TCNB/TR-8701

FEBRUARY 1987

PACIFIC SALMON COMMISSION

THE NORTHERN BOUNDARY AND TRANSBOUNDARY RIVER
TECHNICAL COMMITTEES

REPORT TCNB/TR (87) 1

STOCK IDENTIFICATION OF SOCKEYE SALMON

USING BIOLOGICAL MARKERS

Prepared for

The Northern Panel
of
The Pacific Salmon Commission

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FOREWORD

This report was prepared in response to the Northern Panel request generated during the February 17-18, 1986 Commission meetings in Vancouver.

The Panel requested:

"Stock Identification - District 104 and 106

> The Northern Panel directs the joint technical committee and national research scientists responsible for the design of the U.S.-Canada cooperative research program to carefully evaluate the research effort directed at sockeye stock separation in the Noyes Island and District 106 fishery in 1986. The objective of the program is to identify stock composition by week by fishery. The Panel realizes that the late stage in the development of the 1986 program and other priorities may not allow a major expansion of effort, but they should determine if program adjustments would better address the stated objectives and could be accomplished within the framework of the existing overall program. Regardless of the outcome of this deliberation the Panel will request a complete review of the sockeye stock separation program for 1987."

The response of the Northern Boundary Technical Committee comprises three parts:

1) An oral presentation to be given at the Pacific Salmon Commission meetings November 16-21, 1986.

2) A written report to accompany the oral presentation.

3) Summaries of sockeye stock identification sampling activities and a bibliography are provided as appendices to the report.

The following report was prepared to evaluate the research directed at sockeye stock identification. It describes and compares the various kinds of biological markers used in differentiating sockeye populations, and explains two different approaches used to estimate sockeye stock composition in the Northern Boundary area.

Stock Identification of Sockeye Salmon Using Biological Markers.

1.0 OBJECTIVES

Recent advances in statistical methods and computational capabilities have made it feasible to estimate the stock composition of mixed-stock fishery samples by examining biological attributes that differ between stocks. If satisfactory biological "markers" can be found, stock composition could be determined routinely without resorting to expensive and laborious tagging studies. A variety of biological markers have been studied in sockeye salmon populations, and it is generally accepted that the reliability of stock composition estimates using these markers is potentially equal to that of estimates derived from tagging studies. The purpose of this report is first, to describe and compare the various kinds of biological markers which are useful for differentiating sockeye populations, and second, to explain the two different approaches that have been used to estimate sockeye stock composition in the Northern Boundary area (northern British Columbia - Southeast Alaska). This report also summarizes recent sampling activities for sockeye stock identification and includes recommendations for further research.

2.0 DESCRIPTION OF BIOLOGICAL MARKERS

2.1 Scale Patterns

The pattern of circulus formation in sockeye scales records an individual fish's growth history. Most of the scale features used to differentiate stocks are associated with growth in freshwater where different stocks occupy discrete environments that may differ in temperature and in the availability of food. Scale patterns are particularly useful for sockeye salmon because the vast majority of juvenile sockeye inhabit lakes for a year or more, thus most members of a population share a fairly uniform environment. A large number of scale features can be measured from a single scale but usually these can be expressed as two or three uncorrelated markers. The most basic scale features are the number of circuli, and the distance between circuli in each year of freshwater growth.

Scale patterns have proven very useful for in-season management within large river systems (e.g., the Fraser River, Cook and Guthrie 1987) or where a relatively small number of stocks contribute to mixed-stock fisheries (e.g., the Lynn Canal, McPherson 1986). Their utility in analyzing mixed-stock fishery samples with contributions from a large number of stocks ("coastwide mixtures") is less certain owing to probable variation in scale

patterns from year to year and age group to age group which necessitates extensive resampling of individual stocks (see Section 3.2). A total of about 120 stocks have been sampled to

date, but only about 60 are resampled routinely each year (Appendix 1). The Alaska Department of Fish and Game (ADFG) uses scale pattern data to estimate stock composition of sockeye catches in Southeast Alaskan Districts 106, 108 and 111 on a weekly basis (in-season) for principal age classes. Since scales are also collected routinely from many other fishing areas (Southeast Alaskan Districts 102, 103, 104, 105, and 107 and British Columbia Areas 3, 4 and 5) as well as all significant escapements to provide age composition data and for post-season stock composition analysis, additional stock identification studies could be conducted without additional collection costs. It is anticipated that scale ageing and digitizing systems which should soon be operational, will significantly reduce the cost and time required for analysis.

2.2 Age Composition

Sockeye salmon populations frequently differ dramatically in both freshwater and marine age composition. Freshwater age typically varies from 0. (i.e., no freshwater annular marks indicating that fry did not spend a winter in freshwater) to 3. (i.e., three winters spent in freshwater). Age 1. sockeye are prevalent in most coastal and clearwater interior lake systems whereas 2. sockeye are prevalent in glacial lakes.

Marine age is a useful marker, in principle, since much variation exists among populations. However, its practical value is limited owing to great variability from year to year within a stock and because sockeye of different age groups often migrate through fisheries at different times during a season (McPherson 1986). Even so, age composition can be used for estimating stock composition where samples can be obtained over the entire run, and pooled to provide representative "seasonal" samples of the catch. The age composition in a seasonal mixture sample of fish from a particular stock should then be representative of that stock whereas the age composition of fish from that stock sampled in the fishery in any single week may not be representative.

2.3 Parasite Prevalence

Parasite prevalence refers to the proportion of fish in a population that are infected by a particular parasite. Many different parasites are found in sockeye salmon, but for stock identification in the Northern Boundary area, researchers have focused on a protozoan brain parasite (*Myxobolus neurobius*). Little is known of the life cycle of this species but the presence of this parasite is thought to be determined by characteristics of the freshwater rearing environment. Again, because sockeye juveniles share the same lake environment, they probably share the same risk of being parasitized. A total of 81 sockeye populations have been examined for the parasite (Appendix 2). The vast majority of Southeast Alaskan stocks appear to be infected heavily whereas relatively few Canadian stocks are infected. For this reason, the proportion of parasitized sockeye in a mixed-stock fishery sample can be interpreted as the maximum contribution from Southeast Alaskan stocks. Brain parasite data have been used to estimate stock composition in weekly sockeye samples from Southeast Alaskan Districts 101, 106 and 111; and Canadian Areas 1, 3, 4, 23, and in the Stikine, Taku and Nass Rivers.

Other parasites have been used to differentiate up to seven stocks in the Fraser River system with excellent precision. However, the prevalence of these parasites is less well studied and their usefulness in the Northern Boundary area has not been demonstrated.

2.4 Genetic Markers

Methods for detecting genetic differences among stocks are gaining widespread popularity in fisheries research. Several different procedures for detecting genetic variation have been developed. The most widely used involves electrophoresis to detect variation in the electrical properties of simple enzymes. The genetic mechanism for this variation is then determined in cross-breeding studies. The sockeye populations (approximately 60) represented in Figure 1 (and Appendix 3) have been screened for differences in the frequency of alternative alleles that code for specific biological characteristics. In sockeye, only about six of these enzymes are polymorphic (i.e., exhibit more than one form), but three of these vary greatly among populations and are very useful for stock identification in the Northern Boundary area. Technology is evolving rapidly in this field, and it seems likely that other useful genetic markers will be discovered in the near future. Already, electrophoretic techniques to assay a fourth polymorphic enzyme have improved to the point where it will soon be added to the stock identification data base.

Other procedures are also being developed to detect genetic differences in mitochondrial tRNA or nuclear DNA itself, rather than in the enzymes that the DNA produces. This should permit

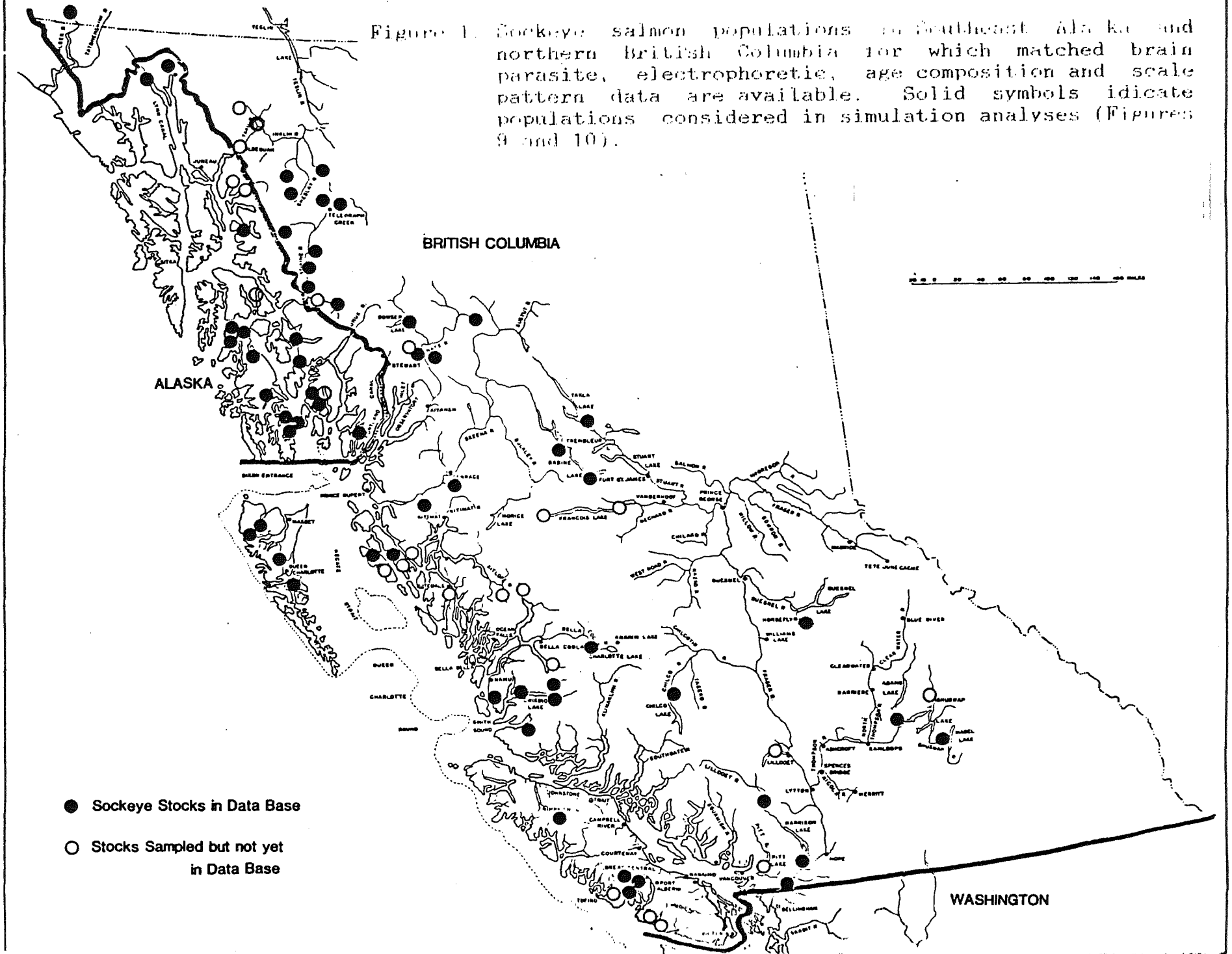


Figure 1. Sockeye salmon populations in Southeast Alaska and northern British Columbia for which matched brain parasite, electrophoretic, age composition and scale pattern data are available. Solid symbols idicate populations considered in simulation analyses (Figures 9 and 10).

the detection of much more genetic variation among stocks. However, the usefulness or feasibility of these new procedures has not yet been demonstrated for sockeye salmon.

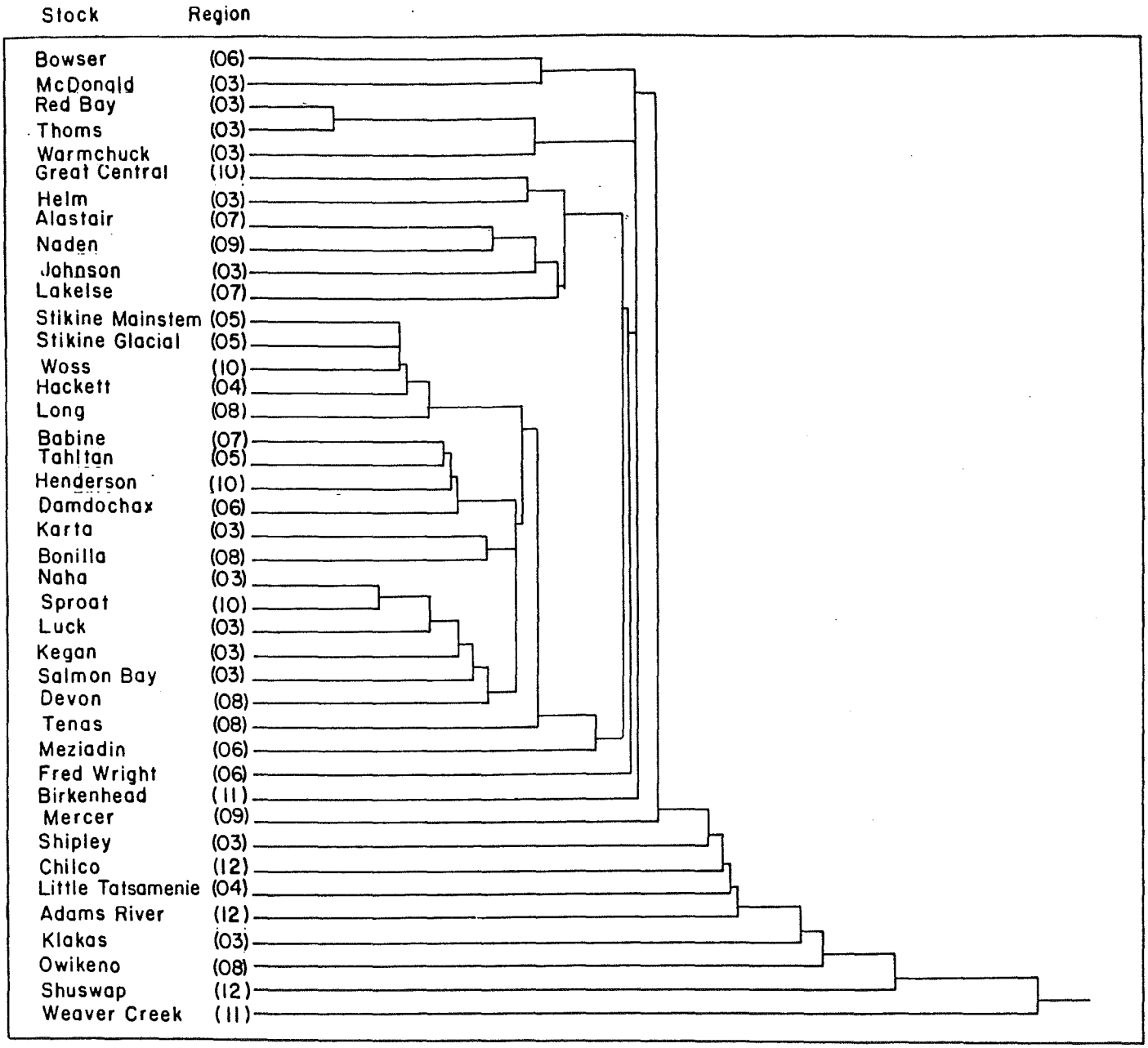
3.0 COMPARISON OF BIOLOGICAL MARKERS

3.1 Stock Resolution Potential

Some biological markers permit differentiation of more stocks than others. For example the brain parasite can be used to make minimum estimates of the contribution of 100% parasitized or 100% non-parasitized groups but the presence of stocks with intermediate levels of parasitism precludes definitive classification of fish. Similarly, sockeye can be one of four possible fresh water age groups -- 0., 1., 2., or 3. -- in varying proportions in each stock making age composition data of limited value in differentiating between stocks. In principle, scale patterns can differentiate more groups because there are measured differences in scale features between stocks. However, in practice there is a limited range of values possible which leads to overlap in the frequency distributions of scale features from stock to stock limiting the number of stocks which can be differentiated. Electrophoretic methods typically detect 2-6 different genotypes for each enzyme in sockeye populations so that each fish sampled must fall into one of only several categories. However, when two different enzymes are considered simultaneously, each with, say 3 genotypes, the potential number of categories increases to 2 or 8. Thus, using markers in combination dramatically increases stock resolution potential. This approach is explored in Section 4.2.

Similarity among stocks can be defined in terms of a "distance" calculated from the probabilities of drawing a fish with particular scale patterns, (or genotypes) from each population. The similarity dendrograms illustrated in Figures 2-5 show which sockeye populations resemble one another in terms of three scale features (Figure 2), freshwater age (Figure 3), brain parasite prevalence (Figure 4) and five polymorphic enzymes (combined, Figure 5). The distance scale is constant in all of these dendrograms to permit comparison. The vertical lines linking horizontal lines indicate the relative distance separating the linked stock-group; stocks joined by vertical lines on the extreme left hand margin are virtually indistinguishable using the marker in question, whereas those joined together farther to the right are easier to differentiate. Note that the dendrogram based on three scale features (Figure 1) shows the greatest stock resolution potential. However, it should be noted that the distance measurement in the dendrogram reflects both the real differences among stocks and differences due to sampling error associated with small samples. Markers which can take on many different values (such as scale circulus counts) can be most

Figure 2. Similarity dendrogram for 41 sockeye populations based on scale pattern data only. Three scale features were considered for age 1.3 sockeye only--the number of circuli laid down during (1) the first year of freshwater growth, (2) during "spring growth" in fresh water in the second year, and (3) during marine growth in the remainder of the second year. Samples range in size from 4 to 125 (10 samples <15) and were collected between 1979 and 1986. Distances between populations calculated using procedure of Wood et al. (1987b) for Figure 2-8.



Regions are defined in Figures 2-8 as: Alsek watershed (01); Lynn Canal Southeast Alaska District 112 (02); Southeast Alaska Districts 101-111 (03); Taku watershed (04); Stikine watershed (05); Nass watershed (06); Skeena watershed (07); British Columbia central and north coast Areas 5-12 (08); Queen Charlotte Islands (09); Vancouver Island (10); lower Fraser watershed (11); upper Fraser watershed, above Hell's Gate (12).

Figure 3. Similarity dendrogram for 52 sockeye populations based on freshwater age composition only. Samples range in size from 49 to 3010 and were collected between 1979 and 1986.

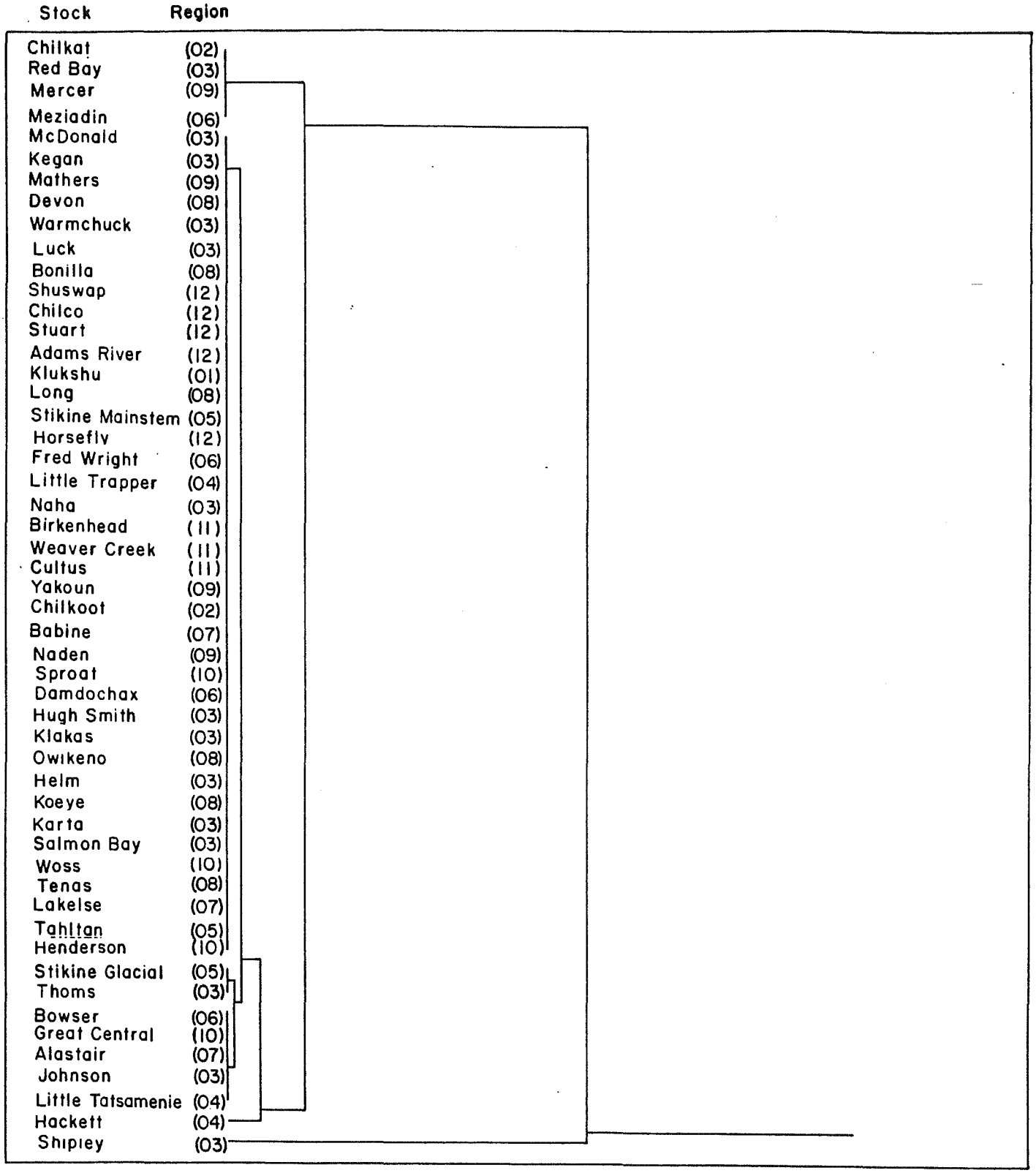


Figure 4 Similarity dendrogram for 52 sockeye populations based on brain parasite (Myxobolus neurobius) prevalence only. Samples range in size from 21 to 1039 and were collected between 1982 and 1985.

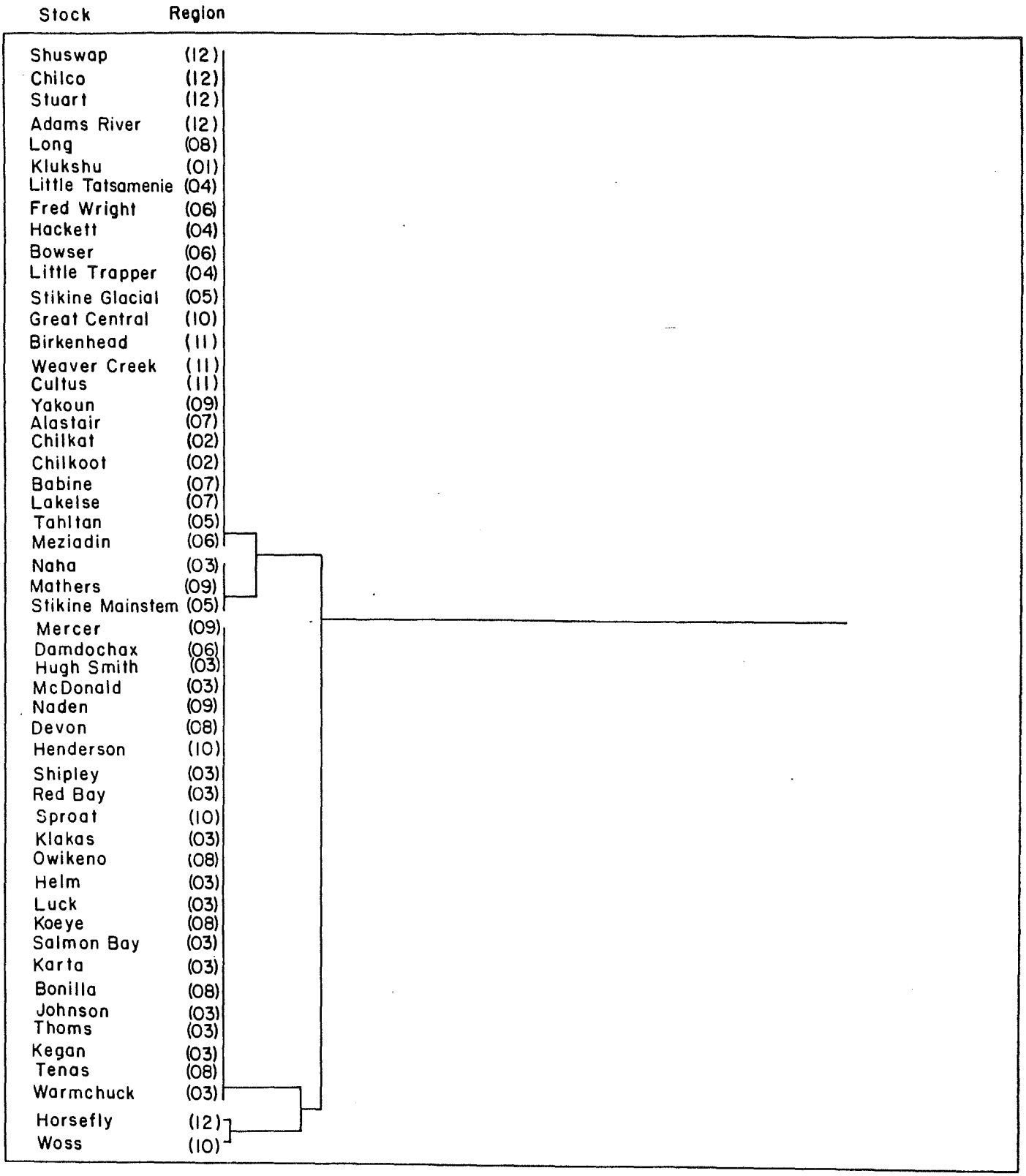
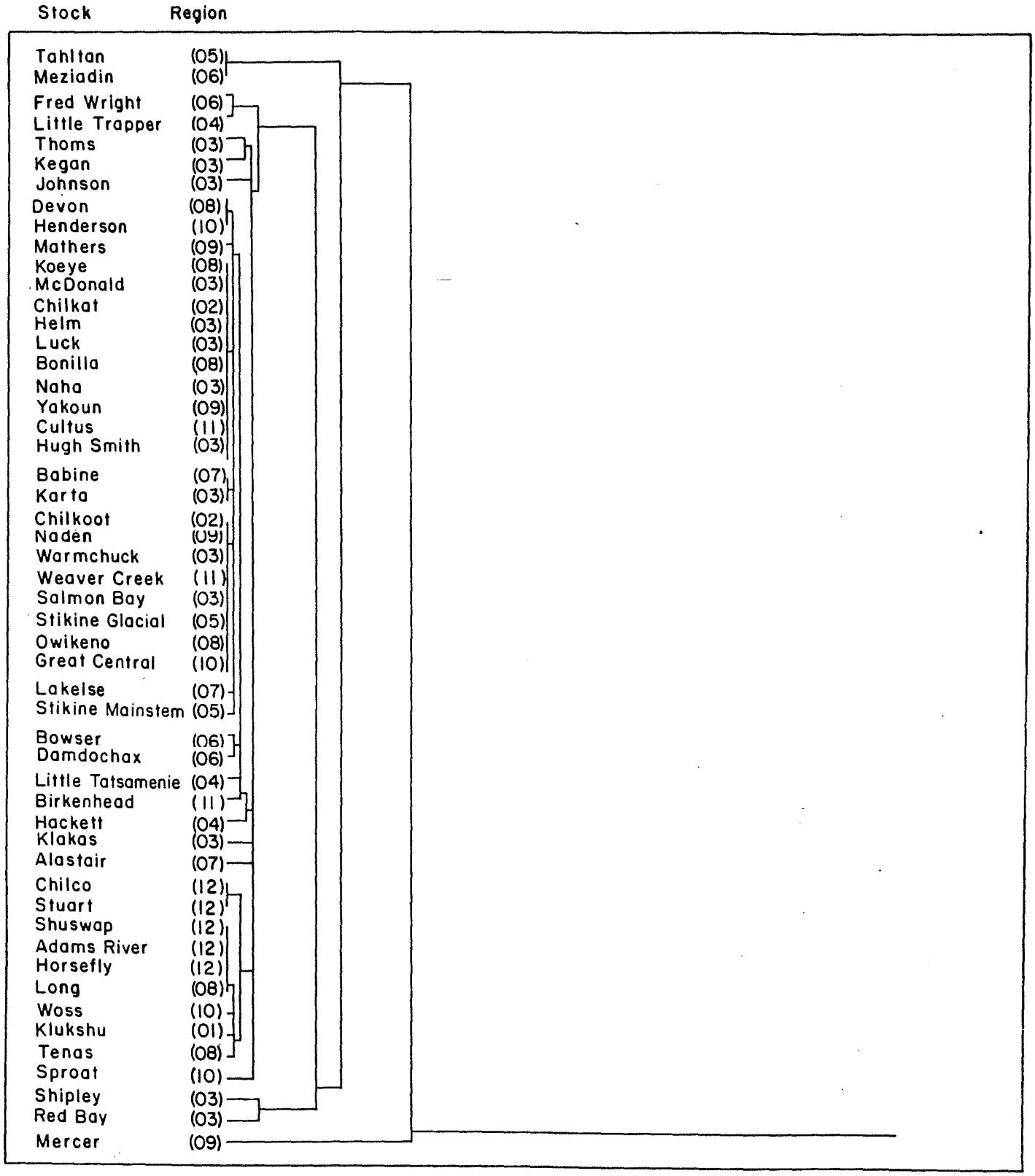


Figure 5. Similarity dendrogram for 52 sockeye populations based on electrophoretic differences in five polymorphic enzymes (Pgm-1, Pgm-2, Ldh-4, Idh-3 and Idh-4). Samples range in size from 26 to 710 and were collected between 1982 and 1985.



affected by sampling errors. Thus, large sample sizes are required to detect real differences among stocks where differences in scale features are not large.

3.2 Stability of Markers Over Time

Stability between years in a biological trait within a stock is one of several important criteria for selecting among biological markers. A marker is stable if its probability of occurrence within a population does not change from year to year, so that individual stocks need not be resampled frequently. The stability properties of scale features and freshwater age are summarized for example stocks in Table 1. Because scale patterns reflect growth history, which probably depends on climate, fish density and the availability of food, they can be expected to vary from year to year within populations. This is evident to some extent in Table 1. In general, however, variation within stocks seems to be less than variation among stocks. Simulation studies are required to determine the degree to which stock composition estimates are influenced by this kind of variability. Although superior estimates are usually obtained using scale data from the corresponding year (Marshall et al. 1984), it may still prove useful to use historical scale data when current data is unavailable. This is an important topic for further research since the cost effectiveness of scale analysis will be greatly determined by the amount of annual resampling that is required.

Freshwater age composition also varies from year to year in some populations (Table 1) but, again, where variation within populations is less than between populations, it may be possible to get satisfactory stock composition estimates with historical data. Marine age composition often varies dramatically from year to year (Foerster 1968).

The prevalence of the brain parasite appears to be remarkably stable from year to year (Table 2) although the mechanism for this stability is not understood. The best evidence for stability comes from Great Central and Sproat Lakes on Vancouver Island where the parasite prevalence has varied narrowly between 0 - 8.4% and 99.4 - 100.0% respectively over a period of 8 years (Quinn et al. 1987).

The theory of population genetics predicts that all genetic markers will be stable within isolated randomly mating populations provided there is no survival advantage associated with the alternative genes. Indeed, virtually all sockeye stocks that have been sampled repeatedly exhibit very little variation in gene frequencies (Table 2). It is this property that makes genetic markers attractive for stock identification studies. The data in Tables 1 and 2 span only several years at most. Thus, any gradual trends in population characteristics would not be detected. Even where markers appear to be stable over several

Table 1. Year to year variability in biological markers from scales of sockeye salmon.

Stock	Year	Sample size		Scale feature 1/ NC1	NC2	NC3	ID1	ID2	ID3	Fresh water age composition 0	1	2	3	Sample size
Tahltan L.	1982 2/									0.00	0.82	0.18	0.00	441
	1983	111	mean	12.46	27.10	35.35	35.35	5.08	95.76	0.00	0.94	0.06	0.00	1,883
			SD	0.18	0.09	0.21	1.63	0.90	3.30					
	1984	44	mean	11.87	1.86	27.50	31.38	2.16	97.34	0.00	0.93	0.07	0.00	85
			SD	1.23	0.53	2.72	3.27	1.02	9.70					
	1985	26	mean	11.42	1.31	25.31	31.52	2.69	97.46	0.00	0.98	0.02	0.00	126
			SD	1.72	0.47	2.02	4.08	1.27	6.58					
	1986	200	mean	11.84	1.53	27.39	31.56	2.74	94.28	0.00	0.90	0.10	0.00	719
			SD	0.11	0.04	0.18	1.07	0.38	2.56					
Chutine L.	1984	15	mean	7.80	1.53	30.67	23.74	2.90	111.24	0.00	0.57	0.42	0.01	80
			SD	1.78	0.92	3.60	4.69	2.07	11.97					
	1985	7	mean	7.29	3.71	28.57	21.55	8.19	108.02	0.00	0.44	0.55	0.00	45
			SD	2.36	2.14	3.31	5.87	5.09	10.00					
	1986 2/									0.00	0.41	0.59	0.00	161
Chutine R.	1984	36	mean	8.36	2.03	28.58	25.28	4.27	107.16	0.02	0.95	0.03	0.00	61
			SD	2.34	1.63	3.71	7.23	3.79	13.00					
	1985	16	mean	8.00	2.31	29.06	23.27	5.44	111.03	0.04	0.96	0.00	0.00	47
			SD	2.03	1.01	2.46	6.02	2.65	9.43					
	1986 2/									0.01	0.94	0.05	0.00	99
Skud R.	1984	18	mean	8.17	2.39	30.06	25.58	5.06	109.63	0.23	0.73	0.05	0.00	44
			SD	1.65	0.98	2.98	4.64	2.52	10.03					
	1985	39	mean	8.77	1.85	28.64	26.81	4.15	109.95	0.21	0.79	0.00	0.00	66
			SD	2.01	0.90	2.43	6.50	2.21	8.79					
Iskut R.	1983 2/									0.00	1.00	0.00	0.00	51
	1984	70	mean	8.73	2.36	28.58	24.05	5.01	113.45	0.02	0.95	0.02	0.00	140
			SD	1.70	1.18	3.71	4.24	2.95	14.08					
	1985	152	mean	8.79	1.94	29.48	25.95	4.24	113.59	0.18	0.78	0.05	0.00	156
			SD	1.72	0.92	2.67	5.53	2.26	9.54					
	1986 2/									0.00	0.97	0.03	0.00	68
Babine L.	1967	506	mean	11.11	-----	29.79	32.63	-----	113.45					
			SD	2.01	-----	3.12	5.80	-----	14.08					
	1968	1172	mean	12.42	-----	28.56	37.94	-----	109.18					
			SD	1.82	-----	3.15	5.78	-----	11.21					
	1982 2/									0.00	1.00	0.00	0.00	158

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Table 1. Mean and standard deviation of variables used in scale pattern analysis from 1.3 age sockeye salmon. (continued)

Stock	Year	Sample size		Scale variable NC1	NC2	NC3	ID1	ID2	ID3	Fresh water age composition 0	1	2	3	Sample size
Hugh Smith	1982	50	mean	11.20	2.02	32.30	26.94	4.06	108.71	0.00	0.93	0.07	0.00	3,009
			SD	1.70	0.82	2.20	3.56	1.52	8.64					
	1983	10	mean	8.90	1.70	33.30	25.10	3.84	122.48	.00	0.67	0.32	0.00	1,107
			SD	0.55	0.26	0.76	4.89	3.01	8.69					
	1984	10	mean	10.90	1.60	31.20	30.23	3.38	111.71	0.00	0.70	0.30	0.00	1,591
			SD	1.97	0.84	2.39	14.26	6.87	41.30					
	1985	10	mean	11.30	1.90	28.50	28.47	3.66	105.74	0.00	0.75	0.25	0.01	1,170
			SD	1.50	0.99	1.18	14.00	9.29	29.32					
	1986	10	mean	11.10	2.80	30.80	28.73	5.89	99.97	0.00	0.94	0.06	0.00	666
			SD	3.04	1.81	2.44	29.92	15.06	34.72					
McDonald L.	1982	50	mean	8.20	0.88	33.20	19.05	1.78	116.08	0.00	0.79	0.21	0.00	629
			SD	1.60	0.44	2.70	3.56	1.02	9.65					
	1983	10	mean	9.70	1.30	30.60	24.00	2.08	116.38	.00	0.55	0.45	0.00	1,366
			SD	0.52	0.21	0.83	5.95	2.27	13.44					
	1984	10	mean	7.89	1.00	33.70	21.23	1.42	114.35	0.00	0.83	0.17	0.00	929
			SD	0.78	0.00	2.63	2.52	0.79	11.19					
	1985	10	mean	8.40	2.30	32.20	18.57	4.75	116.10	0.00	0.77	0.23	.00	537
			SD	1.71	1.06	1.55	19.85	8.72	18.81					
	1986	10	mean	9.00	1.90	32.30	23.55	4.17	111.28	0.00	0.71	0.29	0.00	497
			SD	1.70	0.57	2.54	12.84	8.82	49.31					
Naha L.	1982	50	mean	11.10	0.50	31.00	27.69	1.02	106.43	0.00	0.98	0.02	0.00	184
			SD	1.70	0.61	2.00	3.81	1.27	9.65					
	1983	10	mean	13.30	1.40	33.90	31.42	2.59	120.45	.00	0.85	0.15	.00	1,648
			SD	0.40	0.22	1.02	4.49	2.04	14.09					
	1984	5	mean	13.40	1.00	30.20	33.12	0.30	114.86	0.00	0.84	0.16	0.00	500
			SD	1.34	0.00	1.30	3.35	0.68	7.48					
	1985	10	mean	13.60	2.00	28.20	33.63	3.71	109.68	0.00	1.00	.00	0.00	405
			SD	2.37	0.67	4.76	15.09	5.17	57.03					
	1986	10	mean	13.80	2.20	32.80	33.10	4.11	121.16	.00	0.90	0.10	0.00	810
			SD	1.62	1.14	1.99	14.71	9.71	40.62					
Helm L.	1982	50	mean	13.90	3.32	30.20	33.27	7.11	113.03	0.00	1.00	0.00	0.00	276
			SD	1.80	0.96	2.50	4.32	2.29	13.46					
	1983	11	mean	12.27	2.18	30.82	31.66	4.62	122.17	0.00	0.24	0.76	0.00	274
			SD	0.62	0.18	0.54	5.53	1.87	14.24					
	1985	10	mean	12.50	3.80	29.70	31.17	7.21	439.20	0.00	0.98	0.02	0.00	367
			SD	2.17	1.14	2.31	13.60	8.78	38.56					
	1986	10	mean	13.00	3.20	30.10	31.29	5.89	109.14	0.00	0.97	0.03	0.00	320
			SD	0.94	0.63	2.85	11.15	3.91	48.59					
Johnson L.	1982	50	mean	12.30	2.26	31.60	29.97	4.83	115.57	0.00	0.65	0.35	0.00	337
			SD	2.10	0.83	2.30	4.57	2.03	9.14					
	1983	10	mean	13.80	1.10	33.00	34.95	1.68	121.08	0.00	0.59	0.41	0.00	563
			SD	0.29	0.10	0.98	3.98	1.53	14.75					
	1984	10	mean	13.50	1.00	30.80	32.56	0.23	118.16	0.00	0.38	0.62	0.00	240
			SD	2.59	0.00	2.25	5.81	0.72	6.84					
	1985	10	mean	12.60	2.60	30.40	31.60	5.11	111.38	0.00	0.50	0.49	0.01	358
			SD	2.95	1.17	2.87	33.51	9.47	44.40					
	1986	3	mean	13.00	2.67	33.67	35.64	6.27	131.49	0.00	0.60	0.40	0.00	10
			SD	1.00	1.16	1.53	10.02	7.64	15.04					

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Table 1. Mean and standard deviation of variables used in scale pattern analysis from 1.3 age sockeye salmon. (continued)

Stock	Year	Sample size		Scale variable NC1	NC2	NC3	ID1	ID2	ID3	Fresh water age composition 0	1	2	3	Sample size
Kegan L.	1982	50	mean	11.50	0.82	33.20	27.43	1.78	117.60	0.00	0.78	0.22	0.00	1,776
			SD	1.20	0.60	2.40	2.79	1.27	10.41					
	1983	10	mean	9.90	1.10	35.30	1.05	2.08	126.70	.00	0.59	0.41	0.00	1,699
			SD	0.61	0.10	0.75	4.13	0.93	8.50					
	1984	10	mean	10.30	1.10	34.90	24.18	0.94	116.05	0.00	0.59	0.41	0.00	321
			SD	1.64	0.32	3.30	4.15	1.29	6.97					
	1985	10	mean	10.80	1.70	33.60	26.82	3.66	130.58	0.00	0.79	0.21	0.00	444
			SD	1.40	0.82	2.68	14.64	8.49	36.74					
	1986	10	mean	10.50	1.10	34.30	26.85	1.91	126.24	0.00	0.88	0.12	0.00	208
			SD	1.08	0.32	2.11	11.92	3.14	47.81					
Klakaa L.	1982	50	mean	7.70	3.74	31.20	18.29	7.37	113.03	0.00	0.98	0.02	0.00	356
			SD	1.70	1.31	3.60	2.79	2.54	13.46					
	1983	10	mean	9.00	1.20	32.70	23.09	2.62	123.32	.00	0.89	0.11	0.00	691
			SD	0.47	0.13	0.68	4.43	0.83	17.03					
	1984	10	mean	7.80	1.10	30.80	15.04	0.94	108.94	0.00	0.96	0.04	0.00	270
			SD	0.44	0.10	0.79	3.14	1.00	12.79					
	1985	10	mean	7.00	1.60	32.80	15.06	2.90	130.45	0.02	0.95	0.03	0.00	318
			SD	1.41	0.70	2.62	15.99	6.38	46.88					
W. Chuck L.	1982	50	mean	14.90	0.82	29.70	39.62	1.78	109.22	0.00	0.85	0.15	0.00	332
			SD	2.00	0.56	3.20	5.08	1.27	12.19					
	1983	10	mean	13.80	1.00	31.40	38.74	1.80	118.19	0.00	0.84	0.16	0.00	1,755
			SD	0.29	0.00	0.73	4.22	0.89	12.99					
	1984	9	mean	12.89	1.00	29.67	33.95	1.13	111.73	0.00	0.75	0.15	0.00	572
			SD	1.62	0.00	2.92	4.16	1.09	12.37					
	1985	10	mean	14.10	1.70	30.20	37.82	3.20	127.00	0.00	0.82	0.18	0.00	686
			SD	2.33	0.48	1.88	19.21	6.35	25.84					
	1986	10	mean	12.80	1.50	32.00	34.47	2.97	116.74	0.00	0.93	0.07	0.00	359
			SD	1.32	0.71	2.50	16.49	5.70	31.97					
Luck L.	1982	50	mean	12.00	1.04	32.10	28.45	2.03	117.09	0.00	0.86	0.14	0.00	365
			SD	1.40	0.49	2.60	3.05	1.02	10.67					
	1983	10	mean	11.20	1.00	33.50	28.78	0.97	126.95	.00	0.82	0.18	0.00	445
			SD	0.68	0.00	0.48	3.49	1.59	10.50					
	1984	10	mean	11.80	1.00	32.10	29.29	1.52	114.27	0.00	0.85	0.15	0.00	335
			SD	1.23	0.00	2.47	2.24	0.83	11.30					
	1985	10	mean	11.20	2.30	30.50	27.94	5.03	120.14	0.00	0.76	0.24	0.00	265
			SD	1.88	1.83	3.84	11.25	14.20	48.00					
	1986	10	mean	9.90	3.70	33.70	22.86	7.70	123.39	0.00	0.67	0.33	0.00	222
			SD	1.37	1.16	2.83	1.37	9.95	36.49					
Salmon Bay L.	1982	50	mean	10.80	1.02	33.80	23.88	2.03	111.76	0.00	0.91	0.09	0.00	1,302
			SD	1.80	0.25	2.70	3.81	0.51	8.13					
	1983	10	mean	11.00	1.80	31.80	26.31	3.51	111.05	0.00	0.85	0.15	0.00	527
			SD	0.49	0.25	0.83	4.41	0.69	11.68					
	1984	10	mean	11.80	1.40	31.30	28.19	2.49	113.03	0.00	0.99	0.01	0.00	592
			SD	1.40	0.90	2.36	3.94	1.83	11.08					
	1985	10	mean	10.50	2.30	31.30	23.47	5.23	117.98	0.00	0.89	0.11	0.00	1,342
			SD	1.84	1.06	2.60	11.21	12.24	39.88					
	1986	10	mean	10.70	3.10	33.50	23.85	6.27	114.30	0.00	0.87	0.13	0.00	1,257
			SD	2.41	0.99	3.03	18.21	8.54	39.42					

-Continued-

Table 1. Mean and standard deviation of variables used in scale pattern analysis from 1.3 age sockeye salmon. (continued)

Stock	Year	Sample size		Scale variable NC1	NC2	NC3	ID1	ID2	ID3	Fresh water age composition 0	1	2	3	Sample size
Red Bay L.	1982	50	mean	14.40	0.44	30.30	35.05	0.76	105.16	0.00	0.91	0.09	0.00	316
			SD	1.60	0.64	1.90	3.80	1.02	9.40					
	1983	10	mean	9.10	1.00	31.40	23.90	1.04	106.86	0.00	0.62	0.38	0.00	367
			SD	0.28	0.00	1.04	3.14	1.38	10.53					
	1984	10	mean	9.10	1.50	30.10	20.93	1.96	95.63	0.00	0.9	0.1	0.00	271
			SD	0.53	0.22	1.16	5.61	2.27	21.83					
	1985	10	mean	11.80	1.20	26.40	29.44	1.98	105.54	0.00	0.85	0.15	0.00	520
			SD	1.93	0.63	3.81	14.75	4.49	43.90					
	1986	10	mean	10.70	1.50	30.50	28.93	2.74	106.17	0.00	0.92	0.08	0.00	498
			SD	1.57	0.71	2.76	12.25	6.34	40.82					
Thoma L.	1982	50	mean	14.50	0.42	28.40	37.34	0.76	107.44	0.00	0.47	0.53	0.00	508
			SD	1.90	0.54	7.60	3.81	1.02	19.55					
	1983	10	mean	13.50	1.30	28.90	34.11	2.26	109.50	0.00	0.29	0.71	0.00	419
			SD	0.45	0.15	0.85	4.62	2.33	10.71					
	1984	10	mean	13.40	1.00	30.20	34.26	1.68	110.49	0.00	0.56	0.44	0.00	607
			SD	0.43	0.00	0.96	6.63	1.24	16.79					
	1985	10	mean	13.00	1.70	27.00	36.30	3.43	110.16	0	0.52	0.48	0.00	337
			SD	0.86	0.30	0.56	7.33	2.49	8.62					
	1986	4	mean	13.25	1.75	29.25	35.94	3.43	117.22	0	0.11	0.87	0.02	375
			SD	0.95	0.25	1.44	9.61	0.50	18.28					

1/ NC1=number of circuli in first freshwater zone.
NC2=number of circuli in spring "plus" growth zone.
NC3=number of circuli in first ocean zone.
ID1=distance in mm/100 of first freshwater zone.
ID2=distance in mm/100 of spring "plus" growth zone.
ID3=distance in mm/100 of first ocean zone.
2/ Data not yet analyzed.

Table 2. Year to year variability of brain parasite prevalence and common (100) allele frequencies for polymorphic enzymes of sockeye salmon.

Stock	Year	Brain Parasite: Sample Size	Brain Parasite: Proportion Infected	Frequency of common alleles for polymorphic enzymes: PGM-1 Sample Size	PGM-1 Freq.	PGM-2 Sample Size	PGM-2 Freq.	LDH-4 Sample Size	LDH-4 Freq.
Hugh Smith L.	1982	30	0.933	50	0.190	50	0.850	50	0.910
	1983	75	0.947	96	0.172	95	0.879	96	0.979
	1986	1/		1/		1/		1/	
McDonald L. weir	1982	30	0.933	50	0.080	50	0.850	50	0.980
	1983	25	0.880	93	0.124	99	0.849	100	0.960
McDonald L.	1983	75	0.947	100	0.129	100	0.848	100	0.965
	1986	50	0.980	50	1/				
Naha R.	1983	57	0.298	104	0.125	104	0.745	104	0.923
	1984	100	0.390	104	0.152	104	0.640	100	0.840
	1986	79	0.481	79	1/				
Helm L.	1983	50	1.000	50	0.120	50	0.760	50	0.960
	1986	51	0.980	50	1/				
Kegan L.	1982	30	1.000	100	0.360	99	0.551	100	0.995
	1983	50	0.880	100	0.335	100	0.540	100	1.000
	1986	50	1.000	50	1/				
Karta L.	1982	30	0.967	50	0.200	50	0.760	50	0.950
	1983	50	0.940	100	0.175	100	0.715	100	0.995
	1986	10	0.800	10	1/				
Luck L.	1983	50	0.980	50	0.110	50	0.790	50	0.950
	1986	21	0.476	21	1/				
Salmon Bay L.	1982	30	1.000	69	0.232	69	0.841	69	0.993
	1983	45	0.889	75	0.227	75	0.883	76	0.993
	1986	41	1.000	50	1/				

-continued-

Table 2. Year to year variability of brain parasite and common (100) allele frequencies for polymorphic enzymes of sockeye salmon (continued).

		Brain Parasite		Frequency of common alleles for polymorphic enzymes					
Stock	Year	Sample Size	Prop. Infected	Sample Size	PGM-1 Freq.	Sample Size	PGM-2 Freq.	Sample Size	LDH-4 Freq.
Red Bay L.	1983	70	1.000	69	0.159	57	0.430	68	0.949
	1986	52	0.962	52	1/				
Thoma L.	1983	75	0.987	74	0.339	75	0.640	75	1.000
	1986	50	1.000	50					
Speel L.	1983	50	0.900	100	0.18	100	0.82	100	0.95
	1986	100	0.850	100	1/				
Crescent L.	1983	50	0.980	100	0.13	100	0.68	100	0.905
	1986	50	1/						
Tahltan L.	1982	30	0.000	96	0.188	98	0.959	98	0.378
	1983	100	0.000	89	0.140	102	0.936	102	0.431
	1985	99	0.010	98	0.189	97	0.969	100	0.430
Chutine L.	1984	100	0.090	99	0.328	99	0.854	100	0.945
	1985	50	0.040	49	0.357	49	0.837	50	0.950
	1986	64	0.000	64	1/				
Chutine R.	1984	62	0.470	61	0.246	61	0.820	62	0.855
	1985	50	0.440	48	0.167	48	0.792	50	0.880
	1986	50	0.400	50	1/				
Skud R.	1984	50	0.660	48	0.188	48	0.833	50	0.890
	1985	67	0.490	65	0.162	65	0.831	68	0.926
Iskut R.	1983	110	0.150	60	0.183	111	0.784	112	0.915
	1984	151	0.150	149	0.164	148	0.824	151	0.854
	1985	336	0.140	335	0.204	331	0.796	332	0.886
Babine R.	1982	60	0.000	448	0.184	475	0.732	481	0.961
	1983	200	0.000	197	0.188	249	0.755	251	0.977
Meziadin L.	1982			92	0.174	99	0.955	99	0.434
	1983	130	0.000	94	0.117	96	0.953	100	0.325
	1984	100	0.000	100	0.110	100	0.935	100	0.430
Fred Wright L.	1983	130	0.020	98	0.107	99	0.838	100	0.690
	1984	100	0.060	99	0.091	99	0.843	96	0.589

-continued-

Table 2. Year to year variability of brain parasite and common (100) allele frequencies for polymorphic enzymes of sockeye salmon (continued).

Stock	Year	Brain Parasite: Sample Size	Brain Parasite: Prop. Infected	Frequency of common alleles for polymorphic enzymes: Sample Size	PGM-1 Freq.	Sample Size	PGM-2 Freq.	Sample Size	LDH-4 Freq.
Bowser L.	1983	130	0.010	46	0.087	65	0.923	65	0.762
	1984	87	0.000	86	0.145	85	0.912	86	0.791
Damdochax L.	1983	130	0.860	73	0.151	100	0.860	100	0.860
	1984	100	1.000	98	0.138	98	0.857	99	0.818
Long L.	1983	100	0.000	83	0.470	84	0.845	84	0.994
	1984	154	0.000	100	0.540	100	0.815	98	0.980
Owikeno L.	1982	150	1.000	100	0.270	99	0.833	100	0.960
	1984	100	0.990	100	0.280	99	0.879	100	0.980

1/ Data soon to be available.

years, it would be prudent to resample populations at regular intervals (perhaps every five years) to be confident of long term stability.

3.3 Homogeneity of Markers With Respect To Age and Sex

Another desirable property of biological markers is that their probability of occurrence within a population be independent of age or sex. For example, it has been demonstrated that scale features typically vary from age group to age group within a population (Anas and Murai 1961). This complicates the stock composition analysis and necessitates much larger sample sizes to ensure adequate sampling of all principal age groups. Freshwater and early marine scale features do not appear to be influenced by the sex of the fish (Table 3).

It is well known that marine age composition varies greatly between the sexes, since fish maturing after only one year at sea are almost invariably male ("jacks"). Freshwater age composition does not appear to vary with sex (Table 3).

Brain parasite prevalence and genetic markers are not dependent on sex (Table 4). There is some indication, however, that brain parasite prevalence is slightly lower in sockeye that spend less than one year in fresh water (Wood et al. 1987a) presumably because they are exposed to the parasite source for a shorter time. This is unlikely to be of consequence since age 0. fish are rare in most populations.

3.4 Sampling Considerations

Scales are collected each year from most significant commercial fisheries and escapements of sockeye salmon to the determine age composition of the population. Scales from commercial catches can be easily collected when the fish are delivered to processing facilities since handling, damage to the fish, and interference with processing routines is minimal. Scale samples can also be collected from spawning escapements without harming fish. However, because environmental conditions change from year to year and the distribution of scale traits is complicated, large sample sizes and independent analyses for all major age classes are required. Trained personnel are required for consistent interpretation of scale features. Duplicate scale impressions can easily be made; these are compact and can be stored for future reference.

Age composition data are collected routinely from most fisheries and spawning populations for other stock assessment objectives. Resorption of scales in escapement and some catch samples can make determination of marine age difficult, but otoliths, fin rays, or length frequency curves can be used to corroborate ages. Freshwater age composition can usually be determined even from badly resorbed scales.

Table 3. Variability with respect to sex of biological markers from scales of sockeye salmon.

Stock	Year	Sex	Sample Size		Scale feature 1/ NC1	NC2	NC3	ID1	ID2	ID3	Freshwater age 0.	1.	2.	Sample Size
Iskut R.	1985	M	34	mean	8.76	1.88	29.79	25.55	4.02	112.90	0.17	0.79	0.04	66
				SD	1.50	0.98	2.82	5.22	2.56	10.20				
		F	93	mean	8.81	1.96	29.48	26.08	4.20	113.78	0.21	0.74	0.05	84
				SD	1.84	0.87	2.56	5.88	2.05	9.67				
Little Tatsamenie L.	1985	M	21	mean	8.52	1.71	26.76	27.24	4.25	100.20	0.02	0.57	0.40	54
				SD	2.48	1.01	2.47	6.16	2.84	11.90				
		F	12	mean	9.00	1.42	27.00	30.65	2.97	105.50	0.00	0.57	0.40	44
				SD	2.37	0.79	1.81	7.12	1.93	11.90				
McDonald L.	1982	M	29	mean	8.59	1.07	34.07	19.08	1.95	117.65	0.00	0.74	0.26	335
				SD	1.52	0.26	2.46	3.86	1.06	8.33				
		F	21	mean	8.19	1.00	32.00	18.97	1.66	113.77	0.00	0.84	0.16	294
				SD	1.66	0.00	3.66	3.48	0.93	11.23				
Naha L.	1982	M	21	mean	11.90	1.10	30.48	29.41	1.59	106.93	0.00	1.00	0.00	97
				SD	1.84	0.45	2.16	4.27	1.43	10.03				
		F	29	mean	10.69	1.00	31.48	26.64	0.52	107.09	0.00	0.97	0.03	87
				SD	1.42	0.00	1.84	2.97	0.81	10.03				

1/ Scale features are for age 1.3 sockeye salmon only.
NC1=number of circuli in first freshwater zone.
NC2=number of circuli in spring "plus" growth zone.
NC3=number of circuli in first ocean zone.
ID1=distance in mm/100 of first freshwater zone.
ID2=distance in mm/100 of spring "plus" growth zone.
ID3=distance in mm/100 of first ocean zone.

Table 4. Variability with respect to sex of brain parasite prevalence and common (100) allele frequencies for polymorphic enzymes of sockeye salmon.

				Brain Parasite		Frequency of common alleles for polymorphic enzymes					
				Sample	Proportion	Sample	PGM-1	Sample	PGM-2	Sample	LDH-4
Stock	Year	Sex	Age	Size	Infected	Size	Freq.	Size	Freq.	Size	Freq.
Iskut R.	1985	M	1.3	50	0.16	50	0.240	50	0.750	50	0.890
			All	96	0.20	96	0.214	96	0.771	96	0.885
		F	1.3	132	0.17	132	0.235	132	0.803	133	0.891
			All	177	0.15	177	0.209	177	0.814	177	0.890
Little Tatsamenie L.	1985	M	1.3	27	0.00	27	0.185	27	0.926	27	0.833
			All	55	0.00	55	0.100	55	0.927	55	0.873
		F	1.3	14	0.00	14	0.143	14	0.964	14	0.821
			All	44	0.00	43	0.151	43	0.884	44	0.909
Owikeno L.	1984	M	1.2	47	0.98	47	0.245	47	0.883	47	0.989
			All	61	0.98	61	0.246	60	0.900	61	0.984
		F	1.2	19	1.00	19	0.237	19	0.868	19	1.000
			All	39	1.00	39	0.346	39	0.846	39	0.974
Meziadin L.	1984	M	2.2	29	0.00	29	0.241	29	0.948	29	0.466
			All	48	0.00	47	0.277	47	0.936	47	0.426
		F	2.2	36	0.00	36	0.222	36	0.917	36	0.389
			All	51	0.00	52	0.192	52	0.933	52	0.423

Parasite samples (whole heads) can be easily collected in processing facilities but care must be taken to obtain complete and uncontaminated samples. Heads must be removed with a consistent style of cut which some processors do not use. This results in some loss of income, and thus, resistance on the part of the processor. Care must be taken when removing the brain for analysis to avoid contamination. The parasite Myxobolus is encysted and will not deteriorate until the brain rots so that escapement samples can easily be collected from carcasses. If carcasses are not found, it is necessary to kill fish to obtain samples although spawned out or precocious males can often be used. Brains may be removed in the field to save space and weight. Samples should be frozen or refrigerated until analyzed. Large sample sizes are not necessary due to the simple statistical distribution of the trait (i.e., presence or absence). Samples are not usually retained after analysis but they can be preserved by freezing.

Tissues required for electrophoresis are more difficult to obtain from processors because the eye, liver and heart tissues are removed from the fish at slightly different locations during processing. This makes it difficult to cross-reference the samples. Removing muscle tissue reduces the market value of fish and makes samples more expensive to obtain. For this reason, enzymes found only in muscle tissue have not yet been used for sockeye stock composition analysis of commercial fisheries. Samples must be frozen immediately and stored at very low temperatures to preserve enzyme activity. Some loss of enzyme activity has been encountered during long fishery openings when the fish had been dead for up to four days before they were available for sampling. Escapement samples must be obtained from live fish although spawned out or precocious "jack" males may be used. Preservation of tissue samples can be difficult in remote field locations since dry ice or adequate freezer space is usually unavailable locally and the duration of sampling activities is limited by the length of time samples can be kept. These problems can be avoided by preserving samples in liquid nitrogen, although this is a more expensive procedure. Intermediate sample sizes (approximately 100) are required to determine gene frequencies accurately. Enzyme activity cannot be preserved indefinitely but photographic records of electrograms can be stored. Electrophoretic procedures are probably the least subjective of the techniques discussed in this report.

Obtaining the matched scale-parasite and scale-parasite-electrophoretic samples necessary for high resolution stock composition analyses is logistically difficult and requires organization and expertise. It is much easier, although sometimes more expensive, to obtain matched samples from test fishery vessels. However, these samples may be less representative of the actual commercial catch. Sampling activities in processing plants adversely affect processing speed and procedures. The best solution might be to

award sampling contracts to processing plants to provide the required samples under professional direction. Even under the best of conditions care must be taken not to mislabel samples and the procedure requires approximately 50 sampler hours to process 300 fish. Selection of "jack" males on the spawning grounds results in problems for the age-specific scale pattern analyses as fish of these young age classes are not commonly found in commercial catches.

3.5 Sample Collection and Analysis Costs

The cost of collecting a scale averages $1.87 (U.S.) while analysis averages $.90 (U.S.). Collection costs for brain parasites or electrophoretic samples vary widely depending on how and where samples are collected. Generally, once fish specimens are obtained, all types of data can be collected at little additional cost. Collection costs in processing plants may be substantially higher for electrophoretic samples, however. Analysis of brain parasites averages $0.75 (Canadian) per sample while electrophoretic analysis of a single sample for 5 loci averages $2.50 (Canadian).

4.0 APPROACHES TO ESTIMATING STOCK COMPOSITION

Each kind of biological marker discussed in Section 3 has proven useful for distinguishing sockeye stocks in particular situations, usually where the number of stocks contributing to a fishery is small. However, for coastwide mixtures in the Northern Boundary area where many stocks are vulnerable to mixed stock fisheries, no single kind of marker can differentiate between all individual stocks. Two approaches have been used to make these stock identification problems tractable. The first approach (described by Marshall et al. 1984), involves pooling samples from major stocks to form a reduced number of "composite stocks", thus simplifying the stock composition analysis by compromising stock resolution. The second approach facilitated by recent advances in statistical methods and computing capabilities, described by Wood et al. (1987b), increases stock resolution potential by using a variety of biological markers simultaneously. To answer detailed management questions raised by the panels, the latter approach offers the best chance of success.

4.1 Pooling Stocks to Simplify Analysis

Scale pattern analysis as currently used by ADFG requires that stocks be pooled into groups based on geographical proximity prior to analysis. This method was developed to meet the original objective of the U.S.-Canada Salmon Treaty of providing weekly estimates of the national origin of sockeye salmon taken in interception fisheries. This was convenient because all Alaskan stocks contributing to these fisheries are from relatively small

coastal systems which share a wet, cool maritime climate. In contrast, most Canadian stocks thought to contribute to these fisheries originate from a few large river systems in which the majority of spawning and rearing areas are situated east of the Coast Range mountains where the climate is more continental. These differences in freshwater rearing environment usually result in significant differences in scale patterns. Scale pattern analysis has since evolved to the point where separate estimates of contributions are routinely provided for the largest Canadian systems. However, scale pattern analysis alone does not provide the capability to separate the many Alaskan or small Canadian stocks contributing to these fisheries. The technique of pooling stocks prior to analysis involves assumptions about the presence or absence and relative abundance of contributing stocks. In addition, it cannot detect the presence of stocks not included in the model.

4.2 Increasing Stock Resolution Potential

Stock resolution can be enhanced by using several kinds of biological markers simultaneously. The similarity dendrograms in Figures 6-8 illustrate this improvement. The dendrogram in Figure 6 is produced by combining the brain parasite with five electrophoretic markers; adding freshwater age (Figure 7) and freshwater age and three scale features (Figure 8) provide still greater stock resolution potential. (The distance scale is identical in Figures 6-8 but twice that in Figures 2-5.) These dendrograms are calculated from data collected over several years, and the scale features pertain only to the most common age group (age 1.3). Thus, the reliability of the dendrogram depends very much on the stability of these markers over time.

Although stock resolution can always be improved by combining markers, some stocks will usually remain difficult to differentiate. For example, in Figure 8, Hackett River and mainstem Stikine River sockeye cluster together far to the left and hence, will be very difficult to detect individually. While their individual contributions to a mixed-stock fishery cannot be identified, their collective contribution can be estimated more precisely. Similarly, the collective contribution by Hackett River, mainstem Stikine River, Stikine glacial lakes and Long Lake can be estimated still more precisely. In fact, any required level of precision on stock composition estimates can be achieved by summing estimates of contributions by individual stocks which are difficult to differentiate. This improvement in precision comes at the cost of decreased stock resolution--the numbers below the five vertical lines in Figures 6-8 indicate the actual number of stock-groupings resolved when estimates are summed at the corresponding distance value.

Similarity dendrograms provide perspective on the relative capabilities of different markers or combinations of markers, and predict which stocks will be difficult to differentiate. Simulations are required, however, to determine the reliability of

Figure 6. Similarity dendrogram for 52 sockeye populations based on combined data from Figures 4 and 5. This data set is abbreviated "PG" to denote the combination of parasite and genetic markers.

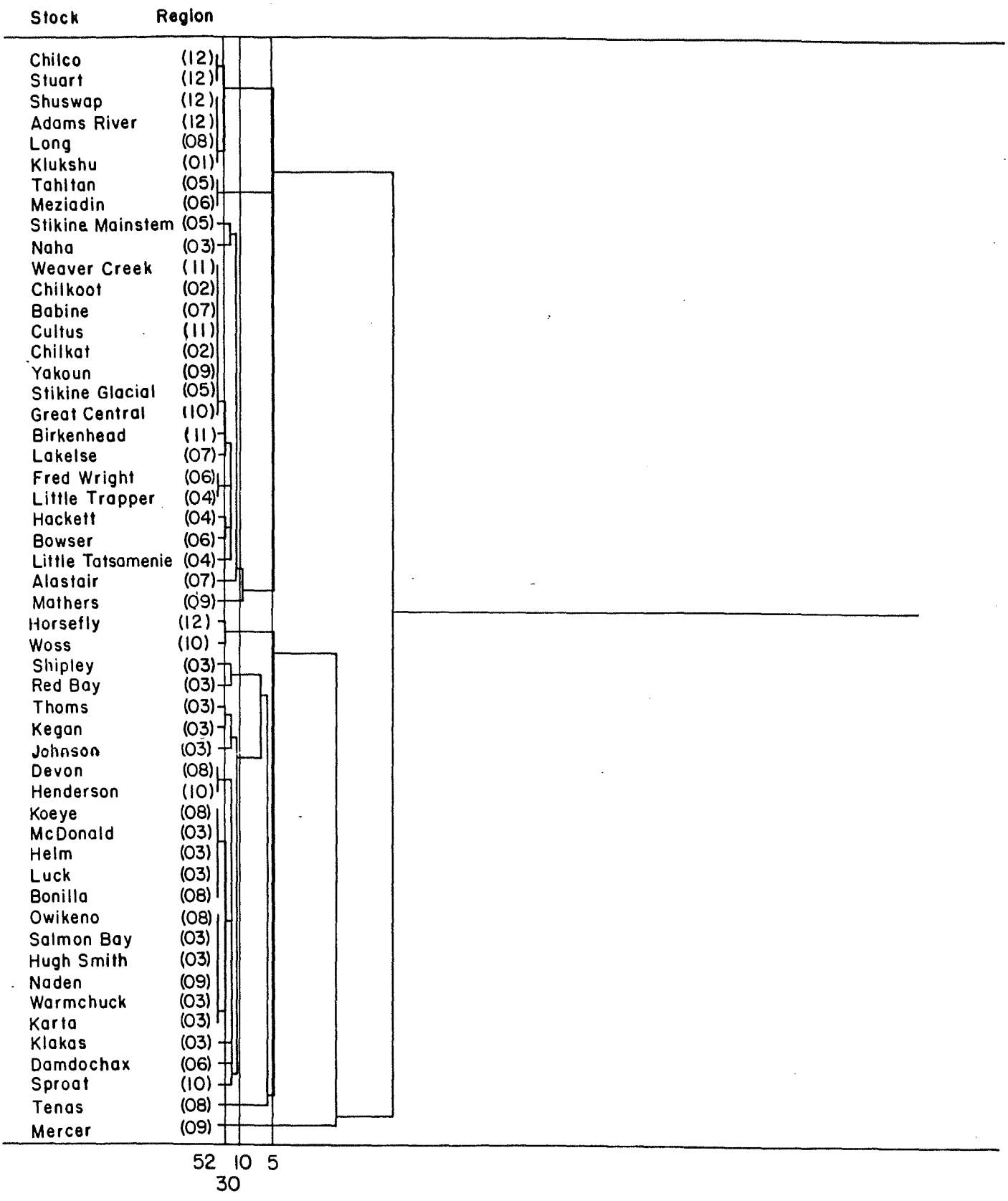


Figure 7. Similarity dendrogram for 52 sockeye populations based on combined data from Figures 3, 4 and 5. This data set is abbreviated "PGA" to denote the combination of parasite, genetic and freshwater age markers.

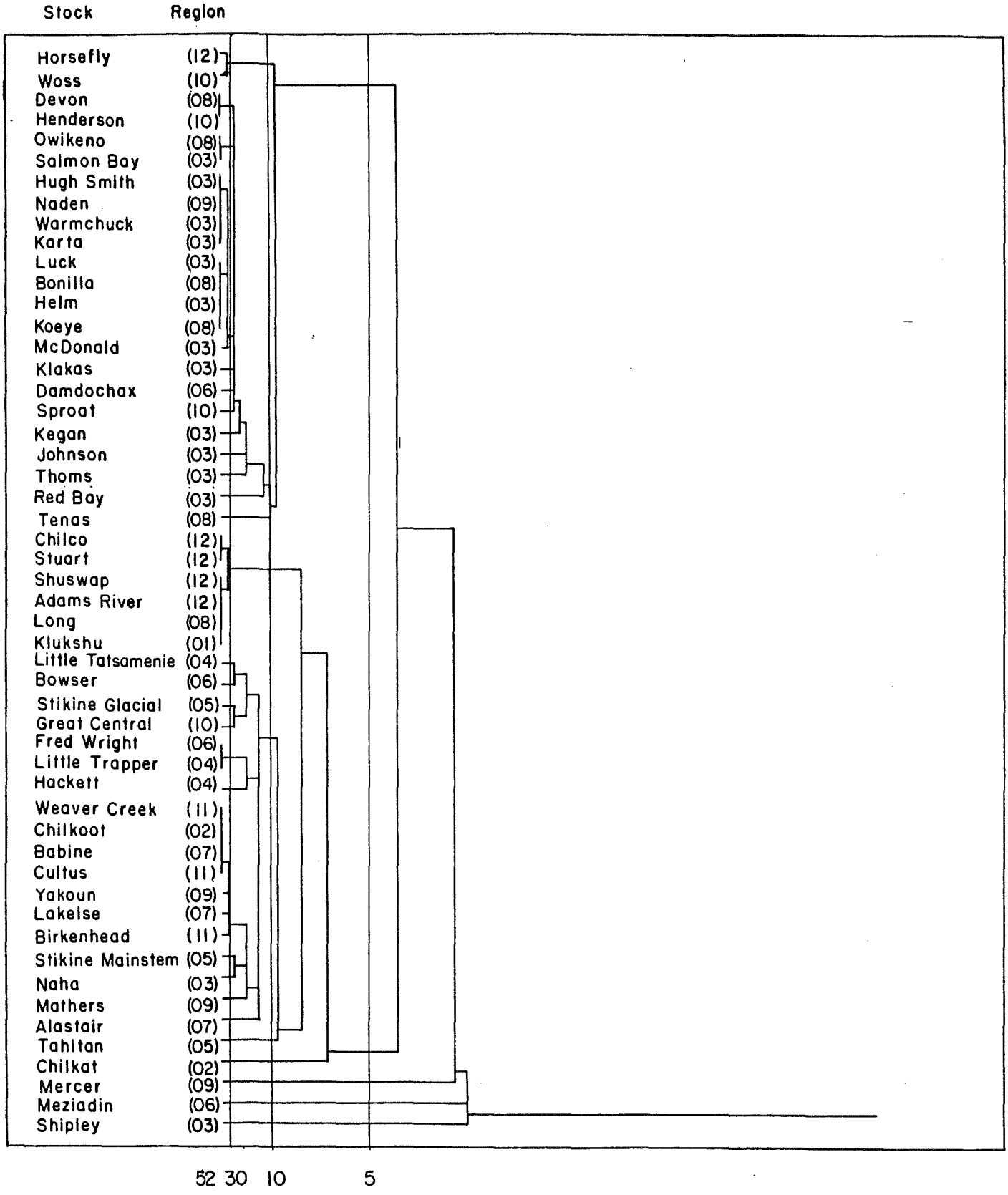
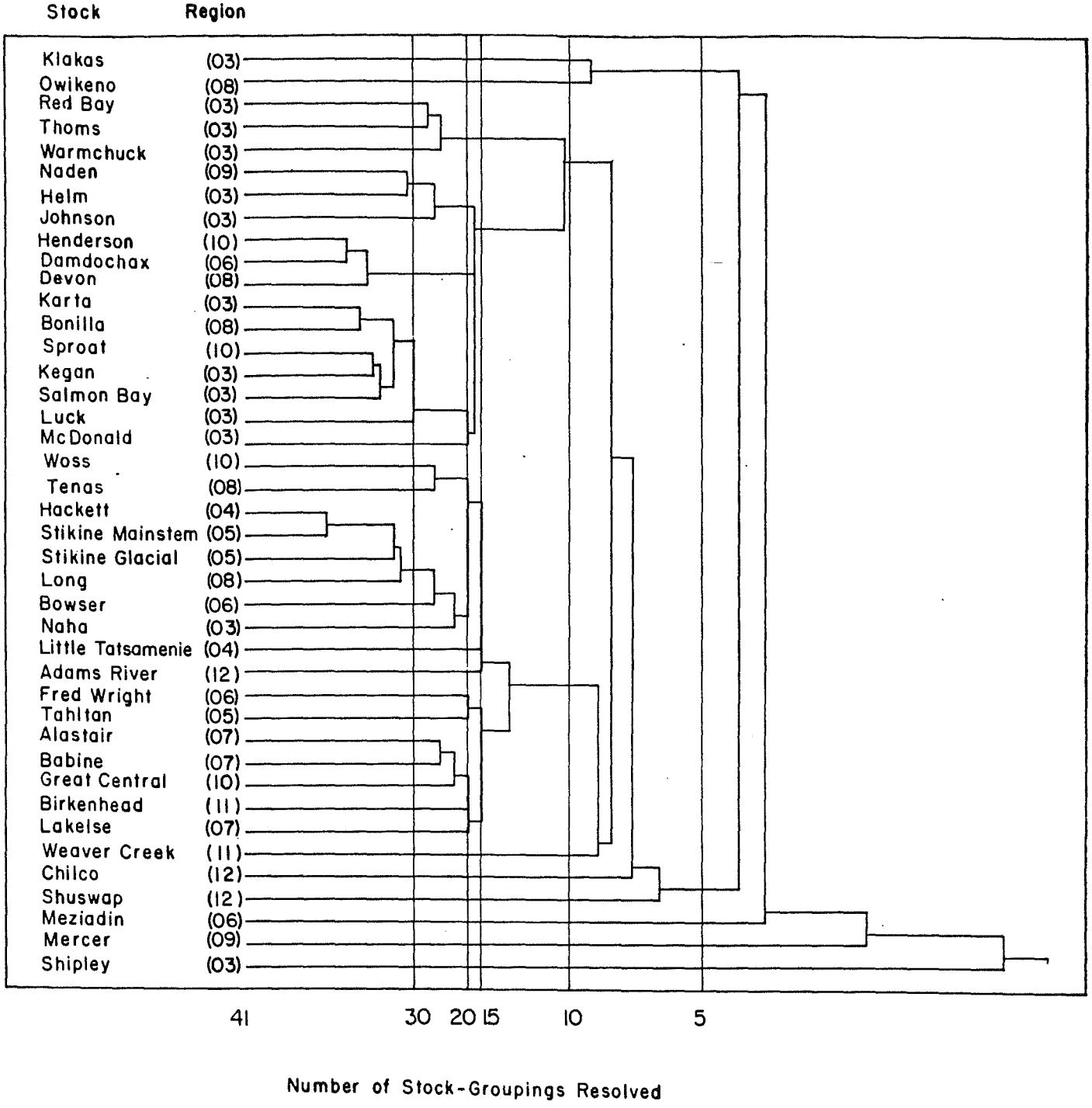


Figure 8. Similarity dendrogram for 41 sockeye populations based on combined data from Figures 2, 3, 4 and 5. This data set is abbreviated "PGAS" to denote the combination of parasite, genetic, freshwater and age and scale pattern markers.



estimates of stock composition at any particular level of stock-grouping. To illustrate this point, two hypothetical mixture samples were generated each containing 500 fish. The first contained fish from Tahltan Lake only, and the second contained fish from McDonald Lake only. Each mixture was drawn randomly from the respective stocks. In addition, standards from each of the individual stocks were drawn randomly from the original samples to simulate sampling error. Stock composition of the mixture samples was estimated three times using a maximum likelihood mixture model (Fournier et al. 1984) with the brain parasite and five electrophoretic markers (PG), the brain parasite, electrophoretic and freshwater age markers (PGA), and finally, the brain parasite, electrophoretic, freshwater age and three scale markers (PGAS). This procedure was repeated 100 times for each of the two mixture types to determine the variance of the estimates due to random sampling. The results are summarized in

Figure 9 and 10 for each combination of markers, and at seven different levels of grouping to improve precision. It is clear that contributions from McDonald Lake are badly underestimated using the brain parasite and electrophoretic markers (mean estimated proportion = 0.17 or 17%; the correct value is 100%), but that error is reduced dramatically when additional markers are used (mean estimated proportion = 0.87 or 87% using all markers) (Figure 9). Similarly, estimates improve in both accuracy and precision as they are summed within larger stock groupings, until error is virtually eliminated (Figure 10). Including freshwater age as a marker allows accurate detection of Tahltan Lake sockeye which otherwise could not be distinguished reliably from Meziadin Lake sockeye. This improvement could be very helpful in assessing stock composition of sockeye catches in Alaskan Districts 104 and 106.

The simulation results in Figures 9 and 10 demonstrate that, in principle, techniques are currently available to estimate stock composition in complex mixed-stock fisheries with considerable precision. However, it should be noted that these results depend on the assumption that all individual stocks have been sampled randomly, and that these samples are representative of their respective contribution to the mixture sample. Because, samples were obtained in different years, it has been assumed implicitly that the markers are stable. Since this is not strictly true (see Section 3.2), results from real mixed-stock fishery problems are likely to be inferior to those presented here, unless all stocks are resampled annually. It is also important to assess the reliability of stock composition estimates based on historical data in further simulation studies.

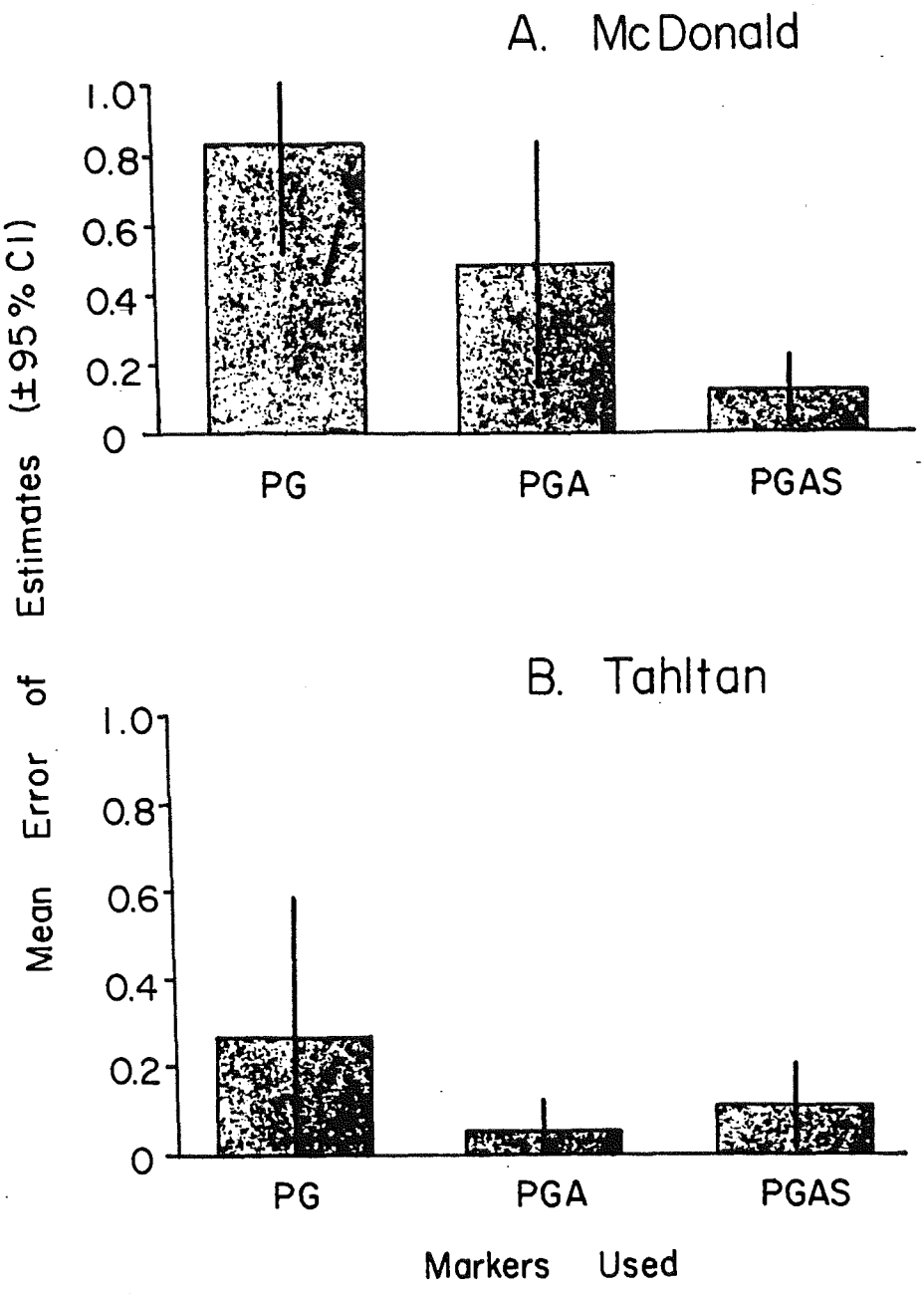


Figure 9. Simulation results showing the effect of combining biological markers to increase accuracy and precision of stock composition estimates without compromising the number of stocks to be differentiated. PG denotes the use of parasite and genetic markers; PGA, parasite, genetic and freshwater age markers; and PGAS, parasite genetic, freshwater age and scale pattern markers. The correct solution is 100% McDonald Lake in Figure 9A and 100% Tahltan lake in Figure 9B.

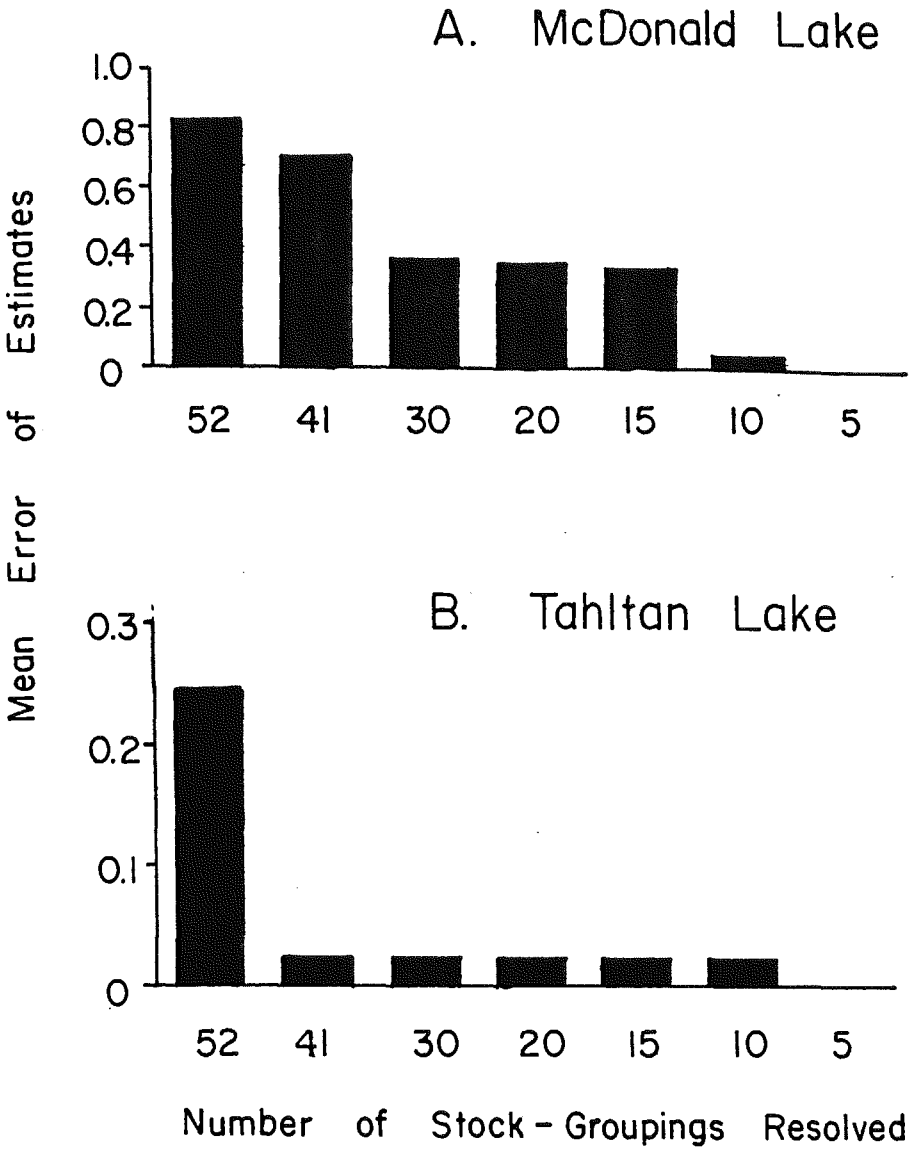


Figure 10. Simulation results showing the effect of summing estimates for poorly differentiated stocks to increase the accuracy and precision of stock composition estimates for a reduced number of stock-groupings. Only parasite and genetic markers were used. The correct solution is 100% McDonald Lake in Figure 10A and 100% Tahltan Lake in Figure 10B.

5.0 TECHNICAL COMMITTEE GOALS

Recent research activities by the Northern Boundary and Transboundary River Technical Committees have led to the development of sophisticated stock identification techniques for sockeye salmon. It is now possible, in principle, to detect contributions to mixed-stock fisheries by up to 40 or 50 individual sockeye stocks. In practice, the need for annual resampling must be evaluated to determine if the benefits derived from reliable estimates justify the sampling costs. Therefore, the Technical Committee recommends the following research objectives:

1. Resample several sockeye populations to assess long-term stability of biological markers used for stock identification.

2. Undertake simulation studies to assess the influence of annual variability in biological markers on the reliability of stock composition estimates based on historical data.

3. Continue to evaluate and to search for additional stable parasite and genetic markers.

4. Complete collection of baseline samples.

5. Investigate the potential for using biological markers for stock identification of other Pacific salmon species.

6.0 LITERATURE CITED

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Appendix 1. Summary of scale samples collected routinely from sockeye salmon spawning escapements in southern Southeast Alaska and Canada, 1982-1986. This table does not include matched electrophoretic-parasite-scale samples (see Appendix 3).

State/ Province	Statistical Area	System	Year				
			1982	1983	1984	1985	1986
Alaska	101-11	Filmore L.	143	146			
		Hugh Smith L.	3,009	1,107	1,591	1,170	2,172
	101-45	Leask L.	257	58		35	370
	101-80	McDonald L.	629	1,366	927	537	610
	101-90	Naha L.	184	1,648	500	405	1,001
		Helm L.	276	274	29	367	350
	102-20	Paul L.	106		123		
	102-30	Johnson L.	337	563	240	358	14
		Kegan L.	1,776	1,699	321	444	240
	102-60	Karta L.	1,429	921	224	1851	595
	103-15	Klakas L.	356	691	180	318	
	103-25	Hetta L.	745	114	199	436	500
	103-60	Klawock L.	725	100	191		700
	103-80	Warm Chuck L.	332	1,755	572	686	414
	103-90	Sarkar L.	538	140	316	457	416
	105-31	Kushneahin L.	30	29	50	100	104
	105-42	Sutter L.	177		69		65
	105-43	Shipley L.	92		105		
	106-10	Trumpeter L.	120	452	75	480	276
		Luck L.	365	445	335	265	488
	106-30	Sweetwater L.	346				276

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Appendix 1. Summary of scale samples collected routinely from sockeye salmon spawning escapements in southern Southeast Alaska and Canada, 1982-1986. This table does not include matched electrophoretic-parasite-scale samples (continued)(see Appendix 3).

State/ Province	Statistical Area	System	Year 1982	1983	1984	1985	1986
	106-41	Salmon Bay L.	1,302	527	592	1,342	1528
		Red Bay L.	316	367	271	520	608
	106-42	Kah Sheets L.	25	194	161		26
	106-44	Petersburg L.	31	242	474	237	551
	107-30	Thoms L.	508	419	607	337	530
	109-20	Falls L.	532	727	688	879	
	109-52	Kutlaku L.	345		492	413	525
	109-62	Alecks L.	396				520
	111-32	Crescent	611	1648	1140	1303	1047
	111-50	Speel	312	793	765	396	1203
	01	Yakoun L.		100			
	02	Mercer L.		300		125	
B.C.	03	Bowser L.	20	65		164	
		Damdochax L.	85	173	50	100	
		Fred Wright L	23	295	50	100	
		Meziadin L.	1075	1200	1200	1200	
	10	Long L.	65			135	
	12	Nimpkish L.			44	80	

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Appendix 1. Summary of scale samples collected routinely from sockeye salmon spawning escapements in southern Southeast Alaska and Canada, 1982-1986. This table does not include matched electrophoretic-parasite-scale samples (continued)(see Appendix 3).

State/ Province	Statistical Area	System	Year 1982	1983	1984	1985	1986
B.C.	23	G. Central L.	800	800	800	400	400
		Henderson L.	200	200	200	5	100
		Sproat L.	1000	1000	1000	450	400
	29	Adams R.	350	253	120	368	
		Birkenhead R.	720	585	328	596	1/
		Chilko L.	595	209	498	588	1/
		Cultus L.	130	120	262	84	1/
		Horsefly L.	240	134	202	473	1/
		Sushwap R.	360	221	4	62	1/
		Stellako R.	136	258	247	273	1/
		Weaver Ck.	480	710	168	570	1/
		Stuart L.	458	450	1900	1064	1/
Transboundary Systems							
Stikine		Stikine R. (mainstem)		100		490	66
		Christina L.			68	130	168
		Chutine R.			54	90	109
		Iskut R.		24	125	159	
		Skud			40	68	
		Tahltan L.	1460	2125	2197	2641	760
Taku		Hackett R.				278	250
		Kuthai L.	219		242		
		L. Tatsamenie L.		255	183	1000	750
		L. Trapper L.	611	1939	1300	1358	850
Alsek		Klukshu R.	523	1565	400	1700	1006

1/ Sample size data not yet available.

Appendix 2. Summary of brain parasite samples collected from sockeye salmon spawning escapements in southern Southeast Alaska and Canada, 1982-1986.

State/ Province	Statistical Area	System	Year				
			1982	1983	1984	1985	1986
Alaska	101-11	Hugh Smith L.	30	75			
	101-45	Leask L.					41
	101-80	McDonald L.	30	100			50
	101-90	Naha L.		57	50		50
		Helm L.		50			51
	102-30	Johnson L.		50			
		Kegan L.	30	50			50
	102-60	Karta L.	30	50			10
	103-15	Klakas L.		50			
	103-80	Warm Chuck L.		50			32
	103-90	Sarkar L.					44
	105-42	Sutter L.					36
	105-43	Shipley		49			
	106-10	Luck L.		50			21
	106-41	Salmon Bay L.	30	45			51
		Red Bay L.		70			52
	106-44	Petersburg L.					50
	107-30	Thoms L.		50			50
	111-33	Speel L.		50			100
	111-35	Crescent L.		50			50

- continued -

Appendix 2. Summary of brain parasite samples collected from sockeye salmon spawning escapements in southern Southeast Alaska and Canada, 1982-1986 (continued).

State/ Province	Statistical Area	System	Year 1982	1983	1984	1985	1986
B.C.	01	Naden R.	50	26			
	02	Yakoun L.	50				
		Mercer L.	50	100			
		Mathers L.	50				
	03	Bowser L.		64	87		183
		Damdochax L.		100	100		100
		Fred Wright L.		100	100		190
		Meziadin L.	100	100	100		294
	04	Alastair L.	100	100			
		Babine L. (early)			100	158	
		Fulton R.	100	100		300	
		Four Mile R.	71				
		Pinkut R.	100	151		200	
		Lakelse L.	48	100			
	05	Banks L.					100
		Bonilla L.		100			
		Devon L.				100	
		Lowe L.					93
		Mikado L.					100
	06	Canoona R.					100

- continued -

Appendix 2. Summary of brain parasite samples collected from sockeye salmon spawning escapements in southern Southeast Alaska and Canada, 1982-1986 (continued).

State/ Province	Statistical Area	System	Year 1982	1983	1984	1985	1986
B.C.	07	Kitlope L.					50
		Tankeeah L.					100
	08	Kimsquit L.					100
		Koeye L.				100	
		Tenas L.				100	
	09	Owikeno L.	100		100		
	10	Long L.	84		154		
	12	Woss L.				100	
	23	Cheewhat L.		100			
		G. Central L.		143			
		Henderson L.		154			
		Sproat L.		183			
	29	Adams R.	100	100			
		Birkenhead R.	72				150
		Chilko L.		100			
		Cultus L.				100	
		Horsefly R.				100	150
		Shuswap R.	100				150
		Takla L.	100				100
		Stellako R.	100				150

- continued -

Appendix 2. Summary of brain parasite samples collected from sockeye salmon spawning escapements in southern Southeast Alaska and Canada, 1982-1986 (continued).

State/ Province	Statistical Area	System	Year				
			1982	1983	1984	1985	1986
B.C.	29	Weaver Ck.	100				150
		Anderson L.					200
		Seymour R.					150
		Nadina R.					100
		Pitt L.					150
		Harrison L.					137
Transboundary Systems							
Stikine		Stikine R. (mainstem)	105	118			106
		Christina L.			76		
		Chutine L.			100	50	64
		Chutine R.			62	50	50
		Iskut R.		110	151	159	150
		Scud R.			50	68	
		Tahltan L.	100	102		100	
Taku		Taku R. (mainstem)					466
		Nakina R. (mainstem)					53
		Hackett R.				63	
		Kuthai L.					74
		L. Tatsamenie L.				100	
		L. Trapper L.	103	100			
Alsek		Klukshu R.		94			

Appendix 3. Summary of matched electrophoretic-parasite-scale samples collected from spawning escapements in southern Southeast Alaska and Canada, 1982-1986.

State/ Province	Statistical Area	System	Year 1982	1983	1984	1985	1986
Alaska	101-11	Hugh Smith L.	50	96			
	101-45	Leask L.					41
	101-80	McDonald L.	50	100			50
	101-90	Naha L.		100	50		50
		Helm L.		50			51
	102-30	Johnson L.		80			
		Kegan L.	100	100			50
	102-60	Karta L.	50	100			10
	103-15	Klakas L.		100			
	103-80	Warm Chuck L.		100			
	103-90	Sarkar L.					44
	105-42	Sutter L.					36
	105-43	Shipley		50			
	106-10	Luck L.		50			21
	106-41	Salmon Bay L.	69	75			51
		Red Bay L.		70			52
	106-44	Petersburg L.					50
	107-30	Thoms L.		75			50
	111	Speel L.		50			100
	111	Crescent L.		50			50

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Appendix 3. Summary of matched electrophoretic-parasite-scale samples collected from spawning escapements in southern Southeast Alaska and Canada, 1982-1986 (continued).

State/ Province	Statistical Area	System	Year 1982	1983	1984	1985	1986
B.C.	01	Naden R.	50	26			
	02	Yakoun L.	50				
		Mercer L.	50	100			
		Mathers L.	50				
	03	Bowser L.		64	87		183
		Damdochax L.		100	100		100
		Fred Wright L.		100	100		190
		Meziadin L.	100	100	100		294
	04	Alstair L.	100	100			
		Babine L. (early)			100	158	
		Fulton R.	100	100		300	
		Four Mile R.	71				
		Pinkut R.	100	151		200	
		Lakelse L.	48	100			
	05	Banks L.					100
		Bonilla L.		100			
		Devon L.				100	
		Lowe L.					93
		Mikado L.					100
	06	Canoona R.					100
	07	Kitlope L.					50

- continued -

Appendix 3. Summary of matched electrophoretic-parasite-scale samples collected from spawning escapements in southern Southeast Alaska and Canada, 1982-1986 (continued).

State/ Province	Statistical Area	System	Year 1982	1983	1984	1985	1986
B.C.							
	07	Tankeeah L.					100
	08	Kimsquit L.					100
		Koeye L.				100	
		Tenas L.				100	
	09	Owikeno L.	100		100		
	10	Long L.	84		154		
	12	Woss L.				100	
	23	Cheewhat L.		100			
		G. Central L.		143			
		Henderson L.		154			
		Sproat L.		183			
	29	Adams R.	100	100			
		Birkenhead R.	72				100
		Chilko L.		100			
		Cultus L.				100	
		Horsefly				100	100
		Shuswap R.	100				100
		Takla L.	100				100
		Stellako R.	100				100
		Weaver Ck.	100				100

- continued -

Appendix 3. Summary of matched electrophoretic-parasite-scale samples collected from spawning escapements in southern Southeast Alaska and Canada, 1982-1986 (continued).

State/ Province	Statistical Area	System	Year				
			1982	1983	1984	1985	1986
B.C.	29	Anderson L.					200
		Seymour R.					100
		Fraser L.					100
		Pitt L.					100
		Harrison L.					100
Transboundary Systems							
Stikine		Stikine R. (mainstem)	105	118			106
		Christina L.			76		
		Chutine L.			100	50	64
		Chutine R.			62	50	50
		Iskut R.		110	151	159	150
		Scud R.			50	68	
		Tahltan L.	100	102		100	
Taku		Taku R. (mainstem)					466
		Nakina R. (mainstem)					53
		Hackett R.				63	
		Kuthai L.					74
		L. Tatsamenie L.				100	
		L. Trapper L.	103	100			
Alsek		Klukshu R.		94			

Appendix 4. Summary of scale samples from commercial and test fishery sockeye salmon landings in southern Southeast Alaska and northern British Columbia, 1982-1986. This table does not include matched electrophoretic-parasite-scale samples (see Appen. 6).

State/ Provence	Stat. Area	Fishery	Year 1982	1983	1984	1985	1986
Alaska 1/	101	Comm. gillnet	3,082	5,649	5,904	7,181	7,536
		Comm. seine	1,486	1,847	3,440	4,049	5,231
	102	Comm. seine	772	749		698	762
	103	Comm. seine		555	77	832	1,497
	104	Comm. seine	2,365	6,566	4,558	4,576	6,881
	105	Comm. seine		527	25	669	54
	106	Comm. gillnet	2,497	5,273	6,316	12,073 3/	10,880 4/
		Comm. seine		384	342		620
		Test gillnet			1,359	3,929	1,367
	107	Comm. seine	113	129	204		377
	108	Comm. gillnet	792	11	819	448	1,735
		Test gillnet			640	1,287	781
B.C.	01	Commercial					500 5/
	03	Commercial	2000 5/	2000 5/	2000 5/	2000 5/	4000 5/
		Naas R. test	2000 5/	2000 5/	2000 5/	2000 5/	2000 5/
	04	Commercial	2000 5/	2000 5/	2000 5/	2000 5/	4000 5/
	05	Commercial	1000 5/	1000 5/	1000 5/	1000 5/	2500 5/
		Skeena R. test	2500 5/	2500 5/	2500 5/	2500 5/	2500 5/
Trans-boundary		lwr. Stikine R. test	700	700	750	1900	
		upr. Stikine R. test	60	60	50	300	20
		lwr. Taku R. comm.	100	700	1461	867	650
		lwr. Taku R. fishwheel			2022	3362	4745

1/ Sampling goal for all significant fisheries in Southeast Alaska is 700 scales and associated length and sex data for each week a District is open to fishing. In instances where few fish were caught weekly sample sizes may be less than 700.

2/ 1986 figures are preliminary.

3/ Includes 6,095 samples from the Clarence Strait portion and 5,987 from the Sumner Strait portion of the district.

4/ Includes 4,826 samples from the Clarence Strait portion and 6,095 from the Sumner Strait portion of the district.

5/ Approximate figures.

Appendix 5. Summary of brain parasite samples from commercial and test fishery sockeye salmon landings in southern Southeast Alaska and northern British Columbia, 1982-1986. This table does not include matched electrophoretic-parasite-scale samples (see Appen. 6).

State/ Provence	Stat. Area	Fishery	Year 1983	1984	1985	1986
Alaska	101	Comm. gillnet		1054	746	
	104	Comm. seine		538	-	
	106	Comm. gillnet			1468	2035
	108	Comm. gillnet				315
	111	Comm. gillnet				1225
B.C.	03	Nass R. test		343		
trans-boundary		lwr. Stikine R. test	100	611		
		lwr. Taku R. comm.			513	650

Appendix 6. Summary of matched electrophoretic-parasite-scale samples from commercial and test fishery sockeye salmon landings in southern Southeast Alaska and northern British Columbia, 1982-1986.

State/ Provence	Stat. Area	Fishery	Year 1984	1985	1986
Alaska	104	Comm.seine			2184
	106	Test gillnet			800
B.C.	01	Test seine	724	999	1656
	02	Test seine	150 1/		
	03	Test seine	1604	1471	1520
	03	Nass R. test			1125
	04	Test seine	1041		
Trans-boundary		lwr. Stikine R. test		1883	665
		upr. Stikine R. test		302	

1/ Matched parasite data not collected.

Appendix 7: References Available or in Preparation on Sockeye Salmon Stock Identification with Biological Markers.

Scale Patterns:

Bethe, M.L., and P.V. Krasnowski. 1979. Stock separation studies of Cook Inlet sockeye salmon based on scale pattern analysis. Alaska Dept. of Fish and Game, Info. Leaf. No. 180. 31 p.

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