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Biological Characteristics of Nass River Sockeye Salmon (*Oncorhynchus nerka*) and Their Utility for Stock Composition Analysis of Test Fishery Samples

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BIOLOGICAL CHARACTERISTICS OF NASS RIVER SOCKEYE SALMON (*Oncorhynchus nerka*) AND THEIR UTILITY FOR STOCK COMPOSITION ANALYSIS OF TEST FISHERY SAMPLES

by

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Sockeye salmon *(Oncorhynchus nerka)* were collected from principal spawning sites and a test fishery within the Nass River to evaluate the potential for estimating stock composition using genetic and other biological characteristics. Samples from spawning sites were examined for age and length composition, scale pattern characteristics, prevalence of the brain parasite *Myxobolus arcticus*, and protein electrophoretic variation at up to 33 loci. Characteristics correlated with rate of growth (age, length and scale patterns) varied significantly among most rearing lakes reflecting differences in lake productivity. *Myxobolus arcticus* was very prevalent (>90%) in Damdochax Lake sockeye, rare (<6%) in all other stocks except Gingut Creek sockeye (29-31%). Significant variation in allozyme allele frequencies were detected among most rearing lakes. Significant variation in allele frequencies was also observed between two spawning sites within Fred Wright Lake and between creek and lakeshore sites within Meziadin Lake. Estimation of stock composition in test fishery catches using biological characteristics appears to be a valuable tool for enumerating sockeye runs in the Nass River. All five major stock groupings could be identified with reasonable accuracy (bias <9%) in simulations using representative samples. However, in practice, the Bowser and Fred Wright lake stock groupings may be confounded. Gingut Creek sockeye were the earliest migrating sockeye past the test fishery and Damdochax Lake sockeye the latest. Meziadin Lake sockeye were prevalent throughout the duration of the test fishery. Of the five major stock groupings examined in this report, Meziadin Lake had the largest sockeye escapements (average 194,987; 1986-1992) and Damdochax Lake the smallest (average 7,593).

RÉSUMÉ

Rutherford, D. T., C. C. Wood, A. L. Jantz, and D. R. Southgate. 1994. Biological characteristics of Nass River sockeye salmon (*Oncorhynchus nerka*) and their utility for stock composition analysis of test fishery samples. Can. Tech. Rep. Fish. Aquat. Sci. 1988: 65 p.

Du saumon rouge (*Oncorhynchus nerka*) a été collecté par pêche expérimentale dans les principales zones de frai de la rivière Nass afin d'évaluer le potential des caractéristiques génétiques et biologiques dans l'estimation de la composition des stocks. Les échantillons prélevés dans les zones de frai ont été examinés pour déterminer leur âge et leur longueur, les caractères des écailles, la fréquence du parasite cérébral *Myxobolus arcticus* et la variation de l'électrophorèse des protéines dans un nombre allant jusqu'à 33 loci. Les caractéristiques liées au taux de croissance (âge, longueur et caractères des écailles) variaient de manière significative dans la plupart des lacs d'élevage et elles reflétaient les différences de productivité des lacs. *Myxobolus arcticus* était très abondant (>90 %) chez le saumon rouge du lac Damdochax et il était rare (<6 %) dans tous les autres stocks sauf chez le saumon rouge de Gingut Creek (29-31 %). Des variations significatives des fréquences alléliques des allozymes ont été décelées dans la plupart des lacs d'élevage. Des variations significatives des fréquences alléliques ont également été observées entre deux zones de frai du lac Fred Wright ainsi qu'entre les zones des cours d'eau et du littoral du lac Meziadin. L'estimation au moyen des caractéristiques biologiques de la composition des stocks capturés par pêche expérimentale semble être un outil utile pour dénombrer les montaisons de saumon rouge dans la rivière Nass. Les cinq principaux groupes de stocks ont pu être identifiés de manière raisonnablement exacte (biais de <9 %) dans des simulations effectuées à l'aide d'échantillons représentatifs. Cependant, en pratique, les groupes de stocks des lacs Bowser et Fred Wright se confodent. Le saumon rouge de Gingut Creek a été le premier à remonter les installations expérimentales et celui de lac Damdochax a été le dernier. Le saumon rouge du lac Meziadin était abondant durant toute la durée de la pêche expérimentale. Des cinq principaux groupes de stock examinés ici, celui du lac Meziadin a montré le plus grand nombre d'échappées de saumon rouge (moyenne de 194,987; 1986-1992) et celui du lac Damdochax le plus faible (moyenne de 7,593).

INTRODUCTION

The Nass River, located in northern British Columbia, supports large numbers of sockeye salmon (*Oncorhynchus nerka*) and is the fourth largest producer of sockeye in British Columbia. Only the Fraser River, Skeena River and Rivers Inlet have total sockeye runs exceeding those of the Nass River (Starr et al. 1984). Total annual returns to the Nass River averaged 420,000 sockeye (range 130,000-910,000) from 1970-1990 (Starr et al. 1984; Irvine et al. 1992). Returns have increased since 1990, from 897,123 in 1991 to a record return of 1,407,113 sockeye in 1992. The major sockeye spawning areas in the Nass are associated with Meziadin, Bowser, Damdochax, and Fred Wright lakes and Gingut Creek (Salmon Escapement Database System (SEDS), Serbic 1991; Fish Habitat Inventory and Information Program. 1991a, 1991b). Meziadin Lake supports the largest run of sockeye within the Nass (Starr et al. 1984; Haugan et al. 1989; Southgate et al. 1988; Southgate 1990,1991,1992). Escapement data for Meziadin Lake are considered to be reliable (Starr et al. 1984) as all sockeye pass through a fishway and counting facility at Victoria Falls, near the outlet of the lake.

The Nass River gillnet test fishery plays a key role in the management of Nass River sockeye stocks by providing managers with an index of daily sockeye escapement to the Nass River system. The test fishery has been conducted annually since 1963 on the lower Nass River approximately 16 km upstream of the commercial fishing boundary (details available in Dickson and Vroom 1970; Todd 1965; Todd and Dickson 1970; and Southgate et al. 1990).

In this report, we present details of a stock identification program initiated by the Department of Fisheries and Oceans (DFO) in 1986 to provide independent estimates of run timing and spawning escapements for each major sockeye population within the Nass River. First, we document variation in biological characteristics of mature sockeye collected from spawning escapements from 1984-1992. Next, we demonstrate the capabilities of maximum likelihood stock composition analysis using various combinations of biological characteristics for simulated mixtures under ideal conditions. We then present actual results from the test fishery program, including stock-specific CPUE, run timing, and estimated spawning escapements from 1986-1992.

METHODS

COLLECTION OF SAMPLES

Live sockeye were collected from spawning escapements to five major areas within the Nass River: Bowser Lake, Damdochax Lake, Fred Wright Lake, Meziadin Lake, and

Gingut Creek (Fig. 1). Bowser Lake is glacially turbid and spawning areas within the lake could not be identified visually. Sockeye were collected from a single site along the shore of Bowser Lake where catch rates have been consistently high. The Damdochax system supports the farthest migrating sockeye stock in the Nass River. Spawning occurs in Damdochax Lake, Wiminasik River and Lake and the main feeder creeks into Wiminasik Lake. Our samples were taken at the mouth of Wiminasik River, approximately 0.2 km upstream of Damdochax Lake, where the majority of spawning occurs. Within Fred Wright Lake two distinct spawning locations were sampled: Bonney Creek and the Upper Kwinageese River, both of which flow into Fred Wright Lake. Some spawning occurs in the Lower Kwinageese River and above Kwinageese Lake but numbers there are low relative to Bonney Creek and the Upper Kwinageese River. Meziadin sockeye spawn in many tributaries to Meziadin Lake and in the lake itself. Meziadin Lake is glacially turbid so that lakeshore spawning sites could not be observed directly. Spawning sockeye were collected from two tributaries (Hanna and Tintina Creeks) and a lakeshore site. Additional samples were also taken at the Meziadin Fishway located near the outlet of Meziadin Lake. All Gingut Creek samples were taken approximately 6 km upstream from the confluence with the Tseax River.

At most sites, live sockeye were collected using tangle nets with 110-mm mesh. Sockeye from lakeshore spawning sites were collected using sunken gillnets. Typically, spawning ground sites were sampled only once over a period of 1-2 days during peak spawning activity (Table 1). At the Meziadin fishway, sockeye were sampled daily throughout the run.

Adult sockeye samples were collected from the Nass River gillnet test fishery annually from 1986-1992. Up to 175 sockeye per week were sampled for the duration of the test fishery. A representative sample of the entire annual run was obtained by subsampling each week's sampled catch in proportion to run size, as indicated by the test fishery catch per unit effort (CPUE).

SAMPLING PROCEDURES

Most fish were sampled in the field for post-orbital hypural length, sex ,scales, otoliths, brains (to examine for the parasite, *Myxobolus arcticus*) and heart, liver, eyeball, and skeletal muscle tissues (for protein electrophoretic analysis) (Table 1). All fish were alive when captured and tissues were frozen within 4-8 h of death to preserve enzyme activity. Forceps and knives were wiped and rinsed carefully after sampling each fish to avoid contaminating subsequent specimens with *M. arcticus* spores. Otoliths were stored in trays or vials containing a glycerine/water solution. Scales were mounted on gummed cards.

SCALE AND OTOLITH ANALYSIS

Total age of sockeye in the test fishery samples was determined from scales only. Age of mature sockeye in escapement samples was determined from scales and/or the surface of otoliths as described by Bilton and Jenkinson (1968). Otolith ages were used to interpret scale growth zones when it was not possible to determine total age from scales alone owing to resorption of scale margins in spawning fish.

Two scale pattern measurements, the number of circuli (NC_i) and incremental distances or widths (ID_i) within the i^{th} annual growth zone were recorded for each year of freshwater and the first year of marine growth. Consequently, the number of scale pattern measurements available depends on age class as follows:

Age	First year growth in fresh water	Second year growth in fresh water	"Spring" growth	First year marine
0.*	(NC_1)	N/A	N/A	(NC_2)
1.*	(NC_1)	N/A	(NC_2)	(NC_3)
2.*	(NC_1)	(NC_2)	(NC_3)	(NC_4)

The number of circuli (NC) and the incremental distances (ID) between circuli within growth zones were measured along the anterior-posterior axis of scale images projected at 100X magnification using a computerized digitizing tablet (Fig. 2). Incremental distances were measured between inside edges of circuli.

Age composition by brood year for Meziadin Lake sockeye was calculated from escapement samples taken at the fishway. Exploitation rates for Meziadin sockeye were assumed to be constant over years and escapement counts are representative of run strength.

PARASITE EXAMINATION

Brains were examined for the presence of the parasite *M. arcticus*, by digesting brain tissue in a pepsin-hydrochloric acid solution. Following centrifugation, the sediment was examined microscopically for the presence of spores. Parasite prevalence refers to the proportion of the brain samples carrying the parasite. The intensity of infection within individual fish was not evaluated.

PROTEIN ELECTROPHORETIC ANALYSIS

Tissue samples were stored at ≤ -20°C and later analyzed by horizontal starch gel electrophoresis as described by Utter et al. (1983). Allozyme variation was assayed at 33 loci which exhibit simple Mendelian segregation (Table 2). Of these, five were isoloci (e.g. *sMDH-B1,2*) that could not be scored individually and we assumed conservatively that any variation occurred at only one of the duplicate loci. A locus was considered polymorphic if the frequency of the most common allele was <0.95. Alleles and loci are designated using the nomenclature proposed by Shaklee et al. (1990).

Allozyme allele frequencies were computed by summing alleles across all genotypes and dividing by the total number of alleles (2n). Likelihood ratio chi-square tests were used to determine whether genotype frequencies at each locus deviated significantly from Hardy-Weinberg equilibrium. Hierarchical genetic structuring of sockeye stocks within the Nass River was analyzed by comparing gene diversity among stocks using the standardized genetic variance statistic (F_{st}) (Wright 1965; Chakraborty 1980). A dendrogram of genetic similarity was constructed using unbiased genetic identities (Nei 1978) and unweighted pair group method (Sneath and Sokal 1973). This dendrogram was based on five polymorphic loci screened in all samples (*sAAT-3**, *ALAT**, *LDH-B2**, *PGM-1**, *PGM-2**).

STOCK COMPOSITION ANALYSIS

Reference samples

Biological data from sockeye escapement samples were used to characterize six "reference stocks"; Bowser Lake, Damdochax Lake, Bonney Creek, Upper Kwinageese River, Meziadin Lake and Gingut Creek. Four different combinations of biological characteristics ("marker sets") were used to estimate the stock composition of the simulated mixture samples. These marker sets are denoted GP, GPA, GPAS, and S, where G denotes the four biochemical genetic markers (*ALAT**, *LDH-B2**, *PGM-1**, *PGM-2**); P, the brain parasite *M. arcticus* ; A, freshwater age; and S, scale circulus counts in annual growth zones.

Genetic and parasite data from escapement samples in different years were pooled. However, to avoid problems associated with annual variation, reference data for scale patterns and age composition always corresponded to the year in question. Scale and age data from 1986 were used for analysis of simulated mixtures of known composition, reference data from the corresponding year were used for analysis of actual test fishery samples. To comply with assumptions in the maximum likelihood analysis that markers be independent of one another, circulus counts were transformed to uncorrelated "scale factors" using principal components analysis. These scale factors are continuous variables and approximately normally distributed.

Genotypic frequencies for reference stocks were "smoothed" to multinomial distributions specified by the observed allele frequencies (assuming Hardy-Weinberg equilibrium within stocks). Brain parasite prevalence and freshwater age composition data were summarized as empirical frequency distributions of two-bin and four-bin histograms, respectively. To facilitate mixture analysis with existing software, scale factors were represented as discrete variables in smoothed 11-bin histograms where all frequencies were those expected for a normal distribution with a corresponding mean and variance.

Marker set S was available for all principal age classes (1.2, 1.3 ,2.2 and 2.3) from only two of the six reference stocks, Meziadin and Bowser lakes. Some of these age classes were rare or non-existent in escapement samples from the four remaining reference stocks. Consequently, only Meziadin and Bowser lakes could be considered in simulations using marker set S for all four age classes because frequency distributions must be defined for each marker in each reference stock in the conditional likelihood method of Fournier et al. (1984). However, five reference stocks (all except Gingut Creek) were used in simulations with marker set S for the 1.3 age class only. All six reference stocks were included in the simulations using the GP and GPA marker sets. Simulations involving 2, 5 and 6 reference stocks are referred to as "2-stock", "5-stock", and "6-stock" mixture problems, respectively. Note that results indicating the performance of various marker sets are directly comparable for all 6-stock problems because identical mixture samples were analyzed; similarly, results from all 5-stock problems are comparable, as are results from all 2-stock problems. However, mixture samples used in the 6-stock, 5-stock, and 2-stock problems are not comparable with one another as the complexity of the problem depends on which stocks are included in the reference samples.

A similarity dendrogram for the six reference stocks was constructed using log-likelihood ratio distances (Wood 1989) calculated for the GPA marker set to reflect the overall potential for differentiating individual stocks using the combined power of differences in allozyme allele frequencies, *M. arcticus* prevalence, and freshwater age composition.

Simulated Mixtures

To evaluate the potential reliability of stock composition estimates for Nass River sockeye, we analyzed "test" mixtures of known stock composition using the maximum likelihood method of Fournier et al. (1984) and bootstrap resampling procedures to introduce random sampling error independently to both the test mixtures and reference samples. The test mixtures comprised 100 fish each, all selected randomly from a single stock to highlight potential errors. Mixture 1 was 100% Bowser sockeye, mixture 2, 100% Damdochax sockeye, mixture 3, 100% Bonney sockeye, mixture 4, 100% Kwinageese sockeye, mixture 5, 100% Gingut sockeye and mixture 6, 100% Meziadin sockeye. Each mixture was resampled, and its composition reestimated, 100 times. Means and standard deviations were computed from the 100 estimated proportions for each mixture. The Monte Carlo simulations used in this paper follow the general procedures described by Wood et al. (1989). The 95% confidence intervals were determined empirically from the 100 bootstrapped estimates by rejecting 3 estimates from each end of the distribution.

Test fishery analysis

Stock composition of the test fishery was estimated by maximum likelihood analysis using six reference stocks as described in the preceding section. The only exception was that *ALAT** was not assayed in the 1987 fishery samples, and could not be included in marker set G for that year. Also note that reference samples included genetic and parasite data from all escapement samples (1984-1989 pooled) since these traits are stable over time (Wood et al. 1988), but they include freshwater age data only from escapement samples collected in the same year as the test fishery samples being analyzed. This seemed prudent because freshwater age was not stable over time for some of the stocks examined in this report. The stock composition estimate reported for each test fishery sample is the maximum likelihood estimate; its standard deviation was estimated by bootstrap resampling both the test fishery sample and the reference samples to generate an additional 100 estimates of stock composition.

Stock composition was estimated for both weekly and annual test fishery samples. All fish sampled within a given week were included in the weekly mixture sample. Annual samples were derived by pooling random subsamples from each week's sampled catch where subsample size was proportional to the weekly catch per unit effort (CPUE) in the test fishery.

Stock-specific CPUE was calculated by multiplying the mixing proportion for a given stock by the corresponding weekly CPUE in the test fishery. Cumulative run timing curves were calculated by normalizing weekly stock-specific CPUE estimates so that they summed to one over the entire season.

Escapement estimates were computed using stock composition estimates from the annual test fishery samples in conjunction with the Meziadin fence counts and in-river catch data as follows: First, the total sockeye salmon catch in-river was allocated to individual Nass stocks using stock composition estimates from the test fishery, assuming that catch was proportional to abundance. Second, the total Meziadin run was calculated by summing the fence count and the catch of Meziadin sockeye salmon. Third, the total sockeye salmon run past the test fishery was calculated by dividing the total Meziadin run by the estimated proportion of Meziadin sockeye in the test fishery. Finally, escapements to other stocks were calculated by multiplying the in-river run by their respective mixing proportions in the test fishery and subtracting their respective catches in the river. More precisely:

1) $IRC_i = P_i IRC_{Nass}$
2) $TR_{Mez} = E_{Mez} + IRC_{Mez}$
3) $TR_{Nass} = TR_{Mez} / P_{Mez}$
4) $E_i = P_i TR_{Nass} - IRC_i$

where IRC = in river catch, TR = total run, P = mixing proportion (from stock composition estimates), and E = escapement. Subscripts denote stock where "$_{Mez}$" is Meziadin and "$_{Nass}$" is all stocks combined.

RESULTS

AGE COMPOSITION

Freshwater age composition varied significantly among lakes ($p<0.001$, χ^2). Age 2.* fish were most abundant in the samples from the two largest lakes, Bowser and Meziadin lakes, where proportions ranged from 0.21-0.66 and 0.34-0.80, respectively (Table 3, Fig. 3). Age 1.* fish were the dominant age class in samples from Damdochax Lake, Bonney Creek and Kwinageese River with proportions ranging from 0.81-1.00. The Gingut Creek samples were unusual in that they comprised mostly age 0.* fish (range 0.97-1.00).

Freshwater age composition varied significantly among spawning sites within Meziadin Lake ($p<0.001$), but not within Fred Wright Lake ($p>0.111$). No significant annual variation was observed in freshwater age for sockeye from Gingut Creek ($p>0.115$). However samples from Bowser, Damdochax, Fred Wright and Meziadin lakes exhibited significant annual variation in freshwater age ($p<0.029$, Table 3).

The 1.3 age class was the dominant age at return for sockeye from Bowser, Damdochax and Fred Wright lakes averaging 37, 60 and 57 percent respectively (Table 3). Age 2.2 was typically the dominant age at return (by brood year) for sockeye from Meziadin Lake averaging 49% (Table 4). The dominant age at return (by sample year) for Gingut Creek was age 0.3 sockeye (83%). No difference in age at return was evident between sexes.

LENGTH DISTRIBUTION AND SEX RATIO

Post-orbital hypural length within an age class varied significantly among lakes ($P<0.001$, ANOVA). Meziadin sockeye were typically the largest, and Bowser and Bonney sockeye the smallest (Table 5). For example, age 1.3 sockeye from Meziadin Lake averaged 548 and 527 mm for males and females respectively, whereas age 1.3 fish from Bonney Creek averaged 497 and 483 mm for males and females respectively. Age 1.2 sockeye from Meziadin

Lake averaged 479 and 468 for males and females respectively, and age 1.2 sockeye from Bowser Lake averaged 447 and 449 mm for males and females.

Sex ratio ranged from 28-66% female among the samples (Table 3). This variation and bias in sex ratio probably arises for two reasons: first, sex ratios sometimes change throughout the spawning period (Lorz and Northcote 1965: McCart 1970) and not all stocks were sampled at the time of peak spawning activity; and second, the sampling gear tended to select males over females because the large teeth and hooked snouts of males increased their probability of entanglement in nets.

SCALE PATTERNS

Mean circulus counts for NC_1 were typically higher for age 1.* fish (range 8.2 - 14.6) than for age 2.* fish (range and 5.4 - 9.2) (Table 6, Fig. 4). Circulus counts in freshwater growth zones usually differed among lakes (P always$<$0.06) but rarely among sampling sites within lakes. No significant differences in circulus counts for freshwater growth zones were observed among sites in Fred Wright Lake ($P>0.160$). Within Meziadin Lake differences among sites were not significant for growth zone 1 (NC_1) in any age class ($P>0.08$), but marginally significant differences among sampling sites were observed for other growth zones in some age classes (NC_2 for age 1.3 and 2.2, 1986, $P<0.04$; NC_3 for age 2.2, 1986,$P<0.03$). Significant annual variation was observed in freshwater growth zones ($P<0.000$). In fact sampling year effects were just as significant as lake effects for NC_1 from age 1.2 sockeye ($F=31.30$ and 31.89) and the year-lake interaction was highly significant ($P<0.001$).

Bowser Lake, the most glacially turbid of the lakes sampled, tended to have the lowest circulus counts and growth zone widths of the populations sampled. Average circulus counts for NC_1 ranged from 8.19 - 9.25 for age 1.* sockeye from Bowser Lake. In contrast average circulus counts for NC_1 from Damdochax Lake ranged from 10.11 - 14.64. The corresponding incremental distances (mm x 100) for ID_1 ranged from 24.11 - 27.34 for Bowser Lake and 31.57 - 43.36 for Damdochax Lake.

PARASITE PREVALENCE

The prevalence of the myxosporean parasite, *Myxobolus arcticus*, differed significantly among stocks ($P<0.001,\chi^2$) ranging from 0-100% among the stocks sampled (Table 7). Damdochax sockeye exhibited the highest prevalence ($>$90% in each of the 3 yr sampled), Gingut sockeye an intermediate prevalence (31% in 1987 and 29% 1988), and all other stocks, a very low prevalence (<6% in each of the years sampled).

PROTEIN ELECTROPHORETIC VARIATION

Six of the 33 protein-coding loci examined by electrophoresis were polymorphic to the extent that the common (100) allele frequencies were less than 0.95 (Table 8). These were *sAAT-3** (range for 100 allele 0.941-1.000), *ALAT** (0.444-0.697) *LDH-B2** (0.319-0.987), *PEPC** (0.870-1.000), *PGM-2** (0.800-0.970), *PGM-1** (0.056-0.195). Average heterozygosity over 31 loci (excluding *PEPA** and *PEPC** which were examined in a limited number of samples) ranged from 0.033-0.054 among 14 collections. Of 81 chi-square tests for deviation of genotypic frequencies from Hardy-Weinberg equilibrium, 6 were statistically significant at the 5% critical value corrected for multiple comparisons (i.e $p_{crit.} = 0.0008$). The significant deviations occurred at 4 different loci in 5 different collections (indicated in Table 8), and always involved a deficiency of heterozygotes.

Allozyme allele frequencies in replicate samples from different years were not significantly different except at *ALAT** in the Kwinageese River collections ($P < 0.005$, likelihood ratio chi-square) (Fig. 5). Standardized genetic variances of allele frequencies (F_{st}) averaged over 32 loci indicated that 92.5% of total genetic variation occurred within spawning sites, and only 0.3% occurred among years within sampling sites. Variation among sites within lakes accounted for 1.4% and variation among nursery lakes, 5.9% of the total variation.

Meziadin sockeye were genetically very distinct from other stocks especially at *LDH-B2**. *LDH-B2**100 frequencies ranged from 0.319-0.490 in the Meziadin samples compared with 0.612-0.987 in the non-Meziadin samples. No significant differences in allele frequencies were observed between Bowser Lake and each of the two sampling sites in Fred Wright Lake. Also, allele frequencies from Damdochax Lake were not significantly different from Kwinageese River. However, significant differences in allele frequencies (P always <0.05) were observed among all other lakes, including Gingut Creek.

Significant differences in allele frequencies at *LDH-B2** and *PGM-1** were observed between the two spawning sites within Fred Wright Lake. *LDH-B2** 100 allele frequencies ranged from 0.605-0.689 in Bonney Creek and from 0.805-0.815 in Kwinageese River ($P < 0.001$); *PGM-1**100 allele frequencies ranged from 0.056-0.091 in Bonney Creek and from 0.170-0.195 in Kwinageese River ($P < 0.001$) (Table 8). For this reason, Bonney and Kwinageese sockeye have been considered as separate populations, and as separate reference stocks in subsequent stock composition analyses. However their mixing proportions have been summed to provide a single estimate for Fred Wright Lake, a more convenient stock grouping for fisheries management. Significant differences in allele frequencies ($P < .001$) at *LDH-B2** were observed between the lakeshore and creek samples from Meziadin Lake. However, these samples were not used as separate reference stocks because the differences were small, and most samples were obtained from the fishway and represent a mix of creek and lakeshore sites.

STOCK COMPOSITION

Simulated Mixtures

Stock composition analysis of mixtures of known composition demonstrated that the variation in biological characteristics observed among Nass sockeye populations can be used to estimate their mixing proportions in test fishery catches. In the full 6-stock mixture problem using the GPA marker set, estimated mixing proportions for Damdochax, Gingut and Meziadin sockeye were consistently reliable; bias <2%, and 95% confidence intervals always included the true value. For mixtures #2, 5, and 6, mean estimates and 95% confidence intervals for Damdochax, Gingut and Meziadin were 98.4% (95-100%), 100% (99-100%) and 98.3% (88-100%) (Table 9). These stocks are unique: Gingut sockeye are predominantly age 0.*; Meziadin sockeye typically carry the *LDH-B2**115 allele; and Damdochax sockeye are virtually all infected with *Myxobolus arcticus*. In contrast estimated mixing proportions for Bonney sockeye were less reliable (mean=80.6% 95% confidence interval 58-100% for mixture 3) because they were difficult to distinguish from Kwinageese sockeye (Fig. 6, Table 9). Kwinageese and Bowser sockeye are also very similar with respect to genetic traits and *Myxobolus* prevalence, but can often be differentiated by freshwater age composition; however, the potential for error will vary annually as a result of variation in Bowser Lake freshwater age composition.

Estimated mixing proportions from the 2-stock mixture problems involving Meziadin and Bowser sockeye were very reliable using either the GPA, GPAS, or S, marker set. Bias was never greater than 3% with 95% confidence intervals of 85-100% and 87-100% for Bowser and Meziadin in Mixtures 1 and 6, respectively.

Results from the 5-stock problem (age 1.3 fish only) showed that marker set S could provide very reliable mixing proportion estimates for the Damdochax, Bonney and Kwinageese mixtures, but not for the Bowser and Meziadin mixtures (Table 9). Adding genetic and parasite data (the GPS marker set) greatly improved estimates for the Meziadin mixture but not for the Bowser mixture. This confirmed earlier conclusions that freshwater age is the most important marker for differentiating Bowser and Fred Wright sockeye.

Test Fishery

Annual and weekly stock composition estimates, for the test fisheries in 1986-1992, are summarized in Table 10. Estimated annual contributions from Meziadin Lake averaged 65% and ranged from 41% (in 1989) to 86% (in 1992). Annual contributions by

Damdochax or Gingut sockeye never exceeded 6% and 11%, respectively. Estimated contributions from Bowser and Fred Wright lakes averaged 11% (range 2-20%) and 15% (range 5-32%), respectively. Although there may be considerable error in partitioning the Bowser and Fred Wright sockeye stocks, their combined contribution can be estimated with greater certainty, and has averaged 26% (range 14-46%).

Run Timing

Gingut sockeye were the earliest migrating sockeye in the Nass River, on average 50% of the stock passed the test fishery by day 175 (about June 25, range d 170-180). Bowser sockeye were the next earliest, on average 50% of the run passed the test fishery by day 180 (about June 30, range d 175-190). Damdochax sockeye were the latest with 50% passing the test fishery by day 200 (about July 19, range d 190-205). Run timing was variable for both Bonney Creek and Kwinageese River with 50% of the run passing the test fishery by day 190 (about July 10), however, this ranged from d 170-205. Meziadin sockeye were prevalent throughout the entire test fishery and had an intermediate run timing with 50% of the stock passing the test fishery by day 185 (about July 5, range d 180-190), (Fig. 8 and 9, Table 10).

Spawning Escapement Trends

Sockeye spawning escapements to Meziadin Lake were the largest in the Nass River, ranging from 45,288-592,118 sockeye between 1986 and 1992. Estimated escapements to Fred Wright Lake (Bonney Creek and Kwinageese River) ranged from 13,740-71,549 sockeye over the same period. However these estimates are likely confounded with estimates for Bowser Lake which ranged from 14,051-50,140 sockeye. Large increases in escapement have been recorded at Meziadin Lake since 1990. However, no obvious trends in escapements for non-Meziadin sockeye stocks were apparent from 1986-1992 (Fig. 10, Table 11).

DISCUSSION

Substantial variation exists among the major sockeye salmon stocks in the Nass River with respect to freshwater age composition, scale patterns, the prevalence of the brain parasite *M. arcticus*, length, and allozyme allele frequencies, especially at the *LDH-B2** locus. These biological characteristics are potentially very useful for identifying the stocks in mixed stock fisheries, and especially in test fishery samples in the lower Nass. Under ideal conditions, using the characteristics described in this report we were able to differentiate with reasonable accuracy (bias <9%), five major stock groupings; Bowser Lake, Damdochax Lake, Fred Wright Lake, Gingut Creek and Meziadin Lake. Combining Bowser and Fred Wright lakes into a single stock grouping decreased the bias for this grouping to <7%.

Bowser Lake samples closely resembled the Kwinageese River samples from Fred Wright Lake with respect to genetic, parasite and scale pattern data; only by adding freshwater age composition could these stocks be differentiated. Unfortunately freshwater age composition in the Bowser Lake samples varied significantly from year to year. We are uncertain how much of this variation was real and how much arose from selectivity and bias in sampling multiple age groups on the spawning ground in the lake. If these samples are not representative of the Bowser Lake population then our ability to differentiate Bowser and Fred Wright sockeye stocks will not be as good as our analyses of simulated mixtures suggest.

Gingut sockeye are unique in that they have no access to lake-rearing habitat. Most are "sea-type" sockeye that lack a freshwater annulus in their scales. Other sea-type sockeye populations are known to spawn in the lower Nass, although Gingut Creek appears to support the largest single concentration. The sockeye escapement estimates for Gingut Creek will almost certainly include the other sea-type populations because of their unique freshwater age composition. This probably explains why our escapement estimates for Gingut Creek are consistently higher than reported from direct visual counts in Gingut Creek (SEDS).

Meziadin sockeye are unique within the Nass River system, and hence, readily differentiated from other Nass sockeye stocks. Fortunately Meziadin sockeye are also the most abundant in the Nass, and their spawning escapements can be determined reliably at the fishway on Victoria Falls near the lake's outlet. With this count, it is possible to compute fairly accurate estimates of escapement for non-Meziadin stocks using relative estimates of abundance (i.e. stock-specific CPUE) from the lower river test fishery.

It is virtually impossible to enumerate sockeye visually in glacially turbid lakes and tributaries of the Nass system, or to survey directly the many small river spawning sites. Thus, stock composition analysis can be a valuable tool for estimating escapement in the Nass River System. Stock composition analysis with test mixtures of known composition demonstrate that the current stock identification program is quite serviceable under ideal conditions. The main shortcoming is the lack of differentiation between Fred Wright (Kwinageese) and Bowser sockeye, and the need to rely on freshwater age composition data which vary over time, and on samples which may not always be representative of the actual populations.

In practice, the accuracy of this indirect approach to estimating escapements depends on ensuring that all major sockeye stocks are included. We have sampled all major sockeye nursery lakes within the Nass. Some small lakes (e.g. Oweegee Lake) are not represented but their contribution to total Nass escapement is thought to be minimal. Other non-lake rearing populations ought to be represented by the Gingut Creek "stock" grouping.

It is also important that samples from both the escapements and test fishery be representative of the actual runs and that test fishery CPUE be a reliable index of relative abundance. The reliability of these data is probably the weakest link in our current procedure for estimating annual stock composition and escapements. Recent studies of the Skeena River test fishery indicate that factors such as gear saturation, size selectivity, and stock-specific vulnerability may bias both catch samples and CPUE data (Cox-Rogers and Jantz 1993).

In conclusion, sufficient variation exists among the major sockeye salmon stocks of the Nass River to permit reliable stock identification given representative samples. Obtaining representative samples continues to be the greatest challenge facing the Nass River test fishery program. Despite potential problems with existing sampling procedures, the test fishery program, and stock composition analysis in general, have proven to be powerful and cost effective tools for the management and assessment of Nass River sockeye.

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TABLES

Table 1. Summary of sockeye salmon collections from the Nass River system. Site numbers correspond to Figure 1.

Location	Collection Site: Name (#)	Year	Date	Number Sampled For: Hypural Length	Sex	Otoliths	Scales	Brain Parasite	Allozymes
Bowser Lake	Bowser L. (1)	1984	Sep. 9	87	87	87	87	87	87
		1986	Sep. 6	183	183	183	183	100	100
		1987	Sep. 3	91	91	75	91	75	75
		1988	Sep. 6	112	112	112	112	0	0
		1989	Sep. 8	195	195	195	195	0	100*
		1990	Sep.12	218	218	218	218	0	0
		1991	Sep.10	184	184	184	184	0	0
		1992	Sep. 2	157	157	157	157	0	0
Damdochax Lake	Damdochax L. (2)	1984	Sep. 8	100	100	50	50	100	100
		1986	Sep. 5	100	100	100	75	100	100
		1987	Sep. 2	100	100	100	100	100	100
		1988	Sep. 6	82	82	82	82	0	0
		1989	Sep. 7	100	100	100	100	0	100*
		1990	Sep.13	100	100	100	100	0	0
		1991	Sep. 9	124	124	124	124	0	0
		1992	Sep. 1	100	100	100	100	0	0
Fred Wright Lake									
	Bonney Ck. (3)	1984	Sep. 7	100	100	100	100	100	100
		1986	Aug.21	90	90	90	90	90	90
		1987	Aug.20	90	90	90	90	90	90
		1988	Sep. 1	50	50	50	50	0	0
		1989	Aug.29	75	75	75	75	0	0
		1990	Sep.11	107	107	107	107	0	0
		1991	Sep.10	100	100	100	100	0	0
		1992	Sep. 3	100	100	100	100	0	0
	Kwinageese R. (4)	1986	Aug.18	100	100	100	100	100	100
		1987	Aug.21	100	100	100	100	100	100
		1988	Sep. 1	56	56	56	56	0	0
		1989	Aug.30	75	75	75	75	0	0
Meziadin Lake									
	Fishway (5)	1984	Jul. 4-Sep. 7	1125	1125	100	1125	100	100
		1986	Jul.21-Aug.31	1000	1000	0	1000	0	0
		1987	Jul.23-Aug.15	960	1047	100	1050	100	100
		1988	Jul. 9-Aug.18	1000	899	0	899	0	0
		1989	Jul.11-Sep. 7	1109	935	75	935	0	75*
		1990	Jul.17-Sep. 7	1400	1276	0	1276	0	0
		1991	Jul.14-Aug.21	1000	904	0	904	0	0
		1992	Jul.18-Aug.26	1000	898	0	898	0	0
	Hanna Ck. (6)	1986	Aug.19	100	100	100	100	100	100
		1989	Aug.23	25	25	25	0	0	0
	Tintina Ck. (7)	1986	Aug.20	100	100	100	100	100	100
	lakeshore (8)	1986	Sep. 3	94	94	94	94	94	94
Gingut Ck	Gingut Ck. (9)	1987	Aug.12-16	75	75	75	75	75	75
		1988	Aug.12	93	93	93	93	93	93
Monkley Dump	Test Fishery (10)	1986	Jun. 3-Aug. 6	1439	1439	1439	1439	1103	1103
		1987	Jun. 6-Jul.31	1021	1021	1021	1021	752	752
		1988	Jun.10-Jul.29	1177	1177	1177	1177	701	701
		1989	Jun. 3-Aug. 9	1192	1192	1192	1192	846	846
		1990	Jun. 7-Aug. 8	1313	1313	1313	1313	963	963
		1991	Jun. 5-Aug. 2	1952	1952	1952	1952	943	943
		1992	Jun. 9-Aug. 4	2054	2054	2054	2054	852	852

* only eye tissue collected for analysis of PEPC*

Table 2. Enzymes and tissues used to investigate genetic variation. Tissues: E, eye; H, heart; L, liver; M, skeletal muscle. Buffers: AC, amine citrate (Clayton and Tretiak 1972); RW, Tris, citric acid, lithium hydroxide, and boric acid (Ridgway et al. 1970); MF, Tris, boric acid, EDTA, pH 8.5 (Markert and Faulhaber 1965).

Enzyme name	Enzyme Number	Locus	Tissue	Buffer
Aconitate hydratase	4.2.1.3	*sAH**	L	AC
Adenosine deaminase	3.5.4.4	*ADA-2**	L	AC
Alanine aminotransferase	2.6.1.2	*ALAT**	M	MF
Aspartate aminotransferase	2.6.1.1	*sAAT-1,2**	E	AC
		*sAAT-3**	H	AC
Dipeptidase	3.4.*.*	*PEPA**	M	MF
Glyceraldehyde-3-phosphate dehydrogenase	1.2.1.12	*GAPDH-4**	E	AC
Glycerol-3-phosphate dehydrogenase	1.1.1.8	*G3PDH-1,2**	M	AC
Glucose-6-phosphate isomerase	5.3.1.9	*GPI-B1,2**	M	MF
Isocitrate dehydrogenase (NADP+)	1.1.142	*mIDHP-1**	M	AC
		*mIDHP-2**	M	AC
		*sIDHP-1**	L	AC
		*sIDHP-2**	L	AC
Lactate dehydrogenase	1.1.1.27	*LDH-A1**	M	MF
		*LDH-A2**	M	MF
		*LDH-B1**	H	AC
		*LDH-B2**	L	RW
		*LDH-C**	E	MF
Malate dehydrogenase	1.1.137	*sMDH-A1,2**	L	AC
		*sMDH-B1,2**	M	AC
Malic enzyme (NADP+)	1.1.1.40	*ME**	M	AC
		*sMEP-1**	M	AC
Mannose-6-phosphate isomerase	5.3.1.8	*MPI**	H	AC
Peptidase gly-leucyl	3.4.*.*	*PEPC**	E	MF
Phosphoglucomutase	5.4.2.2	*PGM-1**	H	AC
		*PGM-2**	M	MF
Phosphogluconate dehydrogenase	1.1.1.44	*PGDH**	M	AC
Superoxide dismutase	1.15.1.1	*sSOD**	L	RW

Table 3. Age and sex composition of sockeye escapement samples (excluding jacks).

Location	Year	Proportion Female	N	Age 0.2	0.3	1.2	1.3	1.4	2.1	2.2	2.3
Bowser L.	84	0.39	87	-	-	0.18(16)	0.46(40)	-	-	0.15(13)	0.20(17)
	86	0.55	160	-	-	0.27(43)	0.34(54)	0.01(1)	-	0.18(28)	0.21(34)
	87	0.51	75	-	-	0.13(10)	0.64(48)	-	0.01(1)	0.13(10)	0.07(5)
	88	0.41	109	-	-	0.18(20)	0.20(22)	-	-	0.40(44)	0.20(22)
	89	0.40	195	-	-	0.10(19)	0.32(63)	-	-	0.22(42)	0.36(71)
	90	0.30	208	-	-	0.08(16)	0.26(54)	-	-	0.21(43)	0.45(94)
	91	0.34	155	-	-	0.21(33)	0.23(35)	-	-	0.23(35)	0.34(52)
	92	0.50	157	-	-	0.10(15)	0.49(77)	0.00(1)	-	0.22(34)	0.18(29)
	Mean	0.43				0.16	0.37			0.22	0.25
Damdochax L.	84	0.43	50	-	-	0.28(14)	0.62(31)	-	-	0.06(3)	0.04(2)
	86	0.55	65	-	-	0.03(2)	0.97(63)	-	-	-	-
	87	0.51	99	-	-	0.06(6)	0.90(89)	-	-	0.03(3)	0.01(1)
	88	0.66	80	-	-	0.85(68)	0.09(7)	-	-	0.04(3)	0.03(2)
	89	0.59	96	-	-	0.41(39)	0.53(51)	-	-	0.04(4)	0.02(2)
	90	0.60	100	-	-	0.04(4)	0.85(85)	-	-	0.06(6)	0.05(5)
	91	0.56	95	-	-	0.53(50)	0.39(37)	-	-	0.02(2)	0.06(6)
	92	0.65	100	-	-	0.52(52)	0.44(44)	-	-	0.02(2)	0.02(2)
	Mean	0.57				0.34	0.60			0.03	0.03
Fred Wright L. Bonnie Ck.	84	0.37	50	-	-	0.20(10)	0.76(38)	-	-	-	-
	86	0.57	77	-	-	0.91(70)	0.09(7)	-	-	-	-
	87	0.62	87	-	-	0.14(12)	0.86(75)	-	-	-	-
	88	0.28	50	-	-	0.78(39)	0.18(9)	-	-	0.02(1)	
	89	0.32	73	-	-	0.96(70)	0.03(2)	-	-	0.01(1)	-
	90	0.42	95	-	-	0.07(7)	0.91(86)	-	-	0.01(1)	0.01(1)
	91	0.41	96	-	-	0.15(14)	0.66(63)	-	0.01(1)	0.18(17)	0.01(1)
	92	0.37	99	-	-	0.12(12)	0.80(79)	-	-	-	0.07(7)
	Mean	0.42				0.42	0.54		0.00	0.03	0.01
Kwinageese R.	86	0.61	79	-	-	0.22(17)	0.76(60)	-	-	0.03(2)	-
	87	0.33	99	-	-	0.02(2)	0.96(95)	-	-	-	0.02(2)
	88	0.48	55	-	-	0.25(14)	0.56(31)	-	-	0.04(2)	0.15(8)
	89	0.47	69	-	-	0.87(60)	0.09(6)	-	-	0.01(1)	-
	Mean	0.47				0.34	0.59			0.02	0.04
Gingut Ck.	87	0.57	36	-	0.97(35)						
	88	0.33	80	0.31(25)	0.69(55)	-	-	-	-	-	-
	Mean	0.45		0.16	0.83						
Meziadin L. Fishway[a]	84	0.52	99	-	-	0.10	0.10	-	-	0.67	0.13
	86	0.46	910	-	-	0.15	0.32	-	-	0.36	0.18
	87	0.48	1007	-	-	0.18	0.22	-	-	0.49	0.11
	88	0.56	901	-	-	0.13	0.16	0.00	0.00	0.66	0.06
	89	0.38	938	-	-	0.20	0.30	-	-	0.19	0.30
	90	0.66	1276	0.00	-	0.19	0.11	-	-	0.56	0.13
	91	0.60	913	-	-	0.51	0.11	-	0.00	0.33	0.05
	92	0.54	898	-	-	0.55	0.11	-	-	0.30	0.04
	Mean	0.52				0.25	0.18			0.44	0.12
Hanna Ck.	86	0.61	86	-	-	0.56(48)	0.09(8)	-	-	0.35(30)	-
	89	0.48	25	-	-	0.12(3)	0.36(9)	-	-	0.28(7)	0.24(6)
	Mean	0.55				0.34	0.23			0.32	0.12
Tintina Ck.	86	0.50	86	-	-	0.45(39)	-	-	-	0.53(46)	0.01(1)
lakeshore	86	0.49	55	-	-	0.04(2)	0.35(19)	-	-	0.35(19)	0.27(15)

[a] age composition weighted by daily fish counts through fishway (1986-1992)

Table 4. Age composition of Meziadin Lake sockeye escapement samples, compiled by brood year.

Brood Year	Age 1.2		1.3		2.2		2.3	
1986	0.16	(22981)	0.17	(25315)	0.51	(75943)	0.16	(23684)
1985	0.09	(9058)	0.13	(13305)	0.67	(67734)	0.11	(11507)
1984	0.27	(15208)	0.26	(13586)	0.16	(8605)	0.29	(15724)
1983	0.19	(25918)	0.14	(18718)	0.57	(77210)	0.10	(13586)
1982	0.14	(17316)	0.25	(31678)	0.56	(70555)	0.05	(7019)

Table 5. Mean post-orbital hypural length distributions by sex and age in sockeye escapement samples. Standard deviations are given in parentheses.

		Age 0.2				Age 0.3				Age 1.2			
		Male		Female		Male		Female		Male		Female	
Location	Year	N	HL	N	HL	N	HL	N	HL	N	HL	N	HL
Bowser L.													
	84	0	- (-)	0	- (-)	0	- (-)	0	- (-)	11	446(37.05)	5	440(9.88)
	86	0	- (-)	0	- (-)	0	- (-)	0	- (-)	21	452(31.85)	22	453(16.44)
	87	0	- (-)	0	- (-)	0	- (-)	0	- (-)	5	438(54.15)	5	476(19.81)
	88	0	- (-)	0	- (-)	0	- (-)	0	- (-)	13	457(28.17)	7	449(25.40)
	89	0	- (-)	0	- (-)	0	- (-)	0	- (-)	12	461(42.79)	7	458(12.54)
	90	0	- (-)	0	- (-)	0	- (-)	0	- (-)	11	417(31.64)	5	429(25.35)
	91	0	- (-)	0	- (-)	0	- (-)	0	- (-)	21	446(28.79)	12	432(40.48)
	92	0	- (-)	0	- (-)	0	- (-)	0	- (-)	9	451(23.69)	6	458(13.29)
	Total									103	447(34.45)	69	449(25.69)
Damdochax L.													
	84	0	- (-)	0	- (-)	0	- (-)	0	- (-)	13	460(20.94)	1	455(-)
	86	0	- (-)	0	- (-)	0	- (-)	0	- (-)	1	479(-)	1	451(-)
	87	0	- (-)	0	- (-)	0	- (-)	0	- (-)	1	500(-)	5	501(19.49)
	88	0	- (-)	0	- (-)	0	- (-)	0	- (-)	25	469(29.72)	43	441(15.75)
	89	0	- (-)	0	- (-)	0	- (-)	0	- (-)	17	486(21.85)	22	471(15.86)
	90	0	- (-)	0	- (-)	0	- (-)	0	- (-)	0	- (-)	4	423(23.36)
	91	0	- (-)	0	- (-)	0	- (-)	0	- (-)	27	449(25.44)	23	446(21.74)
	92	0	- (-)	0	- (-)	0	- (-)	0	- (-)	21	455(33.65)	31	448(17.67)
	Total									105	463(29.82)	130	451(22.97)
Fred Wright L. Bonney Ck.													
	84	0	- (-)	0	- (-)	0	- (-)	0	- (-)	5	417(33.87)	5	455(32.14)
	86	0	- (-)	0	- (-)	0	- (-)	0	- (-)	34	507(34.12)	36	499(23.05)
	87	0	- (-)	0	- (-)	0	- (-)	0	- (-)	1	470(-)	5	430(25.50)
	88	0	- (-)	0	- (-)	0	- (-)	0	- (-)	29	449(19.15)	10	432(21.51)
	89	0	- (-)	0	- (-)	0	- (-)	0	- (-)	47	460(21.43)	23	462(23.47)
	90	0	- (-)	0	- (-)	0	- (-)	0	- (-)	2	425(28.28)	5	425(11.73)
	91	0	- (-)	0	- (-)	0	- (-)	0	- (-)	10	417(20.23)	4	426(17.99)
	92	0	- (-)	0	- (-)	0	- (-)	0	- (-)	8	436(31.14)	4	426(13.15)
	Total									136	463(39.85)	92	466(22.97)
Kwinageese R.													
	86	0	- (-)	0	- (-)	0	- (-)	0	- (-)	1	548(-)	16	488(29.93)
	87	0	- (-)	0	- (-)	0	- (-)	0	- (-)	1	490(-)	1	440(-)
	88	0	- (-)	0	- (-)	0	- (-)	0	- (-)	7	490(43.11)	7	446(29.68)
	89	0	- (-)	0	- (-)	0	- (-)	0	- (-)	28	474(20.23)	32	454(20.21)
	Total									37	480(28.18)	56	463(29.04)
Gingut Ck.													
	87	0	- (-)	0	- (-)	16	501(17.37)	19	469(20.38)	1	455(-)	0	- (-)
	88	20	430(62.83)	5	462(31.35)	31	498(20.81)	24	469(18.39)	0	- (-)	0	- (-)
	Total	20	430(62.83)	5	462(31.35)	47	499(19.55)	43	469(19.06)	1	455(-)		
Meziadin L. fishway *													
	84	0	- (-)	0	- (-)	0	- (-)	0	- (-)	0	- (-)	3	459(20.08)
	86	0	- (-)	0	- (-)	0	- (-)	0	- (-)	34	475(28.88)	61	468(21.92)
	87	0	- (-)	0	- (-)	0	- (-)	0	- (-)	76	494(28.03)	82	484(21.18)
	88	0	- (-)	0	- (-)	0	- (-)	0	- (-)	47	499(29.71)	68	469(27.11)
	89	0	- (-)	0	- (-)	0	- (-)	0	- (-)	108	469(32.05)	62	469(24.33)
	90	0	- (-)	0	- (-)	0	- (-)	0	- (-)	85	480(24.23)	162	463(27.66)
	91	0	- (-)	0	- (-)	0	- (-)	0	- (-)	151	473(35.36)	273	469(24.86)
	92	0	- (-)	0	- (-)	0	- (-)	0	- (-)	169	480(28.40)	223	463(24.13)
	Total									670	479(31.47)	939	468(25.48)
Hanna Ck.													
	86	0	- (-)	0	- (-)	0	- (-)	0	- (-)	20	535(16.69)	28	514(16.85)
	89	0	- (-)	0	- (-)	0	- (-)	0	- (-)	0	- (-)	3	490(5.00)
	Total									20	535(16.69)	31	511(17.54)
Tintina Ck.													
	86	0	- (-)	0	- (-)	0	- (-)	0	- (-)	20	537(15.90)	19	516(28.69)
lakeshore													
	86	0	- (-)	0	- (-)	0	- (-)	0	- (-)	0	- -	2	464(37.48)

		Age 1.3				Age 2.2				Age 2.3			
		Males		Females		Males		Females		Males		Females	
Location	Year	N	HL	N	HL	N	HL	N	HL	N	HL	N	HL
Bowser L.													
	84	22	517(14.48)	18	491(17.40)	12	444(14.90)	1	425(-)	7	501(12.12)	10	496(13.36)
	86	14	523(28.03)	40	483(30.63)	15	468(17.05)	13	452(13.73)	16	521(21.65)	18	502(29.08)
	87	27	555(21.68)	21	545(20.85)	9	483(43.24)	1	480(-)	2	538(24.75)	3	523(25.17)
	88	7	516(16.94)	15	497(20.33)	27	469(23.44)	17	443(18.47)	15	517(15.08)	7	495(26.77)
	89	36	529(26.72)	27	528(17.83)	25	469(28.68)	17	461(14.66)	44	541(21.47)	27	519(16.85)
	90	40	510(27.91)	14	495(31.41)	30	436(23.98)	13	424(26.07)	62	514(23.24)	32	485(24.85)
	91	25	495(16.39)	10	504(11.88)	24	449(34.75)	11	445(23.72)	36	506(21.17)	16	501(25.82)
	92	32	512(25.70)	45	486(22.82)	20	457(23.25)	14	443(14.38)	16	512(34.97)	13	491(24.42)
	Total	203	520(28.82)	190	501(31.57)	162	457(29.71)	87	445(21.70)	198	519(25.86)	126	500(26.13)
Damdochax L.													
	84	25	511(20.83)	6	506(18.25)	3	484(12.17)	0	- (-)	1	516(-)	1	490(-)
	86	30	535(18.48)	33	515(16.99)	0	- (-)	0	- -)	0	- (-)	0	- (-)
	87	44	550(22.14)	45	541(19.11)	2	508(53.03)	1	495(-)	0	- (-)	0	- (-)
	88	1	500(-)	6	505(21.45)	1	550(-)	2	450(14.14)	1	510(-)	1	535(-)
	89	20	564(34.15)	31	527(17.41)	3	507(17.56)	1	475(-)	0	- (-)	2	505(21.21)
	90	38	523(21.30)	47	493(22.34)	0	- (-)	6	431(22.45)	2	508(10.61)	3	477(27.54)
	91	19	507(19.02)	18	478(26.01)	0	- (-)	2	488(3.54)	2	510(0.00)	4	486(4.79)
	92	14	509(23.28)	30	497(13.02)	0	- (-)	2	443(10.61)	0	- (-)	2	495(21.21)
	Total	191	531(29.34)	216	511(27.79)	9	504(29.76)	14	451(28.57)	6	510(5.67)	13	492(21.47)
Fred Wright L. Bonney Ck.													
	84	17	484(22.74)	21	476(20.77)	0	- (-)	0	- (-)	0	- (-)	0	- (-)
	86	1	524(-)	6	503(8.45)	0	- (-)	0	- (-)	0	- (-)	0	- (-)
	87	17	514(14.39)	25	495(17.29)	0	- (-)	0	- (-)	0	- (-)	0	- (-)
	88	5	501(15.17)	4	465(19.58)	1	465(-)	0	- (-)	0	- (-)	0	- (-)
	89	1	525(-)	1	555(-)	1	485(-)	0	- (-)	0	- (-)	0	- (-)
	90	51	496(21.12)	36	489(21.37)	0	- (-)	1	460(-)	1	500(-)	0	- (-)
	91	35	499(22.32)	28	473(22.02)	10	446(26.33)	7	436(18.35)	0	- (-)	1	456(-)
	92	49	493(20.32)	30	478(17.49)	0	- (-)	0	- (-)	5	512(9.08)	2	458(10.61)
	Total	176	497(21.65)	151	483(22.08)	12	451(26.73)	8	439(19.03)	6	519(17.73)	3	457(7.55)
Kwinageese R.													
	86	25	530(27.64)	34	520(22.78)	1	491(-)	1	422(-)	0	- (-)	0	- (-)
	87	64	520(17.72)	31	510(13.66)	0	- (-)	0	- (-)	2	530(28.28)	0	- (-)
	88	16	511(21.64)	15	491(16.97)	1	475(-)	1	515(-)	4	514(11.82)	4	489(7.50)
	89	5	528(9.08)	1	530(-)	0	- (-)	1	440(-)	0	- (-)	0	- (-)
	Total	110	525(21.31)	82	511(21.02)	2	483(11.31)	3	459(49.33)	6	519(17.73)	4	489(7.50)
Gingut Ck.													
	87	0	- (-)	0	- (-)	0	- (-)	0	- (-)	0	- (-)	0	- (-)
	88	0	- (-)	0	- (-)	0	- (-)	0	- (-)	0	- (-)	0	- (-)
	Total												
Meziadin L. fishway[a]													
	84	3	558(10.41)	0	- (-)	4	485(33.17)	6	490(14.51)	9	528(14.14)	0	- (-)
	86	125	544(23.85)	93	523(25.29)	156	509(30.02)	190	487(23.32)	177	567(21.16)	74	546(21.48)
	87	103	556(29.48)	80	540(28.17)	290	531(25.76)	309	515(22.64)	74	571(23.73)	33	554(20.94)
	88	40	546(21.38)	49	525(26.37)	286	501(30.95)	365	484(27.49)	26	556(31.22)	18	546(38.38)
	89	106	558(25.19)	79	528(30.44)	116	490(31.29)	106	491(28.03)	253	575(27.61)	108	554(27.71)
	90	47	544(29.83)	69	524(27.63)	239	493(27.89)	509	478(28.18)	62	557(25.05)	103	537(27.77)
	91	43	534(24.12)	37	517(37.52)	133	493(27.17)	214	479(28.14)	37	539(24.45)	24	517(40.19)
	92	53	536(27.57)	32	520(32.19)	162	502(27.23)	201	488(26.17)	36	553(23.11)	21	527(22.17)
	Total	523	548(27.31)	443	527(29.62)	1386	505(31.90)	1930	488(29.12)	667	567(26.90)	385	544(29.22)
Hanna Ck.													
	86	2	551(16.26)	6	523(9.09)	10	515(28.00)	20	491(22.54)	0	- (-)	0	- (-)
	89	4	566(21.75)	5	529(13.42)	5	539(31.31)	2	488(17.68)	4	571(20.16)	2	533(10.61)
	Total	6	561(20.07)	11	525(11.18)	15	523(30.33)	22	491(21.81)	4	571(20.16)	2	533(10.61)
Tintina Ck.													
	86	0	- -	0	- -	22	509(27.74)	24	493(21.47)	0	- (-)	1	521(-)
lakeshore													
	86	11	548(25.05)	8	530(33.04)	6	495(17.63)	13	497(25.30)	7	556(37.70)	8	554(27.10)

[a] Data sets revised from those use in Haugan *et al.* 1988; Southgate (1990,1991,1992).

Table 6. Mean number of circuli and incremental distances (mm x 100) by scale zone in sockeye escapement samples. Standard deviations are given in parentheses.

Age Class	Location	Year	N	NC1(SD)	NC2(SD)	NC3(SD)	ID1(SD)	ID2(SD)	ID3(SD)
1.2	Bowser L.	1984	12	9.25(1.49)	1.42(0.67)	30.67(3.09)	25.94(4.70)	3.04(1.98)	110.48(9.41)
		1986	33	8.58(1.25)	1.42(1.30)	29.39(3.37)	26.61(4.37)	2.80(3.14)	98.90(13.18)
		1987	9	8.78(3.56)	2.67(1.23)	25.56(3.32)	26.31(11.11)	6.57(2.96)	90.76(9.06)
	Damdochax L.	1984	11	14.64(0.81)	1.09(0.30)	27.00(1.34)	43.46(4.19)	1.99(0.81)	100.66(6.04)
		1986	2	10.50(0.71)	0.00(0.00)	26.50(2.12)	31.57(1.25)	0.00(0.00)	97.00(0.91)
		1987	4	11.50(2.38)	0.50(1.00)	27.50(2.38)	40.59(8.20)	0.79(1.60)	98.03(3.92)
	Fred Wright L.								
	Bonney Ck.	1984	6	14.17(1.33)	1.50(0.55)	25.67(2.42)	39.12(2.97)	3.16(1.82)	93.95(6.04)
		1986	40	10.08(1.29)	0.28(0.64)	29.95(2.91)	33.12(3.57)	0.57(1.34)	99.44(8.31)
		1987	11	13.27(2.24)	0.73(1.42)	23.00(3.19)	35.50(6.56)	1.47(2.87)	84.82(12.84)
	Kwinageese R.	1986	11	10.46(1.37)	0.00(0.00)	28.18(2.68)	32.68(3.37)	0.00(0.00)	95.43(8.78)
		1987	1	12.00(-)	0.00(-)	24.00(-)	33.09(-)	0.00(-)	83.39(-)
	Meziadin L.								
	Fishway	1984	8	10.38(1.06)	1.50(0.54)	29.88(2.03)	34.28(3.37)	3.45(1.26)	114.83(6.42)
	Hanna Ck.	1986	38	11.37(1.44)	0.18(0.46)	30.45(3.10)	36.98(3.83)	0.36(0.91)	103.38(10.40)
		1989	3	9.00(1.00)	0.33(0.58)	31.67(2.08)	31.72(4.77)	0.81(1.40)	119.28(10.12)
	Tintina Ck.	1986	25	11.28(1.75)	0.40(0.71)	29.16(4.24)	36.60(3.80)	0.79(1.42)	97.97(12.68)
	lakeshore	1986	2	13.00(1.41)	0.50(0.71)	27.50(0.71)	36.66(3.22)	1.61(2.28)	100.20(2.86)
1.3	Bowser L.	1984	28	8.57(1.79)	1.39(0.69)	32.36(3.38)	25.07(5.40)	2.79(1.60)	110.04(13.22)
		1986	42	8.81(2.13)	1.50(1.17)	29.81(5.39)	27.34(5.75)	3.11(2.74)	100.53(18.00)
		1987	37	8.19(1.70)	1.97(1.44)	29.92(3.09)	24.11(3.81)	4.19(3.59)	98.52(9.37)
	Damdochax L.	1984	27	12.19(1.08)	0.93(0.27)	27.85(2.21)	38.74(3.19)	2.05(1.14)	100.08(14.09)
		1986	62	12.74(2.25)	0.39(0.95)	28.65(2.77)	39.84(6.03)	1.01(2.45)	98.86(8.82)
		1987	56	10.11(1.56)	0.52(0.95)	28.66(2.20)	32.23(4.52)	1.08(1.89)	99.37(7.65)
	Fred Wright L.								
	Bonney Ck.	1984	20	13.40(2.33)	1.60(0.82)	26.94(2.75)	39.17(5.51)	3.27(2.05)	95.40(12.41)
		1986	7	10.14(1.57)	0.00(0.00)	28.14(1.57)	34.43(4.44)	0.00(0.00)	93.61(5.19)
		1987	41	9.46(1.68)	0.27(0.59)	28.39(2.73)	27.85(4.10)	0.57(1.32)	97.56(8.56)
	Kwinageese R.	1986	40	9.75(1.43)	0.15(0.43)	30.30(3.02)	32.28(3.61)	0.37(1.02)	102.00(9.55)
		1987	72	9.21(1.32)	0.31(0.64)	28.92(2.25)	27.17(3.16)	0.61(1.30)	99.82(8.59)
	Meziadin L.								
	Fishway	1984	8	12.00(0.93)	1.25(0.46)	29.63(3.38)	38.10(2.77)	2.71(1.07)	106.36(10.22)
	Hanna Ck.	1986	8	11.38(1.06)	0.13(0.35)	31.88(1.13)	36.89(3.50)	0.21(0.59)	106.78(10.30)
		1989	7	10.14(1.57)	0.71(0.76)	28.14(3.08)	31.63(3.91)	1.87(1.86)	108.72(9.38)
	lakeshore	1986	19	10.53(1.65)	3.26(1.66)	29.00(3.22)	34.05(3.86)	7.71(4.01)	103.39(12.67)

Age Class	Location	Year	N	NC1(SD)	NC2(SD)	NC3(SD)	NC4(SD)	ID1(SD)	ID2(SD)	ID3(SD)	ID4(SD)
2.2	Bowser L.	1986	26	6.43(1.07)	9.73(1.85)	0.15(0.46)	27.27(2.55)	19.34(3.39)	22.31(3.97)	0.32(0.99)	99.88(8.78)
		1987	9	5.78(1.20)	9.00(2.00)	0.00(0.00)	23.56(2.51)	16.37(4.61)	19.52(3.86)	0.00(0.00)	84.86(8.40)
	Damdochax L.	1987	1	6.00(-)	- (-)	0.00(-)	23.00(-)	22.18(-)	- (-)	0.00(-)	78.85(0.81)
	Fred Wright L.										
	Kwinageese R.	1986	2	7.00(2.83)	9.00(1.41)	0.00(-)	22.00(0.00)	23.84(4.26)	26.97(9.71)	0.00(0.00)	86.50(0.81)
	Meziadin L.										
	Hanna Ck.	1986	30	8.40(1.00)	10.00(2.34)	1.25(1.59)	25.58(2.59)	29.15(3.16)	24.67(5.08)	2.49(3.16)	103.40(12.54)
		1989	5	7.60(1.52)	8.80(1.92)	0.00(0.00)	26.40(3.29)	24.23(4.32)	20.41(4.18)	0.00(0.00)	103.01(11.55)
	Tintina Ck.	1986	45	9.22(1.33)	11.50(1.68)	0.00(0.00)	28.11(3.00)	29.76(3.49)	26.66(3.95)	0.00(0.00)	107.48(12.77)
	lakeshore	1986	19	8.90(1.24)	11.25(1.57)	0.50(0.97)	26.75(2.52)	30.21(3.86)	26.19(4.10)	0.92(1.86)	108.62(11.84)
2.3	Bowser L.	1986	34	6.82(1.19)	9.35(2.88)	0.42(0.78)	28.69(3.26)	19.18(3.54)	21.38(5.94)	0.92(1.61)	95.38(10.03)
		1987	5	6.40(2.07)	10.20(2.78)	0.00(0.00)	28.80(6.57)	18.20(5.22)	26.37(13.59)	0.00(0.00)	96.99(23.85)
	Damdochax L.	1987	1	6.00(-)	7.00(-)	0.00(-)	26.00(-)	24.98(-)	15.49(-)	0.00(-)	97.10(-)
	Meziadin L.										
	Hanna Ck.	1989	5	7.40(0.55)	9.00(1.58)	0.00(0.00)	25.20(4.09)	27.29(1.96)	22.31(4.54)	0.00(0.00)	106.87(5.30)
	Tintina Ck.	1986	1	8.00(-)	11.00(-)	0.00(-)	28.00(-)	27.19(-)	31.18(-)	0.00(-)	106.90(-)
	lakeshore	1986	15	7.60(1.60)	11.92(2.81)	1.50(1.93)	27.67(2.61)	26.03(5.08)	29.15(7.47)	3.00(4.02)	99.31(8.91)

Table 7. Prevalence of the brain parasite, *Myxobolus arcticus*, in sockeye escapement samples.

Location	Year	Number Examined	Number Infected	Proportion Infected
Bowser L.	1984	87	0	0.00
	1986	100	0	0.00
	1987	75	0	0.00
Damdochax L.	1984	100	100	1.00
	1986	100	91	0.91
	1987	100	91	0.91
Fred Wright L.				
Bonney Ck.	1984	100	6	0.06
	1986	90	0	0.00
	1987	90	0	0.00
Kwinageese R.	1986	100	1	0.01
	1987	100	2	0.02
Gingut Ck.	1987	75	23	0.31
	1988	93	27	0.29
Meziadin L.				
Fishway	1984	100	0	0.00
	1987	100	2	0.02
Hanna Ck.	1986	99	0	0.00
Tintina Ck.	1986	100	0	0.00
lakeshore	1986	94	0	0.00

Table 8. Summary of allozyme allele frequencies in sockeye escapement samples. Significant deviations from Hardy Weinberg equilibrium denoted by #.

Locus	N/allele	Bowser L.				Damdochax L.				Bonney Ck.			Kwinageese R.		Gingut Ck.		Meziadin L.					
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
*sAAT-3**	(N)	77	98	#51	0	76	100	80	0	96	89	90	86	83	74	93	#96	92	97	93	0	99
	100	.961	.969	.941	-	.954	.945	.969	-	.990	.989	1.000	.977	.988	1.000	1.000	.984	.995	.979	1.000	-	.985
	117	.039	.031	.059	-	.046	.055	.031	-	.010	.011	.000	.023	.012	.000	.000	.016	.005	.021	.000	-	.015
*ALAT**	(N)	0	100	64	0	0	99	#96	0	0	90	87	98	95	72	93	0	94	98	97	0	95
	91	-	.595	.477	-	-	.697	.667	-	-	.444	.466	.592	.495	.590	.522	-	.574	.597	.655	-	.584
	100	-	.235	.352	-	-	.111	.141	-	-	.339	.316	.204	.316	.382	.398	-	.388	.337	.325	-	.337
	95	-	.165	.172	-	-	.172	.188	-	-	.217	.218	.184	.189	.028	.081	-	.016	.046	.021	-	.042
	108	-	.005	.000	-	-	.020	.005	-	-	.000	.000	.020	.000	.000	.000	-	.021	.020	.000	-	.037
*LDH-B2**	(N)	86	100	75	0	99	100	#100	0	100	90	89	100	100	75	93	100	94	99	100	0	99
	100	.791	.755	.773	-	.818	.860	.860	-	.605	.689	.612	.805	.815	.987	.962	.430	.319	.394	.475	-	.490
	115	.209	.245	.227	-	.177	.140	.135	-	.395	.311	.388	.195	.180	.013	.038	.570	.681	.606	.525	-	.510
	85	.000	.000	.000	-	.005	.000	.005	-	.000	.000	.000	.000	.005	.000	.000	.000	.000	.000	.000	-	.000
*PEPC**	(N)	0	99	0	100	0	97	0	#100	0	90	0	97	0	0	#93	0	94	99	0	74	100
	100	-	.985	-	.895	-	.985	-	.870	-	.961	-	.990	-	-	.957	-	1.000	.990	-	1.000	.995
	105	-	.015	-	.105	-	.015	-	.130	-	.039	-	.010	-	-	.043	-	.000	.010	-	.000	.005
*PGM-1**	(N)	86	99	75	0	98	100	100	0	99	90	90	100	100	75	93	100	94	99	100	0	100
	100	.140	.101	.067	-	.138	.150	.115	-	.091	.089	.056	.195	.170	.113	.140	.110	.112	.086	.160	-	.090
	NULL	.860	.899	.933	-	.862	.850	.885	-	.909	.911	.944	.805	.830	.887	.860	.890	.888	.914	.840	-	.910
*PGM-2**	(N)	85	99	70	0	98	100	100	0	99	90	90	100	100	75	93	100	94	99	100	0	100
	100	.912	.955	.929	-	.857	.850	.880	-	.889	.867	.922	.805	.830	.800	.828	.935	.941	.970	.970	-	.970
	133	.088	.045	.071	-	.143	.150	.105	-	.111	.133	.078	.195	.170	.200	.172	.065	.059	.030	.030	-	.030
	166	.000	.000	.000	-	.000	.000	.015	-	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	-	.000
*sAAT-1,2**	(N)	87	99	75	0	99	100	99	0	99	90	89	100	100	75	93	100	94	99	100	0	100
	100	1.000	1.000	1.000	-	1.000	1.000	1.000	-	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	-	1.000
*ADA-2**	(N)	87	100	69	0	98	100	95	0	98	90	89	100	96	75	93	98	94	98	98	0	100
	100	1.000	1.000	1.000	-	1.000	1.000	1.000	-	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	-	1.000
*sAH**	(N)	86	100	75	0	87	100	97	0	98	90	87	100	100	73	93	98	94	99	100	0	98
	100	1.000	1.000	1.000	-	1.000	1.000	1.000	-	1.000	1.000	1.000	1.000	.995	1.000	1.000	1.000	1.000	1.000	.990	-	1.000
	117	.000	.000	.000	-	.000	.000	.000	-	.000	.000	.000	.000	.005	.000	.000	.000	.000	.000	.010	-	.000
*G3PDH-1,2**	(N)	86	100	71	0	99	100	100	0	98	90	90	100	95	75	93	100	94	98	100	0	100
	-100	1.000	1.000	1.000	-	1.000	1.000	1.000	-	1.000	1.000	1.000	1.000	1.000	1.000	.995	1.000	1.000	1.000	1.000	-	1.000
	-150	.000	.000	.000	-	.000	.000	.000	-	.000	.000	.000	.000	.000	.000	.005	.000	.000	.000	.000	-	.000
*GAPDH-4**	(N)	79	97	75	0	85	99	99	0	100	88	90	93	99	75	93	95	93	99	96	0	100
	100	1.000	1.000	1.000	-	1.000	1.000	1.000	-	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	-	1.000
*GPI-B1,2**	(N)	78	100	69	0	98	99	95	0	98	90	90	99	99	69	93	100	93	94	100	0	100
	100	1.000	1.000	1.000	-	.985	.980	1.000	-	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	-	1.000
	132	.000	.000	.000	-	.015	.020	.000	-	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	-	.000
*mIDHP-1**	(N)	84	100	72	0	98	100	100	0	100	90	90	100	99	75	93	94	93	98	100	0	100
	100	1.000	1.000	1.000	-	1.000	1.000	1.000	-	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	-	1.000

*mIDHP-2**	(N)	84	100	72	0	98	100	100	0	100	90	90	100	99	75	93	94	93	98	100	0	100
	100	1.000	1.000	1.000	-	1.000	1.000	1.000	-	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	-	1.000
*sIDHP-1**	(N)	87	100	75	0	97	100	99	0	98	90	89	100	100	75	93	100	94	99	100	0	100
	100	1.000	1.000	1.000	-	1.000	1.000	1.000	-	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	-	1.000
*sIDHP-2**	(N)	87	100	75	0	97	100	99	0	98	90	89	100	100	75	93	100	94	99	100	0	100
	100	1.000	1.000	1.000	-	1.000	1.000	1.000	-	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	-	1.000
*LDH-A1**	(N)	87	100	75	0	100	100	100	0	100	90	90	100	100	75	93	100	94	94	100	0	100
	100	1.000	1.000	1.000	-	1.000	1.000	1.000	-	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	-	1.000
*LDH-A2**	(N)	87	100	75	0	100	100	100	0	100	90	90	100	100	75	93	100	94	94	100	0	100
	100	1.000	1.000	1.000	-	1.000	1.000	1.000	-	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	-	1.000
*LDH-B1**	(N)	87	99	75	0	99	100	99	0	99	90	89	100	100	75	93	99	94	99	100	0	100
	100	1.000	1.000	1.000	-	1.000	1.000	1.000	-	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	-	1.000
*LDH-C**	(N)	78	100	26	0	89	97	58	0	97	88	70	93	54	75	93	97	93	96	93	0	100
	100	1.000	1.000	1.000	-	1.000	1.000	1.000	-	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	-	1.000
*sMDH-A1,2**	(N)	87	100	75	0	99	100	100	0	100	88	89	100	100	75	93	100	94	99	100	0	100
	100	1.000	1.000	1.000	-	1.000	1.000	1.000	-	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	-	1.000
*sMDH-B1,2**	(N)	87	100	72	0	98	100	100	0	100	90	90	100	100	75	93	100	94	98	100	0	99
	100	1.000	1.000	1.000	-	1.000	1.000	1.000	-	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	-	1.000
*ME**	(N)	87	100	75	0	99	100	100	0	100	90	90	98	99	75	93	100	93	98	100	0	100
	100	1.000	1.000	1.000	-	1.000	1.000	1.000	-	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	-	1.000
*sMEP-1**	(N)	87	100	75	0	99	100	100	0	100	90	90	98	99	75	93	100	93	98	100	0	100
	100	1.000	1.000	1.000	-	1.000	1.000	1.000	-	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	-	1.000
*MPI**	(N)	85	99	75	0	99	100	98	0	99	90	89	100	99	75	93	100	94	99	98	0	98
	100	1.000	1.000	1.000	-	1.000	1.000	1.000	-	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	-	1.000
*PEPA**	(N)	0	99	0	100	0	97	0	100	0	90	0	97	0	0	93	0	94	99	0	74	100
	100	-	1.000	-	1.000	-	1.000	-	.995	-	1.000	-	1.000	-	-	.995	-	1.000	1.000	-	1.000	1.000
	106	-	.000	-	.000	-	.000	-	.005	-	.000	-	.000	-	-	005	-	.000	.000	-	.000	.000
*PGDH**	(N)	87	100	71	0	98	100	98	0	99	90	90	100	100	75	93	99	94	98	99	0	100
	100	1.000	1.000	1.000	-	1.000	1.000	1.000	-	1.000	.994	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	-	1.000
	108	.000	.000	.000	-	.000	.000	.000	-	.000	.006	.000	.000	.000	.000	.000	.000	.000	.000	.000	-	.000
*sSOD-1**	(N)	87	100	66	0	96	100	100	0	96	90	90	100	99	75	93	99	94	99	100	0	100
	100	1.000	1.000	1.000	-	1.000	1.000	1.000	-	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	-	1.000

Key to samples

1 Bowser L. 1984
2 Bowser L. 1986
3 Bowser L. 1987
4 Bowser L. 1989
5 Damdochax L. 1984
6 Damdochax L. 1986
7 Damdochax L. 1987
8 Damdochax L. 1989
9 Bonney Ck. 1984
10 Bonney Ck. 1986
11 Bonney Ck. 1987
12 Kwinageese R. 1986
13 Kwinageese R. 1987
14 Gingut Ck. 1987
15 Gingut Ck. 1988
16 Meziadin L. (fishway) 1984
17 Meziadin L. (lakeshore) 1986
18 Meziadin L. (Hanna Ck.) 1986
19 Meziadin L.(fishway) 1987
20 Meziadin L.(fishway) 1989
21 Meziadin L. (Tintina Ck.) 1986

Table 9. Results of stock composition analysis with test mixtures of known composition (simulations). N=100 for each mixture. G denotes the use of five genetic markers; P, the brain parasite; A, freshwater age; and S, scale patterns. True proportion is 1.00 for all entries in bold type along the diagonal. Standard deviations in parentheses.

A. Six-stock problem without scale pattern data.

Mixture Composition	Traits Used	Estimated Mixing Proportions: Bowser L.	Damdochax L.	Bonney Ck.	Kwinageese R.	Gingut Ck.	Meziadin L.	Fred Wright L.*
100% Bowser L.	GPA	**0.917**(0.069)	0.000(0.000)	0.005(0.018)	0.010(0.025)	0.000(0.000)	0.068(0.059)	0.015(0.032)
	GP	**0.756**(0.202)	0.000(0.000)	0.068(0.115)	0.132(0.147)	0.002(0.013)	0.043(0.060)	0.200(0.200)
100% Damdochax L.	GPA	0.009(0.014)	**0.984**(0.015)	0.000(0.001)	0.001(0.004)	0.000(0.000)	0.006(0.009)	0.001(0.004)
	GP	0.003(0.010)	**0.989**(0.018)	0.001(0.003)	0.004(0.013)	0.000(0.000)	0.003(0.007)	0.005(0.013)
100% Bonney Ck.	GPA	0.003(0.015)	0.008(0.010)	**0.806**(0.130)	0.171(0.128)	0.000(0.000)	0.011(0.022)	**0.977**(0.027)
	GP	0.160(0.205)	0.006(0.009)	**0.743**(0.212)	0.076(0.096)	0.011(0.021)	0.006(0.021)	**0.819**(0.210)
100% Kwinageese R.	GPA	0.039(0.052)	0.001(0.005)	0.044(0.073)	**0.915**(0.094)	0.000(0.000)	0.000(0.001)	**0.959**(0.052)
	GP	0.133(0.178)	0.000(0.000)	0.021(0.051)	**0.830**(0.175)	0.012(0.022)	0.003(0.008)	**0.851**(0.180)
100% Gingut Ck.	GPA	0.000(0.000)	0.000(0.000)	0.000(0.000)	0.000(0.000)	**1.000**(0.000)	0.000(0.000)	0.000(0.000)
	GP	0.033(0.055)	0.000(0.003)	0.016(0.039)	0.065(0.086)	**0.885**(0.086)	0.000(0.000)	0.081(0.086)
100% Meziadin L.	GPA	0.000(0.000)	0.004(0.008)	0.013(0.032)	0.000(0.000)	0.000(0.000)	**0.983**(0.033)	0.013(0.032)
	GP	0.001(0.007)	0.002(0.007)	0.006(0.025)	0.000(0.000)	0.000(0.000)	**0.991**(0.027)	0.006(0.025)

B. Five-stock problem with and without scale pattern data for age 1.3 fish only.

Mixture Composition	Traits Used	Estimated Mixing Proportions: Bowser L.	Damdochax L.	Bonney Ck.	Kwinageese R.	Meziadin L.	Fred Wright L.*
100% Bowser L.	GP	**0.731**(0.215)	0.000(0.000)	0.075(0.130)	0.158(0.162)	0.036(0.046)	0.233(0.210)
	GPS	**0.784**(0.064)	0.000(0.000)	0.003(0.019)	0.210(0.064)	0.003(0.008)	0.213(0.065)
	S	**0.768**(0.067)	0.002(0.007)	0.002(0.009)	0.225(0.067)	0.004(0.011)	0.227(0.068)
100% Damdochax L.	GP	0.003(0.007)	**0.987**(0.017)	0.003(0.008)	0.004(0.008)	0.003(0.007)	0.007(0.012)
	GPS	0.001(0.005)	**0.998**(0.006)	0.000(0.001)	0.000(0.000)	0.001(0.004)	0.000(0.001)
	S	0.007(0.020)	**0.956**(0.064)	0.016(0.050)	0.000(0.000)	0.020(0.034)	0.016(0.051)
100% Bonney Ck.	GP	0.194(0.200)	0.007(0.009)	**0.705**(0.188)	0.086(0.115)	0.008(0.022)	**0.791**(0.208)
	GPS	0.004(0.027)	0.008(0.012)	**0.970**(0.051)	0.018(0.043)	0.000(0.000)	**0.988**(0.028)
	S	0.002(0.018)	0.044(0.082)	**0.945**(0.087)	0.008(0.033)	0.000(0.000)	**0.989**(0.083)
100% Kwinageese R.	GP	0.120(0.162)	0.001(0.002)	0.017(0.050)	**0.859**(0.163)	0.003(0.011)	**0.876**(0.161)
	GPS	0.019(0.040)	0.000(0.000)	0.000(0.002)	**0.980**(0.041)	0.000(0.001)	**0.980**(0.041)
	S	0.009(0.026)	0.000(0.000)	0.000(0.000)	**0.974**(0.043)	0.017(0.035)	**0.974**(0.043)
100% Meziadin L.	GP	0.000(0.001)	0.002(0.005)	0.012(0.046)	0.001(0.007)	**0.985**(0.047)	0.013(0.046)
	GPS	0.000(0.001)	0.002(0.005)	0.001(0.008)	0.029(0.045)	**0.968**(0.047)	0.030(0.045)
	S	0.009(0.060)	0.001(0.006)	0.000(0.000)	0.216(0.107)	**0.774**(0.131)	0.216(0.107)

C. Two-stock problem with scale data for age 1.2, 1.3, 2.2, and 2.3 fish.

Mixture Composition	Traits Used	Estimated Mixing Proportions: Bowser L.	Meziadin L.
100% Bowser L.	GPA	**0.973**(0.042)	0.027(0.042)
	GPAS	**0.997**(0.012)	0.003(0.012)
	S	**0.977**(0.033)	0.023(0.033)
100% Meziadin L.	GPA	0.004(0.017)	**0.996**(0.017)
	GPAS	0.010(0.021)	**0.990**(0.021)
	S	0.022(0.031)	**0.978**(0.031)

*Bonney and Kwinageese summed

Table 10. Sockeye stock composition estimates for the Nass River test fishery, 1986 to 1992. Standard deviations in parentheses. The composition for all weeks combined was estimated after pooling subsamples from each week.

Year	Week	Stat Week	N	Proportion					
				Bowser L.	Damdochax L.	Bonney Ck.	Kwinageese R.	Meziadin L.	Gingut Ck.
1986	JUN 3 - JUN 22	24&25	54	0.000 (0.010)	0.012 (0.014)	0.312 (0.100)	0.000 (0.017)	0.358 (0.091)	0.317 (0.060)
	JUN 23 - JUN 29	26	192	0.112 (0.080)	0.016 (0.009)	0.226 (0.063)	0.024 (0.031)	0.530 (0.070)	0.090 (0.021)
	JUN 30 - JUL 6	27	244	0.099 (0.074)	0.010 (0.009)	0.040 (0.062)	0.140 (0.053)	0.681 (0.065)	0.030 (0.010)
	JUL 7 - JUL 20	28&29	225	0.267 (0.101)	0.049 (0.014)	0.068 (0.063)	0.059 (0.052)	0.553 (0.073)	0.005 (0.004)
	JUL 21 - JUL 27	30	160	0.170 (0.097)	0.067 (0.022)	0.000 (0.010)	0.205 (0.068)	0.558 (0.074)	0.000 (0.000)
	JUL 28 - AUG 6	31&32	206	0.053 (0.061)	0.028 (0.013)	0.000 (0.001)	0.070 (0.043)	0.849 (0.048)	0.000 (0.000)
	all weeks[a]	24-32	669	0.139 (0.059)	0.029 (0.007)	0.042 (0.042)	0.115 (0.044)	0.635 (0.047)	0.040 (0.008)
1987	JUN 15 - JUN 21	25	142	0.076 (0.109)	0.049 (0.026)	0.001 (0.025)	0.174 (0.094)	0.396 (0.073)	0.304 (0.051)
	JUN 22 - JUN 28	26	108	0.105 (0.088)	0.000 (0.000)	0.001 (0.003)	0.084 (0.074)	0.554 (0.072)	0.256 (0.046)
	JUN 29 - JUL 5	27	85	0.089 (0.077)	0.030 (0.021)	0.028 (0.069)	0.006 (0.037)	0.743 (0.088)	0.104 (0.035)
	JUL 6 - JUL 12	28	137	0.258 (0.106)	0.065 (0.025)	0.010 (0.066)	0.005 (0.034)	0.634 (0.082)	0.028 (0.017)
	JUL 13 - JUL 19	29	120	0.210 (0.123)	0.081 (0.026)	0.003 (0.007)	0.153 (0.086)	0.554 (0.075)	0.000 (0.000)
	JUL 20 - JUL 26	30	80	0.245 (0.170)	0.087 (0.032)	0.100 (0.121)	0.106 (0.141)	0.462 (0.095)	0.000 (0.000)
	JUL 27 - JUL 31	31	76	0.005 (0.052)	0.102 (0.034)	0.016 (0.032)	0.041 (0.045)	0.836 (0.060)	0.000 (0.000)
		25-31	524	0.202 (0.080)	0.060 (0.012)	0.002 (0.016)	0.096 (0.058)	0.563 (0.039)	0.075 (0.015)
1988	JUN 6 - JUN 19	24&25	75	0.009 (0.058)	0.000 (0.006)	0.269 (0.110)	0.074 (0.085)	0.211 (0.078)	0.437 (0.055)
	JUN 20 - JUN 26	26	133	0.137 (0.092)	0.028 (0.020)	0.132 (0.058)	0.004 (0.041)	0.481 (0.093)	0.219 (0.037)
	JUN 27 - JUL 3	27	106	0.148 (0.102)	0.006 (0.011)	0.008 (0.040)	0.122 (0.051)	0.580 (0.096)	0.136 (0.035)
	JUL 4 - JUL 10	28	134	0.245 (0.108)	0.006 (0.007)	0.004 (0.035)	0.006 (0.043)	0.739 (0.101)	0.000 (0.000)
	JUL 11 - JUL 17	29	102	0.000 (0.053)	0.007 (0.013)	0.000 (0.034)	0.272 (0.084)	0.721 (0.080)	0.000 (0.000)
	JUL 18 - JUL 24	30	86	0.001 (0.013)	0.067 (0.034)	0.021 (0.068)	0.199 (0.076)	0.712 (0.069)	0.000 (0.001)
	JUL 25 - JUL 31	31	65	0.002 (0.098)	0.058 (0.037)	0.000 (0.028)	0.114 (0.058)	0.826 (0.088)	0.000 (0.000)
		24-31	524	0.127 (0.063)	0.022 (0.008)	0.034 (0.041)	0.126 (0.046)	0.586 (0.049)	0.105 (0.014)
1989	JUN 3 - JUN 16	23&24	55	0.001 (0.042)	0.012 (0.019)	0.194 (0.107)	0.000 (0.055)	0.428 (0.109)	0.366 (0.065)
	JUN 17 - JUN 23	25	81	0.133 (0.090)	0.000 (0.000)	0.100 (0.076)	0.000 (0.004)	0.341 (0.109)	0.426 (0.052)
	JUN 24 - JUN 30	26	82	0.018 (0.093)	0.000 (0.000)	0.120 (0.080)	0.002 (0.034)	0.707 (0.098)	0.153 (0.041)
	JUL 1 - JUL 7	27	102	0.247 (0.129)	0.034 (0.021)	0.096 (0.090)	0.046 (0.062)	0.558 (0.118)	0.018 (0.018)
	JUL 8 - JUL 14	28	130	0.192 (0.085)	0.104 (0.025)	0.344 (0.113)	0.124 (0.107)	0.237 (0.081)	0.000 (0.002)
	JUL 15 - JUL 21	29	125	0.165 (0.080)	0.076 (0.029)	0.087 (0.106)	0.366 (0.094)	0.304 (0.073)	0.000 (0.000)
	JUL 22 - JUL 28	30	110	0.029 (0.071)	0.127 (0.032)	0.059 (0.102)	0.328 (0.094)	0.458 (0.086)	0.000 (0.000)
	JUL 29 - AUG 4	31	108	0.140 (0.081)	0.054 (0.025)	0.001 (0.001)	0.418 (0.077)	0.375 (0.071)	0.012 (0.012)
	AUG 5 - AUG 11	32	53	0.000 (0.020)	0.046 (0.035)	0.000 (0.040)	0.389 (0.093)	0.563 (0.089)	0.002 (0.023)
		23-32	584	0.135 (0.044)	0.055 (0.010)	0.094 (0.055)	0.227 (0.047)	0.412 (0.049)	0.076 (0.011)

1990	JUN 3 - JUN 16	23&24	35	0.001	(0.039)	0.001	(0.062)	0.001	(0.018)	0.108	(0.062)	0.753	(0.092)	0.136	(0.060)
	JUN 17 - JUN 23	25	98	0.000	(0.003)	0.000	(0.025)	0.101	(0.082)	0.106	(0.066)	0.713	(0.084)	0.079	(0.030)
	JUN 24 - JUN 30	26	138	0.198	(0.079)	0.010	(0.011)	0.006	(0.033)	0.001	(0.016)	0.717	(0.078)	0.069	(0.021)
	JUL 1 - JUL 7	27	154	0.139	(0.096)	0.005	(0.005)	0.005	(0.036)	0.056	(0.036)	0.780	(0.088)	0.015	(0.010)
	JUL 8 - JUL 14	28	140	0.064	(0.070)	0.064	(0.023)	0.109	(0.082)	0.159	(0.073)	0.604	(0.078)	0.000	(0.000)
	JUL 15 - JUL 21	29	164	0.010	(0.046)	0.090	(0.025)	0.121	(0.097)	0.176	(0.083)	0.596	(0.076)	0.006	(0.007)
	JUL 22 - JUL 28	30	101	0.066	(0.082)	0.036	(0.022)	0.000	(0.042)	0.184	(0.063)	0.714	(0.095)	0.000	(0.000)
	JUL 29 - AUG 4	31	82	0.127	(0.119)	0.049	(0.026)	0.003	(0.047)	0.144	(0.079)	0.677	(0.108)	0.000	(0.000)
	AUG 5 - AUG 11	32	51	0.094	(0.107)	0.083	(0.039)	0.000	(0.025)	0.061	(0.061)	0.762	(0.124)	0.000	(0.000)
		23-32	629	0.083	(0.047)	0.044	(0.010)	0.032	(0.046)	0.102	(0.040)	0.714	(0.043)	0.025	(0.006)
1991	JUN 2 - JUN 15	23&24	50	0.000	(0.061)	0.000	(0.000)	0.000	(0.081)	0.000	(0.008)	0.894	(0.100)	0.106	(0.043)
	JUN 16 - JUN 22	25	145	0.018	(0.066)	0.007	(0.007)	0.182	(0.109)	0.001	(0.023)	0.641	(0.099)	0.152	(0.025)
	JUN 23 - JUN 29	26	79	0.000	(0.043)	0.000	(0.003)	0.290	(0.125)	0.000	(0.010)	0.570	(0.125)	0.138	(0.042)
	JUN 30 - JUL 6	27	175	0.128	(0.078)	0.032	(0.016)	0.075	(0.085)	0.021	(0.043)	0.717	(0.097)	0.027	(0.011)
	JUL 7 - JUL 13	28	129	0.080	(0.077)	0.061	(0.023)	0.004	(0.101)	0.087	(0.053)	0.769	(0.097)	0.000	(0.000)
	JUL 14 - JUL 20	29	150	0.214	(0.079)	0.055	(0.020)	0.000	(0.019)	0.000	(0.014)	0.730	(0.071)	0.000	(0.000)
	JUL 21 - JUL 27	30	111	0.060	(0.052)	0.017	(0.016)	0.004	(0.043)	0.000	(0.017)	0.919	(0.062)	0.000	(0.000)
	JUL 28 - AUG 3	31	104	0.001	(0.042)	0.027	(0.017)	0.000	(0.000)	0.000	(0.000)	0.973	(0.045)	0.000	(0.000)
		23-31	674	0.087	(0.046)	0.033	(0.008)	0.044	(0.047)	0.006	(0.015)	0.788	(0.048)	0.042	(0.008)
1992	JUN 7 - JUN 20	24&25	36	0.000	(0.013)	0.000	(0.001)	0.000	(0.020)	0.193	(0.125)	0.750	(0.129)	0.056	(0.032)
	JUN 21 - JUN 27	26	142	0.044	(0.094)	0.000	(0.000)	0.016	(0.090)	0.086	(0.059)	0.842	(0.096)	0.012	(0.012)
	JUN 28 - JUL 4	27	103	0.017	(0.072)	0.000	(0.000)	0.032	(0.081)	0.110	(0.068)	0.841	(0.100)	0.000	(0.000)
	JUL 5 - JUL 11	28	109	0.000	(0.043)	0.007	(0.014)	0.265	(0.173)	0.074	(0.081)	0.653	(0.157)	0.000	(0.000)
	JUL 12 - JUL 18	29	107	0.029	(0.089)	0.024	(0.019)	0.261	(0.168)	0.048	(0.043)	0.625	(0.146)	0.012	(0.011)
	JUL 19 - JUL 25	30	137	0.014	(0.068)	0.035	(0.016)	0.271	(0.148)	0.010	(0.034)	0.670	(0.117)	0.000	(0.000)
	JUL 26 - AUG 1	31	107	0.000	(0.032)	0.021	(0.014)	0.000	(0.055)	0.000	(0.000)	0.980	(0.064)	0.000	(0.000)
	AUG 2 - AUG 8	32	111	0.009	(0.019)	0.001	(0.000)	0.170	(0.147)	0.003	(0.015)	0.818	(0.144)	0.001	(0.000)
		24-32	366	0.023	(0.030)	0.009	(0.005)	0.052	(0.071)	0.052	(0.033)	0.857	(0.071)	0.005	(0.004)

[a] Pooled weekly subsamples selected randomly with sample sizes proportional to weekly test fishery CPUE.

Table 11. Sockeye spawning escapements estimated from stock composition analysis of test fishery samples.

	Spawning Ground Escapement						
Year	Total	Bowser L.	Damdochax L.	Bonney Ck.	Kwinageese R.	Meziadin L.	Gingut Ck.
1986	181741	25254	5305	7613	20876	115443	7250
1987	252026	50140	14945	620	23719	143989	18613
1988	199845	25315	4496	6773	25235	116986	21039
1989	109821	14821	6038	10375	24912	45288	8388
1990	169219	14051	7398	5383	17250	120954	4182
1991	288162	23886	9023	12149	1591	230132	11381
1992	686036	14957	5943	35390	36159	592118	1470

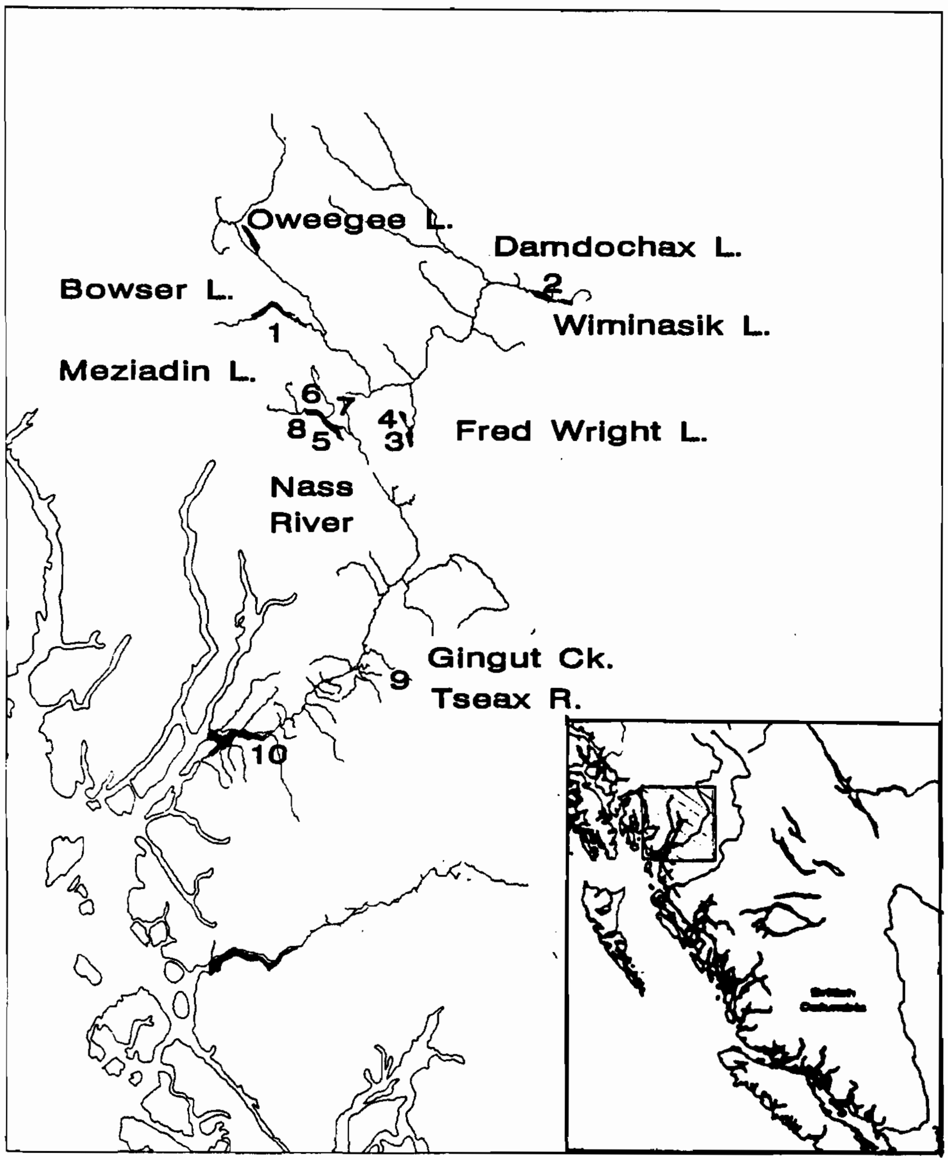


Fig. 1. Map of the Nass River showing principal sockeye populations, sampling sites, and test fishery location. Numbers correspond to sampling sites listed in Table 1.

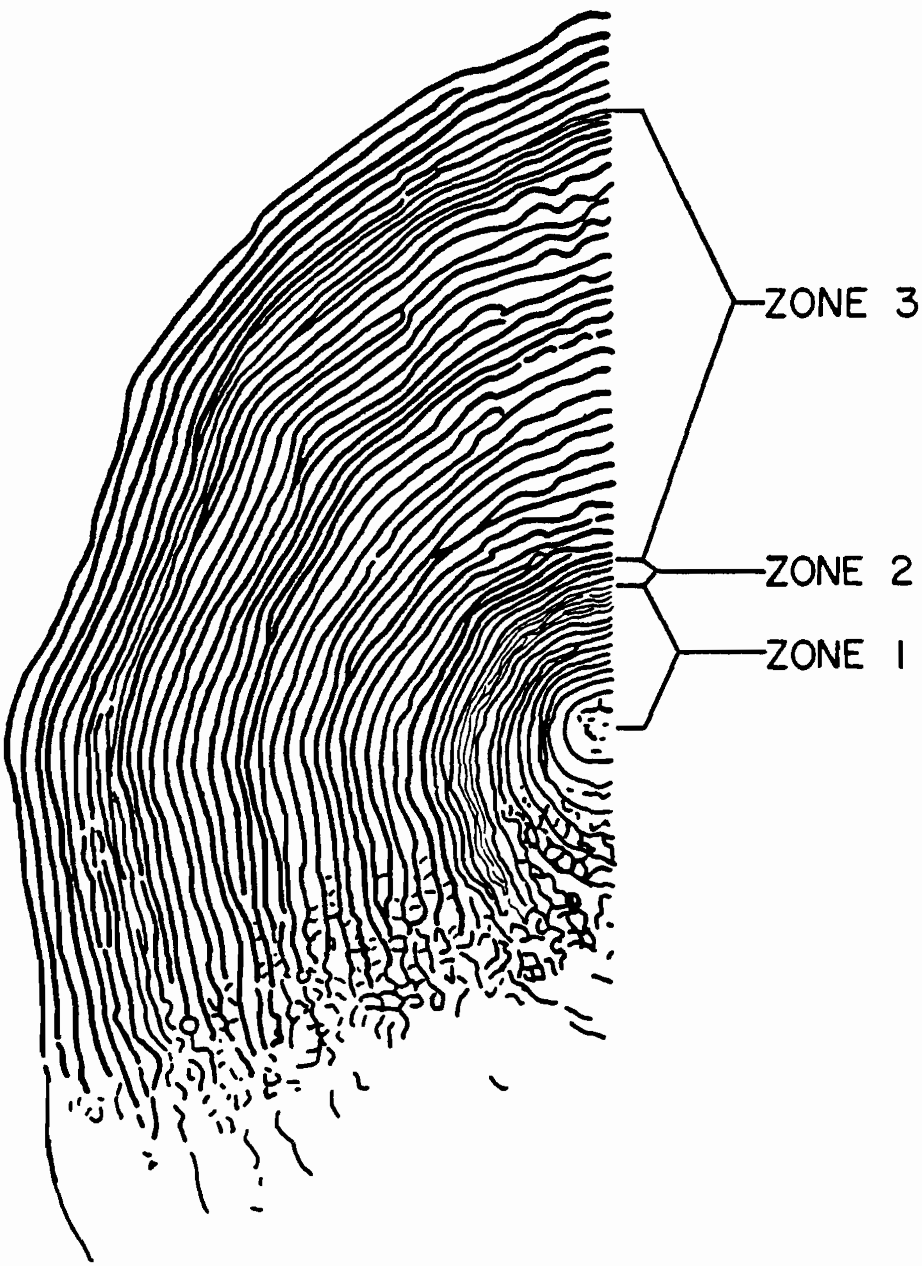


Fig. 2A. Diagram of typical sockeye salmon scale explaining growth zone definitions for age 1.* fish.

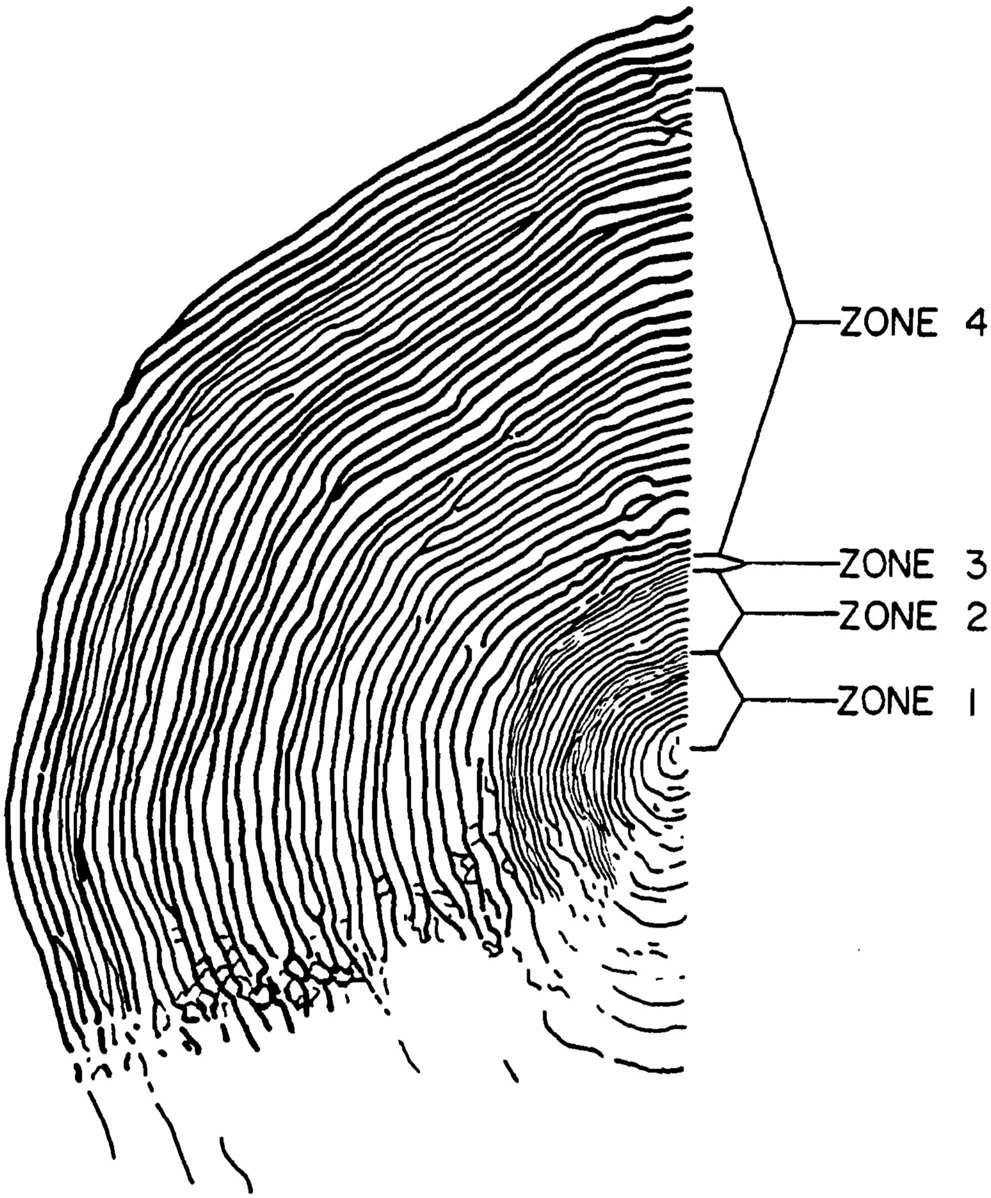


Fig. 2B. Diagram of typical sockeye salmon scale explaining growth zone definitions for age 2.* fish.

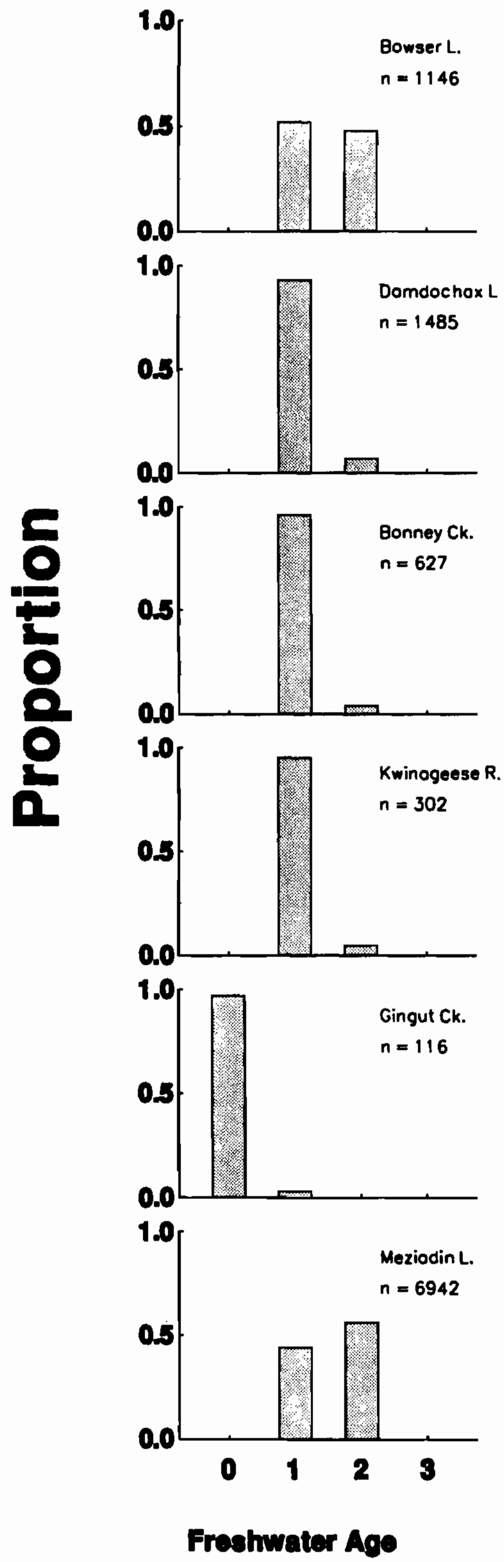


Fig. 3. Freshwater age composition determined from sockeye escapement samples.

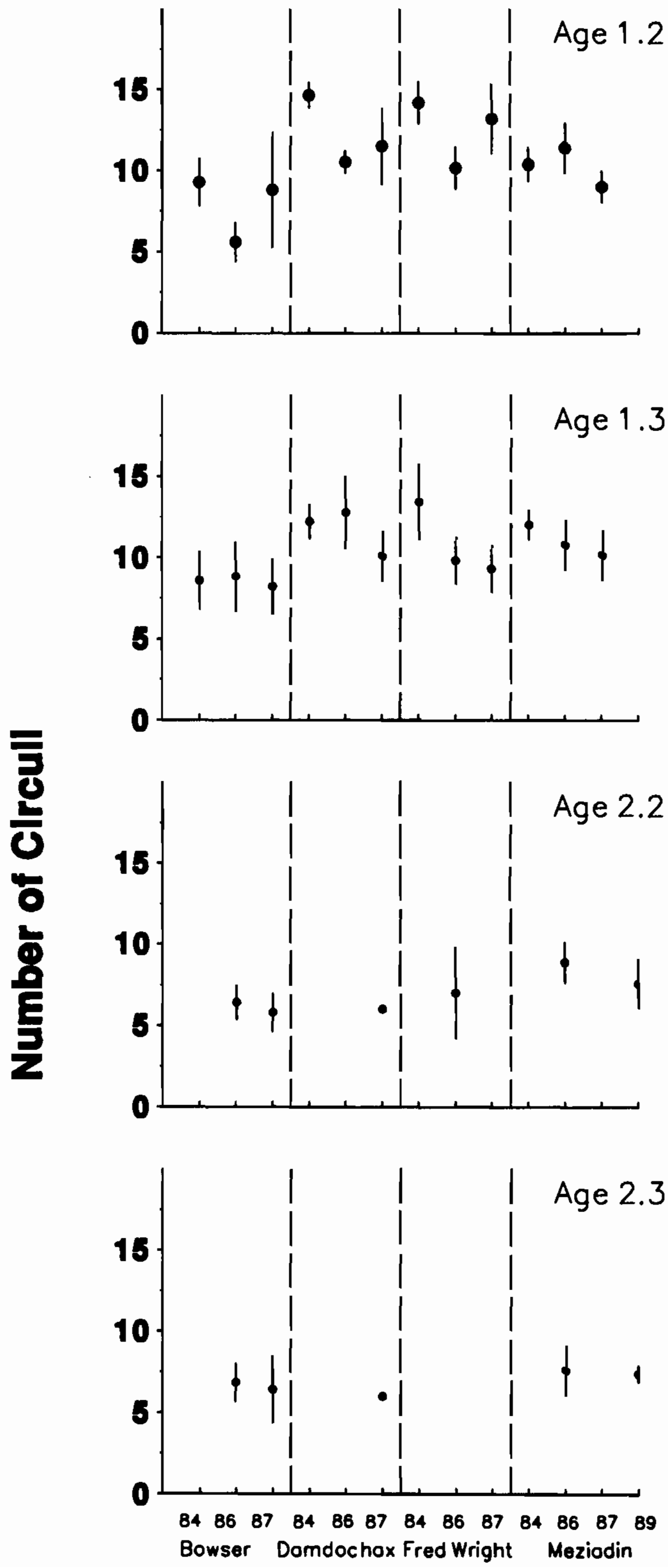


Fig. 4. Variation in mean circuli count (± one standard deviation) among Nass River sockeye populations. Measurements taken from zone 1 of scales from spawning fish.

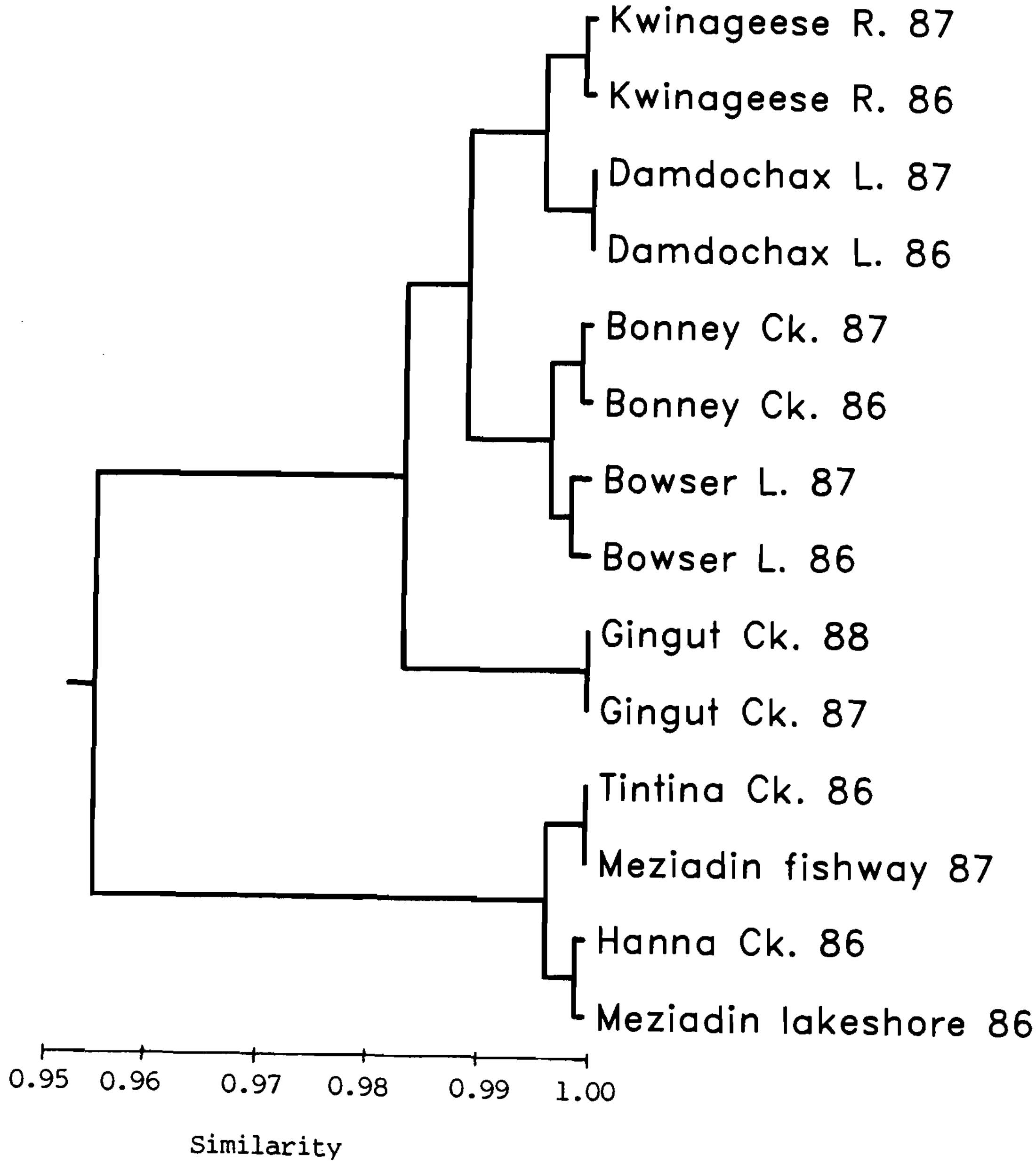


Fig. 5. Similarity dendrogram for Nass River sockeye populations based on Nei's unbiased genetic identity (Nei 1978) and allozyme allele frequencies at *sAAT-3**, *ALAT**, *LDH-B2**, *PGM-1**, *PGM-2**.

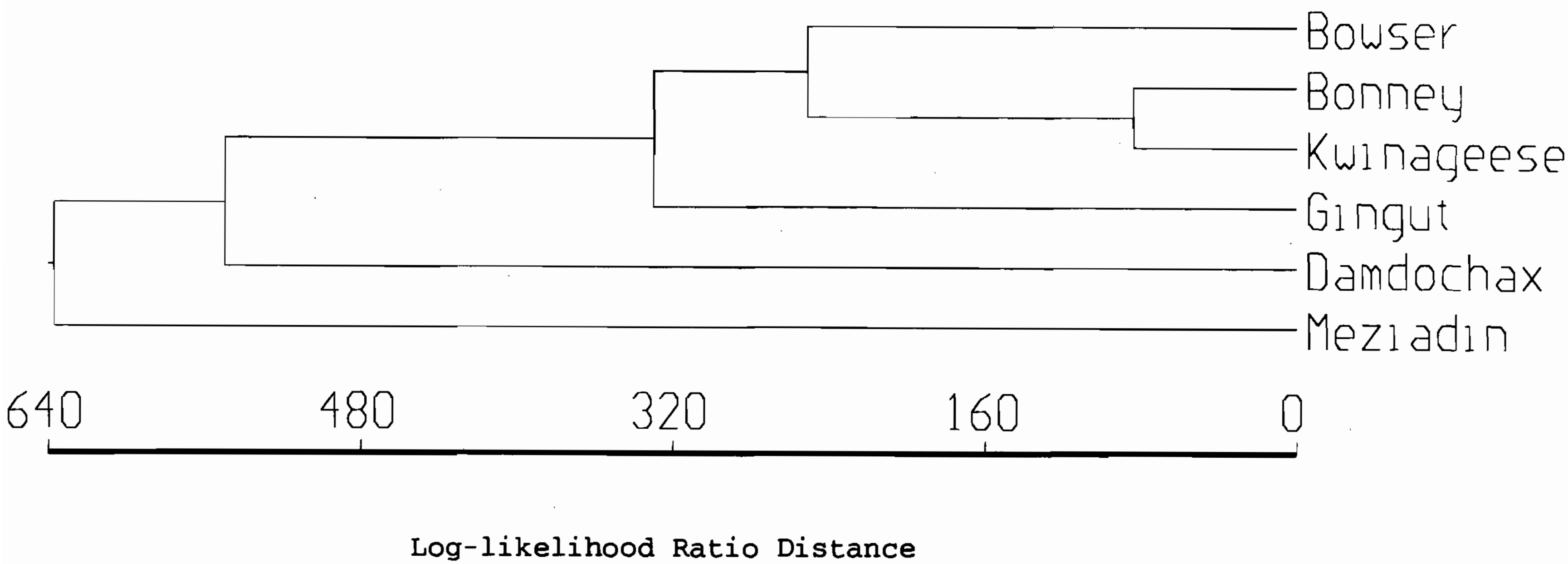
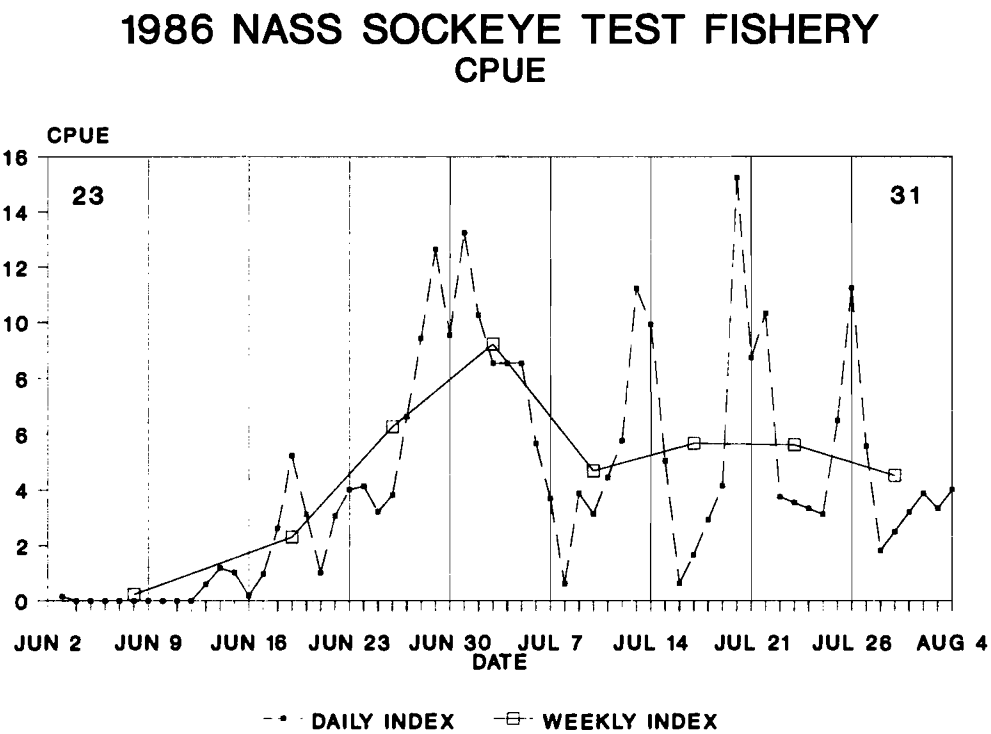


Fig. 6. Similarity dendrogram illustrating the potential for differentiating Nass sockeye populations using genetic, parasite, and age composition data in combination. The log-likelihood ratio distance (Wood 1989) reflects the cumulative differences among populations in allele frequencies at the five most polymorphic loci (*ALAT**, *LDH-B2**, *PGM-1**, *PGM-2**), in the prevalence of the brain parasite *Myxobolus arcticus*, and in freshwater age composition.



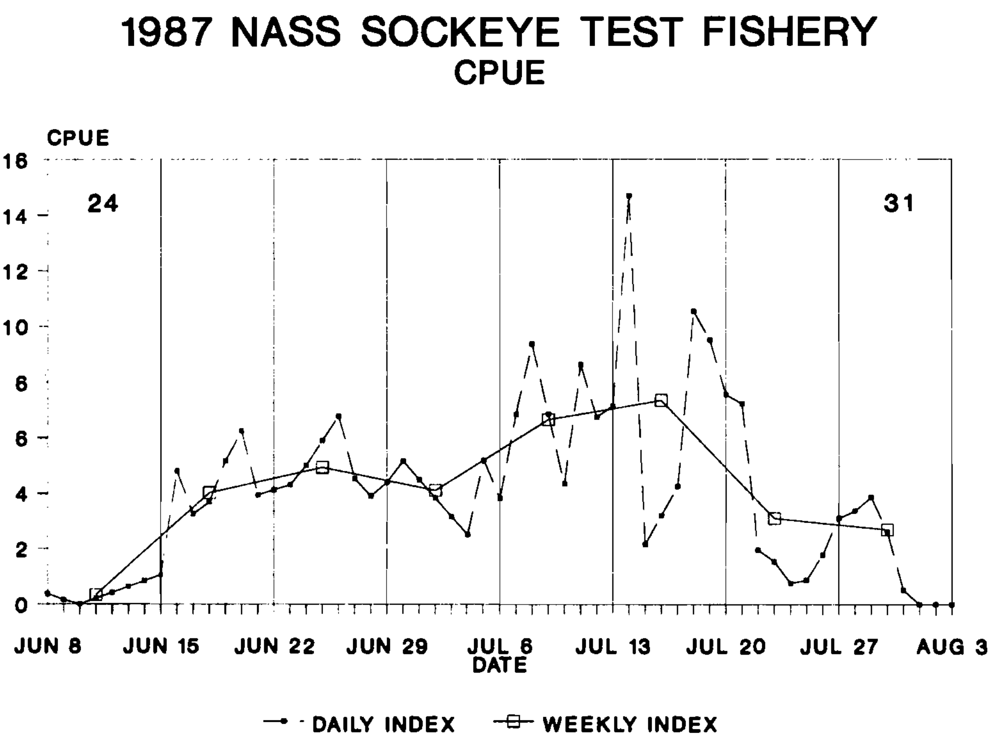
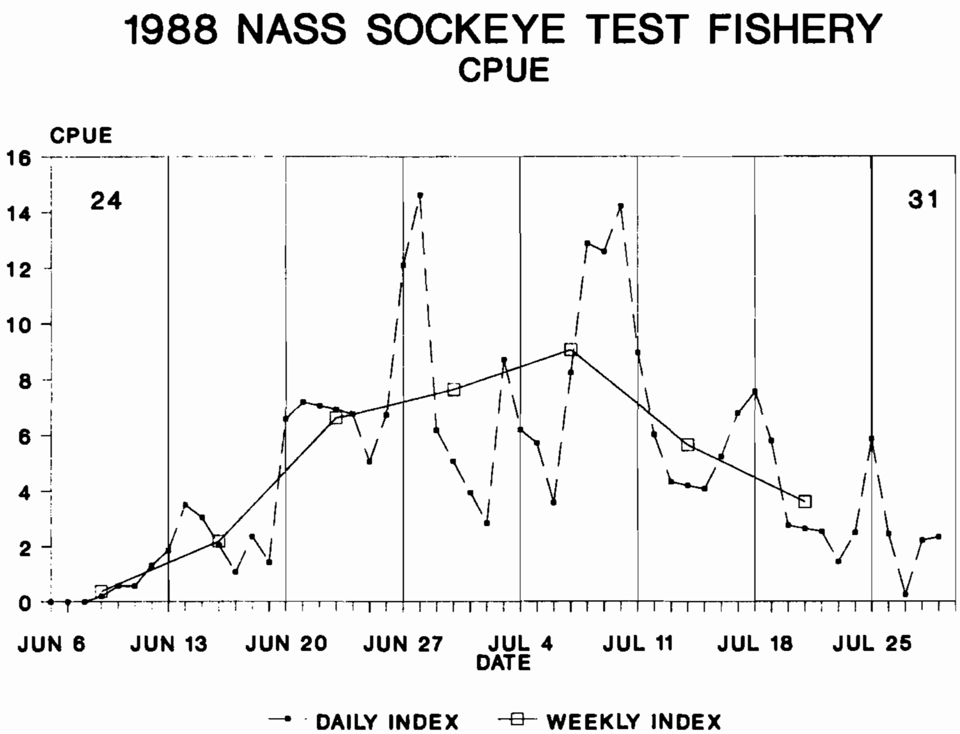


Fig. 7. Daily and weekly catch per unit effort (CPUE) in the Nass River test fishery, 1986-1992.


1988 NASS SOCKEYE TEST FISHERY
CPUE
CPUE
16
14
12
10
8
6
4
2
0
24
31
JUN 6
JUN 13
JUN 20
JUN 27
JUL 4
JUL 11
JUL 18
JUL 25
DATE
DAILY INDEX
WEEKLY INDEX

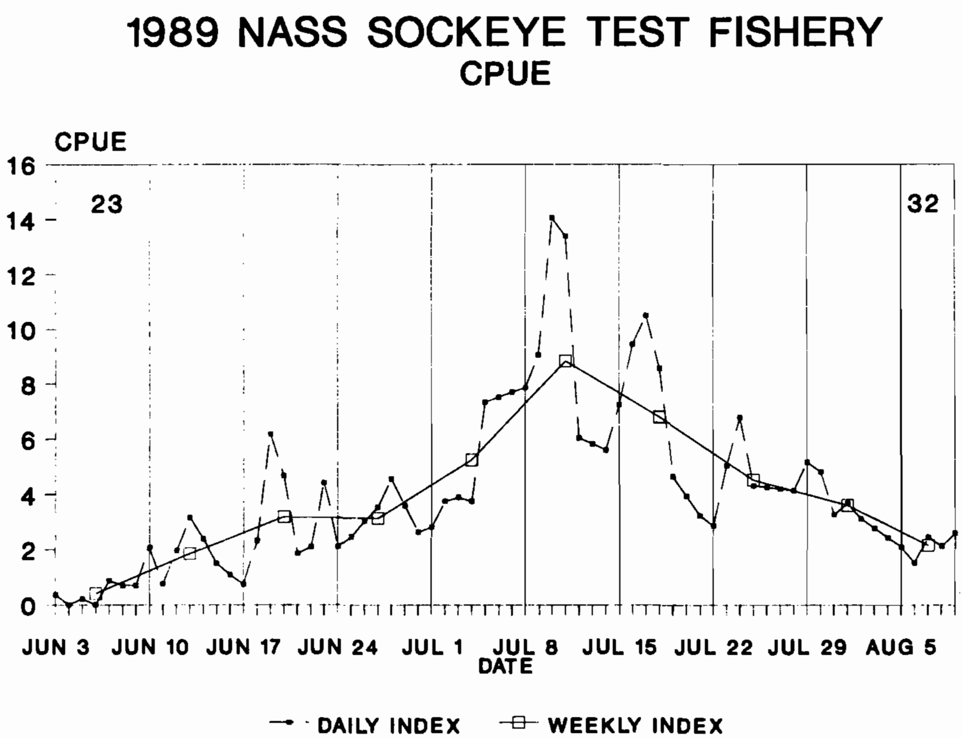
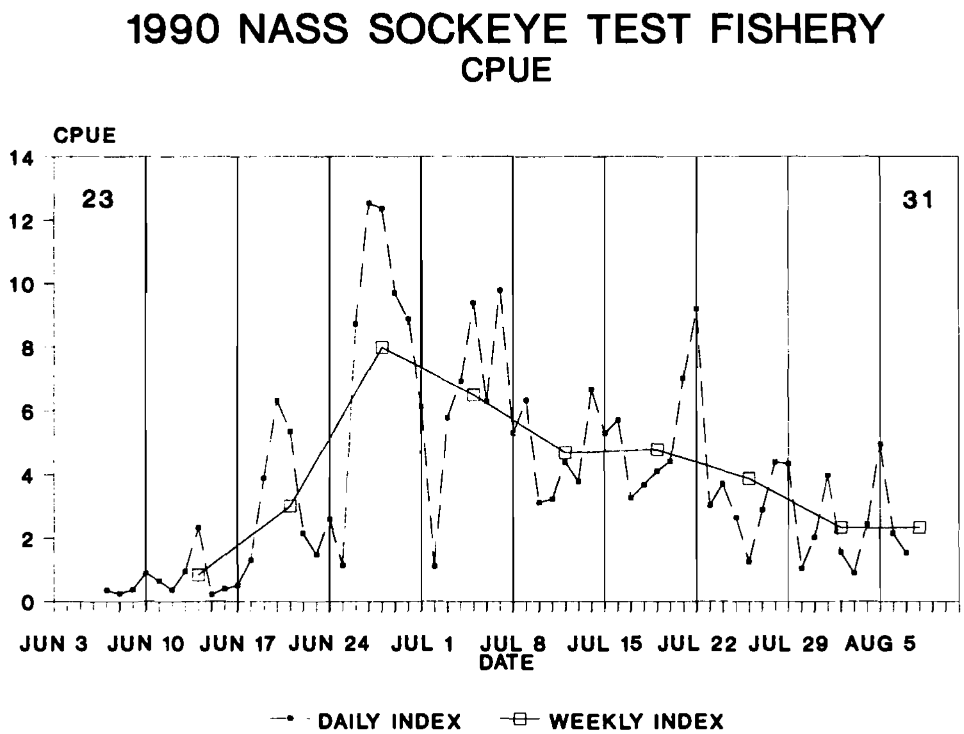

1989 NASS SOCKEYE TEST FISHERY
CPUE
CPUE
16
14
12
10
8
6
4
2
0
23
32
JUN 3
JUN 10
JUN 17
JUN 24
JUL 1
JUL 8
JUL 15
JUL 22
JUL 29
AUG 5
DATE
DAILY INDEX
WEEKLY INDEX

Fig. 7 (cont'd)


1990 NASS SOCKEYE TEST FISHERY
CPUE
CPUE
14
12
10
8
6
4
2
0
23
31
JUN 3 JUN 10 JUN 17 JUN 24 JUL 1 JUL 8 JUL 15 JUL 22 JUL 29 AUG 5
DATE
DAILY INDEX
WEEKLY INDEX

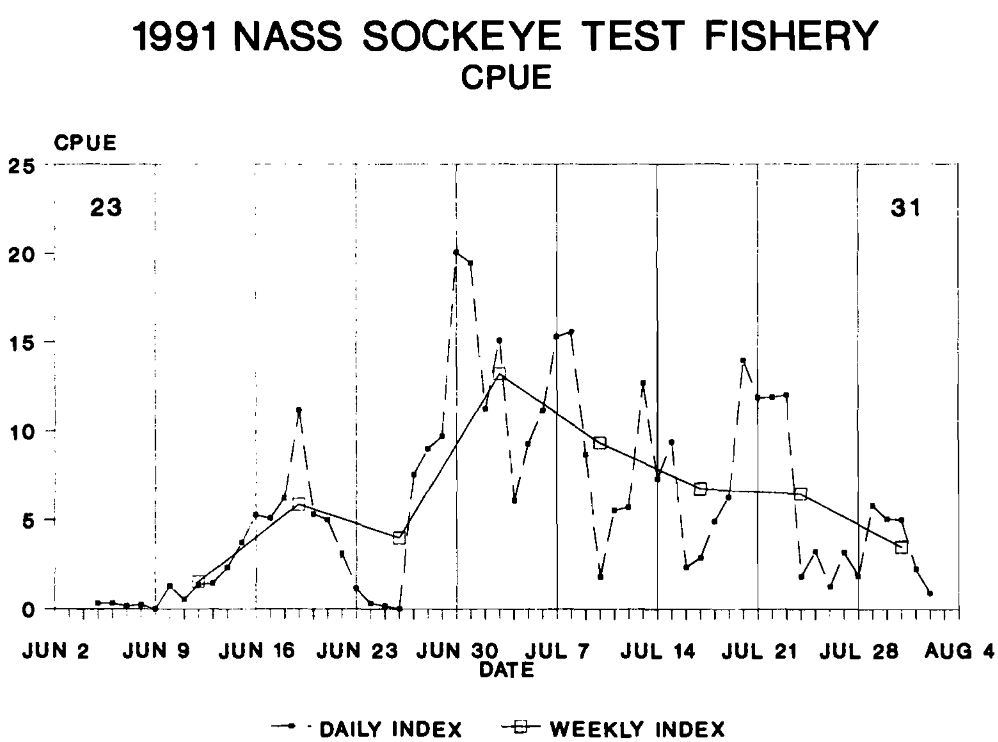

1991 NASS SOCKEYE TEST FISHERY
CPUE
CPUE
25
20
15
10
5
0
23
31
JUN 2 JUN 9 JUN 16 JUN 23 JUN 30 JUL 7 JUL 14 JUL 21 JUL 28 AUG 4
DATE
DAILY INDEX
WEEKLY INDEX

Fig. 7 (cont'd)

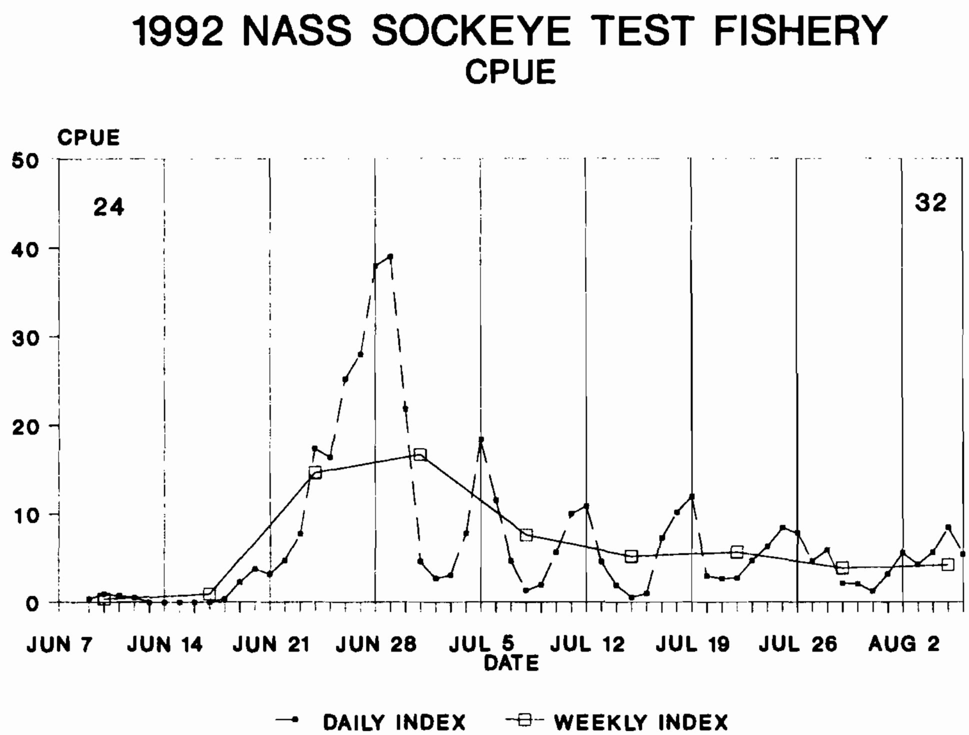
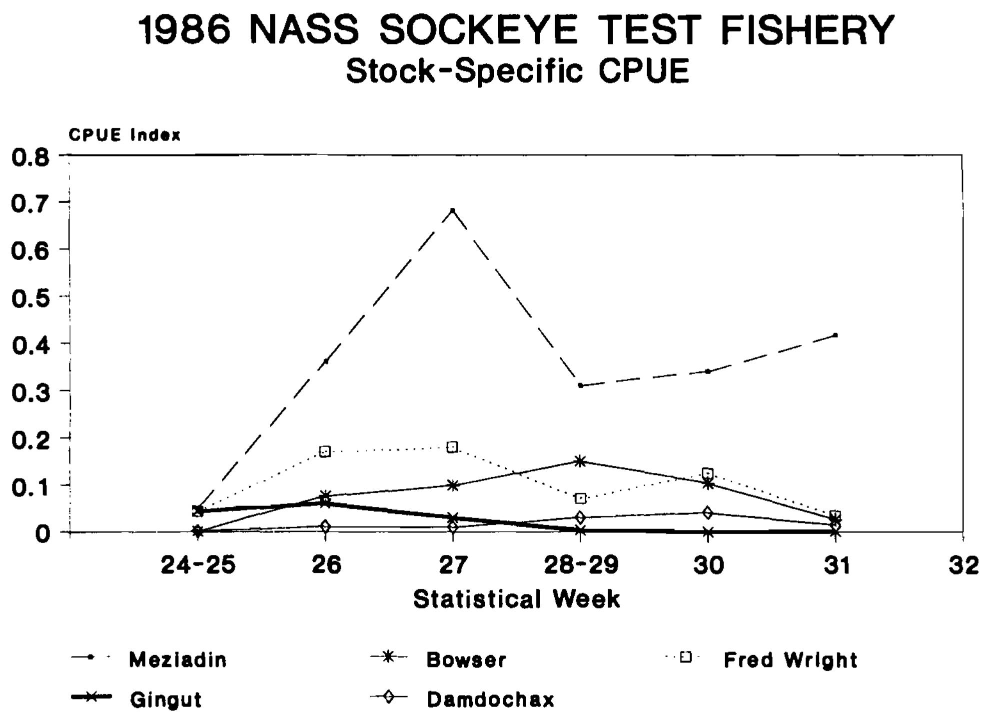

1992 NASS SOCKEYE TEST FISHERY
CPUE
CPUE
50
40
30
20
10
0
24
32
JUN 7
JUN 14
JUN 21
JUN 28
JUL 5
JUL 12
JUL 19
JUL 26
AUG 2
DATE
DAILY INDEX
WEEKLY INDEX

Fig. 7 (cont'd)



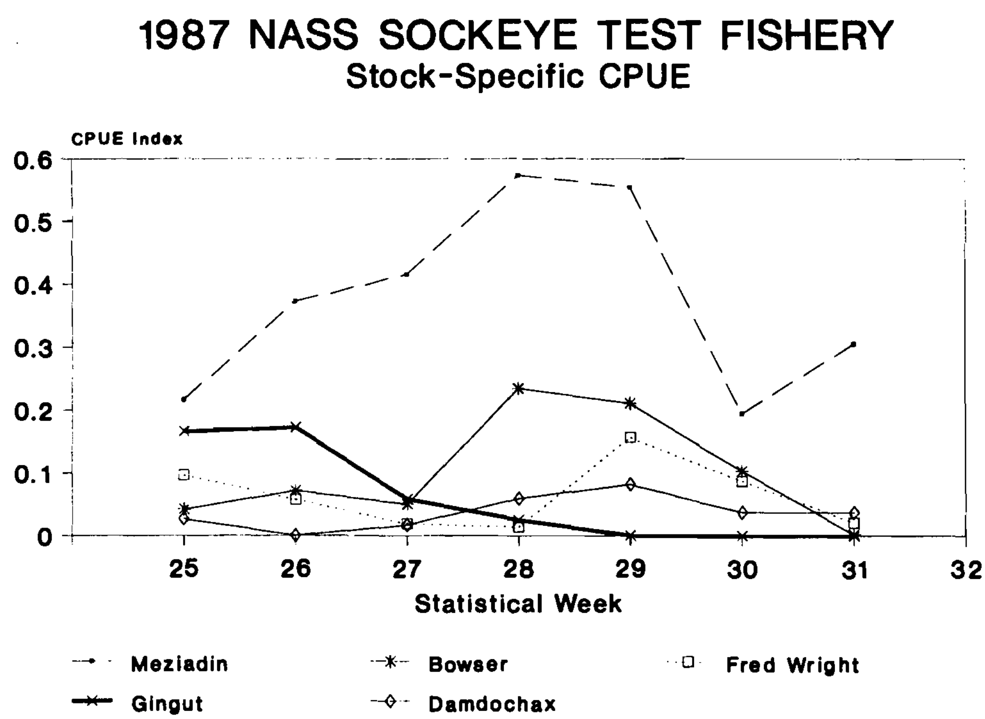
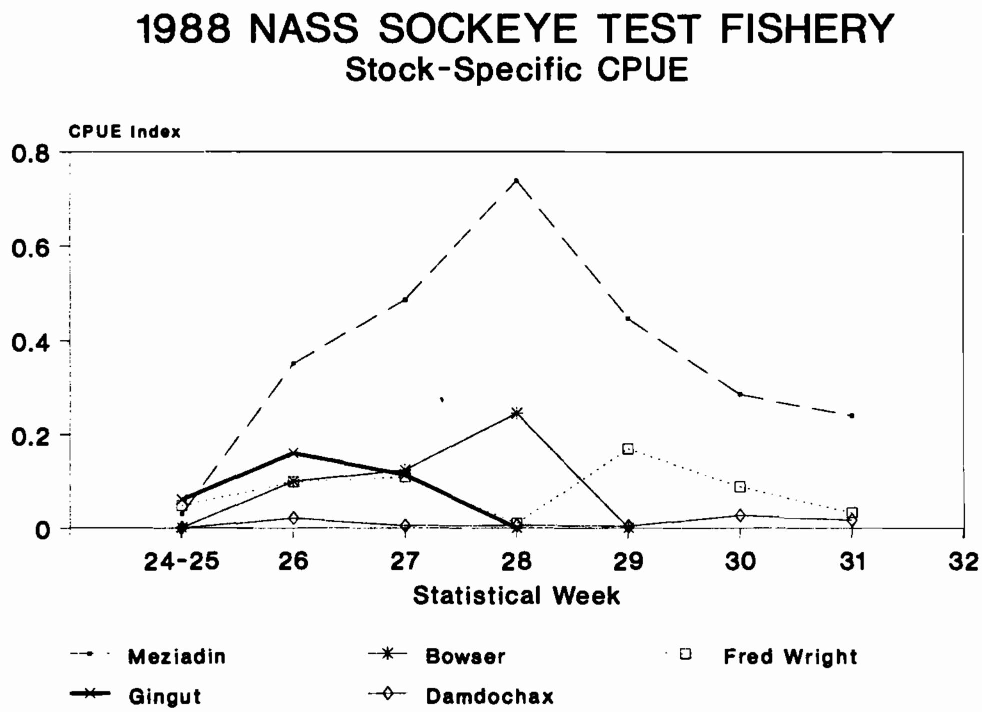


Fig. 8. Weekly stock-specific CPUE in the Nass River test fishery, 1986 to 1992.


1988 NASS SOCKEYE TEST FISHERY
Stock-Specific CPUE
CPUE Index
0.8
0.6
0.4
0.2
0
24-25
26
27
28
29
30
31
32
Statistical Week
Meziadin
Bowser
Fred Wright
Gingut
Damdochax

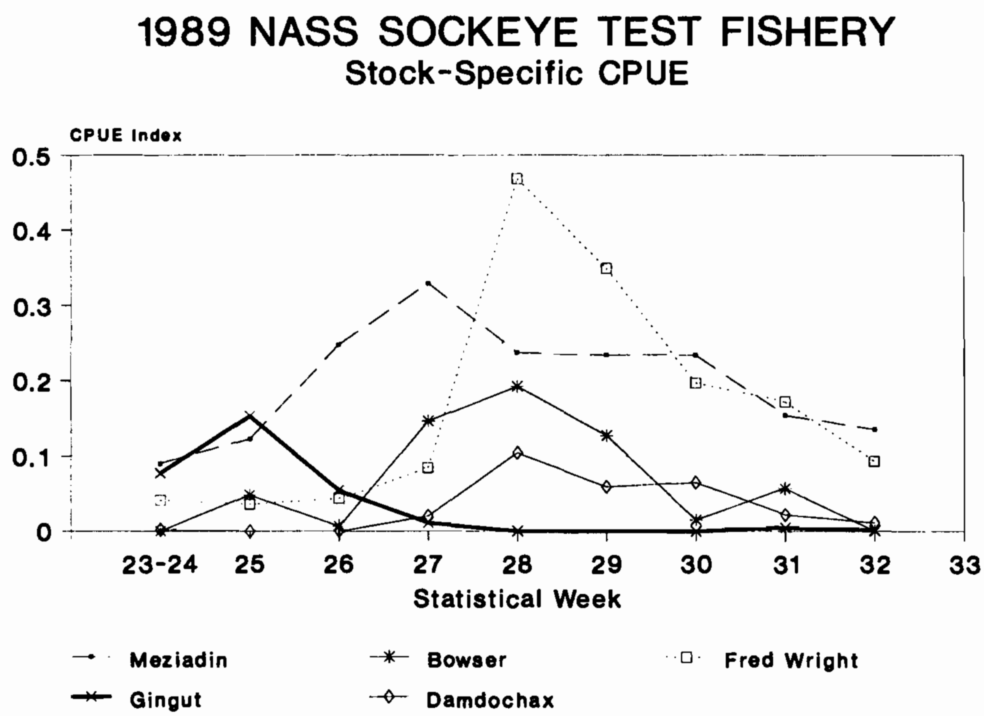
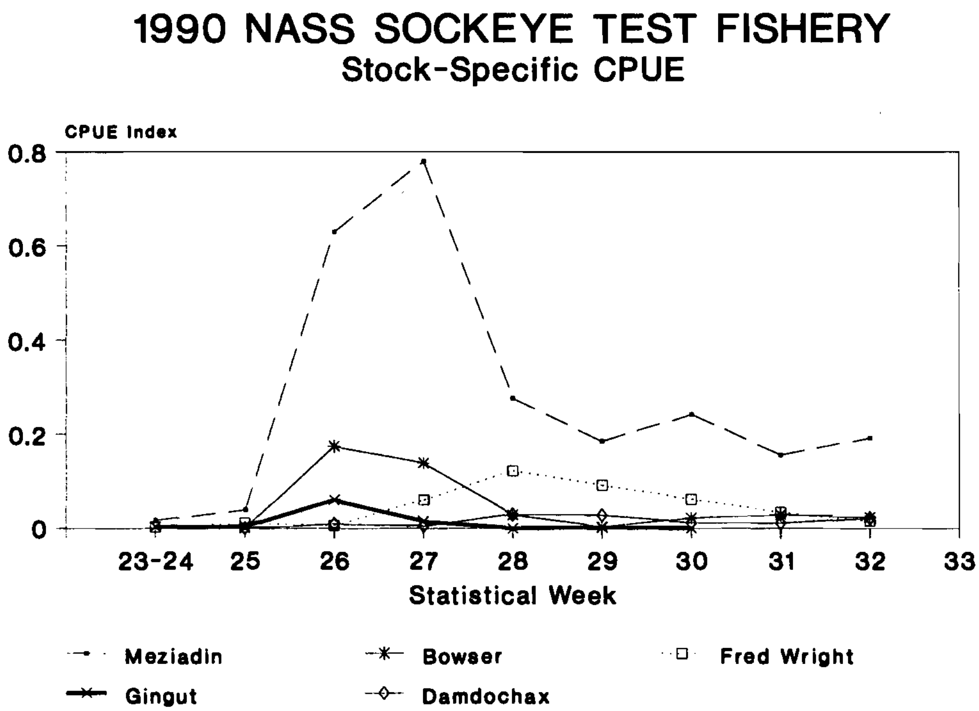

1989 NASS SOCKEYE TEST FISHERY
Stock-Specific CPUE
CPUE Index
0.5
0.4
0.3
0.2
0.1
0
23-24
25
26
27
28
29
30
31
32
33
Statistical Week
Meziadin
Bowser
Fred Wright
Gingut
Damdochax

Fig. 8 (cont'd)


1990 NASS SOCKEYE TEST FISHERY
Stock-Specific CPUE
CPUE Index
0.8
0.6
0.4
0.2
0
23-24
25
26
27
28
29
30
31
32
33
Statistical Week
Meziadin
Bowser
Fred Wright
Gingut
Damdochax

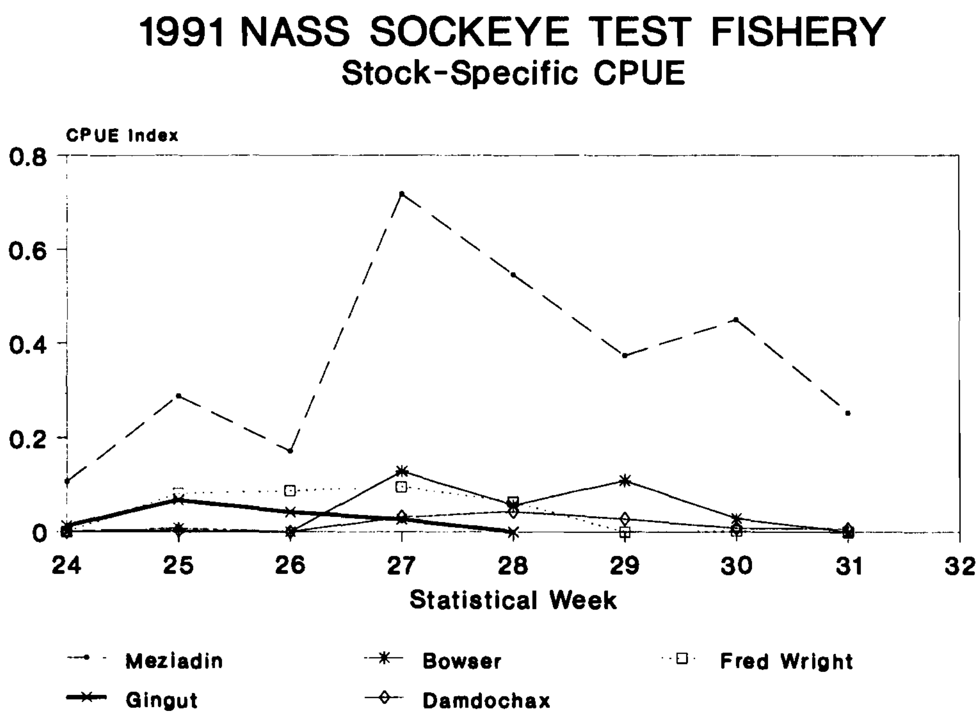

1991 NASS SOCKEYE TEST FISHERY
Stock-Specific CPUE
CPUE Index
0.8
0.6
0.4
0.2
0
24
25
26
27
28
29
30
31
32
Statistical Week
Meziadin
Bowser
Fred Wright
Gingut
Damdochax

Fig. 8 (cont'd)

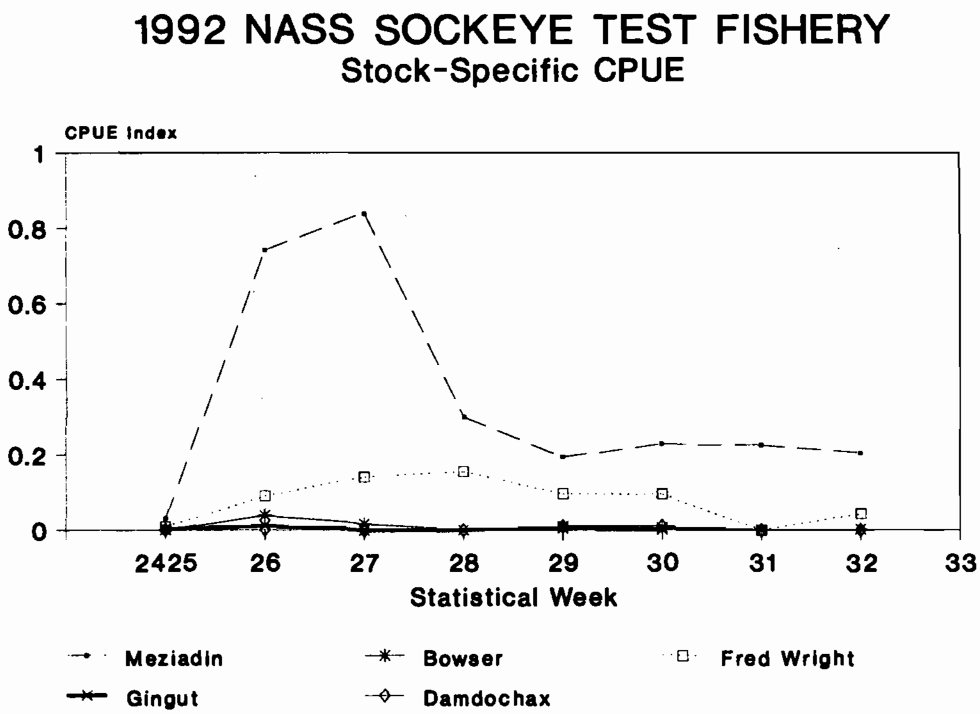

1992 NASS SOCKEYE TEST FISHERY
Stock-Specific CPUE
CPUE Index
1
0.8
0.6
0.4
0.2
0
2425
26
27
28
29
30
31
32
33
Statistical Week
Meziadin
Bowser
Fred Wright
Gingut
Damdochax

Fig. 8 (cont'd)

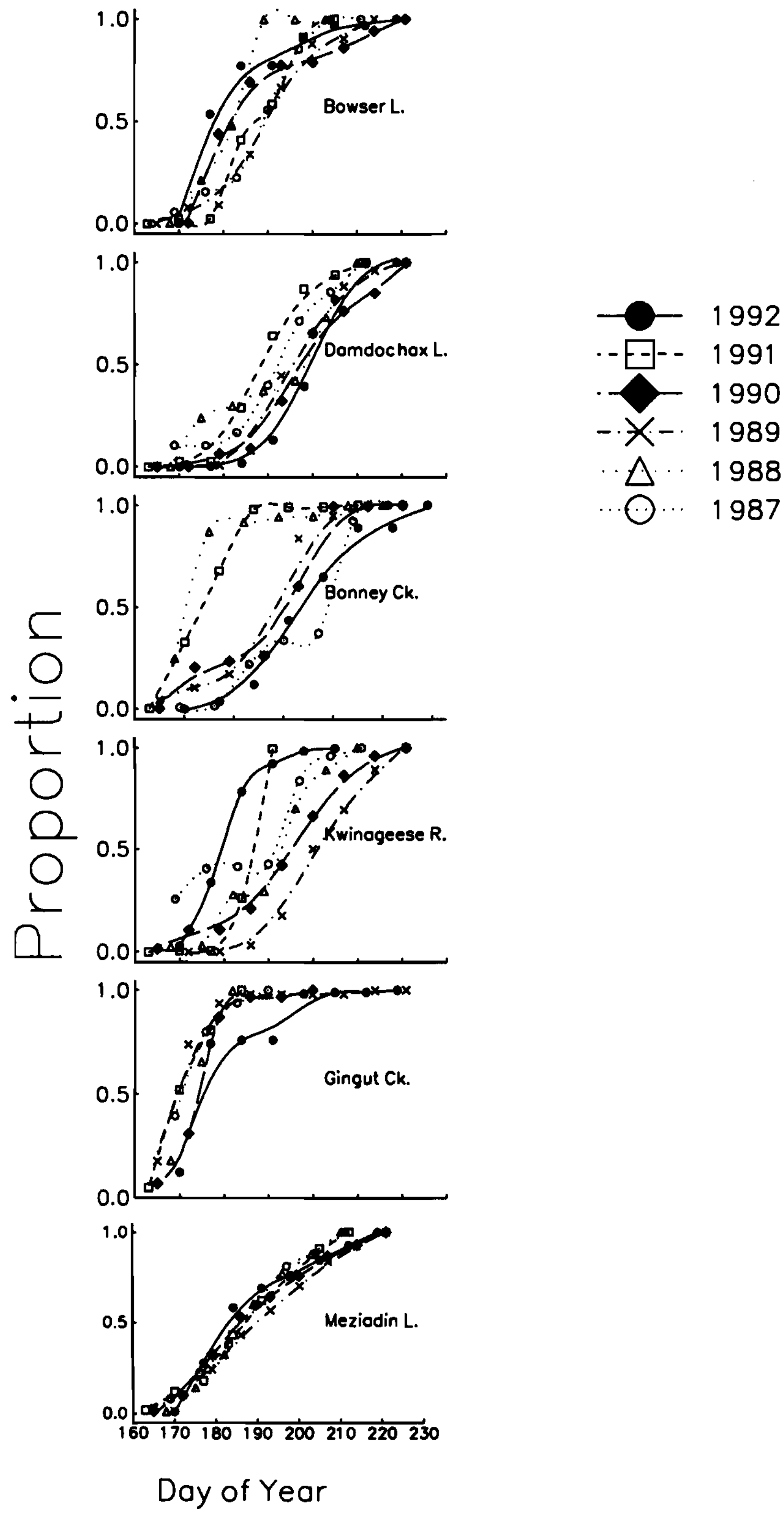


Fig. 9. Cumulative stock-specific run timing curves past the Nass River test fishery, 1987-1992.

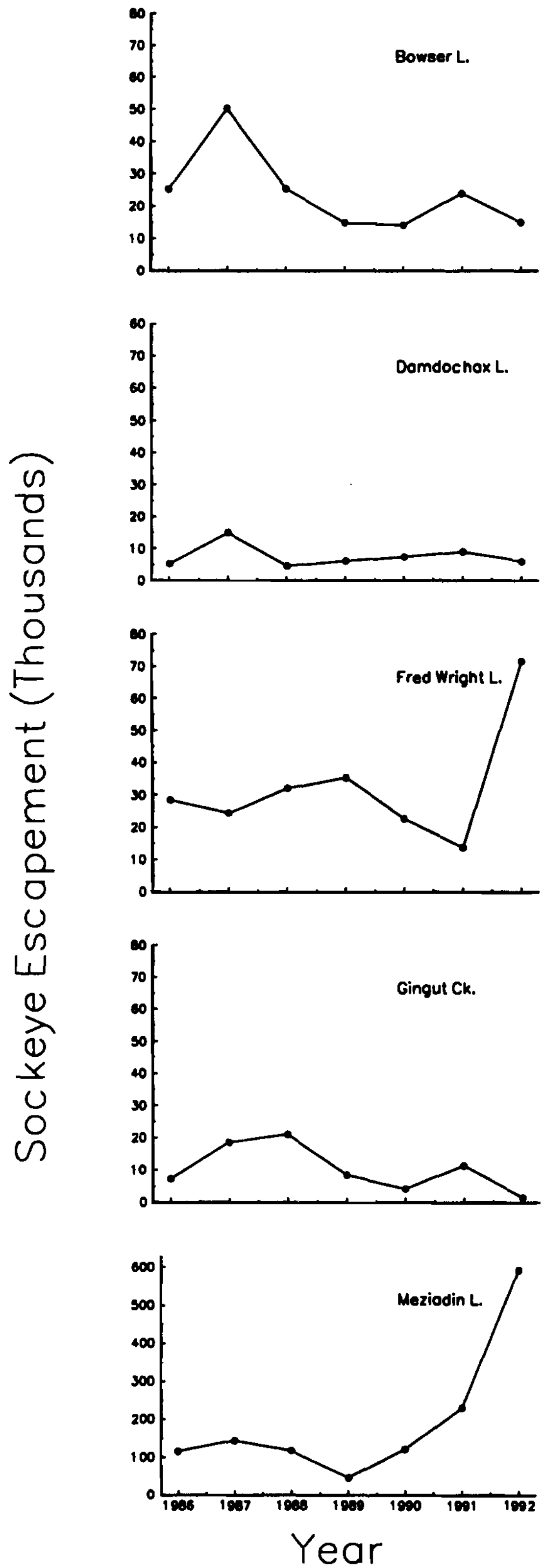


Fig. 10. Trends in estimated spawning escapements for principal Nass River sockeye populations, 1986 to 1992.