canal-Portland Canal-Boca de Quadra									
A.	50	0.83	0.17	0	50	0.83	0.17	0	0
B.	39	0.87	0.13	0	40	0.88	0.12	0	0
C.	40	0.94	0.06	0	40	0.94	0.06	0	0
D.	49	0.92	0.08	0	52	0.88	0.12	0	0
E.	40	0.86	0.14	0	40	0.88	0.12	0	0
F.	49	0.87	0.13	0	51	0.91	0.09	0	0
G.	40	0.88	0.11	0.01	40	0.84	0.16	0	0
H.	39	0.91	0.09	0	40	0.89	0.11	0	0
District 102--East Prince of Wales Island									
I.	40	0.91	0.09	0	40	0.92	0.08	0	0
District 103--West Prince of Wales Island-western islands									
J.	40	0.91	0.09	0	40	0.88	0.12	0	0
K.	40	0.92	0.08	0	40	0.89	0.10	0.01	0
L.	60	0.88	0.12	0	60	0.88	0.12	0.01	0
M.	40	0.91	0.09	0	40	0.92	0.08	0	0
N.	50	0.90	0.10	0	50	0.93	0.07	0	0
O.	40	0.95	0.05	0	40	0.98	0.02	0	0
District 107--Ernest Sound-Bradfield Canal									
P.	39	0.90	0.10	0	40	0.88	0.12	0	0
Q.	40	0.74	0.26	0	40	0.81	0.19	0	0
District 108--Stikine River									
R.	40	0.89	0.11	0	40	0.86	0.10	0.01	0.02
District 110--East Frederick Sound									
S.	40	0.92	0.08	0	40	0.89	0.11	0	0

Table A.--Continued

Drainage	mAh-4 N	100	115	85	79	Alat N	100	112	87
District 101--Behm Canal-Portland Canal-Boca de Quadra									
A.	48	0.91	0	0.03	0.06	50	0.91	0.06	0.03
B.	40	0.98	0.02	0	0	40	0.99	0.01	0
C.	40	0.98	0.01	0	0.01	39	0.92	0.01	0.07
D.	51	0.93	0	0.02	0.05	51	0.92	0.01	0.07
E.	40	0.96	0.01	0.02	0	40	0.92	0.01	0.06
F.	51	0.96	0.02	0.01	0.01	51	0.97	0.02	0.01
G.	40	0.98	0.01	0.01	0	40	0.98	0.02	0
H.	40	1.00	0	0	0	40	0.99	0.01	0
District 102--East Prince of Wales Island									
I.	40	1.00	0	0	0	40	0.94	0.02	0.04
District 103--West Prince of Wales Island-western islands									
J.	40	0.98	0	0.02	0	40	0.92	0.04	0.04
K.	39	0.95	0.01	0.04	0	40	0.99	0.01	0
L.	56	0.95	0.01	0.02	0.03	60	0.92	0.04	0.04
M.	40	0.99	0.01	0	0	40	1.00	0	0
N.	50	0.98	0	0	0.02	50	0.97	0	0.03
O.	40	0.98	0.02	0	0	40	0.96	0.01	0.02
District 107--Ernest Sound-Bradfield Canal									
P.	40	0.96	0	0.01	0.02	40	0.99	0.01	0
Q.	38	0.99	0	0.01	0	40	0.95	0.04	0.01
District 108--Stikine River									
R.	40	0.98	0	0.01	0.01	40	0.99	0.01	0
District 110--East Frederick Sound									
S.	40	0.99	0	0.01	0	40	0.99	0.01	0

Table A.--Continued

Drainage	Ck-1 N	Ck-1 100	Ck-1 80	Ck-2 N	Ck-2 100	Ck-2 120	Gr-1 N	Gr-1 100	Gr-1 fast
District 101--Behm Canal-Portland Canal-Boca de Quadra									
A.	49	1.00	0	49	1.00	0	50	1.00	0
B.	40	0.99	0.01	40	1.00	0	40	1.00	0
C.	40	1.00	0	39	1.00	0	40	1.00	0
D.	50	0.99	0.01	51	1.00	0	50	1.00	0
E.	40	1.00	0	40	1.00	0	40	1.00	0
F.	50	1.00	0	50	1.00	0	47	1.00	0
G.	40	1.00	0	40	1.00	0	40	1.00	0
H.	40	1.00	0	40	1.00	0	40	1.00	0
District 102--East Prince of Wales Island									
I.	40	0.99	0.01	40	1.00	0	30	1.00	0
District 103--West Prince of Wales Island-western islands									
J.	40	1.00	0	40	1.00	0	40	1.00	0
K.	40	1.00	0	40	1.00	0	38	1.00	0
L.	60	1.00	0	60	0.99	0.01	54	1.00	0
M.	40	1.00	0	40	1.00	0	39	1.00	0
N.	43	0.99	0.01	43	1.00	0	50	0.99	0.01
O.	40	1.00	0	40	1.00	0	40	1.00	0
District 107--Ernest Sound-Bradfield Canal									
P.	40	1.00	0	40	1.00	0	39	1.00	0
Q.	40	0.99	0.01	40	1.00	0	40	1.00	0
District 108--Stikine River									
R.	40	0.99	0.01	40	1.00	0	40	1.00	0
District 110--East Frederick Sound									
S.	40	1.00	0	40	1.00	0	40	1.00	0

Table A.--Continued

Drainage	Cybr-1 N	100	120	80	142	Hagh N	100	127	136
District 101--Behm Canal-Portland Canal-Boca de Quadra									
A.	50	0.85	0.14	0.01	0	50	0.96	0.04	0
B.	40	0.85	0.11	0.04	0	40	0.96	0.04	0
C.	40	0.88	0.12	0.00	0	39	1.00	0	0
D.	50	0.74	0.18	0.07	0.01	52	0.95	0.05	0
E.	39	0.77	0.22	0.01	0	40	0.98	0.02	0
F.	51	0.78	0.15	0.06	0.01	51	0.99	0.01	0
G.	40	0.84	0.14	0.02	0	40	0.96	0.04	0
H.	39	0.86	0.11	0.01	0.01	40	0.99	0.01	0
District 102--East Prince of Wales Island									
I.	40	0.81	0.16	0.02	0	40	0.98	0.02	0
District 103--West Prince of Wales Island-western islands									
J.	40	0.86	0.10	0.04	0	40	0.92	0.06	0.01
K.	40	0.86	0.11	0.02	0	40	0.95	0.05	0
L.	40	0.79	0.16	0.05	0	54	0.96	0.04	0
M.	40	0.85	0.14	0.01	0	40	1.00	0	0
N.	50	0.87	0.10	0.02	0.01	49	0.99	0.01	0
O.	40	0.89	0.05	0.06	0	40	0.99	0.01	0
District 107--Ernest Sound-Bradfield Canal									
P.	38	0.79	0.18	0.03	0	40	0.98	0.02	0
Q.	38	0.86	0.11	0.04	0	40	1.00	0	0
District 108--Stikine River									
R.	39	0.82	0.15	0.03	0	40	0.96	0.04	0
District 110--East Frederick Sound									
S.	37	0.72	0.22	0.07	0	40	0.95	0.05	0

Table A.--Continued

Drainage	Gda N	100	117	126	136	142	Idh-1 N	100	35
District 101--Behm Canal-Portland Canal-Boca de Quadra									
A.	49	0.41	0.47	0.12	0	0	50	1.00	0
B.	39	0.36	0.49	0.05	0.05	0.05	40	1.00	0
C.	40	0.38	0.51	0.05	0.05	0.01	36	0.99	0.01
D.	52	0.35	0.43	0.21	0.01	0	52	0.99	0.01
E.	39	0.47	0.32	0.06	0.12	0.03	40	1.00	0
F.	51	0.45	0.40	0.11	0.04	0	51	1.00	0
G.	40	0.38	0.48	0.15	0	0	40	1.00	0
H.	40	0.28	0.49	0.14	0.10	0	40	1.00	0
District 102--East Prince of Wales Island									
I.	40	0.38	0.40	0.19	0.02	0.01	40	1.00	0
District 103--West Prince of Wales Island-western islands									
J.	39	0.37	0.41	0.15	0.05	0.01	40	0.99	0.01
K.	40	0.36	0.40	0.16	0.06	0.01	39	1.00	0
L.	52	0.43	0.42	0.11	0.03	0.01	58	0.99	0.01
M.	40	0.44	0.39	0.08	0.02	0.08	39	1.00	0
N.	50	0.45	0.36	0.19	0	0	48	1.00	0
O.	40	0.31	0.39	0.19	0.10	0.01	40	1.00	0
District 107--Ernest Sound-Bradfield Canal									
P.	39	0.37	0.35	0.15	0.10	0.03	40	1.00	0
Q.	40	0.46	0.44	0.08	0.02	0	40	1.00	0
District 108--Stikine River									
R.	40	0.46	0.40	0.11	0	0.02	39	1.00	0
District 110--East Frederick Sound									
S.	40	0.41	0.49	0.09	0.01	0	40	1.00	0

Table A.--Continued

Drainage	Gpi-2 N	100	130	33	-33	Gpi-3 N	100	90	110
District 101--Behm Canal-Portland Canal-Boca de Quadra									
A.	49	0.99	0.01	0	0	50	0.98	0.01	0.01
B.	40	0.98	0	0	0.02	40	0.99	0	0.01
C.	40	1.00	0	0	0	40	0.98	0.01	0.01
D.	52	0.99	0	0	0.01	52	0.99	0	0.01
E.	40	0.98	0	0.01	0.01	40	1.00	0	0
F.	51	0.99	0	0.01	0	51	0.98	0	0.02
G.	40	0.99	0	0.01	0	40	0.99	0.01	0
H.	40	1.00	0	0	0	40	1.00	0	0
District 102--East Prince of Wales Island									
I.	40	0.98	0	0.02	0	40	0.98	0.02	0
District 103--West Prince of Wales Island-western islands									
J.	40	0.99	0	0	0.01	40	1.00	0	0
K.	40	1.00	0	0	0	40	0.99	0.01	0
L.	60	1.00	0	0	0	60	1.00	0	0
M.	40	1.00	0	0	0	40	1.00	0	0
N.	50	1.00	0	0	0	50	0.99	0	0.01
O.	40	1.00	0	0	0	40	1.00	0	0
District 107--Ernest Sound-Bradfield Canal									
P.	39	0.99	0	0.01	0	40	1.00	0	0
Q.	40	0.95	0	0.05	0	40	0.98	0	0.02
District 108--Stikine River									
R.	40	1.00	0	0	0	40	0.99	0.01	0
District 110--East Frederick Sound									
S.	40	0.99	0	0	0.01	40	1.00	0	0

Table A.--Continued

Drainage	Idh-3 N	100	120	130	150	slow	Pep(Lgg-1) N	100	125	140
District 101--Behm Canal-Portland Canal-Boca de Quadra										
A.	50	0.63	0.30	0.07	0	0	50	0.97	0.03	0
B.	40	0.65	0.29	0.06	0	0	40	0.98	0.02	0
C.	40	0.68	0.24	0.09	0	0	40	1.00	0	0
D.	50	0.67	0.25	0.08	0	0	51	0.99	0.01	0
E.	40	0.64	0.25	0.09	0.02	0	40	1.00	0	0
F.	51	0.77	0.16	0.07	0	0	51	1.00	0	0
G.	40	0.68	0.20	0.12	0	0	40	0.98	0.01	0.01
H.	40	0.66	0.28	0.06	0	0	40	0.99	0.01	0
District 102--East Prince of Wales Island										
I.	40	0.69	0.26	0.05	0	0	40	1.00	0	0
District 103--West Prince of Wales Island-western islands										
J.	40	0.55	0.31	0.12	0	0.01	40	0.99	0.01	0
K.	40	0.64	0.22	0.11	0.01	0	40	0.99	0.01	0
L.	58	0.68	0.23	0.09	0	0	60	0.98	0.02	0
M.	40	0.60	0.32	0.08	0	0	40	0.98	0.02	0
N.	48	0.70	0.27	0.03	0	0	50	0.99	0.01	0
O.	40	0.69	0.25	0.06	0	0	40	1.00	0	0
District 107--Ernest Sound-Bradfield Canal										
P.	40	0.71	0.26	0.02	0	0	40	0.99	0.01	0
Q.	39	0.63	0.31	0.05	0.01	0	40	1.00	0	0
District 108--Stikine River										
R.	40	0.79	0.18	0.04	0	0	40	0.99	0.01	0
District 110--East Frederick Sound										
S.	40	0.65	0.29	0.06	0	0	40	0.99	0.01	0

Table A.--Continued

Drainage	Ldh-1 N	Ldh-1 100	Ldh-1 fast	Ldh-3 N	Ldh-3 100	Ldh-3 160	Ldh-4 N	Ldh-4 100	Ldh-4 120
District 101--Behm Canal-Portland Canal-Boca de Quadra									
A.	50	1.00	0	50	1.00	0	50	1.00	0
B.	40	1.00	0	40	1.00	0	40	0.99	0.01
C.	40	1.00	0	40	1.00	0	40	1.00	0
D.	52	1.00	0	52	1.00	0	52	1.00	0
E.	40	1.00	0	40	0.99	0.01	40	1.00	0
F.	11	1.00	0	51	1.00	0	51	1.00	0
G.	40	1.00	0	40	1.00	0	40	1.00	0
H.	40	1.00	0	40	1.00	0	40	1.00	0
District 102--East Prince of Wales Island									
I.	40	0.99	0.01	40	1.00	0	40	1.00	0
District 103--West Prince of Wales Island-western islands									
J.	40	1.00	0	40	1.00	0	40	1.00	0
K.	40	0.99	0	40	1.00	0	40	1.00	0
L.	60	1.00	0	39	1.00	0	39	1.00	0
M.	40	1.00	0	40	1.00	0	40	1.00	0
N.	50	1.00	0	50	1.00	0	50	1.00	0
O.	40	1.00	0	40	1.00	0	40	1.00	0
District 107--Ernest Sound-Bradfield Canal									
P.	40	0.84	0.16	40	1.00	0	40	0.99	0.01
Q.	40	1.00	0	39	1.00	0	40	0.99	0.01
District 108--Stikine River									
R.	40	1.00	0	40	1.00	0	40	1.00	0
District 110--East Frederick Sound									
S.	38	1.00	0	40	1.00	0	40	1.00	0

Table A.--Continued

Drainage	Pep(L1-1) N	100	83	72	Mdh-1,2 N	100	87	-138	113
District 101--Behm Canal-Portland Canal-Boca de Quadra									
A.	47	0.82	0.18	0	50	0.99	0.01	0	0
B.	37	0.81	0.19	0	40	0.99	0.01	0	0
C.	39	0.65	0.35	0	40	1.00	0	0	0
D.	51	0.81	0.19	0	52	1.00	0	0	0
E.	40	0.74	0.26	0	40	1.00	0	0	0
F.	45	0.77	0.23	0	51	1.00	0	0	0
G.	39	0.79	0.21	0	40	1.00	0	0	0
H.	40	0.71	0.29	0	40	0.99	0	0	0.01
District 102--East Prince of Wales Island									
I.	40	0.68	0.32	0	40	1.00	0	0	0
District 103--West Prince of Wales Island-western islands									
J.	40	0.74	0.26	0	40	1.00	0	0	0
K.	40	0.71	0.29	0	40	1.00	0	0	0
L.	56	0.84	0.15	0.01	60	0.99	0	0	0.01
M.	40	0.72	0.28	0	40	1.00	0	0	0
N.	47	0.71	0.28	0	50	1.00	0	0	0
O.	40	0.81	0.19	0	40	1.00	0	0	0
District 107--Ernest Sound-Bradfield Canal									
P.	40	0.88	0.12	0	40	1.00	0	0	0
Q.	40	0.71	0.29	0	40	0.99	0	0.01	0
District 108--Stikine River									
R.	39	0.71	0.29	0	40	1.00	0	0	0
District 110--East Frederick Sound									
S.	40	0.74	0.26	0	40	0.99	0	0.01	0

Table A.--Continued

		Mdh-3,4						Fh		
Drainage	N	100	130	68	80	67	vfast	N	100	fast
District 101--Behm Canal-Portland Canal-Boca de Quadra										
A.	50	0.89	0.08	0.02	0.01	0	0	49	1.00	0
B.	40	0.92	0.05	0.02	0	0	0	40	1.00	0
C.	40	0.91	0.06	0.02	0	0	0	40	1.00	0
D.	52	0.89	0.06	0.05	0	0	0	52	1.00	0
E.	40	0.91	0.04	0.05	0	0	0	40	1.00	0
F.	51	0.92	0.03	0.05	0	0	0	51	0.99	0.01
G.	40	0.95	0.02	0.02	0	0	0	40	1.00	0
H.	40	0.94	0.02	0.02	0	0.01	0	40	1.00	0
District 102--East Prince of Wales Island										
I.	40	0.94	0.01	0.05	0	0	0	30	1.00	0
District 103--West Prince of Wales Island-western islands										
J.	40	0.89	0.05	0.06	0	0	0	40	1.00	0
K.	40	0.92	0.01	0.05	0.01	0	0	38	1.00	0
L.	60	0.88	0.08	0.04	0	0	0	60	1.00	0
M.	40	0.90	0.05	0.02	0	0.01	0.01	39	1.00	0
N.	50	0.90	0.04	0.05	0	0.01	0	50	1.00	0
O.	40	0.94	0.04	0.02	0	0	0	40	1.00	0
District 107--Ernest Sound-Bradfield Canal										
P.	40	0.89	0.02	0.08	0	0.01	0	40	1.00	0
Q.	40	0.91	0.06	0.02	0	0	0	--	--	--
District 108--Stikine River										
R.	40	0.89	0.05	0.06	0	0	0	40	1.00	0
District 110--East Frederick Sound										
S.	40	0.90	0.02	0.06	0.01	0	0	--	--	--

Table A.--Continued

Drainage	mMe-1 N	100	130	70	Pgm-2 N	-100	-50
District 101--Behm Canal-Portland Canal-Boca de Quadra							
A.	50	0.97	0.02	0.01	50	0.95	0.05
B.	40	1.00	0	0	40	0.95	0.05
C.	40	0.99	0.01	0	40	0.91	0.09
D.	52	0.99	0	0.01	52	0.91	0.09
E.	40	0.99	0.01	0	40	0.95	0.05
F.	51	0.98	0.02	0	50	0.91	0.09
G.	40	0.99	0.01	0	40	0.92	0.08
H.	40	0.98	0.02	0	40	0.90	0.10
District 102--East Prince of Wales Island							
I.	33	0.95	0.05	0	40	0.90	0.10
District 103--West Prince of Wales Island-western islands							
J.	40	0.99	0.01	0	40	0.94	0.06
K.	40	0.98	0.02	0	40	0.95	0.05
L.	60	0.98	0.02	0	60	0.98	0.02
M.	40	0.99	0.01	0	40	0.92	0.08
N.	50	0.97	0.03	0	50	0.94	0.06
O.	40	0.99	0.01	0	40	0.96	0.04
District 107--Ernest Sound-Bradfield Canal							
P.	40	0.98	0.02	0	38	0.96	0.04
Q.	40	0.99	0.01	0	40	0.92	0.08
District 108--Stikine River							
R.	40	0.99	0.01	0	40	0.90	0.10
District 110--East Frederick Sound							
S.	40	0.92	0.06	0.01	40	0.94	0.06

Table A.--Continued

	Mpi				Pgdh				
Drainage	N	100	115	85	N	100	95	90	104
District 101--Behm Canal-Portland Canal-Boca de Quadra									
A.	50	0.99	0.01	0	50	0.93	0.06	0.01	0
B.	40	1.00	0	0	38	0.92	0.08	0	0
C.	40	1.00	0	0	39	0.86	0.12	0.03	0
D.	52	1.00	0	0	50	0.94	0.06	0	0
E.	40	0.99	0.01	0	40	0.84	0.15	0.01	0
F.	51	0.99	0.01	0	51	0.88	0.11	0.01	0
G.	40	1.00	0	0	40	0.89	0.10	0.01	0
H.	40	0.99	0.01	0	40	0.86	0.11	0.02	0
District 102--East Prince of Wales Island									
I.	40	0.98	0.02	0	40	0.94	0.06	0	0
District 103--West Prince of Wales Island-western islands									
J.	40	1.00	0	0	40	0.85	0.10	0.04	0.01
K.	38	0.99	0	0.01	40	0.88	0.08	0.05	0
L.	60	0.99	0.01	0	58	0.91	0.06	0.03	0
M.	39	1.00	0	0	40	0.89	0.10	0.01	0
N.	48	1.00	0	0	50	0.93	0.05	0.02	0
O.	39	1.00	0	0	39	0.89	0.08	0.04	0
District 107--Ernest Sound-Bradfield Canal									
P.	40	1.00	0	0	37	0.95	0.05	0	0
Q.	40	0.99	0.01	0	40	0.89	0.10	0.01	0
District 108--Stikine River									
R.	40	1.00	0	0	40	0.84	0.11	0.05	0
District 110--East Frederick Sound									
S.	40	0.99	0.01	0	40	0.88	0.12	0	0

Table A.--Continued

	Sod-1			Tpi-1			Tpi-2		
Drainage	N	100	276	N	-100	-115	N	-100	200
District 101--Behm Canal-Portland Canal-Boca de Quadra									
A.	49	1.00	0	50	1.00	0	50	1.00	0
B.	40	0.98	0.02	40	0.99	0.01	40	1.00	0
C.	40	1.00	0	40	1.00	0	40	1.00	0
D.	52	1.00	0	50	1.00	0	50	0.99	0.01
E.	40	0.99	0.01	40	1.00	0	40	0.99	0.01
F.	51	1.00	0	51	1.00	0	51	1.00	0
G.	40	1.00	0	40	1.00	0	40	0.99	0.01
H.	40	1.00	0	40	1.00	0	40	1.00	0
District 102--East Prince of Wales Island									
I.	40	1.00	0	39	1.00	0	40	1.00	0
District 103--West Prince of Wales Island-western islands									
J.	40	1.00	0	40	1.00	0	40	1.00	0
K.	40	1.00	0	40	1.00	0	40	1.00	0
L.	60	1.00	0	60	1.00	0	60	1.00	0
M.	40	1.00	0	40	1.00	0	40	1.00	0
N.	49	1.00	0	50	1.00	0	50	1.00	0
O.	40	1.00	0	40	1.00	0	40	1.00	0
District 107--Ernest Sound-Bradfield Canal									
P.	40	1.00	0	40	1.00	0	40	1.00	0
Q.	40	1.00	0	40	1.00	0	40	1.00	0
District 108--Stikine River									
R.	--	--	--	40	1.00	0	40	1.00	0
District 110--East Frederick Sound									
S.	40	1.00	0	40	1.00	0	40	1.00	0

Table A.--Continued

	Pep(Pp-1)			Pep(Pp-2)				mSod		
Drainage	N	100	110	N	100	109	93	N	100	17
District 101--Behm Canal-Portland Canal-Boca de Quadra										
A.	50	0.99	0.01	50	0.66	0.19	0.15	50	0.99	0.01
B.	40	1.00	0	40	0.68	0.18	0.15	35	1.00	0
C.	39	1.00	0	40	0.70	0.16	0.14	--	--	--
D.	52	1.00	0	52	0.64	0.17	0.18	52	1.00	0
E.	40	1.00	0	40	0.51	0.21	0.28	--	--	--
F.	51	1.00	0	50	0.65	0.19	0.16	51	1.00	0
G.	40	1.00	0	40	0.72	0.12	0.15	39	1.00	0
H.	40	1.00	0	40	0.65	0.20	0.15	39	1.00	0
District 102--East Prince of Wales Island										
I.	40	1.00	0	39	0.68	0.21	0.15	--	--	--
District 103--West Prince of Wales Island-western islands										
J.	40	1.00	0	40	0.72	0.16	0.11	--	--	--
K.	40	1.00	0	40	0.75	0.18	0.08	38	1.00	0
L.	60	1.00	0	60	0.68	0.18	0.14	60	1.00	0
M.	40	1.00	0	38	0.64	0.18	0.17	37	1.00	0
N.	50	1.00	0	50	0.69	0.16	0.15	49	1.00	0
O.	40	1.00	0	40	0.66	0.24	0.10	--	--	--
District 107--Ernest Sound-Bradfield Canal										
P.	40	1.00	0	40	0.70	0.16	0.14	--	--	--
Q.	40	1.00	0	40	0.76	0.12	0.11	39	1.00	0
District 108--Stikine River										
R.	40	1.00	0	40	0.61	0.21	0.18	--	--	--
District 110--East Frederick Sound										
S.	40	1.00	0	40	0.70	0.20	0.10	10	0.95	0.05

Table A.--Continued

Drainage	Sdh	Ck-5	Gpi-1	Idh-2	Ldh-2	Ldh-5	Tpi-3	Tpi-4	Pep(Gl-1)
				Sample sizes of monomorphic loci					
District 101--Behm Canal-Portland Canal-Boca de Quadra									
A.	50	50	50	50	50	50	50	50	50
B.	38	40	40	40	40	40	40	40	40
C.	39	40	40	36	40	40	40	40	40
D.	46	50	52	52	52	50	50	50	52
E.	38	40	40	40	40	40	40	40	40
F.	51	50	51	51	11	51	51	51	51
G.	40	40	40	40	40	40	40	40	40
H.	39	40	40	40	40	40	40	40	40
District 102--East Prince of Wales Island									
I.	40	40	40	40	40	40	40	40	40
District 103--West Prince of Wales Island-western islands									
J.	40	39	40	40	40	40	40	40	40
K.	39	39	40	39	40	40	38	38	39
L.	59	59	60	58	60	59	60	60	55
M.	40	40	40	39	40	40	40	40	40
N.	47	47	50	48	50	49	50	50	49
O.	39	31	40	40	40	40	40	40	40
District 107--Ernest Sound-Bradfield Canal									
P.	40	40	39	40	40	40	40	40	40
Q.	38	40	40	40	40	39	40	40	40
District 108--Stikine River									
R.	37	40	40	40	40	40	40	40	40
District 110--East Frederick Sound									
S.	40	39	40	40	40	40	40	40	40