A SURVEY OF THE PARASITE FAUNA OF JUVENILE FRASER RIVER SOCKEYE SALMON, *ONCORHYNCHUS NERKA* (WALBAUM), AND THE USE OF PARASITES IN DISCRIMINATING STOCKS

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Richard Edward Bailey
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NAME: Richard E. Bailey

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EXAMINING COMMITTEE:

Chairman: Dr. L.J. Albright

Dr. J.M. Webster, Senior Supervisor

Dr. G.H. Geen

Dr. L. Margolis, Pacific Biological Station, Nanaimo

Dr. M. Mackauer, Public Examiner

Date approved 9/1/85

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A survey of the parasite fauna of juvenile Fraser River sockeye salmon Oncorhynchus nerka (Walbaum) and the use of parasites in discriminating stocks

Author: _____
(signature)

Richard E. Bailey
(name)

21/12/1984
(date)

ABSTRACT

A quantitative survey of the parasites of 1430 juvenile sockeye salmon, Oncorhynchus nerka (Walbaum), from 15 nursery lakes of the Fraser River drainage system and Nimpkish Lake, British Columbia and Lake Washington, Washington, U.S.A. was undertaken to determine the species composition and ecological relationships of the parasite fauna and to assess the feasibility of using parasites as natural tags for juveniles migrating in the Strait of Georgia.

Fourteen species, one species complex, and four taxa of larval parasites were encountered. Differences in species composition were observed in the lakes. Statistically significant seasonal and annual variability was observed for certain parasites in some lakes, but little variability occurred with other parasites and in other lakes. Significantly different infection prevalences were recorded for some parasites among lakes within and between biogeoclimatic zones. Differences among lakes were least for lakes which were limnologically similar.

Computerized mathematical simulations were performed to assess the feasibility of using parasites as tags for migrating juveniles. Hypothetical, mixed fishery samples of known stock composition were analyzed using a multivariate stock composition analysis model. Estimated compositions closely approximated real compositions for all simulations. However, where mixed fishery samples were dominated by one stock, there was a tendency to underestimate the contribution of that stock and overestimate

contributions of less represented, parasitologically similar stocks.

To determine if the prevalence of Myxobolus neurobius Schuberg and Schroder differs significantly between smolts and returning adults, heads of 325 post-spawned adults were collected and examined from ten localities within the Fraser drainage system. Forty-seven fish from four localities were infected. Infection prevalences ranged from 0.00 to 0.70. Comparisons between adults and juveniles of the same stock revealed no significant differences except for Fraser and Francois lakes.

Taxonomic confusion within the trematode genus Phyllodistomum led to a detailed study of specimens collected during the survey. From comparisons with material previously identified as P. conostomum (Olsson) from British Columbia and Finland, and with published descriptions, it was concluded that specimens from this study belonged to P. conostomum. Possible synonomies are discussed.

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A. INTRODUCTION

The Fraser River is one of the principal sockeye salmon, Oncorhynchus nerka (Walbaum), producing systems of the world. Within the Fraser River there are many individual stocks or races of sockeye salmon. The juvenile fish of these stocks live for one or two years in the lakes of the Fraser watershed, each stock occupying a particular lake or chain of lakes. Sockeye salmon occupy much of the Fraser River system, extending upriver from Pitt Lake, 75 km above the Fraser River estuary, to the northern reaches of the Stuart River drainage system, about 1100 km from the estuary.

The major sockeye salmon stocks of British Columbia and Alaska have been extensively studied during the last 80 years. Studies have been performed on the productivity of the nursery lakes (Goodlad et al. 1974, Stockner and Shortreed 1983), the interactions of fry with other organisms within the lake (e.g., Ricker 1941, Roos 1959), the migrations undertaken during the life of sockeye salmon (Clemens 1951, Quinn 1980, Quinn and Brannon 1982), and many other aspects of sockeye salmon biology. The Fraser River sockeye salmon have been extensively studied by the International Pacific Salmon Fisheries Commission (I.P.S.F.C.), New Westminster, British Columbia (I.P.S.F.C. Bulletins 1945-1983), although these studies were mainly concerned with management aspects of the Fraser stocks. Much of the early work of the I.P.S.F.C. and others has been summarized

by Foerster (1968).

Few parasitological studies have been undertaken on Fraser River sockeye salmon. Notable published studies are those of Bashirullah (1966), Margolis (1963) , and Platzer and Adams (1967). Bangham and Adams (1954) investigated the parasite fauna of fishes of certain lakes throughout British Columbia, including some lakes of the Fraser River system, but they did not examine sockeye salmon from any Fraser River drainage lakes. Outside the Fraser River system, studies on sockeye salmon parasites have been numerous. The following are some examples. Dombroski (1955) and Boyce (1974, 1979) examined the effects of helminth infections on Babine Lake juvenile sockeye salmon. Bangham and Adams (1954) examined Skeena River drainage sockeye for parasites; Pennell et al. (1973) examined Bristol Bay Alaska sockeye; and Konovalov (1971) and other Russian authors have exhaustively examined the parasite fauna of Kamchatkan sockeye salmon. Margolis (1963) studied the parasites of sockeye salmon from many North American stocks, from one Kamchatkan stock, and from many areas of the North Pacific Ocean and Bering Sea.

The present fishery crisis on the west coast requires development and application of improved management techniques. One of the present requirements is an increased understanding of the migration patterns of juvenile and adult sockeye salmon in the Strait of Georgia and Juan de Fuca Strait. Of particular importance in management of Fraser River sockeye salmon is an understanding of the factors determining the coastal route of

adult return to the river. One of the hypotheses being tested by researchers at the Pacific Biological Station is that the route of return is predetermined by the route of seaward migration of the juveniles. Testing of this hypothesis requires that the many Fraser River stocks can be distinguished. Among the methods for differentiating stocks is that based on differences in parasites among stocks (Margolis 1963, 1965, 1982; Konovalov 1971).

The present study was undertaken to determine:

1) The species of parasites present in juvenile sockeye salmon from the nursery lakes of the Fraser River drainage system, and their prevalence and intensity of infection;

2) If there are significant qualitative and/or quantitative differences in the parasite fauna of juvenile sockeye from those lakes; and

3) If parasites found in these fish can be used as natural tags to discriminate among Fraser River and other juvenile sockeye salmon stocks that occur in Georgia, Juan de Fuca, and Johnstone Straits.

B. MATERIALS AND METHODS

I. Sampling of sockeye smolts and presmolts

a. Collection of samples

Sockeye salmon smolts and presmolts were captured from 15 rearing lakes within the Fraser River drainage system, British Columbia. Smolt samples were also collected from Nimpkish Lake on northeastern Vancouver Island, British Columbia and from Lake Washington, Washington State, U.S.A. (see Fig. 1). Sampling localities, collection dates, and the number of smolts or presmolts per sample are listed in Table I.

Samples 1 to 18, 21, 23 to 26, 28 and 30 (see Table I) were collected by staff of the I.P.S.F.C. Samples 19, 20, 22, 27 and 29 were collected by the author and K. Kelly (Pacific Biological Station [P.B.S.]), Fisheries Research Branch, Department of Fisheries and Oceans (D.F.O.), Nanaimo ,British Columbia, in cooperation with I.P.S.F.C. staff. Sample 31 was collected by the Washington State Department of Fisheries, and sample 32 was collected by a D.F.O. Lake Enrichment (P.B.S., Nanaimo) smolt trapping crew.

Smolts were captured in the outlet streams of the rearing lakes, using either 2 ft. x 3 ft. incline, 4 ft. x 4 ft. incline, or 2m x 2m trawl smolt traps, or sampled from a counting

Figure 1. Sockeye salmon, Oncorhynchus nerka (Walbaum), nursery lakes of the Fraser River system, and other systems draining into the Strait of Georgia, Johnstone Strait, and the Strait of Juan de Fuca. (from Groot et al. 1984)

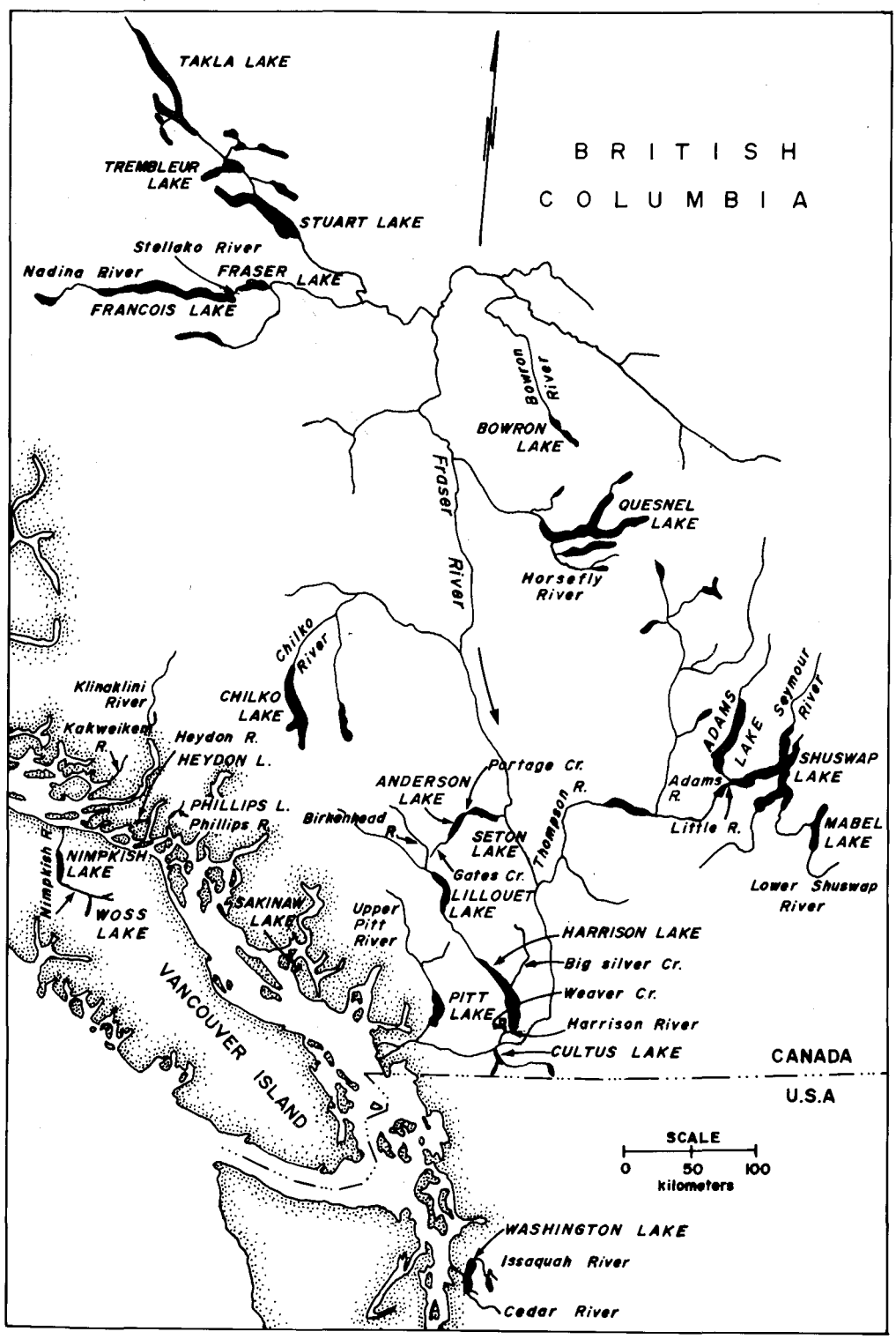

Table I. Locality and date of collection, and size of samples of juvenile sockeye salmon, Oncorhynchus nerka.

Sample No.	Locality	Date	Sample Size(n)	Smolt/Presmolt
01	Pitt Lake	17.11.1975	50	presmolts
02	Cultus Lake	20.04.1976	33	smolts
03	Harrison Lake	26.11.1979	30	presmolts
04	Lillooet Lake	16.08.1978	40	presmolts
05	Seton Creek	21-22.04.1966	47	smolts
06	"	14.05.1979	24	smolts
07	"	25-27.04.1982	50	smolts
08	"	08-10.05 1982	50	smolts
09	"	30-31.05.1982	34	smolts
10	Chilko Lake	05.05.1976	45	smolts
11	"	28.04.1977	50	smolts(2yrs)
12	"	12.05.1977	50	smolts
13	"	25.04.1982	50	smolts
14	"	03.05.1982	49	smolts
15	"	15.05.1982	50	smolts
16	Adams Lake	29-30.04.1976	35	smolts
17	Shuswap Lake	10-14.05.1976	35	smolts
18	"	16.11.1971	50	presmolts
19	Quesnel Lake	25.04.1983	50	smolts
20	Bowron Lake	29.04.1983	50	smolts
21	Stuart Lake	06.05.1971	28	smolts
22	"	26-27.04.1983	50	smolts
23	"	01.10.1978	50	presmolts

Table I (continued)

24	Trembleur Lake	26.09.1978	50	smolts
25	Takla Lake	25.09.1978	47	presmolts
26	Francois Lake	12.05.1971	47	smolts
27	"	27-28.04.1983	50	smolts
28	Fraser Lake	12.05.1971	47	smolts
29	"	28.04.1983	50	smolts
30	"	26.08.1978	39	presmolts
31	Lake Washington	04.1983	50	smolts
32	Nimpkish Lakes	12.05.1982	50	smolts

fence or weir positioned across the outlet stream. Presmolts were captured in the nursery lake in the fall prior to smolt migration using two boat trawls. All fish were either individually wrapped in Whirlpack polyethylene bags, frozen on dry ice, and stored in a chest freezer at -30° celcius, or preserved and stored in bulk, in jars containing 10% buffered formalin.

b. Processing of samples

For each fish, fork length and blotted wet weight were measured, and a scale sample for age determination taken from the location suggested by Clutter and Whitesel (1956). Each fish was subjected to a complete parasitological examination. The following body sites, organs, and tissues were examined using a stereoscopic dissecting microscope: external surfaces, gills, mouth, opercula, nasal cavities, eyes, cranial cavity and brain, esophagus, stomach, caeca, intestine, liver, spleen, kidney, heart, pericardium, urinary bladder, gall bladder, swim bladder, all mesenteries, and the somatic musculature. To facilitate detection of protozoan parasites, especially Myxosporea, smears of mascerated tissue from the kidney, urinary bladder, liver, gall bladder, spleen, posterior intestine, and the brain were examined at magnifications up to 1000x using a phase contrast compound microscope. Kidney and brain tissues from frozen samples were subjected to a digestion and spore concentration technique, involving a pepsin hydrochloric acid digest (Anon.

1977), to facilitate detection of myxosporean infections.

Metazoan parasites encountered during the survey were preserved and stored in aceto-formol alcohol (A.F.A.), prepared according to Cable (1950). Monogenea, Trematoda, Cestoda and Acanthocephala were stained in Semichon's acetic carmine, dehydrated in ethanol, cleared in methyl salicylate and mounted in Canada balsam. Large nematodes were cleared and temporarily mounted in Langerons lactophenol (Cable 1950) for study. Small nematodes were cleared, temporarily mounted, and examined in glycerine. Copepods were preserved, stored and studied in A.F.A. All parasites were measured using a microscope equipped with an ocular micrometer.

II. Sampling of post-spawned adults for *Myxobolus neurobius*

a. Collection of samples

Three hundred and twenty five heads from freshly dead "post-spawned" sockeye salmon were collected from 10 localities within the Fraser River drainage system in the fall of 1983 (Table II). Samples 1 to 8 were collected by the I.P.S.F.C., and samples 9 and 10 were collected by the author and T. Quinn (P.B.S.) in conjunction with I.P.S.F.C. field staff. Recently dead, post-spawned salmon were collected by gaffing, and the heads severed posterior to the opercula. Heads were frozen within 3hr. of capture and stored in a chest freezer at - 30° C until processed.

b. Processing of samples

Heads were thawed, dissected, and the brain and anterior spinal cord removed for examination. The spore concentration technique (Anon., 1977), described earlier, was used to examine samples for detection of *Myxobolus neurobius* Schuberg and Schroder, 1905 spores.

Table II. Locality and size of samples of post-spawned adult sockeye salmon Oncorhynchus nerka, collected in fall 1983 to determine the prevalence of Myxobolus neurobius infections.

Sample No.	Spawning Ground	Rearing Lake	Sample Size(n)
01	Pitt River	Pitt Lake	30
02	Cultus Lake	Cultus Lake	30
03	Birkenhead River	Lillooet and Harrison Lakes	28
04	Weaver Creek	Harrison Lake	30
05	Gates Creek	Seton and Anderson Lakes	30
06	Chilko River	Chilko Lake	49
07	Horsefly River	Quesnel Lake	21
08	Gluske Creek	Stuart,Trembleur and Takla Lakes	30
09	Stellako River	Fraser Lake	37
10	Nadina River	Francois Lake	40

III. Statistical analysis

a. Smolt and presmolt samples

(i) Descriptive statistics

The prevalence of each parasite in each sample was calculated. For the metazoan parasites, mean intensity, and its standard deviation, skewness, and kurtosis values were calculated. These descriptive statistics were calculated using the MIDAS statistical computing package (Fox and Guire 1976), available at Simon Fraser University. Presence/absence ratios were derived for each parasite in each sample except for Diphyllobothrium sp. for which a three-part ratio was derived. That ratio is: number of fish with more than three parasites/ number of infected individuals with three or fewer parasites/ number of uninfected fish. Prevalence and mean intensity were used in accordance with the definitions in Margolis et. al. (1982), i.e. Prevalence: Number of individuals of a host species infected with a particular parasite species divided by the number of potential hosts examined; and Mean intensity: Total number of individuals of a parasite species in a sample of a host species divided by the number of infected individuals of the host species in the sample.

(ii) Differences in parasite fauna of the juvenile sockeye salmon

To determine if significant differences exist in the parasite fauna of juvenile sockeye salmon from the study lakes, and if such differences are characteristic of certain zones of the Fraser River watershed, the study lakes were assigned to four biogeoclimatic zones, based on those proposed by Stockner and Shortreed (1983). The inclusion of two coastal, non-Fraser River drainage lakes, and one coastal Fraser River drainage lake, not included in the Coastal Mountain subzone of zone 3 of Stockner and Shortreed (1983), expanded that subzone sufficiently to permit the separation of the Coastal Mountain lakes zone 4 from the Insular Mountain Zone 3. The resulting classification scheme is therefore:

Zone 1, Northern: Francois, Fraser, Stuart, Trembleur, and Takla lakes.

Zone 2, East Central: Adams, Shuswap, Quesnel, and Bowron lakes.

Zone 3, Insular Mountain: Chilko, Seton, and Lillooet lakes.

Zone 4, Coastal: Harrison, Cultus, Pitt, Lake Washington, and Nimpkish lakes.

Analyses to test for variability in the presence/absence (P/A) ratios of parasites were performed by pooling the data in

the following ways:

1) Within individual lakes

When more than one sample was available from an individual lake, samples were tested for the following kinds of variability of parasite infections.

a) Annual variability : variability between P/A values of parasites between different year classes of smolts. Samples from three separate year-classes were examined from Chilko, Seton, Fraser, and Stuart lakes. Samples from two year-classes were examined from Shuswap and Francois lakes.

b) Seasonal variability : variability in P/A values of parasites between smolts emigrating from a lake during different periods of one year's smolt run. Three samples, one from each of the early, middle, and late parts of the 1982 smolt migration were collected from each of Seton Creek and Chilko Lake.

c) Variability between one- and two-year-old smolts: Two-year-old smolts (occurring commonly only in Chilko Lake in the Fraser River drainage system) were compared against Chilko one-year-olds for differences in P/A values.

Tests for within lake variability were conducted using samples collected mainly from Chilko Lake and Seton Creek, given the convenience of smolt trapping at these two locations. At both locations I.P.S.F.C. operates counting fences, which facilitate extended sampling of smolt runs.

2) Among lakes within geographic zones

At this level of pooling, the variability in P/A values of parasites between lakes within each geographic zone was examined. For those lakes in which multiple samples were analyzed, the data were pooled to yield single P/A values for each parasite for each system. Two-year-old smolts from Chilko Lake were treated as a separate sample at this level.

3) Among geographic zones

At the final level of analysis, the P/A values for each parasite from each zone were tested for variability among zones. P/A values for each parasite for each lake of the zones were pooled to yield one P/A value per parasite per zone.

Tests of variability among samples were performed using the G-test (Sokal and Rohlf 1969). The G-test was employed because the distribution of each parasite species was highly skewed. The data were analysed using a Fortran G-test program (Sokal and Rohlf 1969).

(iii) Determination of the feasibility of using parasites as natural tags

Parasites potentially suitable for use as "natural tags" for juvenile salmon were selected from the list of parasites encountered during the study. Selection criteria for the use of parasites as natural tags included the following:

a) The parasite must be acquired by the host in the home or rearing lake

b) The parasite must remain on or within the host for a

minimum of one month after the host has entered salt water. (For use as a natural tag for adult fish, the parasite must remain with the host for its entire life in the ocean).

To determine the feasibility of accurately estimating the composition of schools of migrating juvenile sockeye in the Strait of Georgia, two runs of four series of simulations each were generated and analysed using the mixed stock composition analysis and simulation model of Fournier et. al. (1984), available at P.B.S.

For the first run of simulations, hypothetical mixed fishery samples consisting of 900 fish of specified composition were generated. Hypothetical learning samples, of 200 fish per stock, were generated for each simulation. For the second run of simulations, mixed hypothetical fishery samples consisting of 500 fish of specified composition were generated. Hypothetical learning samples, of 100 fish per stock, were generated for each simulation. The learning samples were then used to estimate the composition of the mixed hypothetical fishery samples.

The four series of simulations per run each consisted of one hundred repeats of the above procedures. The input data used by the model to generate the mixed fishery and learning samples for each series of simulations were derived from the smolt and presmolt parasite study. The stocks utilized in both runs of the simulations were chosen to be representative of those stocks which make up 95% of the smolt population of Georgia Strait for the four cycle years 1981 to 1984 (Table III).

Table III. Populations used in the Fournier Model simulations to test the feasibility of using parasites to differentiate stocks of Fraser River juvenile sockeye salmon, Oncorhynchus nerka, for the 1981-1984 year classes of smolt emigration.

Year Class			
1981	1982	1983	1984
Chilko 1yr.	Chilko 1yr.	Chilko 1yr.	Chilko 1yr.
Francois	Chilko 2yr.	Harrison	Fraser
Fraser	Fraser	Lillooet	Harrison
Harrison	Harrison	Pitt	Lillooet
Lillooet	Lillooet	Quesnel	Quesnel
Shuswap	Seton	Shuswap	Seton
Stuart	Stuart	Stuart	Shuswap

For the first run of simulations, the proportional contributions of each stock to the simulated mixture were equal, although this would not be expected in the in the naturally-occurring situation in Georgia Strait. For the second run, the proportions of each stock in the simulated fishery approximated the estimated naturally-occurring proportions for the years 1981-1984 inclusive in Georgia Strait, as estimated from I.P.S.F.C. escapement data.

Each simulation yielded an estimate of the stock composition of the hypothetical mixed fishery sample. The results for each series of simulations were analyzed using B.M.D.P. "P7D" (Dixon et. al. 1981), and the means and standard error of the mean were recorded.

b. Comparisons of P/A Ratios for Myxobolus neurobius between smolts and spawning ground adults

Presence/Absence ratios were derived for M. neurobius for each sample of "post-spawners" examined. Adult P/A ratios were then compared against those of juvenile sockeye from equivalent rearing lakes, using the G-test procedures described above. Data from Adams River (Shuswap Lake) adults, furnished by T. McDonald (P.B.S.), enabled the testing of Shuswap Lake juveniles and adults.

C. RESULTS

I. Survey of sockeye smolts and presmolts

a. Survey results

Fourteen hundred and thirty juvenile sockeye salmon from 17 different rearing lakes were examined for parasites. Fourteen species of parasites, one species complex (Neoechinorhynchus spp.), and four taxa of larval or immature parasites were encountered (Table IV). The larval parasite taxa Diphyllobothrium spp., immature Eubothrium sp., immature Proteocephalus sp., and the hymenolepid coenurous larvae may represent only one species each, but each could conceivably represent several species.

Those parasites encountered which could not be assigned to a species included Chloromyxum sp. from Nimpkish Lake. Only four spores were detected from one infected fish. The spores measured 14um-16um in diameter (mean 15.2um) and the polar capsules measured 2um-2.5um long (mean 2.2um). The spores were heavily sculptured. Diplostomulum sp. 1 metacercaria occurred unencysted in the aqueous humour of the eye, while Diplostomulum sp. 2 metacercaria occurred unencysted on the viscera. Tetracotyle sp. metacercaria occurred encysted on the pericardium, viscera, and on the muscles behind the eyeball. Positive identification of Diplostomulum spp. and Tetracotyle metacercariae may require feeding of fresh specimens to suitable bird hosts, and

subsequent recovery of the adult worms.

Neoechinorhynchus sp.(spp?) were found in juvenile sockeye salmon from 12 of the rearing lakes studied. The genus Neoechinorhynchus has recently been reviewed and a new species, N. salmonis, described (Ching 1984). Some of the worms recovered in the present study were assigned to the new species although most of the specimens could not to be assigned to either N. salmonis or N. rutili with any certainty because of fixation effects or immaturity. Ching (pers.comm.) also noted that N. rutili and N. salmonis can occur together in one lake. Hence identification has been assigned as Neoechinorhynchus sp.(spp?).

The prevalence and P/A ratios for all parasites and the mean intensity and its standard deviations for metazoan parasites from each sample are listed in Appendix I. The prevalence of long-lived parasites, potentially suitable as natural tags for each lake are given in Table V. Philonema agubernaculum was the most commonly occurring parasite, infecting at least one host in every lake studied. Diphyllobothrium sp. plerocercoids were the next most common parasite, infections occurring in fish from all lakes except Lillooet. In contrast, some other parasites were rare, for example Chloromyxum sp., Ergasilus nerkae, and hymenolepid coenurous larvae.

Table IV. Parasites encountered during the survey of juvenile sockeye salmon, Oncorhynchus nerka

Parasite		Infection site
Protozoa : Myxosporea		
Chloromyxum coregoni Bauer,1948	**	gall bladder,intestine
Chloromyxum sp.	**	gall bladder,intestine
Myxidium salvelini Konovalov and Shulman,1966	**	urinary bladder,kidney
Myxobolus neurobius Schuberg and Schroder,1905	**	brain,spinal chord
Platyhelminthes : Monogenea		
Gyrodactylus nerkae Cone et al.,1983		external surfaces,gills
Platyhelminthes : Trematoda		
Diplostomulum sp.1 metacercaria	**	eyes
Diplostomulum sp.2 metacercaria	**	body cavity,viscera
Tetracotyle sp. metacercaria	**	mesenteries,eye muscles
Crepidostomum farionis (Muller,1874) Luhe,1909		gall bladder,intestine
Phyllodistomum conostomum (Olssen, 1876) Ohdner,1902	*	ureters,urinary bladder
Platyhelminthes : Cestoda		
Diphyllobothrium sp.plerocercoid	**	mesenteries,stomach wall
Hymenolepid coenurous larva	**	liver
Eubothrium sp.immature		caeca,intestine
Proteocephalus sp.immature		caeca,intestine
Nematoda		
Philonema agubernaculum Simon and Simon,1936	*	swim bladder,body cavity
P.oncorhynchi Kuitinen-Ekbaum,1933	**	swim bladder

Table IV (continued)

Acanthocephala		
Neoechinorhynchus sp.(spp?)	*	caeca,intestine
Crustacea : Copepoda		
Ergasilus nerkae Roberts,1963	*	gills
Salmincola californiensis(Dana,1852) Wilson,1915	*	external surfaces,gills

* Signifies parasite potentially useful as a natural tag for juvenile salmon.
** Signifies parasite potentially useful as a natural tag for adult salmon.

Table V. Prevalence (in %) of selected parasites of juvenile sockeye salmon, Oncorhynchus nerka , from the study lakes. Mulitiple samples of equivalent age from any one lake were pooled.

	Parasite														
Lake	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	2	0	0	0	0	0	0	0	4	0	16	100	8	0	0
2	0	0	61	0	3	0	3	0	18	0	3	100	100	0	12
3	53	0	0	0	0	0	10	0	43	0	73	0	3	0	0
4	0	0	55	0	0	0	0	0	0	0	3	0	0	0	0
5	0	0	0	0	0	0	0	0	44	0	88	0	1	2	0
6	8	0	0	0	17	2	44	0	88	0	3	0	9	0	0
7	24	0	0	0	36	2	86	0	100	0	8	0	40	0	0
8	0	0	0	0	0	0	0	0	9	0	17	0	3	0	11
9	1	0	0	0	5	0	0	0	39	0	74	0	0	0	2
10	38	0	0	62	2	0	0	0	80	2	42	0	0	0	0
11	0	0	0	66	6	0	0	0	58	2	8	0	84	0	14
12	8	0	0	0	36	2	51	2	88	0	69	0	0	0	0
13	0	0	0	0	6	0	12	0	38	0	40	0	0	0	0
14	0	0	0	0	0	0	0	0	2	0	21	0	0	0	0
15	2	0	0	2	8	0	6	5	8	0	65	0	0	0	38
16	1	0	0	0	43	5	65	21	62	2	22	0	27	0	20
17	0	0	36	0	0	0	0	0	88	0	52	0	8	0	38
18	0	2	22	92	0	0	4	0	84	0	8	100	38	0	10

Key:

Lakes	Number
Pitt Lake	1
Cultus Lake	2
Harrison Lake	3
Lillooet Lake	4
Seton Creek(combined)	5
Chilko Lake(comb,1yr)	6
Chilko Lake(2yrs)	7
Adams Lake	8
Shuswap Lake(comb)	9
Quesnel Lake	10
Bowron Lake	11
Stuart Lake(comb)	12
Trembleur Lake	13
Takla Lake	14
Francois Lake(comb)	15
Fraser Lake(comb)	16
Lake Washington	17
Nimpkish Lake	18

Parasite	Letter
Chloromyxum coregoni	A
Chloromyxum sp.	B
Myxidium salvelini	C
Myxobolus neurobius	D
Diplostomulum sp.1 met.	E
Diplostomulum sp.2 met.	F
Tetracotyle sp.met.	G
Phyllodistomum conostomum	H
Diphyllobothrium sp.	I
Hymenolepid coenurous	J
Philonema agubernaculum	K
Philonema oncorhynchi	L
Neoechinorhynchus sp.(spp?)	M
Ergasilus nerkae	N
Salmincola californiensis	O

Zonal differences in the parasite species-composition, prevalence, and mean intensity will be elaborated on in the section on "Stockner-Shortreed" zones, although data in Table V illustrate the patchy nature of the species distributions.

b. Determination of local and zonal differences in the parasite fauna of juvenile sockeye salmon

The results of testing for differences in P/A values of parasites within individual lakes, among lakes within zones, and among geographic zones are presented in Appendix II.

(i). Within-lake variability in the parasite fauna

1. Seasonal variability within individual lakes

Statistically significant seasonal variability of infections in Chilko Lake was observed only for Chloromyxum coregoni and Tetracotyle sp. metacercaria. In contrast, seasonal variability of infection in Seton Creek was statistically significant for all parasites except Diphyllobothrium sp. plerocercoids.

2. Annual variability within individual lakes

Annual variability of parasite infections was statistically insignificant for all species in Seton Creek smolts, insignificant for all species except Myxobolus neurobius and Phyllodistomum conostomum in Francois Lake, and insignificant for all species except Diplostomulum sp. 1 metacercaria and

Diphyllobothrium sp. plerocercoids in Shuswap Lake. In contrast, annual variability was significant for Diplostomulum sp. 2 metacercaria, Tetracotyle sp. metacercaria and Diphyllobothrium sp. plerocercoids in Chilko Lake, significant for all species except C. coregoni in Fraser Lake, and for all species except P. agubernaculum in Stuart Lake. Tetracotyle sp. metacercaria displayed the greatest variability between year-classes.

(ii). Variability among lakes within zones.

Within each biogeoclimatic zone, the P/A values of most species of parasites were significantly different among lakes. Only parasites that were rare within any zone failed to show significant differences in P/A values between lakes, e.g. Diplostomulum sp. 1 metacercaria from zones 2 and 4, Tetracotyle sp. metacercaria from zone 4, P. conostomum from zone 3 and E. nerkae from zone 3. In many instances a parasite occurred commonly in one or two lakes of a zone, but was rare or entirely absent from other lakes of the same zone, e.g. Tetracotyle sp. metacercaria, P. conostomum, N. rutili, and Salmincola californiensis in zone 1. Other parasites were relatively common in all lakes within a zone, although at significantly different P/A values in each lake e.g. P. agubernaculum in zone 2, and Diphyllobothrium sp. plerocercoids in zone 4.

iii. Variability among zones.

There was significant variability in P/A values of all parasites between zones. The distributions of some species were limited to one zone, e.g. Philonema oncorhynchi was limited to zone 4 and E. nerkae limited to zone 3. Phyllodistomum conostomum and Tetracotyle sp. metacercaria were common in zone 1 and rare in other zones. Myxidium salvelini was common in three zone-4 lakes, and absent from every other lake except Lillooet Lake in zone 3. Other parasites were widely distributed across all zones, e.g. Diphyllobothrium sp. plerocercoids, P. agubernaculum, and Neoechinorhynchus sp.

c. Parasites as tags for determining the origin of juvenile sockeye salmon

The results of the Fournier model simulations to test the feasibility of using parasites as tags were very encouraging (Appendix III). For the first four series of simulations in which the representation of each stock in the simulated mixture was equal, the estimated contributions of each stock to the mixture were not significantly different from the actual contribution except for Fraser Lake in 1981 and Stuart Lake in 1983. However, for both these exceptions the predicted contributions were within 10% of the actual contributions.

The results obtained using unequal contributions from each stock also were encouraging. The first three simulation years

yielded no significant differences between the estimated and actual contributions for 1983, one significant difference (Fraser Lake for 1981), and two significant differences for 1982 (Chilko 1 yr olds and Fraser Lake). However the results for 1984 were less accurate , because the estimates for four stocks deviated significantly from the actual values. This was due to the large input of Shuswap Lake fish, some of which were misassigned to Fraser, Lillooet, and Seton Lakes. However, with the exception of Seton Lake, all predictions were within 10% of the actual value. Seton Lake contributed only four fish to the 500-fsh simulated mixtures, while the model estimated Seton Lake's average contribution as 26 fish. This is due to the similarity of the parasite fauna of Seton Creek and Shuswap Lake, with the result that some Shuswap fish were incorrectly assigned to Seton Lake.

II. Survey of adult sockeye salmon for Myxobolus neurobius

Three-hundred-and-twenty-five post-spawned adult sockeye from 10 spawning grounds were examined for M. neurobius. Fourty-seven fish from four lakes were infected. Infection prevalences ranged from 0.00 to 0.70 (Table VI). Significant differences between smolt and adult P/A values for M. neurobius were noted for Stuart, Fraser and Francois lakes (Appendix IV).

Table VI. Prevalence and P/A ratio of Myxobolus neurobius in post-spawned adult Fraser River sockeye salmon.

Spawning Ground (Rearing lake)	No.	P/A	Prevalence
Pitt River (Pitt Lake)	30	0/30	0.000
Cultus Lake (Cultus Lake)	30	0/30	0.000
Birkenhead River (Lillooet, and Harrison lakes)	28	0/28	0.000
Weaver Creek (Harrison Lake)	30	0/30	0.000
Gates Creek (Seton Lake)	30	0/30	0.000
Chilko River (Chilko Lake)	49	0/49	0.000
Adams River (Shuswap Lake) (1)	50	0/50	0.000
Horsefly River (Quesnel Lake)	21	13/8	0.619
Gluske Creek (Stuart system)	30	1/30	0.033
Stellako River (Fraser Lake)	37	5/32	0.135
Nadina River (Francois Lake)	40	28/12	0.700

(1) Adams River data supplied by T.Mc.Donald (P.B.S.).

III. *Phyllodistomum conostomum* taxonomy

Fourty-seven specimens of *P. conostomum* were encountered in juvenile sockeye salmon from four lakes during the survey of smolts and presmolts. The parasites occurred in the ureters of the kidney and in the urinary bladder. The ranges and means of measurements of 10 specimens of *P. conostomum* encountered during the smolt and presmolt survey, 10 specimens from Nechako River *Salmo gairdneri*, and 10 specimens from *Coregonus* spp. from Finland, and the measurements provided by Skrjabin (1953) are listed in Table VII. Thirty eggs were measured per specimen. All measurements, with the exception of eggs, overlap to varying degrees. Statistical comparisons to determine if the measurements differ significantly were not performed due to the differences in sampling times, killing methods, staining, and mounting procedures.

Table VII. Comparison of measurements of Phyllodistomum conostomum from different hosts and geographic localities (All measurements in micrometers, um.)

Measurement		Localities A	B	C[1]	D[2]
Body length	$\bar{x}$	3700	2885	3540	-
	Range	3225-4600	2040-3550	1658-4975	3000-5500
Body width	$\bar{x}$	670	594	757	
	R	525-800	428-816	418-1413	800-1600
Forebody length	$\bar{x}$	900	670	868	3
	R	850-1175	505-735	526-1442	-
Suckers:					
Oral	L.$\bar{x}$	281	244	267	
	R	275-300	205-270	159-339	240-340
	W.$\bar{x}$	250	206	228	
	R	240-260	172-245	130-303	200-320
Ventral	L.$\bar{x}$	281	248	296	
	R	250-325	205-278	180-418	290-440
	W.$\bar{x}$	278	243	293	
	R	250-300	200-278	202-389	260-390
Sucker Ratio (transverse)		1:1.11	1:1.18	1:1.11	1:1.25-1.3
Testes					
Anterior	L.$\bar{x}$	435	416	495	
	R	300-625	245-540	252-721	270-740
	W.$\bar{x}$	190	232	283	
	R	100-300	115-376	180-475	230-480
Posterior	L.$\bar{x}$	541	414	525	
	R	500-600	205-597	267-757	310-820
	W.$\bar{x}$	157	230	270	
	R	100-250	123-385	144-540	240-560
Ovary	L.$\bar{x}$	309	251	303	
	R	250-375	172-327	180-432	250-410

Table VII (continued)

	$W.\bar{x}$	209	191	187	
	R	150-250	123-262	94-353	180-320
Vitellaria					
Right	$L.\bar{x}$	225	156	190	
	R	165-275	106-221	123-274	160-260
	$W.\bar{x}$	142	98	134	
	R	100-200	65-115	87-201	120-240
Left	$L.\bar{x}$	230	152	197	
	R	200-250	115-188	122-303	160-260
	$W.\bar{x}$	147	104	127	
	R	110-250	65-131	87-209	120-240
Eggs (mature)					
	$L.\bar{x}$	39.5	34.0	35.7	
	R	36-42	32-38	29-43	46-55
	$W.\bar{x}$	27.7	25.0	24.8	
	R	24-32	24-27	18-27	32-33

[1] A=Fraser,Francois,and Stuart Lakes,B.C.,from O.nerka juveniles.
B=Nechako River drainage,B.C.,from Salmo gairdneri (Ching, pers.comm.1984)
C=Finland; from Coregonus spp.,courtesy of Dr.D.Gibson,British Museum (Natural History), London
D=Various Russian salmonids; from Skrjabin (1953)

[2] Means not given.

[3] Forebody lengths not given.

D. DISCUSSION

I. Parasite assemblage of juvenile sockeye salmon

a. Survey results

Juvenile sockeye salmon from the nursery lakes studied during the survey were infected with 19 taxa of parasites, of which C. coregoni, M. salvelini, M. neurobius, Gyrodactylus nerkae, Crepidostomum farionis, P. conostomum, P. agubernaculum, P. oncorhynchi and S. californiensis are specific to salmonid fishes. Possibly Chloromyxum sp. from Nimpkish Lake is also specific to salmonids. Diplostomulum sp. 1 and sp. 2, Tetracotyle sp., Diphyllobothrium sp., Neoechinorhynchus sp. (spp?), and Ergasilus nerkae are not specific to salmonid fishes.

Certain species of the genera Eubothrium and Proteocephalus, e.g., E. salvelini and P.exiguus are specific to salmonids but the lack of mature proglottids in worms of these genera during the present survey precluded reliable identification beyond the genus level. Hence, it was not possible to classify the immature worms encountered as specific or non-specific to salmonids. Eubothrium salvelini is commonly encountered in juvenile sockeye salmon in B.C. (Boyce 1979), but other species of Eubothrium have been reported from non-salmonids in B.C. (Margolis and Arthur 1979) and may be represented in the immature forms collected.

Four species of the genus Proteocephalus have been recorded from salmonids in B.C. An additional four species, not specific to salmonids, have also been recorded from B.C. (Margolis and Arthur 1979). The results of the present study indicate the need for a review of the taxonomy of the genus Proteocephalus from B.C. fishes, as was previously noted by Margolis (1982).

Of those parasites not specific to salmonids, most mature in piscivorous birds or mammals and use fish as second intermediate hosts. For Diphyllobothrium spp. and some hymenolepids, planktivorous fish act as second intermediate hosts, becoming infected by ingesting an infected copepod (first intermediate host). Diplostomulum spp. and Tetracotyle sp. infect fish by means of cercarial penetration. The cercariae then develop into metacercariae and may encyst (e.g. as in Tetracotyle) in the fish.

Neoechinorhynchus rutili is widely distributed in the palearctic and nearctic regions in salmonid and non-salmonid fishes (Ching 1984). This parasite matures in fish and requires an ostracod intermediate host (Merritt and Pratt 1964). Neoechinorhynchus salmonis was described from the northern Fraser River watershed by Ching (1984) and is found in salmonids as well as non-salmonids. Ching (1984) noted that many specimens previously ascribed to N. rutili (including some specimens of Bangham and Adams 1954) may now be referred to N. salmonis.

Ergasilus nerkae is the only parasite with a direct life cycle encountered during this survey that is not specific to

salmonid fishes. All the parasites specific for salmonids by definition require a salmonid fish host for one stage of their life cycle. Of the parasites specific to salmonids, only C. farionis, P. conostomum, P. agubernaculum and P. oncorhynchi require crustacean intermediate hosts. All other parasites specific to salmonids encountered in the present study are believed to have direct life cycles.

Of the 19 taxa of parasites encountered, 14 were potentially suitable for use as natural tags for juvenile sockeye salmon, i.e., the parasites would remain in or on the host for more than one month after entry into salt water. Nine of these parasites may be suitable for use as tags for adult sockeye, for which they must remain with the host fish for the entire duration of its marine life.

Phyllodistomum conostomum, P. agubernaculum, Neoechinorhynchus sp. (spp?), and S. californiensis have been observed in juvenile sockeye salmon captured in the Strait of Georgia (Author, unpublished data), although none of these parasites have been observed in adult sockeye salmon prior to re-entry into fresh water (T. McDonald, pers.comm.). Phyllodistomum conostomum and P. agubernaculum are probably not sufficiently long-lived for use as adult markers, whereas S. californiensis, E. nerkae and Neoechinorhynchus sp.(spp?) may be unable to tolerate extended exposure to a hypertonic environment.

Parasites potentially suitable for use as adult tags include C. coregoni and Chloromyxum sp., M. salvelini, M. neurobius, Diplostomulum spp. and Tetracotyle sp. metacercariae, Diphyllobothrium spp. plerocercoids, and P. oncorhynchi. Chloromyxum spp. and Myxidium spp. have been recorded from spawning sockeye salmon (T. McDonald, pers.comm.) although it is not clear if the infections were obtained prior to seaward migration or after re-entry into fresh water. Myxobolus neurobius, however, is known to persist throughout the life of the fish (Konovalov 1971; Dana 1982; Margolis 1982).

Diplostomulum spp. metacercariae in the eyes of salmonids have been suggested as useful tags by several authors including Konovalov (1971) and Jennings and Hendrickson (1982). Margolis (1963) and Pennell et al. (1973) noted decreased prevalence and intensity of infection in adult salmon (before re-entry to fresh water) when compared to smolts from the same locality. Both authors concluded that a loss of Diplostomulum metacercariae was occurring during the highseas residence period, although neither author offered an explanation for the losses. After re-entry to fresh water, a rapid rise in infection prevalence and intensity is observed (Pennell et al. 1973). Tetracotyle sp. metacercariae and Diphyllobothrium spp. plerocercoids apparently survive for the duration of the salt water residence. Both taxa have been observed in spawning adult sockeye salmon (Margolis 1963; T. McDonald, pers.comm.), although whether any reduction in prevalence or intensity occurs during the period of ocean

residence is not known.

Philonema oncorhynchi is also known to survive for the entire marine life span of O. nerka. Philonema oncorhynchi matures in synchrony with the maturation of its sockeye salmon host (Bashirullah 1966). Determination of the prevalence and intensity of infection with P. oncorhynchi may be complicated where it coexists with P. agubernaculum. Larvae of P. agubernaculum and P. oncorhynchi are morphologically indistinguishable (Bashirullah 1966, Chacko 1975).

b. Ecological considerations of survey results and biogeoclimatic zone analyses.

The factors affecting the composition of the parasite fauna of juvenile sockeye in each of the nursery lakes studied appear to be complex. Two hypotheses have been proposed on the relationship between a lake and the parasite fauna of its fishes. The hypotheses were summarized by Leong and Holmes (1981). The first hypothesis, proposed by Wisniewski (1958), stresses that the parasite fauna of a lake is dependant on interactions within the entire watershed, including the limnology of the lake, the fish that inhabit the lake, and the birds and mammals occupying the drainage basin around the lake and its tributaries. The alternate hypothesis, proposed by Halvorsen (1971) and Wooten (1973), stated that the parasite fauna of any fish species should be somewhat similar across its entire range, despite local differences in limnology, geography,

and the composition of the coexisting species in the watershed (both aquatic and terrestrial).

Stockner and Shortreed (1983) characterized the sockeye rearing lakes of the Fraser River drainage system, and classified them into broad biogeoclimatic zones. Seasonal and annual comparisons of the parasite fauna of individual lakes, between lakes within each zone, and between each zone revealed complex differences in the parasite faunas.

Comparisons of the parasite fauna between three temporally separate samples from one year's smolt emigration from Chilko Lake revealed that little seasonal variability existed in the fauna for that year class. Seasonal variability is greatest when two or more populations of juveniles from within one lake (or lake system) rear in separate areas of the system, and migrate downstream temporally separated. The 1982 smolt emigration from Chilko Lake represented the peak year of the four-year cycle for one-year-old smolts (one winter of lake residence). Two separate spawning populations are known from Chilko, one spawning in the Chilko River below the lake, the other spawning on shoals in the south end of the lake. It is possible that either smolts migrating from river-spawning fish were numerically dominant, and so masked any significant differences between the fauna of the two stocks, or the two stocks freely intermixed while rearing and acquired a common parasite fauna.

In Seton Creek, there was some variation with time in the parasite fauna of downstream migrants in 1982. This may be

attributed to the availability of two separate rearing areas for Seton juveniles. Most of the spawning occurs at Gates Creek, at the head of Anderson Lake. However, more than 90% of the fry produced at Gates Creek move through Anderson Lake and rear in Seton Lake (J. Woodey pers.comm.). Fish that reared in Anderson Lake were considerably smaller than fish reared in Seton Lake and tended to have higher infections of intestinal cestodes and P. agubernaculum.

Annual variability of infection levels in the parasite fauna of juvenile sockeye tended to be greater among parasites which use sockeye salmon as intermediate hosts and mature in piscivorous birds and mammals. Annual variability was greatest in shallower, less oligotrophic lakes, such as Stuart Lake and Fraser Lake, as opposed to the deep oligotrophic lakes, except Chilko. In the shallower more mesotrophic lakes, the opportunity for interactions between piscivorous birds and small fish increases, and annual fluctuations in local populations of these birds may influence the availability of the cercariae of Diplostomulum and Tetracotyle. The cercariae are shed from littoral or benthic molluscs, and in shallower lakes, the sockeye salmon dwelling in the limnetic zone may reside in closer proximity to the source of infective agents. Chilko Lake is an interesting exception. Chilko is deep and oligotrophic, but trematode metacercariae occur frequently in the smolts, although the infection prevalences vary significantly between years. Therefore, there may be an area of the watershed where

piscivorous birds and juvenile sockeye salmon co-exist. When the sockeye salmon fry emerge from the gravel in the Chilko River, they remain in the river for up to two weeks prior to migrating upstream into Chilko Lake. During this period they are subjected to intense predation by Bonaparte's gulls (I. Williams, pers.comm.). The gulls may also act as definitive hosts for the trematode metacercariae found in sockeye salmon smolts. During the period of river residence and migration to the lake, the fry may be exposed to large numbers of trematode cercariae, which may account for the high numbers of metacercariae found in Chilko juveniles. Larger fry hatches tend to attract more gulls and mergansers, and the availability of infective agents may be altered annually as a result. Also, the mouth of the Chilko River is frequented by mergansers during smolt migrations, one month prior to fry migrations.

Comparisons between the parasite fauna of two-year-old smolts (two winters lake residence) and the fauna of one-year-old smolts from Chilko Lake indicate that there are significantly more metacercariae in two-year-olds. Two-year-olds were also more highly infected with Diphyllobothrium spp. plerocercoids and Neoechinorhynchus spp.

There are two possible explanations for the increased prevalence of trematodes. One hypothesis is that the extra year of lake residence increased the exposure of the fish to the infective agents. The alternate hypothesis is that the young fish spent more time in the littoral zone of the lake prior to

moving into the limnetic zone, thereby increasing their exposure to cercariae. Young sockeye salmon reside in the littoral zone after moving from the river into the lake, and if they must acquire a threshold size prior to migrating to the limnetic zone, then slow growing fish may spend more time in the littoral zone. If the retardation of growth of these fish continues upon entry into the limnetic zone, then they may fail to reach the threshold size required for smolting and so remain in the lake for one more year.

The higher prevalence of Diphyllobothrium spp. plerocercoids may be due to the extended period of lake residence, increasing the chance of ingesting an infected copepod. However, the cyclopoid copepods required as first intermediate hosts for Diphyllobothrium spp. and other helminths (including Philonema spp.) are heavily selected against as a food item for young sockeye salmon, except by fry immediately after entry into some rearing lakes, e.g., Lake Washington (Eggers 1978). This negative selection is due to the smaller size of some cyclopoids in comparison to certain cladocerans. If some juvenile sockeye salmon are slower growing, or grazing pressure on larger plankton is intense, smaller sockeye salmon may feed on Cyclops spp. for a longer period of time, becoming more heavily infected with Diphyllobothrium spp. and other helminths. This problem may be further compounded because Cyclops spp. are the first intermediate hosts for E. salvelini (Boyce 1974), and prolonged consumption of Cyclops may increase

the prevalence and intensity of E. salvelini infections in the fry, further retarding growth. These fry may fail to reach the threshold size required for smolt emigration and remain in the lake for a second year. During the second year of lake residence, feeding on Cyclops spp. may decrease, resulting in fewer new infections.

The increased prevalence and intensity of helminths in two-year-old Chilko smolts is in agreement with the results of Konovalov (1971) and Pennell et al. (1973), who noted increased infections in two-and three-year-lake resident smolts when compared to one-year-old smolts in Kamchatkan and Alaskan sockeye salmon respectively.

The decision to test the parasite data against the biogeoclimatic zones proposed by Stockner and Shortreed (1983) necessitated tentatively accepting their results. While the zones have been slightly modified for use in this study, they are essentially those proposed by Stockner and Shortreed. There is, however, a potential problem with the scheme that they proposed. The data on which the scheme is based were collected during a single sampling period, not a year round sampling effort, hence measurements of nutrient concentrations and other indices of productivity calculated from such measurements may be misleading. However, no other limnological characterization of all the Fraser River sockeye nursery lakes has been published.

Among individual lakes within each of the biogeoclimatic zones there were substantial differences in the parasite faunas

of the juvenile sockeye salmon. In certain cases, one parasite occurred in all of the nursery lakes within one zone, although at significantly different prevalences, for example, P. agubernaculum in all zones, Diphyllobothrium spp. in zones one, two and four. Other parasites were common within one lake of a zone and virtually absent from other lakes of the same zone, for example, P. conostomum in zone one, M. salvelini in zone three, and S. californiensis in zones one, two and four.

Within each zone there is some limnological similarity among the lakes. Stockner and Shortreed (1983) reviewed the chemical and physical limnology of the sockeye salmon nursery lakes of the Fraser River drainage system and attempted to evaluate and compare productivity between zones. Certain characteristics of each zone were apparent, although these characteristics did not uniformly apply to each lake within a zone, i.e., zone one lakes were rated as being the most productive in the Fraser River drainage system, yet Takla Lake of that zone is a deep oligotrophic, unproductive lake, comparable to Adams and Chilko lakes. Within zone two lakes, there was an overall trend toward lower productivity than zone one lakes, yet major differences were reported between the more productive Bowron and Shuswap lakes and the more oligotrophic Adams and Quesnel lakes.

Within and among biogeoclimatic zones, lakes that were most similar limnologically were also more similar parasitologically (especially for helminths). Shallower, productive Fraser and

Stuart lakes were very similar in parasite species composition except for the absence of S. californiensis in Stuart Lake. Stuart Lake fish also had a higher prevalence of Diphyllobothrium spp. plerocercoids and a lower prevalence of P. conostomum. Adams Lake, Takla Lake and Lillooet Lake, all large unproductive lakes, had somewhat impoverished parasite faunas that were fairly similar, with only the intestinal helminths being common in any of the lakes, except for M. salvelini in Lillooet. Fish from all of these lakes had low prevalences of Diphyllobothrium and P. agubernaculum.

While the physical and chemical limnology of a lake may influence the composition of the parasite fauna of its fishes, the availability of reservoir hosts, definitive hosts, and suitable intermediate hosts are also important in determining the composition of the parasite fauna of the fish. Many of the species of parasites encountered during the study mature in salmonid fish, although juvenile sockeye salmon may not be required as hosts for any of the parasites that mature in salmonids. [The required host species is that species in which the highest proportion of the total population of the parasite within the lake matured (Leong and Holmes 1981)]. Other salmonids, such as Salmo gairdneri, Coregonus spp., Prosopium spp., Salvelinus malma, S. namaycush, and O. nerka kennerlyi (kokanee), may act as reservoir hosts for these parasites. Konovalov (1971) was of the opinion that O. nerka (anadromous) has no specific parasites and that they acquire all their

parasites from the fishes with which they coexist. However, parasites such as P. oncorhynchi appear to have evolved with their definitive host and are primarily adapted to sockeye salmon. For a complete discussion of the life history of P. oncorhynchi, see Bashirullah (1966).

Sockeye may act as the required host for some helminths and protozoa, i.e., P. oncorhynchi as listed above, and M. neurobius. The spawning migrations of adult sockeye salmon heavily infected with these parasites provide for the release of many infective stages or spores into the watershed, and if the spawning occurred upstream of the lake or within the lake, infective stages will be available to infect the fry in the following year. It is noteworthy that infections with either of these parasites occur only where upstream or lake spawning occurs. Fish from Chilko and Harrison lakes, both having major fry contributions from downstream spawning areas, had no evidence of P. oncorhynchi or M. neurobius infections.

Eggers (1978) noted that when readily available, larger zooplankters, i.e., Bosmina, Holopedium, and certain Daphnia spp. were selected preferentially to Cyclops spp., which act as intermediate hosts to many helminths. In such lakes, the infection rates of these helminths may be greatly reduced. Foerster (1968) noted that under-yearling sockeye also preferentially feed on certain cladocerans rather than Cyclops spp. even when the two prey items were of similar size. Ricker (1937) speculated that this may be due to the ability of the

more mobile Cyclops spp. to avoid predators.

The occurrence of certain parasites in only one biogeoclimatic zone and not in others is interesting. Philonema oncorhynchi is only found in zone four and P. conostomum is found mainly in zone one. The factors restricting the distributions of these two parasites are not clear. However, temperature alone cannot explain the apparent restriction of P. oncorhynchi to zone four because it has been reported from Bristol Bay, Alaska stocks (Pennell et al. 1973), as well as from the Nass and Skeena rivers in northern B.C. (T. McDonald, pers.comm.). Other parasites, e.g., P. agubernaculum, and the cestodes Eubothrium spp. and Diphyllobothrium spp., were distributed throughout the studied area. The varied distributions of the required intermediate and reservoir hosts most likely influence some of the restricted distributions, whereas species that were widely distributed apparently are tolerant of wide ranging conditions.

c. Applications of parasites as tags

Too few parasite species specific to individual lakes were found to permit the "conventional" application of the data to stock identification by the use of parasites as tags (i.e., using the "Principal of Alternativity" of Konovalov 1971). However the development of multivariate stock composition models (Fournier et al. 1984) has permitted a new approach to the problem. The Fournier model, initially developed for use with

morphometric, meristic, and genetic information, is easily applied to parasite data. The model is even able to incorporate infection-intensity parameters, as well as prevalence, if so desired.

Initial studies separating two or three stocks or groups of stocks of fish using parasites as markers were performed by Margolis (1963), Margolis et al. (1966), and Kabata (1959, 1963, 1967). For the most part, these early studies used only one or two parasites for identification. The presence of a parasite in one stock and its absence in another stock were the criteria used for separation. Low prevalences complicated the separations and intensity generally was not considered.

Although it has been demonstrated that significant seasonal and/or annual variation of infection occurs for certain parasites, it was decided to test the ability of the Fournier-model to resolve mixed fishery samples with the available data. Unfortunately samples were not available from every lake for any one year-class, and repetetive sampling to test for seasonal variation was only feasible at Seton Creek and Chilko Lake. While it is possible that the variability may negate some of the ability of the model to accurately differentiate between the stocks, annual sampling and examination of smolts from each stock contributing to the mixed fisheries would reduce the negative impact of such variability.

Using the multivariate model, and 14 parasites as markers, even in cases where only slight differences exist between

stocks, accurate separation of several stocks now appears to be feasible. As noted earlier, the stocks chosen for testing the model represent those seven stocks that for each year of the four-year-cycle (1981-1984) contribute at least 95% of the total smolt output from the Fraser River. The implications of including more stocks, especially those represented at low levels, into the model have not yet been tested, although further testing is required prior to field use of the technique. Fournier et al. (1984) discuss examples of use of the model with morphometrics, genetics, and meristics, and detailed the potential for using more stocks, and also the possibilities for missassigning individual fish to stocks that are represented at very low levels. There was a trend in the simulations to over-assign fish to stocks of low abundance, while under-assigning fish to stocks of high abundance. This was most clearly evident in the simulations of the 1984 year class . This is consistent with the findings of Fournier et al. (1984).

The accuracy achieved in the simulation experiments is probably the maximum accuracy possible using this technique. The mixed-fishery samples analyzed during the simulations were constructed from the smolt-parasite data and fail to take into account the possible loss of markers. As noted earlier, several of the parasites selected for use as biological tags for juvenile fish may be relatively short-lived in the ocean. As these parasites are lost, the ability of the model to differentiate accurately between stocks may be substantially

reduced. Therefore, prior to use for stock identification purposes, the parasites chosen for use as markers should be further investigated to determine their life span in the ocean.

At present, most of the Fraser River sockeye fisheries are managed using scale patterns as the method of determining stock composition. Henry (1961) discussed the use of scales for markers in Fraser River sockeye salmon. Konovalov (1971) suggested that scales as well as parasites be used for stock identification. He constructed a simple multivariate model for separating the major Kamchatkan and North American sockeye salmon stocks using scale and parasite data. Another study presently in progress, is attempting to differentiate between northern B.C. and southeastern Alaskan sockeye using parasites, scales, and electrophoretic characters. This study is also using the Fournier et al. (1984) model (C. Wood, pers.comm.). The use of genetics, scales, and parasites may allow even greater accuracy of separation, given the large number of potential markers available.

II. Myxobolus neurobius in post-spawned adult sockeye.

The survey of M. neurobius infections in post-spawned adult sockeye from Fraser spawning grounds and the tests for significant differences of infection prevalences between smolts and adults from the same stocks yielded some curious results. Stuart, Fraser, and Francois lakes sockeye salmon all had significantly greater prevalences of infection with M. neurobius in adults than in smolts. Whether the infections with M. neurobius occurred at a late stage of lake residence and so were not detected in smolt samples examined from both lakes, or whether the infections matured extremely slowly so that spores were not visible in smolts, or whether the infections were acquired during the seaward migration is not clear. Any river infections would have to occur in the Nechako River, above the junction of the Stuart River, because almost all Stuart River fish remain uninfected. It is possible that the cold water of the northern lakes may retard the growth and maturation of M. neurobius, hence delaying the production of spores.

Quesnel Lake adults returned to the spawning grounds with an equivalent infection prevalence to the smolts that migrated from the lake in spring of the same year. It would be revealing to examine the returning adults corresponding to smolts examined for M. neurobius. Unfortunately Bowron Lake adults were unavailable and so the tests for differences were not applied. Infections are apparently not being acquired in the lower Fraser

River, as happens with Ceratomyxa shasta in chinook salmon, Oncorhynchus tshawytscha, smolts (Ching and Munday 1984). Otherwise all up river stocks would return infected. The single infected adult sockeye captured in the upper Stuart system may have been either a stray from Bowron, Quesnel, Fraser or Francois lakes or a fish that was reared and became infected with M. neurobius in the Stuart drainage. The latter explanation appears improbable because more than 200 juveniles were examined from that system, and all were negative for M. neurobius. Two rainbow trout (Salmo gairdneri) examined from the Stuart River were also negative for M. neurobius. For further use of M. neurobius as a parasite tag for Fraser River sockeye, additional surveys of post-spawned adults would be advisable, to test for annual variability of infection in infected stocks.

III. Taxonomy of Phyllodistomum conostomum

Phyllodistomum conostomum is a holarctic species, described initially by Olssen (1876) and redescribed by Nybelin (1926). It belongs to the family Gorgoderidae, and the members of the genus Phyllodistomum were redescribed by Pigulevsky in Skrjabin (1953). The descriptions and measurements given for P. conostomum in Skrjabin (1953) concur with those taken from Fraser River O. nerka juveniles and from Coregonus spp. from Finland, except for the size of the eggs. Specimens of P. conostomum from S. gairdneri in the Nechako River were somewhat smaller than those from O. nerka and Coregonus spp., although egg sizes from these worms were very similar. Konovalov (1971) reported P. conostomum from salmonids on the Kamchatka Peninsula. The measurements he listed agreed most closely with specimens obtained from S. gairdneri from the Nechako River. Unfortunately, Konovalov did not provide measurements of eggs. The discrepancies in published body sizes for P. conostomum may be due to several causes. One explanation may involve fixation and staining techniques. Berland (1982) noted that body shape, size, and thus measurements, are greatly influenced by the mode of fixation, relaxation, killing, staining, and mounting. Moreover, the worms may not all have been in an equivalent state of maturity . Season of sampling also directly affects the results. Worms recovered from presmolts (September) in Fraser Lake measured less than one millimeter, yet mature worms

recovered from smolts collected in April and May measured an average of 3.7 millimetres.

Several other species of the genus Phyllodistomum may possibly be synonyms of P. conostomum. Bakke and Lien (1978) noted that P. conostomum may be a junior synonym of P. umblae (Fabricius, 1780). Dr. T. Bakke, (Zoological Museum, University of Oslo, Norway) is at present reviewing the relationship between P. conostomum and P. umblae. Sandeman and Pippy (1967) described P. limnosa as a new species on the basis of the presence of an accessory oral sucker. I believe that this is insufficient reason for describing a new species of the genus because every species of the genus that I have examined (both freshwater and marine) have possessed the accessory oral sucker (see Bakke and Lien 1978 for photomicrographs of the accessory sucker of P. conostomum). The measurements, including egg sizes, given for P. limnosa correspond with those of P. conostomum from Fraser River O. nerka and Finnish Coregonus spp.

Sandeman and Pippy (1967) compared P. limnosa with P. lachancei from Salvelinus fontinalis in Quebec and concluded that the two species were similar except for the presence of the accessory oral sucker in P. limnosa. Therefore, I would suggest that a re-examination of P. lachancei and P. limnosa be undertaken to determine if they are indeed junior synonyms of P. conostomum.

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E. APPENDICES

Appendix I

Prevalence, P/A ratio and intensity data summary for Fraser River juvenile sockeye salmon parasite survey.

Parasite	# Pres/# Abs	Prevalence	Intensity	S.D.(I)
1) Pitt Lake 17.11.1975 n=50 (presmolts)				
Chloromyxum coregoni	1/49	0.0200	N/A.	N/A.
Diphyllobothrium sp.	0/2/48	0.0400	1.0000	0.0000
Eubothrium sp.	27/23	0.5400	1.3333	0.6202
Proteocephalus sp.	43/7	0.8600	13.186	18.141
Philonema agubernaculum	8/42	0.1600	1.0000	0.0000
P.oncorhynchi	50/0	1.0000	31.660	28.398
Neoechinorhynchus sp.(spp?)	4/46	0.0800	1.0000	0.0000
2) Cultus Lake 20.04.1976 n=33 (smolts)				
Myxidium salvelini	20/13	0.6061	N/A.	N/A.
Gyrodactylus nerkae	28/5	0.8485	13.000	27.991
Diplostomulum sp.1	1/32	0.0303	1.0000	
Tetracotyle sp.	1/32	0.0303	1.0000	
Diphyllobothrium sp.	0/6/27	0.1818	1.3333	0.5164
Eubothrium sp.	4/29	0.1212	1.0000	0.0000
Proteocephalus sp.	30/3	0.9091	6.9667	5.4487
Philonema agubernaculum	1/32	0.0303	1.0000	
P.oncorhynchi	33/0	1.0000	435.67	194.24
Neoechinorhynchus sp.(spp?)	33/0	1.0000	11.970	5.5705
Salmincola californiensis	4/29	0.1212	2.0000	1.1547
3) Harrison Lake 26.11.1978 n=30 (presmolts)				
Chloromyxum coregoni	16/14	0.5333	N/A.	N/A.
Tetracotyle sp.	3/27	0.1000	1.0000	0.0000
Diphyllobothrium sp.	0/13/17	0.4333	1.6154	0.6504
Eubothrium sp.	11/19	0.3667	2.8182	2.5620
Proteocephalus sp.	16/14	0.5333	8.4375	13.023
Philonema agubernaculum	22/8	0.7333	2.6364	1.8656
Neoechinorhynchus sp.(spp?)	1/29	0.0333	2.0000	
4) Lillooet Lake 16.08.1978 n=40 (presmolts)				
Myxidium salvelini	22/18	0.5500	N/A.	N/A.
Eubothrium sp.	40/0	1.0000	7.5500	4.4431
Proteocephalus sp.	40/0	1.0000	14.700	6.6147
Philonema agubernaculum	1/39	0.0250	1.0000	

5) Seton Creek 21-22.04.1966 n=47 (smolts)

Diphyllobothrium sp.	0/17/30	0.3617	1.3529	0.6063
Eubothrium sp.	14/33	0.2979	1.5714	2.1381
Proteocephalus sp.	20/27	0.4255	6.8000	6.8947
Philonema agubernaculum	45/2	0.9575	4.7333	5.3445
Ergasilus sp.	1/46	0.0213	1.0000	

6) cntd. 14.05.1979 n=24 (smolts)

Diphyllobothrium sp.	0/8/16	0.3333	1.5000	0.7559
Eubothrium sp.	5/19	0.2083	1.4000	0.5477
Proteocephalus sp.	13/11	0.5417	10.077	14.210
Philonema agubernaculum	22/2	0.9167	8.3182	16.322

7) cntd. 25-27.04.1982 n=50 (smolts)

Diphyllobothrium sp.	0/23/27	0.4600	1.3913	0.6564
Eubothrium sp.	16/34	0.3200	1.6250	1.2583
Proteocephalus sp.	35/15	0.7000	9.0286	12.764
Philonema agubernaculum	49/1	0.9800	9.0000	9.3986
Neoechinorhynchus sp.(spp?)	3/47	0.0600	1.6667	1.1547
Ergasilus sp.	3/47	0.0600	1.0000	0.0000

8) cntd. 08-10.05.1982 n=50 (smolts)

Diphyllobothrium sp.	1/25/24	0.5200	1.4615	1.1038
Eubothrium sp.	15/35	0.3000	1.8000	1.2071
Proteocephalus sp.	20/30	0.4000	3.8500	3.4683
Philonema agubernaculum	33/17	0.6600	4.2121	4.6821

9) cntd. 30-31.05.1982 n=34 (smolts)

Diphyllobothrium sp.	0/16/18	0.4706	1.1250	0.3416
Eubothrium sp.	10/24	0.2941	1.9000	0.9944
Proteocephalus sp.	29/5	0.8529	7.8276	7.9645
Philonema agubernaculum	31/3	0.9118	10.097	14.384

10) Chilko Lake 05.05.1976 n=45 (smolts)

Gyrodactylus nerkae	4/41	0.0889	1.2500	0.5000
Diplostomulum sp.1	5/40	0.1111	1.4000	0.3612
Diplostomulum sp.2	1/44	0.0222	1.0000	
Tetracotyle sp.	25/20	0.5556	3.1200	2.7887
Phyllodistomum sp.	1/44	0.0222	1.0000	
Diphyllobothrium sp.	23/20/2	0.9556	4.4419	3.4662
Eubothrium sp.	14/31	0.3111	1.5714	0.6462
Proteocephalus sp.	44/1	0.9778	29.659	18.779
Neoechinorhynchus sp.(spp?)	6/39	0.1333	1.1667	0.4083

11) cntd. 28.04.1977 n=50 (smolts) 2yr.olds.

Chloromyxum coregoni	12/38	0.2400	N/A.	N/A.
Gyrodactylus nerkae	5/45	0.1000	2.4000	2.6080
Diplostomulum sp.1	18/32	0.3600	1.7778	1.2150
Diplostomulum sp.2	1/49	0.0200	1.0000	
Tetracotyle sp.	43/7	0.8600	4.3953	3.7868
Crepidostomum farionis	1/49	0.0200	1.0000	
Diphyllobothrium sp.	42/8/0	1.0000	6.1800	3.0685
Eubothrium sp.	28/22	0.5600	2.3929	1.5236
Proteocephalus sp.	26/24	0.5200	18.115	31.968
Philonema agubernaculum	4/46	0.0800	1.2500	0.5000
Neoechinorhynchus sp.(spp?)	20/30	0.4000	2.0000	1.2978

12) cntd. 12.05.1977 n=50 (smolts)

Chloromyxum coregoni	12/38	0.2400	N/A.	N/A.
Gyrodactylus nerkae	6/44	0.1200	1.3333	0.5164
Diplostomulum sp.1	5/45	0.1000	1.0000	0.0000
Diplostomulum sp.2	4/46	0.0800	1.0000	0.0000
Tetracotyle sp.	5/45	0.1000	1.4000	0.5477
Diphyllobothrium sp.	15/34/1	0.9800	3.4286	3.1950
Eubothrium sp.	34/16	0.6800	2.3529	1.2999
Proteocephalus sp.	50/0	1.0000	63.080	88.719
Philonema agubernaculum	2/48	0.0400	1.0000	0.0000
Neoechinorhynchus sp.(spp?)	2/48	0.0400	1.0000	0.0000

13) cntd. 25.04.1982 n=50 (smolts)

Diplostomulum sp.1	5/45	0.1000	1.0000	0.0000
Tetracotyle sp.	3/47	0.0600	1.0000	0.0000
Diphyllobothrium sp.	4/35/11	0.7800	2.0769	1.0609
Eubothrium sp.	6/44	0.1200	1.1667	0.4083
Proteocephalus sp.	31/19	0.6200	5.4839	6.5006
Philonema agubernaculum	1/49	0.0200	2.0000	
Neoechinorhynchus sp.(spp?)	4/46	0.0800	1.0000	0.0000

14) cntd. 03.05.1982 n=49 (smolts)

Chloromyxum coregoni	3/46	0.0612	N/A.	N/A.
Diplostomulum sp.1	10/39	0.2041	1.1000	0.3612
Tetracotyle sp.	20/29	0.4082	2.7500	5.7388
Diphyllobothrium sp.	11/27/11	0.7755	3.3421	3.1732
Eubothrium sp.	40/9	0.8163	2.8750	1.5390
Proteocephalus sp.	46/3	0.9388	20.435	17.282
Philonema agubernaculum	1/48	0.0204	1.0000	
Neoechinorhynchus sp.(spp?)	5/44	0.1020	1.0000	0.0000

15) cntd. 15.05.1982 n=50 (smolts)

Chloromyxum coregoni	4/46	0.0800	N/A.	N/A.
Gyrodactylus nerkae	10/40	0.2000	2.0000	1.3333
Diplostomulum sp.1	10/40	0.2000	1.2000	0.4216
Diplostomulum sp.2	1/49	0.0200	1.0000	
Tetracotyle sp.	21/29	0.4200	2.1905	1.7498
Diphyllobothrium sp.	18/28/4	0.9200	3.4130	2.6631
Eubothrium sp.	33/17	0.6600	2.6364	1.7822
Proteocephalus sp.	44/6	0.8800	14.250	18.949
Philonema agubernaculum	3/47	0.0600	1.0000	0.0000
Neoechinorhynchus sp.(spp?)	6/44	0.1200	6.6667	12.910

16) Adams Lake 29-30.04.1976 n=35 (smolts)

Diphyllobothrium sp.	0/3/32	0.0857	1.0000	0.0000
Eubothrium sp.	11/24	0.3143	3.2727	3.5522
Proteocephalus sp.	31/4	0.8857	17.839	15.018
Philonema agubernaculum	6/29	0.1714	1.6667	1.0328
Neoechinorhynchus sp.(spp?)	1/34	0.0286	2.0000	
Salmincola californiensis	4/31	0.1143	1.2500	0.5000

17) Little River 10-14.05.1976 n=35 (smolts)

Chloromyxum coregoni	1/34	0.0286	N/A.	N/A.
Diphyllobothrium sp.	0/22/13	0.6286	1.5455	0.7386
Eubothrium sp.	14/21	0.4000	2.7143	2.8401
Proteocephalus sp.	34/1	0.9714	12.559	8.3128
Philonema agubernaculum	25/10	0.7143	3.5200	3.8635

18) Shuswap Lake 16.11.1971 n=50 (presmolts)

Diplostomulum sp.1	4/46	0.0800	1.0000	0.0000
Diphyllobothrium sp.	1/10/39	0.2200	1.2727	0.9045
Eubothrium sp.	22/28	0.4400	1.9545	1.2141
Proteocephalus sp.	50/0	1.0000	10.640	5.4464
Philonema agubernaculum	38/12	0.7600	1.7632	1.1954
Salmincola californiensis	2/48	0.0400	1.0000	0.0000

19) Quesnel Lake 26.04.1983 n=50 (smolts)

Chloromyxum coregoni	19/31	0.3800	N/A.	N/A.
Myxobolus neurobius	31/19	0.6200	N/A.	N/A.
Diplostomulum sp.1	1/49	0.0200	1.0000	
Diphyllobothrium sp.	11/29/10	0.8000	2.7250	2.2531
Hymenolepid coenourous	1/49	0.0200	1.0000	
Eubothrium sp.	8/42	0.1600	2.0000	1.8516
Proteocephalus sp.	22/28	0.4400	2.7727	3.2061
Philonema agubernaculum	21/29	0.4200	1.6667	0.9129

20) Bowron Lake 29.04.1983 n=50 (smolts)

Myxobolus neurobius	33/17	0.6600	N/A.	N/A.
Diplostomulum sp.1	3/47	0.0600	1.0000	0.0000
Crepidostomum farionis	2/48	0.0400	2.0000	1.4142
Diphyllobothrium sp.	1/28/21	0.5800	1.3103	0.8495
Hymenolepid coenourous	1/49	0.0200	1.0000	
Eubothrium sp.	20/30	0.4000	4.2500	3.9454
Proteocephalus sp.	47/3	0.9400	19.766	15.463
Philonema agubernaculum	4/46	0.0800	1.0000	0.0000
Neoechinorhynchus sp.(spp?)	42/8	0.8400	3.6667	2.3339
Salmincola californiensis	7/43	0.1400	1.4286	0.7868

21) Stuart River 06.05.1971 n=28 (smolts)

Diplostomulum sp.1	8/20	0.2857	1.0000	0.0000
Diplostomulum sp.2	2/26	0.0714	1.5000	0.0707
Tetracotyle sp.	12/16	0.4286	1.5833	0.9003
Phyllodistomum conostomum	1/27	0.0357	1.0000	
Diphyllobothrium sp.	9/19/0	1.0000	3.1429	1.6934
Proteocephalus sp.	13/15	0.4643	2.3846	1.3868
Philonema agubernaculum	15/13	0.5357	1.6000	0.7368

22) cntd. 26-27.04.1983 n=50 (smolts)

Chloromyxum coregoni	10/40	0.2000	N/A.	N/A.
Diplostomulum sp.1	25/25	0.5000	1.7600	1.1648
Tetracotyle sp.	37/13	0.7400	2.0270	1.3014
Phyllodistomum conostomum	1/49	0.0200	1.0000	
Diphyllobothrium sp.	39/11/0	1.0000	5.5000	2.3755
Eubothrium sp.	11/39	0.2200	1.5455	1.2933
Proteocephalus sp.	27/23	0.5400	2.5556	2.6651
Philonema agubernaculum	33/17	0.6600	1.9697	1.0454

23) Stuart Lake 01.10.1978 n=50 (presmolts)

Diplostomulum sp.1	13/37	0.2600	2.4615	1.3914
Tetracotyle sp.	16/34	0.3200	2.3125	1.9906
Phyllodistomum conostomum	1/49	0.0200	1.0000	
Diphyllobothrium sp.	6/31/13	0.7400	2.2432	1.4416
Eubothrium sp.	26/24	0.5200	5.1538	9.9386
Proteocephalus sp.	16/34	0.3200	2.5625	2.3085
Philonema agubernaculum	36/14	0.7200	11.389	8.6198

24) Trembleur Lake 26.09.1978 n=50 (presmolts)

Diplostomulum sp.1	3/47	0.0600	1.0000	0.0000
Tetracotyle sp.	6/44	0.1200	1.3333	0.8165
Diphyllobothrium sp.	0/19/31	0.3800	1.1579	0.3746
Eubothrium sp.	20/30	0.4000	2.3500	1.8432
Proteocephalus sp.	43/7	0.8600	3.6977	3.0279
Philonema agubernaculum	40/10	0.8000	3.1250	2.4723

25) Takla Lake 25.09.1978 n=47 (presmolts)

Diphyllobothrium sp.	1/46	0.0213	1.0000	
Eubothrium sp.	38/9	0.8085	4.6316	3.6124
Proteocephalus sp.	38/9	0.8085	5.9474	5.4423
Philonema agubernaculum	10/37	0.2128	1.9000	1.9120

26) Francois Lake 12.05.1971 n=47 (smolts)

Diplostomulum sp.1	4/43	0.0851	1.0000	0.0000
Tetracotyle sp.	3/44	0.0638	1.3333	0.5774
Diphyllobothrium sp.	0/6/41	0.1277	1.0000	0.0000
Eubothrium sp.	14/33	0.2979	2.3571	2.1700
Proteocephalus sp.	3/44	0.0638	2.3333	1.5275
Philonema agubernaculum	30/17	0.6383	3.6000	3.2968
Salmincola californiensis	17/30	0.3617	1.4118	0.5073

27) cntd. 27-28.04.1983 n=50 (smolts)

Chloromyxum coregoni	2/48	0.0400	N/A.	N/A.
Myxobolus neurobius	4/46	0.0800	N/A.	N/A.
Diplostomulum sp.1	4/46	0.0800	1.0000	0.0000
Tetracotyle sp.	3/47	0.0600	1.6667	1.1547
Phyllodistomum conostomum	5/45	0.1000	1.2000	0.4472
Diphyllobothrium sp.	0/2/48	0.0400	1.0000	0.0000
Eubothrium sp.	3/47	0.0600	1.0000	0.0000
Proteocephalus sp.	4/46	0.0800	2.0000	1.4142
Philonema agubernaculum	33/17	0.6600	2.8182	3.0665
Salmincola californiensis	20/30	0.4000	1.4500	0.6863

28) Fraser Lake 12.05.1971 n=47 (smolts)

Diplostomulum sp.1	25/22	0.5319	1.9200	1.0770
Tetracotyle sp.	29/18	0.6170	1.6207	0.7752
Phyllodistomum conostomum	2/45	0.0426	1.0000	0.0000
Diphyllobothrium sp.	7/32/8	0.8298	2.4872	1.2747
Eubothrium sp.	18/29	0.3830	3.3333	2.5437
Proteocephalus sp.	1/46	0.0213	1.0000	
Philonema agubernaculum	6/41	0.1277	1.1667	0.4083
Neoechinorhynchus sp.(spp?)	6/41	0.1277	1.3333	0.5164
Salmincola californiensis	16/31	0.3404	1.1875	0.5439

29) cntd. 28.04.1983 n=50 (smolts)

Chloromyxum coregoni	1/49	0.0200	N/A.	N/A.
Diplostomulum sp.1	6/44	0.1200	1.6667	1.0328
Tetracotyle sp.	48/2	0.9600	2.2917	1.7005
Phyllodistomum conostomum	16/34	0.3200	1.2500	0.4472
Diphyllobothrium sp.	1/29/20	0.6000	1.7667	0.8976
Hymenolepid coenourous	3/47	0.0600	1.0000	0.0000
Eubothrium sp.	25/25	0.5000	5.0800	4.5636
Proteocephalus sp.	15/35	0.3000	1.3333	0.8165
Philonema agubernaculum	15/35	0.3000	1.1333	0.3519
Neoechinorhynchus sp.(spp?)	20/30	0.4000	1.5000	1.0000
Salmincola californiensis	10/40	0.2000	1.1000	0.3162

30) cntd. 26.08.1978 n=39 (presmolts)

Diplostomulum sp.1	28/11	0.7180	2.0357	0.9993
Diplostomulum sp. 2	7/32	0.1795	1.1429	0.3779
Tetracotyle sp.	11/28	0.2821	1.3636	0.5045
Crepidostomum farionis	1/38	0.0256	1.0000	
Phyllodistomum conostomum	11/28	0.2821	1.2727	0.4671
Diphyllobothrium sp.	0/15/24	0.3846	1.2000	0.5606
Eubothrium sp.	31/8	0.7947	7.7742	8.9320
Proteocephalus sp.	2/37	0.0513	1.5000	0.7071
Philonema agubernaculum	16/23	0.4103	1.6250	1.0247
Neoechinorhynchus sp.(spp?)	1/38	0.0256	1.0000	

31) Lake Washington 04.1983 n=50 (smolts)

Myxidium salvelini	18/32	0.3600	N/A.	N/A.
Crepidostomum farionis	13/37	0.2600	2.6154	3.5482
Diphyllobothrium sp.	15/29/6	0.8800	3.2045	1.8246
Proteocephalus sp.	16/34	0.3200	4.0625	5.3600
Philonema agubernaculum	26/34	0.5200	1.4615	0.8115
Neoechinorhynchus sp.(spp?)	4/46	0.0800	6.5000	3.7859
Salmincola californiensis	19/31	0.3800	1.4737	0.7723

32) Nimpkish Lakes 12.05.1982 n=50 (smolts)

Chloromyxum sp.	1/49	0.0200	N/A.	N/A.
Myxidium salvelini	11/39	0.2200	N/A.	N/A.
Myxobolus neurobius	46/4	0.9200	N/A.	N/A.
Tetracotyle sp.	2/48	0.0400	1.5000	0.7071
Diphyllobothrium sp.	4/38/8	0.8400	1.7857	1.0009
Proteocephalus sp.	49/1	0.9800	19.061	21.020
Philonema agubernaculum	4/46	0.0800	1.2500	0.5000
P.oncorhynchi	50/0	1.0000	212.80	373.13
Neoechinorhynchus sp.(spp?)	19/31	0.3800	1.4211	0.8377
Salmincola californiensis	5/45	0.1000	1.0000	0.0000

Appendix II

Results of G-tests testing for seasonal and annual variability of the parasite fauna within lakes, variability between lakes within biogeoclimatic zones, and between zones of the Fraser River watershed, Nimpkish Lake and Lake Washington, U.S.A.

Initially, multiple samples from each lake were compared, for each parasite, to test for variability. Then pooled samples from each lake, within the zones were compared, and finally pooled samples for each zone were compared to test for zonal variability.

ZONE 1 : NORTHERN FRASER.

FRANCOIS LAKE

Samples: 1983 smolts, n=50 ...a.
1971 smolts, n=47 ...b.

For all Gtests performed for Francois Lake, unless otherwise noted, critical G value is 3.841 at P=.05

Parasite	Gtest Results		
Chloromyxum coregoni	2/48	0/47	G=2.6303
	a	b	
Myxobolus neurobius	4/46	0/47	G=5.4033
	a	b	
Diplostomulum sp.1 met.	4/46	4/43	G=0.0517
	a	b	
Tetracotyle sp.met.	3/47	3/44	G=0.0539
	a	b	

Phyllodistomum conostomum

5/45 0/47 G=6.8221

a b

Diphyllobothrium sp.

2/48 6/41 G=2.4913

a b

Philonema agubernaculum

33/17 30/17 G=0.0907

a b

Salmincola californiensis

20/30 17/30 G=0.0320

a b

FRASER LAKE

Samples: 1983 smolts,n=50.....a.
1971 smolts,n=47.....b.
1978 presmolts,n=39...c.

For all Gtests performed for Fraser Lake,unless otherwise noted,critical G value is 5.991 at P=.05

Chloromyxum coregoni

1/49 0/47 0/39 G=2.0140

a b c

Diplostomulum sp.1 met.

6/44 25/22 28/11 G=38.0893

a b c

Subset #1

25/22 28/11 G=3.1624

Diplostomulum sp.2 met.

0/50 0/47 7/32 G=18.4598

a b

Subset #1

0/50 0/47 G=0.0

Tetracotyle sp.met.

48/2	29/18	11/28	G=50.8431
a	b	c	

Entire set significant.

Phyllodistomum conostomum

16/34	11/28	2/45	G=15.3243
a	c	b	

Subset #1

16/34 11/28 G=0.1498

Diphyllobothrium sp.

39/8	30/20	15/24	G=18.7797
b	a	c	

Subset #1

30/20 15/24 G=4.0981

Philonema agubernaculum

16/23	15/35	6/41	G=9.4120
c	a	b	

Subset #1

16/23 15/35 G=1.1700

Subset #2

15/35 6/41 G=4.3662

Neoechinorhynchus sp.(spp?)

20/30	6/41	1/38	G=23.0508
a	b	c	

Subset #1

6/41 1/38 G=3.3311

Salmincola californiensis

16/31	10/40	0/39	G=22.3913
b	a	c	

Subset #1

16/31 10/40 G=2.4483

STUART LAKE

samples: 1983 smolts,n=50.....a.
1971 smolts,n=28.....b.
1978 presmolts,n=50...c.

For all Gtests performed for Stuart Lake,unless otherwise noted,critical G value is 5.991 at P=.05

Chloromyxum coregoni

10/40 0/28 0/50 G=20.1462

a b c

Subset #1

0/28 0/50 G=0.01

Diplostomulum sp.1 met.

25/25 8/16 13/37 G=7.0593

a b c

Subset #1

25/25 8/16 G=3.4596

Subset #2

8/18 13/37 G=0.0600

Diplostomulum sp.2 met. (critical G value = 3.841,P=.05)

2/26 0/50 G=4.1927

b a,c

Entire set significant.

Tetracotyle sp.met.

37/13 12/16 16/34 G=19.1789

a b c

Subset #1

12/16 16/34 G=0.9110

Phyllodistomum conostomum (critical G value = 3.841,P=.05)

1/27 1/49 G=0.1119

b a,c

Diphyllobothrium sp.

50/0 28/0 37/13 G=26.7190

a b c

Subset #1

50/0 28/0 G=0.0

Philonema agubernaculum

36/14 33/17 15/13 G=2.6617

c a b

ZONE 1 COMBINED

Samples: Francois Lake, combined, n=97.....a.
Fraser Lake, combined, n=136.....b.
Stuart Lake, combined, n=128.....c.
Trembleur Lake, 1978, presmolts, n=50...d.
Takla Lake, 1978, presmolts, n=47.....e.

For all Gtests performed for Zone 1 Combined, unless otherwise noted,critical G value is 9.488 at P=.05

Chloromyxum coregoni

10/118 2/95 1/135 0/47 0/50 G=16.7482

c a b e d

Subset #1

2/95 1/135 0/47 0/50 G=2.8729

Myxobolus neurobius

4/93 0/47 0/50 0/128 0/136 G=12.5495

a e d c b

Subset #1

4/93 0/47 0/50 G=5.6294

subset #2

0/47 0/50 0/128 0/136 G=0.0

Diplostomulum sp.1 met.

59/77 46/82 8/89 3/47 0/47 G=87.0969

b c a d e

Subset #1

59/77 46/82 G=1.5285

Subset #2

8/89 3/47 0/47 G=6.5610

Diplostomulum sp.2 met.

7/129 2/126 0/47 0/50 0/97 G=12.8737

b c e d a

Subset #1

7/129 2/126 0/47 0/50 G=8.4516

Subset #2

2/126 0/47 0/50 0/97 G=3.7091

Tetracotyle sp.met.

88/48 65/63 6/44 6/91 0/47 G=162.9051

b c d a e

Subset #1

88/48 65/63 G=5.2614

Subset #2

6/44 6/91 0/47 G=8.3239

Phyllodistomum conostomum

29/107 5/92 3/125 0/47 0/50 G=48.3137

b a c e d

Subset #1

5/92 3/125 0/47 0/50 G=7.0812

Diphyllobothrium sp.

115/13 84/52 19/31 8/89 1/46 G=238.5248

c b d a e

Subset #1

84/52 19/31 G=8.3541

Subset #2

8/89 1/46 G=2.4075

Philonema agubernaculum

40/10 84/44 63/34 37/99 10/37 G=86.4092

d c a b e

Subset #1

40/10 84/44 63/34 G=4.3377

Subset #2

37/99 10/37 G=0.6612

Neoechinorhynchus sp.(spp?)

27/109 0/47 0/50 0/97 0/128 G=69.6987

b e d a c

Subset #1

0/47 0/50 0/97 0/128 G=0.0

Salmincola californiensis

37/60 26/110 0/47 0/50 0/128 G=105.1774

a b e d c

Subset #1

0/47 0/50 0/128 G=0.0

ZONE 2 : EAST CENTRAL FRASER

SHUSWAP LAKE

Samples: 1976 smolts,n=35.....a.
1971 presmolts,n=50...b.

For all Gtests performed for Shuswap Lake,unless otherwise noted,critical G value is 3.841 at P=.05

Chloromyxum coregoni

1/34 0/50 G=1.7917

a b

Diplostomulum sp.1 met.

4/46 0/35 G=4.3827

b a

Diphyllobothrium sp.

22/13 11/39 G=14.6318

a b

Entire set significant

Philonema agubernaculum

38/12 25/10 G=0.2230

b a

Salmincola californiensis

2/48 0/35 G=2.1562

b a

ZONE 2 COMBINED

Samples: Shuswap Lake, combined, n=85.....a.
Adams Lake, 1976 ,smolts, n=35.....b.
Bowron Lake, 1983, smolts, n=50....c.
Quesnel Lake, 1983, smolts, n=50...d.

For all Gtests performed for Zone 2 Combined, unless otherwise noted,critical G value is 7.815 at P=.05

Chloromyxum coregoni

19/31 1/84 0/35 0/50 G=56.7600

d a b c

Subset #1

1/84 0/35 0/50 G=1.3922

Myxobolus neurobius

33/17 31/19 0/35 0/50 G=134.7940

c d b a

Subset #1

33/17 31/19 G=0.1737

Subset #2

0/35 0/50 G=0.0

Diplostomulum sp.1 met.

3/47 4/81 1/49 0/35 G=3.9722

c a d b

Diphyllobothrium sp.

40/10 29/21 33/52 3/32 G=52.4332

d c a b

Subset #1

40/10 29/21 G=5.7507

Subset #2

29/21 33/52 G=4.6714

Philonema agubernaculum

63/22 21/29 6/29 4/46 G=75.1275

a d b c

Subset #1

21/29 6/29 G=6.1648

Subset #2

6/29 4/46 G=1.6288

Neoechinorhynchus sp.(spp?)

42/8 1/34 0/50 0/85 G=164.3271

c b d a

Subset #1

1/34 0/50 0/85 G=3.1839

Salmincola californiensis

7/43 4/31 2/83 0/50 G=14.4381

c b a d

Subset #2

7/43 4/31 2/83 G=7.4979

Subset #2

2/83 0/50 G=1.8681

ZONE 3 : INSULAR MOUNTAIN

CHILKO LAKE

1) Within year class comparisons.

Samples: 25.04.1982, smolts, n=50...a.
03.05.1982, smolts, n=49...b.
15.05.1982, smolts, n=50...c.

For Gtests performed for Chilko Lake within year class samples unless otherwise noted,critical G value is 5.991 at P=.05

Chloromyxum coregoni

4/46 3/46 0/50 G=6.0297

c b a

Subset #1

4/46 3/46 G=0.1332

Subset #2

3/46 0/50 G=4.3155

Diplostomulum sp.1 met.

10/39 10/40 5/45 G=2.6650

b c a

Diplostomulum sp.2 met.

1/49 0/49 0/50 G=2.1973

c b a

Tetracotyle sp. met.

21/29 20/29 3/47 G=23.8437

c b a

Subset #1

21/29 20/29 G=0.0143

Diphyllobothrium sp.

46/4 39/11 38/11 G=5.2017

c a b

Philonema agubernaculum

3/47 1/48 1/49 G=1.5116

c b a

Neoechinorhynchus sp.(spp?)

6/44 5/44 4/46 G=0.4487

c b a

2) Between year classes

Samples: 1982, combined, n=149...a.
1977, smolts, n=50.....b.
1976, smolts, n=45.....c.

For Gtests performed for Chilko Lake between year class samples, unless otherwise noted,critical G value is 5.991 at P=.05

Chloromyxum coregoni

12/38 7/142 0/45 G=21.8979

b a c

Subset #1

7/142 0/45 G=3.7732

Diplostomulum sp.1 met.

25/124 5/40 5/45 G=1.9424

a c b

Diplostomulum sp.2 met.

4/46 1/44 1/148 G=6.8471

b c a

Subset #1

4/46 1/44 G=1.7086

Subset #2

1/44 1/148 G=0.6861

Tetracotyle sp. met.

25/20 44/105 5/45 G=24.2745

c a b

Entire set significant

Phyllodistomum conostomum

1/44 0/50 0/149 G=3.3993

c b a

Diphyllobothrium sp.

49/1 43/2 123/26 G=13.8152

b c a

Subset #1

49/1 43/2 G=0.4681

Subset #2

43/2 123/26 G=5.8241

Philonema agubernaculum

5/144 2/48 0/45 G=2.9450

a b c

Neoechinorhynchus sp.(spp?)

6/39 15/134 2/48 G=2.9489

c a b

3) 1 year old vs. 2 year old smolts.

Samples: 1 year olds ,combined ,n=244...a.
2 year olds ,1977 ,n=50.....b.

For Gtests performed for Chilko Lake 1yr.old vs. 2yr.old samples unless otherwise noted,critical G value is 3.841 at P=.05

Chloromyxum coregoni

12/38 19/225 G=9.4926

b a

Entire set significant

Diplostomulum sp.1 met.

18/32 35/209 G=11.4332

b a

Entire set significant

Diplostomulum sp.2

6/238 1/49 G=0.0394

a b

Tetracotyle sp. met.

43/7 74/170 G=55.2978

b a

Entire set significant

Phyllodistomum conostomum

1/243 0/50 G=0.3736

a b

Diphyllobothrium sp.

50/0 215/29 G=11.4444

b a

Entire set significant

Philonema agubernaculum

4/46 7/237 G=2.4766

b a

Neoechinorhynchus sp.(spp?)

20/30 23/221 G=25.0058

b a

Entire set significant

Seton Creek

1) Within year class comparisons.

Samples: 25-27.04.1982, smolts, n=50...a.
08-10.05.1982, smolts, n=50...b.
30-31.05.1982, smolts, n=34...c.

For Gtests performed for Seton Creek within year class samples, unless otherwise noted,critical G value is 5.991 at at P=.05

Diphyllobothrium sp.

26/24 16/18 23/27 G=0.3987

b c a

Philonema agubernaculum

49/1 31/3 33/17 G=22.1604

a c b

Subset #1

49/1 31/3 G=2.0651

Neoechinorhynchus sp.(spp?)

3/47 0/34 0/50 G=6.0309

a c b

Subset #1

3/47 0/34 G=3.1880

Subset #2

0/34 0/50 G=0.0

Ergasilus nerkae

3/47 0/34 0/50 G=6.0309

a c b

Subset #1

3/47 0/34 G=3.1880

Subset #2

0/34 0/50 G=0.0

2) Between year classes

Samples: 1982, combined, n=134...a.
1979, smolts, n=24.....b.
1966, smolts, n=47.....c.

For Gtests performed for Seton Creek between year class samples, unless otherwise noted,critical G value is 5.991 at P=.05

Diphyllobothrium sp.

65/69 8/16 17/30 G=3.4245

a b c

Philonema agubernaculum

45/2 22/2 113/21 G=5.3546

c b a

Neoechinorhynchus sp.(spp?)

3/131 0/24 0/47 G=2.5746

a b c

Ergasilus nerkae

3/131 1/46 0/24 G=1.0086

a c b

ZONE 3 COMBINED

Samples: Chilko Lake 1 yr. olds, combined, n=244....a.
Chilko Lake 2 yr. olds, n=50.....b.
Seton Creek 1 yr. olds, combined, n=205....c.
Lillooet Lake, 1978, presmolts, n=40.....d.

For all Gtests performed for Zone 3 Combined, unless otherwise noted,critical G value is 7.815 at P=.05

Chloromyxum coregoni

12/38 19/225 0/40 0/205 G=48.6448

b a d c

Subset #1

19/225 0/40 G= 5.9876

Subset #2

0/40 0/205 G=0.0

Myxidium salvelini

22/18 0/50 0/205 0/244 G=128.7801

d b c a

Subset #1

0/50 0/205 0/244 G=0.0

Diplostomulum sp.1 met.

18/32 35/209 0/40 0/205 G=80.4778

b a d c

Subset #1

0/40 0/205 G=0.0

Diplostomulum sp.2 met

6/238 1/49 0/40 0/205 G=8.6019

a b d c

Subset #1

6/238 1/49 0/40 G=1.8454

Subset #2

1/49 0/40 0/205 G=0.0

Tetracotyle sp. met.

43/7 74/170 0/40 0/205 G=224.0388

b a d c

Subset #1

0/40 0/205 G=0.0

Phyllodistomum conostomum

1/243 0/40 0/50 0/205 G=1.5873

a d b c

Diphyllobothrium sp.

50/0 215/29 90/115 0/40 G=232.9388

b a c d

Entire set significant

Philonema agubernaculum

180/25 4/46 7/237 1/39 G=449.2334

c b a d

Subset #1

4/46 7/237 1/39 G=2.6489

Neoechinorhynchus sp.(spp?)

20/30 23/221 3/202 0/40 G=63.3754

b a c d

Subset #1

3/202 0/40 G=1.0767

Ergasilus nerkae

4/201 0/40 0/50 0/244 G=7.7824

c d b a

ZONE 4 : COASTAL

Samples: Harrison Lake, 1978, presmolts, n=30...a.
Cultus Lake, 1976, smolts, n=33.....b.
Pitt Lake, 1975, presmolts, n=50.....c.
Lake Washington, 1983, smolts, n=50....d.
Nimpkish Lakes, 1982, smolts, n=50.....e.

For all Gtests performed for Zone 4 lakes,unless otherwise noted,critical G value is 9.488 at P=.05

Chloromyxum coregoni (critical G value = 7.815)

16/14 1/49 0/33 0/50 G=57.7609

a c b d,e

Subset #1

1/49 0/33 0/50 G=1.9692

Myxidium salvelini

20/13 18/32 11/39 0/30 0/50 G=67.4717

b d e a c

Subset #1

20/13 18/32 G=4.8780

Subset #2

18/32 11/39 G=2.3977

Subset #3

0/30 0/50 G=0.0

Myxobolus neurobius (critical G value = 7.815)

46/4 0/30 0/33 0/50 G=166.1019

e a b c,d

Subset #1

0/30 0/33 0/50 G=0.0

Diplostomulum sp.1 met.(critical G value = 5.991)

1/32 0/30 0/50 G=2.4835

b a c,d,e

Tetracotyle sp. met. (critical G value = 7.815)

3/27 2/48 1/32 0/50 G=6.1385

a e b c,d

Diphyllobothrium sp.

42/8 44/6 13/17 6/27 2/48 G=125.4750

e d a b c

Subset #1

42/8 44/6 G=0.3332

Subset #2

13/17 6/27 G=4.7905

Subset #3

6/27 2/48 G=4.5456

Philonema agubernaculum

22/8 26/24 8/42 4/46 1/32 G=70.2882

a d c e b

Subset #1

22/8 26/24 G=3.6523

Subset #2

8/42 4/46 1/32 G=3.6523

P.oncorhynchi (critical G value = 7.815)

50/0 33/0 0/30 0/50 G=225.9108

c,e b a d

Subset #1

50/0 33/0 G=0.0

Subset #2

0/30 0/50 G=0.0

Neoechinorhynchus sp.(spp?) (critical G value = 7.815)

33/0 19/31 4/46 1/29 G=107.9536

b e c,d a

Subset #1

4/46 1/29 G=0.7610

Salmincola californiensis

19/31 4/29 5/45 0/30 0/50 G=42.4846

d b e a c

Subset #1

19/31 4/29 G=7.1911

Subset #2

4/29 5/45 0/30 G=5.9220

Subset #3

0/30 0/50 G=0.0

BETWEEN ALL ZONES OF THE FRASER RIVER DRAINAGE

Samples: Zone 1. Northern, combined, n=458.....a.
Zone 2. East Central, combined, n=220.....b.
Zone 3. Insular Mountain, combined, n=539...c.
Zone 4. Coastal, combined, n=213.....d.

For Gtests performed over all zones, unless otherwise noted, critical G value is 7.815 at P=.05

Chloromyxum coregoni

20/200 17/196 31/508 13/445 G=15.1323

b d c a

Subset #1

20/200 17/196 31/508 G=3.3619

Subset #2

31/508 13/445 G=5.1639

Myxidium salvelini

49/164 22/517 0/220 0/458 G=151.2184

d c b a

Subset #1

0/220 0/458 G=0.0

Myxobolus neurobius

64/156 46/167 4/454 0/539 G=261.8657

b d a c

Subset #1

64/156 46/167 G=3.2203

Subset #2

4/454 0/539 G=6.2420

Diplostomulum sp.1 met.

101/357 53/486 5/215 1/212 G=112.1046

a c b d

Subset #1

5/215 1/212 G=2.8189

Diplostomulum sp.2 met

9/449 7/532 0/213 0/220 G=12.3137

a c d b

Subset #1

9/449 7/532 0/213 G=6.9351

Subset #2

0/213 0/220 G=0.0

Tetracotyle sp. met.

165/293 117/422 6/207 0/220 G=219.3657

a c d b

Entire set significant

Phyllodistomum conostomum

37/421 1/538 0/213 0/220 G=79.0123

a c d b

Subset #1

1/158 0/213 0/220 G=1.1801

Diphyllobothrium sp.

355/184 107/106 227/231 105/115 G=38.2005

c d a b

Subset #1

107/106 227/231 105/115 G=0.3047

Philonema agubernaculum

234/224 94/126 192/347 61/152 G=39.7031

a b c d

Subset #1

234/224 94/126 G=4.1755

Subset #2

94/126 192/347 G=3.3297

Subset #3

192/347 61/152 G=3.3915

P.oncorhynchi

83/130 0/220 0/458 0/539 G=348.7961

d b a c

Subset #1

0/220 0/458 0/539 G=0.0

Neoechinorhynchus sp.(spp?)

61/152 43/177 46/493 27/431 G=78.6041

d b c a

Subset #1

61/152 43/177 G=4.9195

Subset #2

46/493 27/431 G=2.5779

Ergasilus nerkae

4/535 0/213 0/220 0/458 G=7.8243

c d b a

Subset #1

4/535 0/213 0/220 G=4.7304

Subset #2

0/213 0/220 0/458 G=0.0

Salmincola californiensis

63/395 28/185 13/207 0/539 G=114.0274

a d b c

Subset #1

63/395 28/185 G=0.0464

Subset #2

28/185 13/207 G=6.7395

Appendix III

Results of the Fournier model simulations to test the feasibility of using parasites to differentiate stocks of Fraser River juvenile sockeye salmon.

(i). Equal contribution from each stock to mixture.

Stock	Actual proportion in mixture	X of estimated proportion	S.E.M.
a) 1981 Smolts			
Chilko 1yr.	0.143	0.140	0.002
Francois	0.143	0.144	0.002
Fraser	0.143	0.146	0.001 *
Harrison	0.143	0.145	0.002
Lillooet	0.143	0.144	0.001
Shuswap	0.143	0.143	0.003
Stuart	0.143	0.139	0.002
b) 1982 Smolts			
Chilko 1yr.	0.143	0.147	0.002
Chilko 2yr.	0.143	0.141	0.001
Fraser	0.143	0.141	0.002
Harrison	0.143	0.145	0.002
Lillooet	0.143	0.144	0.001
Seton	0.143	0.141	0.002
Stuart	0.143	0.141	0.020

* significantly different at $P=.05$

Appendix III. cntd.

Stock	Actual proportion in mixture	X of estimated proportion	S.E.M.
c) 1983 Smolts			
Chilko 1yr.	0.143	0.143	0.002
Harrison	0.143	0.145	0.002
Lillooet	0.143	0.143	0.001
Pitt	0.143	0.143	0.000
Quesnel	0.143	0.143	0.001
Shuswap	0.143	0.144	0.002
Stuart	0.143	0.138	0.002 *
d) 1984 Smolts			
Chilko 1yr.	0.143	0.142	0.002
Fraser	0.143	0.142	0.001
Harrison	0.143	0.143	0.002
Lillooet	0.143	0.143	0.001
Quesnel	0.143	0.143	0.001
Seton	0.143	0.133	0.006
Shuswap	0.143	0.153	0.006

* significantly different at $P=.05$

Appendix III. cntd.

(ii). Unequal contribution from each stock to mixture

Stock	Actual proportion in mixture	X of estimated proportion	S.E.M.
a) 1981 Smolts			
Chilko 1yr.	0.210	0.205	0.004
Francois	0.040	0.044	0.003
Fraser	0.240	0.249	0.004 *
Harrison	0.075	0.075	0.002
Lillooet	0.045	0.046	0.001
Shuswap	0.280	0.273	0.004
Stuart	0.110	0.108	0.004
b) 1982 Smolts			
Chilko 1yr.	0.620	0.604	0.005 *
Chilko 2yr.	0.035	0.039	0.002
Fraser	0.090	0.098	0.003 *
Harrison	0.100	0.102	0.002
Lillooet	0.100	0.102	0.001
Seton	0.035	0.035	0.001
Stuart	0.020	0.020	0.002

* significantly different at $\underline{P}$=.05

Appendix III. cntd.

Stock	Actual proportion in mixture	X of estimated proportion	S.E.M.
c) 1983 Smolts			
Chilko 1yr.	0.020	0.024	0.003
Harrison	0.030	0.038	0.004
Lillooet	0.030	0.030	0.001
Pitt	0.020	0.020	0.000
Quesnel	0.550	0.545	0.005
Shuswap	0.050	0.049	0.003
Stuart	0.300	0.294	0.003
d) 1984 Smolts			
Chilko 1yr.	0.060	0.061	0.002
Fraser	0.015	0.023	0.002 *
Harrison	0.080	0.084	0.003
Lillooet	0.030	0.033	0.001 *
Quesnel	0.008	0.009	0.001
Seton	0.008	0.052	0.010 *
Shuswap	0.800	0.738	0.011 *

Appendix IV

Results of Gtests testing for significant differences of Myxobolus neurobius P/A ratios between juvenile and post-spawned adult Fraser River sockeye salmon stocks.

The P/A values listed for juveniles represent the pooled values of all juvenile samples for that stock.For all test results, sample a represents the adult P/A ratio, sample b represents the smolt P/A value.Each spawning ground is underlined, and the rearing lake associated with it is enclosed in parentheses

Critical G value for all tests is 3.841 at P=.05

Nadina River (Francois Lake)

28/12 4/93 G=66.7268

a b

entire set significant

Stellako River (Fraser Lake)

5/32 0/136 G=15.9862

a b

entire set significant

Gluske Creek (Stuart System)

1/29 0/225 G=4.3101

b a

Horsefly River (Quesnel Lake)

13/8 31/19 G=0.0681

b a

Adams River (Shuswap Lake)

0/85 0/50 G=0.0

a b

Chilko River (Chilko Lake)

0/294 0/49 G=0.0

a b

Gates Creek (Seton Creek)

0/205 0/30 G=0.0

b a

Birkenhead River (Lillooet and Harrison Lakes)

(Birkenhead adults were compared only to Lillooet smolts,and Harrison smolts compared only to Weaver Creek adults,and not to Birkenhead adults also.

0/40 0/28 G=0.0

b a

Weaver Creek (Harrison Lake)

0/30 0/30 G=0.0

a b

Cultus Lake (Lake spawners)

0/33 0/30 G=0.0

b a

Pitt River (Pitt Lake)

0/50 0/30 G=0.0

b a

No samples were available for Bowron Lake.