THE UNIVERSITY OF MANITOBA

ABUNDANCE AND ORIGIN OF LAKE WHITEFISH, COREGONUS CLUPEAFORMIS (MITCHILL) CONGREGATING DOWNSTREAM OF THE MISSI FALLS CONTROL DAM, SOUTHERN INDIAN LAKE, MANITOBA

by

NICHOLAS EDWARD BARNES

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ABSTRACT

Large congregations of lake whitefish (Coregonus clupeaformis) accumulating below the Missi Falls control structure at the outlet of Southern Indian Lake (SIL), Manitoba, were studied in the open water seasons of 1986 and 1987 to determine the abundance and origin of these fish. The null hypothesis being tested was that all fish found below the Missi Falls control dam originated from downstream areas. The alternate hypothesis was that fish from Southern Indian Lake were present.

A Jolly-Seber multiple mark-recapture model was utilized to provide estimates of population size, births, deaths and survival rates. The origin of the Missi Falls fish was estimated through morphological comparisons of the Missi Falls fish with fish caught in seven locations surrounding the control structure.

Abundance increased gradually to a peak of 88,764 (± 21,415) fish in the autumn of 1986. Abundance in 1987 peaked in the summer to numbers less than one third of the 1986 autumn estimate. Fish caught in 1986 at Missi Falls were in much better condition with fuller digestive tracts than those caught in 1987.

Morphological comparisons of the Missi Falls fish indicated differences between fish caught in 1986 and 1987. Fish caught in the autumn of 1986 closely resembled fish caught in the locations upstream of the dam. Fish caught in the summer of 1987 most resembled those caught in the near-downstream lakes. There appeared to be gradual changes in the origin of Missi Falls fish

between these two times.

High discharges over Missi Falls in 1986 were similar to the discharge levels which existed prior to the impoundment of SIL. The presence of large numbers of healthy upstream-like fish congregating below Missi Falls in 1986 was evidence to reject the null hypothesis. It is thought that these fish represented an upstream stock whose migratory movements upstream over Missi Falls from downstream feeding areas had been interrupted by the control structure. These fish were probably following Churchill River cues and became trapped below the dam on a movement back to spawn and overwinter in SIL.

Lower discharges over Missi Falls in the open water season of 1987 were from local upstream inflows only, since, at this time, the Churchill River was diverted to another outlet in SIL. Any migratory cues from the Churchill River would therefore not affect fish at Missi Falls at this time. These lower discharges in 1987 resulted in lower downstream lake levels and summer water temperatures which exceeded those preferred by lake whitefish. The congregation of physiologically-stressed, downstream-like fish below Missi Falls in 1987 was evidence to accept the null hypothesis; however some upstream fish were probably also present at this time. It is thought that the increased water temperatures in the downstream lakes in 1987 prompted fish from the downstream lakes to follow a temperature gradient upstream towards the cooler water at Missi Falls.

It would appear that the composition of lake whitefish congregating below Missi Falls can change over time. The relative proportion of both upstream and downstream fish of the Missi Falls population appears to be dependent on environmental factors such as discharge.

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I. INTRODUCTION

Prior to impoundment in 1976, Southern Indian Lake supported one of the largest lake whitefish fisheries in Northern Manitoba. The majority of the catch (85% by weight) was lake whitefish (Bodaly et al, 1984b). Catches were classified as Grade A (Export), light colored fish and most export fish were caught in Area 4.

In 1976, a dam built across the lake outlet at Missi Falls raised the lake level three meters to divert most of the flow of the Churchill River southward to hydro-electric generating stations on the Nelson River. The control dam at Missi Falls has no fish passage facilities. Since impoundment of the lake, the quantity and quality of the commercial whitefish catch and the genetic structure of the whitefish population in the lake has changed (Bodaly et al, 1984b). Five years after impoundment, catch effort was only one-third of pre-impoundment means and the fishery was reclassified to Grade B (continental). More fishing effort was in Area 5, one of the most Northern basins of the lake, where fish were darker colored and more heavily parasitized (Bodaly et al, 1984b). The collapse of the commercial fishing industry was not always apparent in tabulations of catch results (Table 1). This was due to an increase in fishing pressure and the switch to fishing in new areas in the lake, away from traditional fishing grounds.

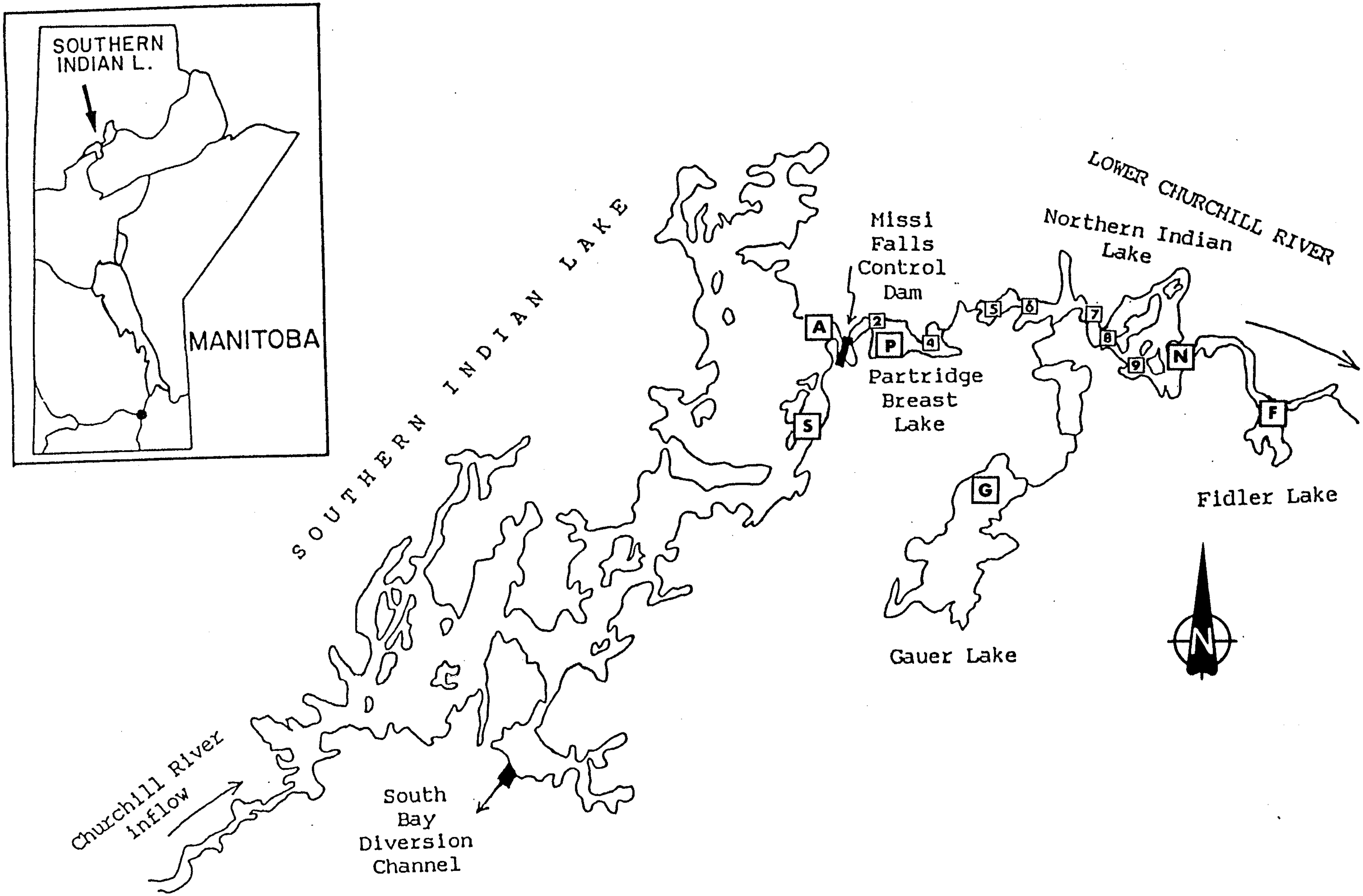
Table 1. Commercial catches (in kg, equivalent round weight) of lake whitefish from four lakes surrounding the Missi Falls control structure. Numbers in parentheses represent number of fishermen. (Courtesy of Freshwater Fish Marketing Board)

Year	Season	Southern Indian L.		Partridge Breast L.		Northern Indian L.		Fidler L.	
		Export	Continental	Export	Continental	Export	Continental	Export	Continental
1970	Summer	248,556	35,086	0	0 (0)	98,192	377 (2)	9,895	0 (2)
	Winter	77,589	0	305	0 (1)	0	0 (0)	0	0 (0)
1971	Summer	245,786	19,672	0	0 (0)	48,993	0 (7)	8,660	135 (4)
	Winter	0	147,662	0	0 (0)	0	0 (0)	0	0 (0)
1972	Summer	160,410	17,487	0	0 (0)	261	0 (1)	0	0 (0)
	Winter	130,616	0	0	0 (0)	0	0 (0)	0	0 (0)
1973	Summer	283,482	0	0	0 (0)	48,786	183 (9)	6,410	0 (6)
	Winter	14,904	0	0	0 (0)	0	0 (0)	0	0 (0)
1974	Summer	0	0	0	0 (0)	0	0 (0)	0	0 (0)
	Winter	0	0	0	0 (0)	6,190	0 (1)	0	0 (0)
1975	Summer	267,870	0	11,458	0 (4)	214,741	913 (16)	9,569	0 (5)
	Winter	60,897	0	0	0 (0)	0	0 (0)	0	0 (0)
1976	Summer	305,020	2,148	0	0 (0)	40,183	0 (15)	0	0 (0)
	Winter	112,744	0	0	0 (0)	0	0 (0)	0	0 (0)
1977	Summer	401,163	765	0	0 (0)	0	0 (0)	0	0 (0)
	Winter	28,139	0	0	0 (0)	0	0 (0)	0	0 (0)
1978	Summer	202,808	159,280	0	0 (0)	45,153	0 (0)	0	0 (0)
	Winter	29,245	6,843	0	0 (0)	0	0 (0)	0	0 (0)
1979	Summer	104,786	272,189	0	0 (0)	3,960	0 (0)	0	0 (0)
	Winter	47,816	3,903	0	0 (0)	0	0 (0)	0	0 (0)
1980	Summer	253,665	134,299	0	0 (0)	42,874	0 (1)	0	0 (0)
	Winter	18,152	18,909	0	0 (0)	0	0 (0)	0	0 (0)
1981	Summer	13,279	281,461	63	0 (2)	22,705	0 (1)	0	0 (0)
	Winter	0	15,782	0	0 (0)	805	0 (3)	0	0 (0)
1982	Summer	134,294	1,386	0	2,122 (4)	7,768	237 (0)	0	0 (0)
	Winter	0	0	0	0 (0)	2,885	0 (0)	0	0 (0)
1983	Summer	172,185	5	0	1,615 (4)	7,332	0 (0)	0	0 (0)
	Winter	52,159	13,556	0	0 (0)	0	0 (0)	0	0 (0)
1984	Summer	127,484	105,202	0	1,234 (2)	3,043	0 (0)	0	0 (0)
	Winter	17,512	7,761	0	43 (1)	0	0 (0)	0	0 (0)
1985	Summer	72,629	101,798	0	1,228 (2)	2,709	0 (0)	614	0 (1)
	Winter	29,482	16,372	0		0	0 (0)	0	0 (0)
1986	Summer	102,129	55,184	0	0 (0)	6,462	0 (0)	6,462	0 (0)
	Winter	5,821	3,500	0	86 (1)	0	0 (0)	0	0 (0)

Extensive limnological and fisheries studies on SIL before river diversion and lake impoundment concluded that hydro-electric development could disrupt traditional lake whitefish migration patterns among the various basins of SIL (Ayles and Koshinsky, 1974). Concern at that time was for postulated movements of fish into the Area 4 basin at spawning time from other basins to the south. After the collapse of the SIL fishery following impoundment and the observations of aggregations of lake whitefish below the Missi Falls control dam, the possibility of exchanges of fish between SIL and the lower Churchill and Rat River valleys was considered (Bodaly et al, 1984b). It was noted that large numbers of fish congregate immediately below the SIL diversion channel at South Bay (Figure 1) as well as at Missi Falls. The size and origin of these accumulations of lake whitefish below Missi Falls were unknown. A similar accumulation of lake whitefish below a control dam was studied in Labrador by Barnes (1981). Bodaly et al (1984b) suggested that declines in catch per unit effort in SIL may be due to major movements of fish out of SIL in response to changes caused by impoundment.

Before diversion there were at least three genetically distinct stocks of whitefish in the SIL area, as indicated by glycerol-3-phosphate-dehydrogenase allele frequencies (Bodaly et al, 1984b). These differences had disappeared after impoundment and river diversion. Also, after

Figure 1. Map of Southern Indian Lake and lower Churchill River study area. Fish sample sites are shown as letters (A = Area 4; F = Fidler Lake; G = Gauer Lake; N = Northern Indian Lake; P = Partridge Breast Lake; S = Strawberry Island). (Missi and Coffer dam sites not shown; see text for explanation). Water temperature sites are shown as numerals (Site 1 is directly downstream of the Missi Falls control dam).


SOUTHERN
INDIAN L.
MANITOBA
SOUTHERN INDIAN LAKE
Missi
Falls
Control
Dam
LOWER CHURCHILL RIVER
Northern Indian
Lake
A
S
2
P
4
5
6
7
8
9
N
F
G
Partridge
Breast
Lake
Fidler Lake
Gauer Lake
N
Churchill River
inflow
South
Bay
Diversion
Channel

diversion, there were no apparent differences in allele frequencies between fish caught in different basins of SIL, at Missi Falls and two lakes downstream of the Missi Falls dam (Gauer and Northern Indian).

Bodaly et al (1984b) also cited Harden-Jones (1956), Volkova (1971) and Swenson (1978) in suggesting that reduced light and turbidity could have affected the distribution and schooling behavior of the whitefish. Bodaly et al (1984b) used Blaxter's (1970) and Hecky's (1984) work to show that post-impoundment daytime light penetration levels are below that required by most fish for effective feeding and schooling. Although Ayles and Koshinsky (1974) had predicted a disruption in whitefish migration patterns prior to the diversion of the Churchill River, and the impoundment of SIL, the potential of the Missi Falls dam as a blockage to the migration of large numbers of commercially valuable fish had not been considered.

Bodaly et al (1984b) hypothesized that prior to river diversion, lake whitefish made an annual migration from SIL into the lower Churchill River and that the blockage of this migration by the Missi Falls control structure has contributed to the collapse of the SIL fishery. This hypothesis predicts that the fish below Missi Falls are from SIL and should most closely resemble SIL fish. Also, if this hypothesis is correct in its supposition that fish passage problems at Missi Falls contributed to the SIL commercial fishery collapse, then the numbers of fish below Missi Falls would be substantial in relation to the size of the SIL commercial catch.

A contrasting hypothesis suggests that since impoundment, fish aggregating below Missi Falls are from downstream lakes and that environmental factors have attracted them upstream to accumulate below the dam. Since the dam has created artificially low water levels in the downstream lakes, temperatures during the summer months could exceed these preferred by lake whitefish. Cooler water flowing out of SIL could create a temperature gradient from Missi Falls to downstream areas which fish could sense and follow.

These two alternate hypotheses were tested with field studies in the open water seasons of 1986 and 1987. Monthly seining off the downstream side of the control structure was conducted. Samples taken at the dam were compared morphologically with samples from two locations in the upstream SIL, and five locations downstream of the dam (Figure 1) in an attempt to determine the origin of the fish at Missi Falls.

Biological analyses included condition factors, digestive tract contents, liver somatic indices and gonad somatic indices. Water temperatures were recorded at Missi Falls and surrounding lakes and discharges over the control structure were also recorded on a monthly basis.

The objectives of this study were two-fold: first, using mark-recapture methods to estimate the numbers and seasonal pattern of lake whitefish abundance below Missi Falls, and second, to attempt to determine, using biological and morphological data, the origin of the fish congregating below the dam.

II. MATERIALS AND METHODS

A. STUDY AREA

1. Pre-impoundment conditions

The Churchill River flows northeasterly across Manitoba and empties into Hudson Bay. The SIL region consists of Precambrian bedrock overlaid by fine-grained glacio-lacustrine deposits (Newbury et al, 1984). It is characterized by boreal forest and has a subarctic continental climate with short cool summers and long cold winters (Newbury et al, 1984).

Prior to impoundment, the fish species diversity of the lakes in the area was relatively low. The large fish community was dominated by a relatively small number of cool-water adapted benthivores such as lake whitefish, *Coregonus clupeaformis*, white sucker, *Catostomus commersoni*, and longnose sucker, *C. catostomus*, planktivores such as ciscoes, *Coregonus artedii*, and piscivores such as northern pike, *Esox lucius*, walleye, *Stizostedion vitreum*, and burbot, *Lota lota* (Bodaly et al, 1984a).

Southern Indian Lake, and those lakes downstream of SIL in the study area are riverine in nature, since the Churchill River flows through them. Prior to the impoundment of SIL, the Churchill River left SIL and passed over a series of rapids, the largest of which was Missi Falls. There were two outlet channels to SIL, the northern most channel being the larger of the two. Prior to diversion, the

Churchill River fell 255m in the 460km of channel between Southern Indian Lake and Hudson Bay (Lake Winnipeg, Churchill and Nelson Rivers Study Board, 1975).

2. Post-Impoundment conditions

In the period between 1973 and 1976, a dam and control structure were built at Missi Falls, at the northern end of SIL. The smaller southern outlet channel was blocked to drain the area of the control structure site. After construction of the control structure, a coffer dam was constructed on the main outflow, and final impoundment of the lake and the diversion of the Churchill River began in June 1976. The lake level was raised three meters over the long-term mean and 75% of the natural flow of the Churchill River ($958m^3s^{-1}$) was diverted south through a channel constructed between South Bay and the headwaters of the Rat River in the Nelson River basin (Newbury et al, 1984). Minimum releases to the lower Churchill River are $14.2m^3s^{-1}$ during the open water season and $42.5m^3s^{-1}$ during the ice cover period (Newbury et al, 1984). Hydroelectric power is produced from dams on the lower Nelson River from the combined flow of the Churchill and Nelson rivers.

Diversion of the Churchill River from its natural outlet has altered the water budgets of various basins in SIL. The most extreme change occurred in South Bay (Figure 1) where residence time has changed from four years to eleven days (Newbury et al, 1984). Increased shoreline erosion contributed to increased turbidity (Hecky & McCullough, 1984), especially in Area 4 (Figure 1) where turbidity is six to eight times pre-impoundment levels. Increased turbidity has caused decreased light penetration by mean values of 30 to 50% (Hecky, 1984), and mean column water temperatures in Area 4 have cooled by an average of 1^0C during open water season. Any increases in numbers planktonic and benthic invertebrates indirectly brought about by increased nutrient levels from flooded shorelines have been indirectly suppressed by lower light levels (Hecky, 1984; Patalas & Salki, 1984; Weins & Rosenberg, 1984).

B. FIELD SAMPLING TECHNIQUES

Lake whitefish were live sampled and batch marked five times in 1986 and four times in 1987 (Table 2) during the open water season to provide Jolly-Seber mark-recapture estimates of population numbers below the Missi Falls control structure, and to provide samples for morphological and biological comparisons with whitefish caught at upstream and downstream locations.

The dam consists of six gates with a small turbine near the south shore. Flow is usually from the middle two gates which are slightly larger than the remaining four and are heated during the winter months. The floor and walls of the bays immediately downstream of each gate are constructed of smooth concrete and slope up toward the gate and were thus ideal for sampling. Access to the water level behind the gates was by permanent ladders on the dam, or inflatable boat if flow was low enough.

Samples were caught immediately downstream of the dam with a seine net. The net was twenty meters long and four meters deep, with a central pocket. It was weighted with diving weights every few meters to ensure that it sank to the bottom.

During periods of high flow (Table 2), only the two most northerly gates could be sampled. One person downstream on the north shore pulled the seine net out from the gate and one person on either side of the gate pulled the seine

Table 2. Missi Falls sampling schedule including catch, mark, temperatures and discharge.

Sampling date	Number of days	Water temperature (deg C)	Discharge (m3/sec)	Number of whitefish caught once	Mark
June 8-10, 1986	3	3.0	520.28	306	adipose fin clip
July 1-6, 1986	6	9.0	923.02	543	dorsal fin clip
Aug 7-9, 1986	3	15.0	542.28	525	left pelvic fin clip
Sept 2-5, 1986	4	11.5	92.59	2444	left pectoral fin clip
Sept 27-30, 1986	4	-	14.16	1518	right pectoral fin clip
June 5-10, 1987	5	6.0	14.16	3079	dorsal fin hole punch
July 4-8, 1987	4	15.0	14.16	2330	anal fin hole punch
Aug 6-10, 1987	5	16.0	14.16	1696	left pelvic fin hole punch
Sept 10-13, 1987	4	11.0	14.16	936	right pelvic fin hole punch

net back to the gate. During periods of low flow, conditions were calm enough to permit the use of an inflatable motor boat to pull out the seine net.

Fish were marked from the lower accessible platform on the gate. Once the seine was hauled in, its central pocket was left in the water and fish were removed four or five at a time with a dip net. Fish were batch marked at each sample time with a mark unique to the sample period (Table 2). In 1986, fish were fin clipped by clipping the last few fin rays with scissors. In 1987, a one-hole paper punch was used to punch a hole through the middle fin ray and surrounding tissue. Holes remained for one to two months and after that time, scar tissue allowed recognition of the mark. Observations such as the presence of abrasions and scars, spawning condition and external parasites were recorded as fish were marked. The presence and location of previous marks were also recorded. Samples of 50 fish were taken at each sample time. They were frozen immediately, then shipped to Winnipeg where they were stored frozen until examined.

Fish were also sampled from locations upstream and downstream of Missi Falls using gill nets. Upstream samples were taken from SIL in Area 4, close to Missi Falls and from SIL near Strawberry Island (Figure 1). Downstream sample sites were Partridge Breast, Northern Indian, Fidler and Gauer lakes (Figure 1). A sample was also obtained 300 meters downstream of the dam using a beach seine, from both the north and south bank.

C. LABORATORY TECHNIQUES

1. Morphometric Measurements

Twenty-one morphometric measurements were taken on each fish. Measurements were taken on the left side of the fish, where possible. Measurements were straight line and did not follow the body contour. The morphometric measurements described below were taken using a measuring board graduated to one millimeter or, where possible, with digital calipers graduated to 0.1 millimeter.

Standard Length	after Lindsey (1962)
Fork Length	after Hubbs and Lagler (1964)
Preorbital Length	after Lindsey (1963)
Orbital Diameter	after Hubbs and Lagler (1964)
Postorbital Length	after Hubbs and Lagler (1964)
Trunk Length	after Casselman et al (1986)
Dorsal Fin-Base Length	after Hubbs and Lagler (1964)
Lumbar Length	after Casselman et al (1986)
Anal Fin Length	after Hubbs and Lagler (1964)
Caudal Peduncle Length	after Hubbs and Lagler (1964)
Head Depth	after Hubbs and Lagler (1964)
Body Depth	after Hubbs and Lagler (1964)
Caudal Peduncle Depth	after Hubbs and Lagler (1964)
Interorbital Width	after Hubbs and Lagler (1964)
Upper Jaw Length	after Hubbs and Lagler (1964)

Upper Jaw width	after Hubbs and Lagler (1964)
Pectoral Fin Length	after Lindsey (1962)
Pelvic Fin Length	after Hubbs and Lagler (1964)
Adipose Fin Length	after Lindsey (1962)
Middle Gill-Raker Length	after Lindsey (1962)
Lower Gill-Arch Length	after Bodaly (1977)

2. Meristic Counts

Nine meristic counts were taken on each whitefish . Counts were made with the naked eye, on the left side of the specimen, where possible.

Lateral Line Scale Count	after Hubbs and Lagler (1964)
Supra-Pelvic Scale Count	after Hubbs and Lagler (1964)
Scales below Lateral Line	after Hubbs and Lagler (1964)
Dorsal Fin-Ray Count	after Hubbs and Lagler (1964)
Anal Fin-Ray Count	after Hubbs and Lagler (1964)
Pectoral Fin-Ray Count	after Hubbs and Lagler (1964)
Pelvic Fin-Ray Count	after Hubbs and Lagler (1964)
Upper Gill-Raker Count	after Kristofferson (1978)
Lower Gill-Raker Count	after Kristofferson (1978)

3. Biological Parameters

Round weight, liver weight and gonad weight were determined for individual fish. Weights were determined to the nearest 0.1 gram. The digestive tract was removed and indices of fullness were estimated for esophagus, stomach and intestine (as in Barnes, 1981). Condition factors (CF) were calculated as follows:

$$CF = \text{whole weight(g)} \times 10^5 / \text{length}(cm^3).$$

Liver somatic indices (LSI) and gonad somatic indices (GSI) were also calculated as in Barnes(1981) as follows:

LSI = liver weight(g) x 100 / [total weight-(liver weight + gonad weight)]

GSI = gonad weight x 100 / [total weight-(liver weight + gonad weight)]

4. Environmental Parameters

Monthly discharges over the Missi Falls control structure were obtained from Manitoba Hydro. Temperatures were recorded monthly at Missi and at gill net sample locations where possible. Temperature data was supplemented with survey results from Rosenberg & Weins (unpublished data).

D. STATISTICAL ANALYSES

1. Population Estimates

The population estimates in this study were obtained from a computer program known as POPAN, developed by Arnason and Baniuk (1978) which utilizes the adaptability of the Jolly-Seber mark-recapture model (Jolly, 1965; Seber, 1965) for an open population of animals. An open population is one in which there is the potential for birth, death, emigration and immigration to occur, and seemed to be well suited to the Missi Falls study. Seber (1982) gives a good overview of the method, which can estimate population size, survival rate of the fish and the number of fish that have joined the population.

Arnason and Baniuk (1980) mention that Manly (1969) modified the model to allow for heterogeneity in survival rates, and that precision can be estimated (Jolly, 1965), and poor precision and sample bias anticipated. Research has uncovered the usefulness and adaptability of the model, and it is one of the preferred techniques in mark-recapture analyses.

Ideally, POPAN requires that each fish is given a unique tag which makes it recognizable from all other fish so that its capture history can be recorded. The mutilation tags which were used did not allow for unique tagging, such as in numbered Floy tags; rather, samples were batch marked, with all of the fish caught in one sample period being given the same mark. Since fish were batch marked with a unique mark for each sample period, the capture histories were still identifiable and POPAN could generate the required estimates. Capture history data was entered in the form of a binary number matrix, and the data could be edited and added to as more samples were taken.

The "full-model" analysis was selected, since fish were thought to be entering and leaving the population over the season. The final run of the program, after the second field season was completed, involved pooling data from the first three months in 1986 with the GROUPING option. This improved the precision of the September 1986 and 1987 results, although information regarding individual sample times within the summer of 1986 was lost. Final results were based on the pooled data, but supplemented with unpooled results from the summer of 1986.

Prior to the first sample trip, POPAN (Arnason and Baniuk, 1978) was used to generate sample histories by simulating a population with user-specified size, "births and deaths", sampling intensity and number of samples. The simulation was beneficial in several regards: with estimates as close to expected results as possible, the effort required to satisfy the assumptions of the model, minimize bias due to violations of assumptions and maintain an acceptable level of precision could be examined. The simulation can be run using several pre-set estimates such as population sizes, survival rates and births, to illustrate the required sample sizes to achieve acceptable estimates of precision. Precision is measured by the coefficient of variation (CV) of the estimate, where:

CV = (100 x standard error of estimate) / estimate.

A coefficient of variation of 20% or less is considered acceptable unless the experimenter needs only rough estimates of the population parameters (Arnason et al, 1982).

The program can also be used to deliberately violate the assumptions of the Jolly-Seber model. The program can make the survival rates heterogenous or dependent on the capture history or age of the animal. The effects of tag loss and temporary emigration were tested, and a pre-simulation report on the rates and mechanisms chosen was produced, as well as and a post-simulation report on the actual behaviour of the total population sizes at each simulated sample time. By comparing the pre- and post-simulation estimates, the degree of bias introduced into the estimates by violating assumptions of known degree and type can be analyzed (Arnason and Baniuk, 1980). The pre-sampling manipulations using estimates of the actual situation were valuable in that they gave the seining crew a target sample size to aim for during each sample period, which would yield acceptable estimates of population parameters. After each sample period, numbers of fish caught and numbers of each tag type seen (capture history) were input to the POPAN program using the ADD paragraph to generate estimates, population size, survival rates and births in the group of fish immediately downstream of the Missi Falls control structure.

2. Morphological Comparisons

Morphometric and meristic character states (Appendix B, Tables 1 and 2) taken from specimens caught in two areas in SIL, at Missi Falls, downstream of the Coffer Dam and in Partridge Breast, North Indian, Fidler and Gauer lakes were compared among locations using multivariate statistics. The body depth variable was omitted from the multivariate comparisons since it was determined that the Missi Falls fish were significantly thinner ($P < 0.0001$) than those from all other locations. The potential for some samples to contain fish of different sizes could have yielded useful information regarding group comparisons. However, both gill-netting and seining techniques were used to sample fish and the potential for sampling bias was present. Therefore a method of suppressing the size differences due to sampling bias was required.

To suppress potential allometric variation (Gould, 1966) between and within groups, the morphometric data were transformed into residuals by adjusting for the size covariate, using a pooled-within group regression slope (Thorpe, 1975). An analysis of covariance using the complete set of data (Appendix B, Table 3), revealed that there were non-parallel regression slopes and different intercepts for certain variables. Therefore, the various groups were adjusted to a common within-groups slope, which overcomes such heterogeneity of the within groups relationships (Thorpe 1975; Reist, 1985). Reist (1984) evaluated an array of univariate techniques that adjust for size variation in morphometric data. He concluded that the use of a regression technique (computation of residuals from a standard size axis) and adjustment to a standard size, allowed for the complete removal of size variation, while minimizing effects. As a comparison, separate analyses were performed on body measurements expressed as ratios of standard length. Meristic variables were left in an unadjusted "raw" state.

Meristic and the transformed morphometric data were combined for all analyses. When the combination included the residual-adjusted morphometric data, the data set is referred to as the residual-adjusted data; when the combination included the ratio-adjusted morphometric data, the data set is referred to as the ratio-adjusted data. Results based on residual-adjusted data were compared with those based on data using the ratio-adjusted variables. Analyses of morphological heterogeneity were undertaken among samples taken at different times at Missi Falls. This temporal examination of samples from a single location was also used to study samples from other locations where pooling of samples over time was contemplated. Attempts were also made to determine whether morhological differences were due to spatial diferences and not merely temporal changes occurring within a single population.

These analyses included discriminant functions analyses, the results of which are presented in summary of reclassification tables (as explained in Appendix A). Results from canonical discriminant functions analyses and principal components analyses were presented as graphical comparisons of the groups.

Unfortunately, the samples obtained from the various locations were obtained at different time periods. Some of the upstream samples were obtained in June of 1986, whereas some of the downstream samples were obtained in October of 1987 (Table 3). It was therefore important to establish that an differences in morphology among locations were due to spatial differences rather than some seasonal changes in morphology within a single population. Therefore, attempts were made to analyse the temporal differences among locations, including Missi Falls.

Northern Indian and Partridge Breast lakes were sampled on two occasions in the autumn, only weeks apart (Table 3). No temporal differences were expected and the subsamples from each lake were pooled. Coffer dam samples were also obtained only weeks apart in the late summer and autumn of 1986 (Table 3), and were therefore also pooled. Only one sample was obtained from the Strawberry Island location, in June, 1986 and was therefore temporally distinct from most downstream samples. Conclusions based on this sample were therefore made with caution.

Because of modest sampling effort, several sampling periods were required to obtain a sufficient sample of fish from Area 4 (Table 3). An analysis of morphological heterogeneity was also undertaken among samples obtained at this location at the various sample times. Techniques involved the discriminant functions analyses and canonical discriminant functions analyses.

In order to determine the origin of the Missi Falls fish it was assumed that they came from one of the various locations sampled during the study period. A discriminant function was constructed from samples taken at all locations except Missi Falls, in order to classify fish caught at Missi Falls as to their likely area of origin. Each sample month at Missi Falls was classified separately to uncover

Table 3. Number of whitefish from each site from which morphometric and meristic data were obtained.

Site	1986					1987					
	Jun	Jul	Aug	Sep	Total	Jun	Jul	Aug	Sep	Oct	Total
S.I.L. Area 4	-	-	17	6	23	5	2	15	-	-	20
S.I.L. Strawberry I.	50	-	-	-	50	-	-	-	-	-	0
Coffer dam	-	-	11	28	39	-	-	-	-	-	0
Missi Falls	46	50	23	24	143	50	65	36	50	-	201
Partridge Breast L.	-	-	-	-	0	-	-	-	6	60	66
Northern Indian L.	-	-	-	-	0	-	-	-	23	22	45
Fidler L.	-	-	-	-	0	-	-	-	14	-	14
Gauer L.	-	-	-	-	0	-	-	-	33	-	33

potential changes in origin during the study period. This technique was also used in the construction of canonical variates, which allowed a graphical representation of results. A principal components analysis, using all samples (including the Missi Falls example) was used to verify conclusions based on the other methods. Univariate t-tests were used to examine the spatial separation of plots of group means. An explanation of all of the statistical techniques used is outlined in Appendix A.

3.0 Biological Parameters

Comparisons were made of biological data gathered from lake whitefish caught at each of the sample months at Missi Falls. Univariate t-tests were used to compare mean values among sample times at Missi Falls. Plots were made of gonad and liver somatic indices, and condition factors, as in Barnes (1981). Histograms of frequencies were also constructed as in Barnes (1981) and compared for digestive tract indices of fullness. All biological parameters were calculated separately for males and females to examine potential differences due to sexual dimorphism. If differences occurred, results for each sex were analyzed separately; where no differences occurred, results were based on the combined data.

III. RESULTS

A. POPULATION ESTIMATES

Lake whitefish dominated the catch at Missi Falls at nearly all sample times (Table 4). They comprised 60 to 70% of the total catch at Missi Falls in each sample period. Other abundant species included northern pike (Esox lucius), longnose sucker (Catostomous catostomus) and walleye (Stizostedion vitreum). Cisco (Coregonus artedii), white sucker (Catostomus commersoni), burbot (Lota lota), lake trout (Salvelinus namaycush) and goldeye (Hiodon alosoides) were also caught occasionally, as well as two species of shiners and a nine-spined stickleback (Pungitius pungitius).

Sample sizes of whitefish collected below the Missi Falls dam were large enough to allow precise population estimates. Large numbers of fish were caught in both study years. The largest number of whitefish (3,235) was caught between June 5 to 10, 1987, and the second largest number (2,444) was caught between September 2 to 5, 1986 (Table 2). The total number of recaptures was also higher in these periods than at other sample periods (Appendix C, Table 1). In 1986, the largest number of recaptures (78) occurred in the late September sample period, the period after the above mentioned September trip when most fish were caught. In 1987, most recaptures occurred in the July period, which followed the June sample period where the largest number of fish were caught. In 1987, both the number of fish

Table 4. Catches for all species from the Missi Falls control structure, 1986-87. (Numbers in parentheses represent percent of total catch).

Species	1986					1987			
	June	July	August	Sept	October	June	July	August	Sept
Lake whitefish	355 (83.7)	598 (82.0)	610 (-)	2,799 (68.5)	1,577 (84.8)	3,235 (85.4)	2,529 (67.0)	1,856 (61.6)	943 (89.3)
Longnose sucker	50 (11.8)	43 (5.9)	643 (-)	121 (3.0)	44 (2.4)	343 (9.1)	334 (8.9)	98 (3.3)	25 (2.4)
Northern pike	13 (3.1)	17 (2.3)	- (-)	1 (0.0)	150 (8.1)	162 (4.3)	719 (19.1)	653 (21.7)	52 (4.9)
Cisco	3 (0.7)	10 (1.4)	39 (-)	191 (4.7)	73 (3.9)	25 (0.7)	54 (1.4)	60 (2.0)	9 (0.9)
Common white sucker	0 (0.0)	11 (1.5)	130 (-)	17 (0.4)	9 (0.5)	4 (0.1)	81 (2.2)	104 (3.5)	1 (0.1)
Walleye	1 (0.2)	0 (0.0)	0 (-)	1 (0.0)	0 (0.0)	6 (0.2)	26 (0.7)	110 (3.7)	25 (0.4)
Burbot	1 (0.2)	2 (0.3)	0 (-)	4 (0.4)	3 (0.2)	12 (0.3)	22 (0.6)	25 (0.8)	0 (0.0)
Lake trout	1 (0.2)	2 (0.3)	0 (-)	2 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Spottail shiner	0 (0.0)	11 (1.5)	0 (-)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	5 (0.0)	0 (0.0)
Emerald shiner	0 (0.0)	22 (3.0)	0 (-)	3 (0.1)	0 (0.0)	0 (0.0)	0 (0.0)	100 (3.3)	0 (0.0)
Unknown Y.O.Y. cyprinids	0 (0.0)	13 (1.8)	21 (-)	945 (23.1)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Ninespine stickleback	0 (0.0)	0 (0.0)	0 (-)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.1)
Goldeye	0 (0.0)	0 (0.0)	0 (-)	2 (0.1)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Total	424 (100.0)	729 (100.0)	1,443 (-)	4,086 (100.0)	1,856 (100.0)	3,787 (100.0)	3,765 (100.0)	3,011 (100.0)	1,056 (100.0)

caught and the number of recaptures seen, gradually declined with each trip after July. Attempts were made to keep the number of fishing days per sample trip relatively constant (Table 2). However, with each successive sample trip in the autumn of 1987, the fishing intensity increased dramatically with fewer fish per seine haul. Consequently, a larger number of seine hauls were required to maintain the high numbers of fish needed for good estimates of the population.

As mentioned in the methods section, the POPAN program was used to generate sampling estimates of probabilities of capture, tag retention and emigration. These parameters were examined once again at the end of the 1986 sample season (Appendix D) to check whether sample sizes were sufficient to achieve the desired level of precision.

The probability of mark loss was zero, which was expected due to the nature of the tags. There was immigration over the 1986 season, and the model indicated that this increased as autumn approached. The model indicated that the capture probability was similar over the season, with a slight decrease in August and a decrease in the autumn months. The test of assumptions indicated that no severe violations were occurring. Precision was maintained at an acceptable level for most estimates, particularly those peak abundances of approximately 88,000 fish which had coefficients of variation of approximately 20%. Mark loss was statistically examined and the nature of the mark effectively eliminated mark loss. Fish marked in the first time period of 1986 appeared and were recognized in the last sample period of 1987. Survival rates were, as mentioned earlier, somewhat heterogeneous between periods; however, it was statistically determined that they were within an acceptable level. Capture probabilities were found to be relatively homogeneous throughout the sample periods. Losses on capture were all accounted for and fish were removed from the population if damaged.

Population estimates based on data from both years were almost ten times greater than pre-sampling expectations (Table 5). The estimated numbers of whitefish rose from 13,492 (± 5,744) in July, 1986, to a peak of 88,764 (± 21,415), in the autumn of 1986 (Table 6). Results in 1987 indicated a drop in numbers from 28,867 (±5,640) in June to a low of 10,701 (±1,652) in July and then a rise to 13,454 (±3,242) in August of that year. Pooling of the June, July and August, 1986 results gave better estimates of the population (Appendix C). The population estimates for July and August of 1986 had coefficients of variation greater than the desired level of precision (Table 6). Birth estimates for all of 1986 and for June 1987 also had large coefficients of variation. However all other estimates of the various population parameters were within acceptable levels of precision; especially the estimates of the large population size in the autumn of 1986.

Table 5. Pre-sampling simulation of population statistics (number and standard deviation) using estimates of sample sizes, births and survival rates.

Month	Estimated actual pop'n size	Estimated sample size	Survival		Coeff of variation	Births		Coeff of variation	Estimated pop'n		Coeff of variation
			rate	s.d.		number	s.d.		size	s.d.	
June	2,000	500	0.50	0.09	18.11	3,000	-	-	2,000	-	-
July	4,000	600	0.50	0.07	14.92	6,000	1,284	21.39	4,000	913	22.82
August	8,000	1,200	0.50	0.05	10.83	10,000	1,649	16.44	8,000	1,417	17.71
September	14,000	2,100	0.50	0.05	9.09	5,000	1,143	22.85	14,000	1,812	12.94
October	12,000	1,800	0.00	0.00	0.00	1,000	-	-	12,000	1,245	10.38
November	7,000	1,750	0.00	0.00	0.00	0	-	-	7,000	-	-

Table 6. Results of Jolly-Seber multiple mark-recapture method (estimate, standard deviation and coefficient of variation) for analysis of the Missi Falls lake whitefish population.

Date	Number of fish tagged	Estimated population size	Estimated population s.d.	Coefficient of variation	Estimated survival rate	Estimated survival s.d.	Coefficient of variation	Births number	Births s.d.	Coefficient of variation
June '86	355	-	-	-	1.0000	0.2753	27.5	-	-	-
July '86	598	13,942	5,744	42.6	0.7660	0.1838	24.0	34,177	19,902	58.2
Aug '86	610	44,818	20,528	45.8	1.0000	0.2102	21.0	43,950	25,213	57.4
Early Sept '86	2,794	88,764	21,415	24.1	1.0000	0.2430	24.3	-	-	-
Late Sept '86	1,577	88,567	23,042	26.0	0.7325	0.1087	23.4	21,528	4,987	23.2
June '87	3,235	28,867	5,640	19.5	0.3244	0.0477	14.7	1,352	1,797	133.0
July '87	2,529	10,701	1,625	15.2	0.2636	0.0616	23.4	10,649	2,673	25.1
Aug '87	1,856	13,454	3,242	24.1	-	-	-	-	-	-
Sept '87	953	-	-	-	-	-	-	-	-	-

The survival rate of the whitefish was much greater in 1986 than in 1987, with the lowest recorded value in 1986 being 0.766 (±0.184). Survival rates in 1987 were as low as 0.264 (±0.062). There were also almost twice as many entries into the population in 1986 than in 1987. These were greatest toward the autumn of 1986, with estimated numbers of 43,960 (±25,213) in August of that year. More fish seemed to arrive in July than in other months of 1987, with entries increasing from 1,352 (±1,797) in June to 10,649 (±2,673) in July.

B. MORPHOLOGICAL COMPARISONS

1. Statistical Examination of the Area 4 Samples.

The Area 4 sample was tested to ensure that pooling of data from several months would result in a relatively homogeneous sample. It was hoped that the two largest samples could be combined (August, 1986 and August, 1987). Comparisons were made among samples caught in Area 4 in different months using discriminant functions analyses and plots of canonical variables. Further comparisons also included the closest (and only other upstream) sample, Strawberry Island.

Discriminant functions analyses of the morphological data set derived from the samples taken in the five sample months from Area 4 suggested that most samples were morphologically distinct from one another. When either residual-adjusted and ratio-adjusted data were used, the summary of reclassification resulted in 100 percent reclassification of each fish into its own sample.

The first two canonical variables accounted for most of the total variation when either types of data were used. When the residual-adjusted data was used for the analysis, the first two canonical variables accounted for 82.0% of the total variation. When the ratio-adjusted data were used for the analysis, the first two canonical variables accounted for 87.5% of the total variation.

Plots of the group means of the first two canonical variables using both the residual-adjusted data (Figure 2) and the ratio-adjusted data (Appendix E, Figure 1) presented similar results. There was no overlap between the standard deviations of any of the samples. The August samples from both study years had the largest mean values for the first canonical variable; however, the August 1987 sample had a significantly larger ($P<0.0001$) mean value for this variable than all other samples when both the residual-adjusted data and the ratio-adjusted data were used. There was no significant difference ($P<0.0001$) between the mean values of these two samples for the second canonical variable when the ratio-adjusted data was used; however, a significant difference ($P<0.0001$) was observed between these two samples when the residual-adjusted data was used. There was also no significant difference ($P<0.0001$) between the mean values of the September, 1986 and the June, 1987 samples for the first canonical variable when both the residual-adjusted data and the ratio-adjusted data were used. Both of these samples had significantly smaller ($P<0.0001$) mean values for this variable than all other samples.

In general, some of the smaller samples, such as the June, 1987 and September, 1986 samples, were often statistically similar. The August samples from both study years often had similar mean values for the first two

Figure 2. Plot of the first and second canonical variables for the Area 4 samples using the residual-adjusted data.

<u>Legend:</u>

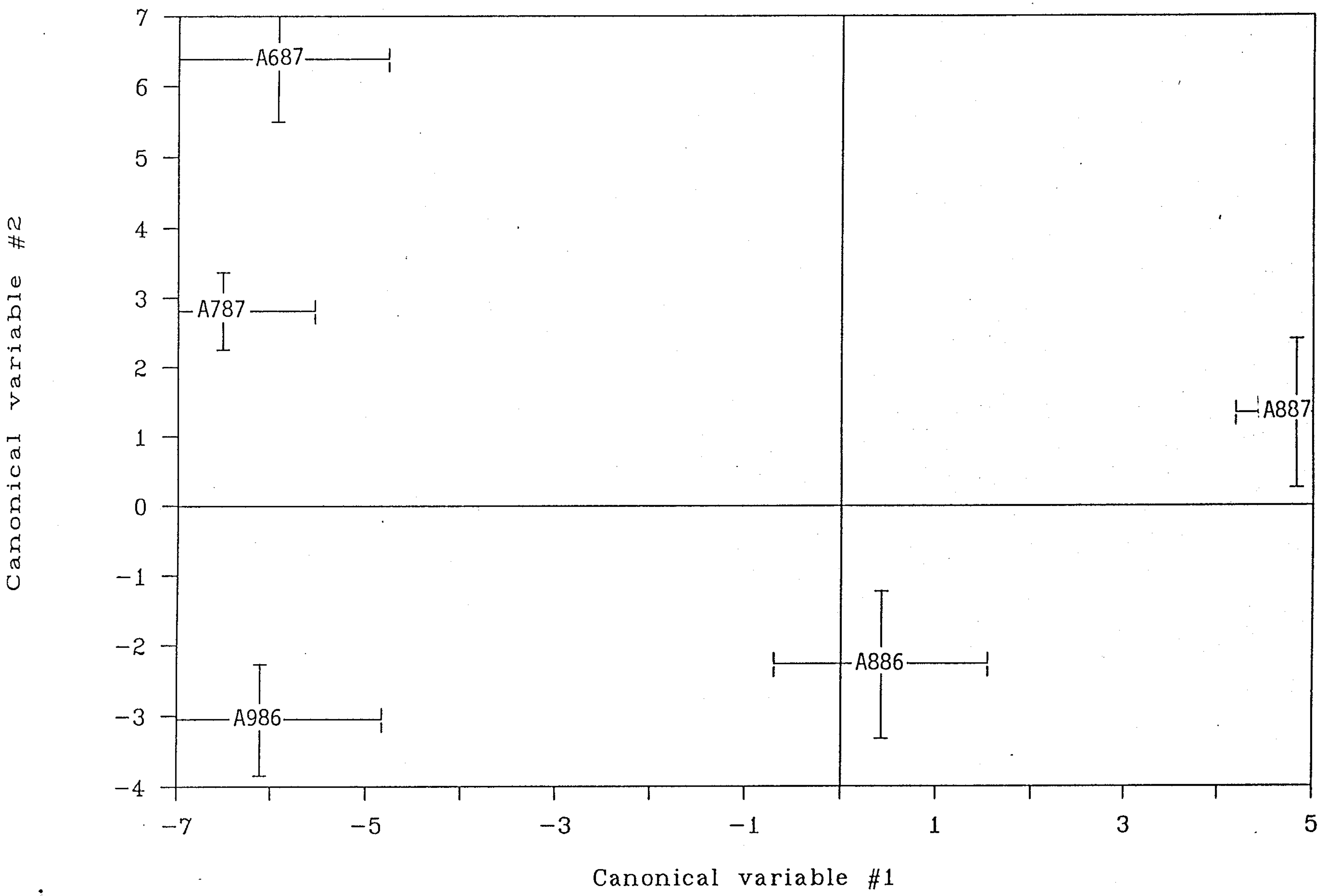
A886 - Area 4, August, 1986 sample.

A986 - Area 4, September, 1986 sample.

A676 - Area 4, June, 1987 sample.

A787 - Area 4, July, 1987 sample.

A887 - Area4, August, 1987 sample.



Canonical variable #2
Canonical variable #1
7
6
5
4
3
2
1
0
−1
−2
−3
−4
−7
−5
−3
−1
1
3
5
A687
A787
A887
A886
A986

canonical variables; however, significant differences between mean values were sometimes observed. Analyses of results indicated that there were no observed trends in Area 4 during the 1986 sampling period which were reflected in the Area 4 samples during the 1987 study period.

When the Strawberry Island sample was included in the analyses, the morphological differences between the two August samples from Area 4 were comparatively less. The discriminant functions analysis summary of reclassification table for both the residual and ratio-adjusted data resulted in one of the August 1987 fish from Area 4 being reclassified into the August 1986 sample. All other fish were reclassified to their own samples.

In a plot of the first two canonical variables, 73.9% of the total variation was acounted for by these two variables when the residual-adjusted data was used. When the ratio-adjusted data was used, the first two canonical variables acounted for 70.4% of the total variation Plots of the group means of the first two canonical variables using the residual-adjusted data (Figure 3) and the ratio-adjusted data (Appendix E, Figure 1) also suggested that the two August samples from Area 4 from each of the study years were morphologically similar. The standard deviations of these two samples overlapped in a plot of the group means of the first and second canonical

Figure 3. Plot of the first and second canonical variables for the upstream samples using the residual-adjusted data.

<u>Legend:</u>

A886 - Area 4, August, 1986 sample.

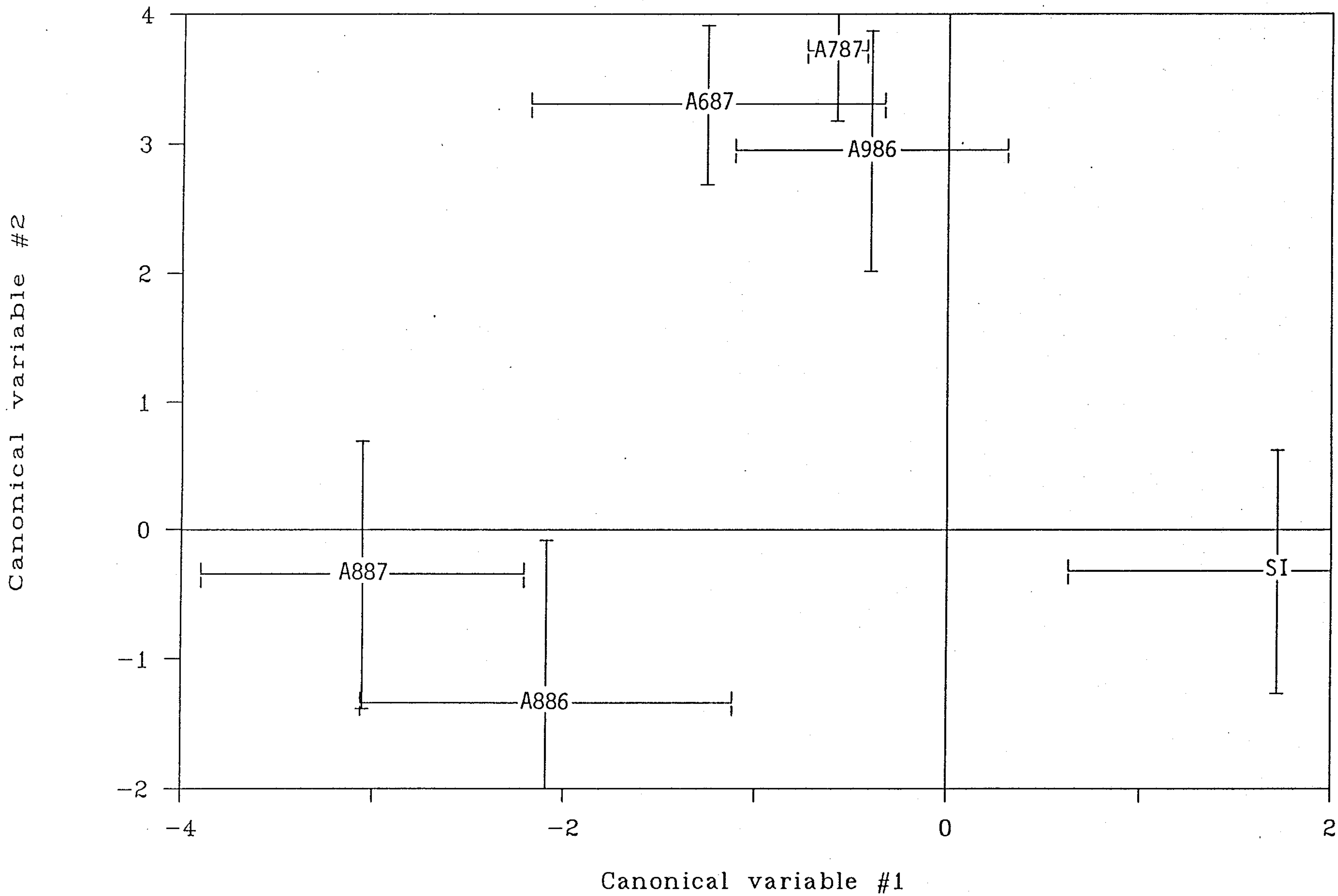
A986 - Area 4, September, 1986 sample.

A687 - Area 4, June, 1987 sample.

A787 - Area 4, July, 1987 sample.

A887 - Area 4, August, 1987 sample.

SI - Strawberry Island, June 1986 sample.



Canonical variable #2
Canonical variable #1
4
3
2
1
0
−1
−2
−4
−2
0
2
A787
A687
A986
A887
A886
SI

variables (Figure 3) and there was no significant difference ($P<0.0001$) between the group means of the two August samples for either the first or second canonical variable, with both the residual-adjusted and the ratio-adjusted data. The August, 1986 and August, 1987 samples from Area 4 had significantly smaller ($P<0.0001$) mean values for these variables than all other samples.

The Strawberry Island sample from June, 1986 had a significantly larger ($P<0.0001$) mean value for the first canonical variable than all other samples when the residual-adjusted data was used. There were no significant differences ($P<0.0001$) among the group means of the September, 1986, June, 1987 and July, 1987 samples from Area 4 when the first canonical variable was examined using the residual-adjusted data. There were no significant differences ($P<0.0001$) among the mean values of the Strawberry Island sample and the September, 1986, June, 1987 and July, 1987 samples from Area 4 for the first canonical variable using the ratio-adjusted data and for the second canonical variable using the residual-adjusted data. The September, 1986 sample from Area 4 had a significantly smaller ($P<0.0001$) mean value from all other samples for the second canonical variable when the ratio-adjusted data was used. In this comparison, there was no significant difference ($P<0.0001$) among group means for all of the other samples.

In general, plots and statistical analyses indicated that when the Strawberry Island sample was included in analyses, there were no significant differences between the August samples of each study year from Area 4. Trends within Area 4 during the 1986 study period did not reflect the changes in morphology which appeared to occur in Area 4 during the 1987 study period.

2. Statistical Examination of the Missi Falls samples.

In general, most analyses suggested that there was a gradual change in the morphology of the Missi Falls lake whitefish, over time. Also, the trends in the morphology of fish at Missi Falls which were observed in 1986 were not observed in 1987; trends over the 1987 study period were actually the inverse of those observed in the 1986 study period. Fish caught at the beginning of the study period, in June and sometimes July, 1986, were somewhat morphologically different to those fish caught in August and September of that year, and bore some resemblance to fish caught in August of 1987. Fish caught in June 1987 and some of those caught in July 1987 still bore some resemblance to the September 1986 fish. However, there appeared to be a gradual change in morphology of the whitefish population over the summer of 1987 at Missi Falls, so that those caught in July and August of 1987 were quite morphologically distinct from fish caught in August and September of 1986. Fish caught in September, 1987 were also morphologically similar to the

August, 1987 fish but bore slight resemblences to the fish caught in September of 1986.

a). Discriminant Functions Analysis

The summary of reclassification results using the residual-adjusted data showed one hundred percent reclassification of each month at Missi Falls to its own month. This suggested that the morphology of fish at Missi Falls was different for each month. When ratio-adjusted data was used (Appendix G, Table 1) results suggested that samples from the various months were not as morphologically distinct. The majority of observations were correctly reclassified for each month; however, the following observations were also noted:

- July, 1986 fish were also reclassified to the June, 1986 and July, 1987 samples
- August, 1986 fish were also reclassified to the September, 1986 sample, but not the August, 1987 sample
- Most of the September, 1986 fish were reclassified to the September, 1986 sample, with small numbers of fish being reclassified to the August, 1986 and September, 1987 samples
- June, 1987 fish were not reclassified to any 1986 sample and successively fewer of these fish were reclassified to the July, August and September, 1987 samples

- July, 1987 fish were reclassified mostly to the July, August and September, 1987 samples
- August, 1987 fish were reclassified mostly to the July, August and September samples of 1987
- September, 1987 fish were not reclassified to the September, 1986 sample but mainly to the September, 1987 sample and the June and July samples of that year.

In general, there were few morphological similarities in between-year comparisons of any given month. There were closer morphological similarities among samples which were obtained in successive months of the same year, such as June and July of 1986 rather than June, 1986 and June, 1987.

b). Canonical discriminant functions analysis

Plots of canonical variables reflected somewhat, results from discriminant functions analysis. When both the residual-adjusted data and the ratio-adjusted data were used in analyses, the first two canonical variables accounted for most of the total variation. When the residual-adjusted data was used, the first two canonical variables accounted for 73.0% of the total variation. When the ratio-adjusted data was used, the first two canonical variables accounted for 68.7% of the total variation.

In a plot of the first two canonical variables using the residual-adjusted data (Figure 4), there was no significant difference ($P<0.0001$) between the mean values of

Figure 4. Plot of The first and second canonical variables for the MIssi Falls samples using the residual-adjusted data.

<u>Legend:</u>

M686 - Missi Falls, June, 1986 sample.

M786 - Missi Falls, July, 1986 sample.

M886 - Missi Falls, August, 1986 sample.

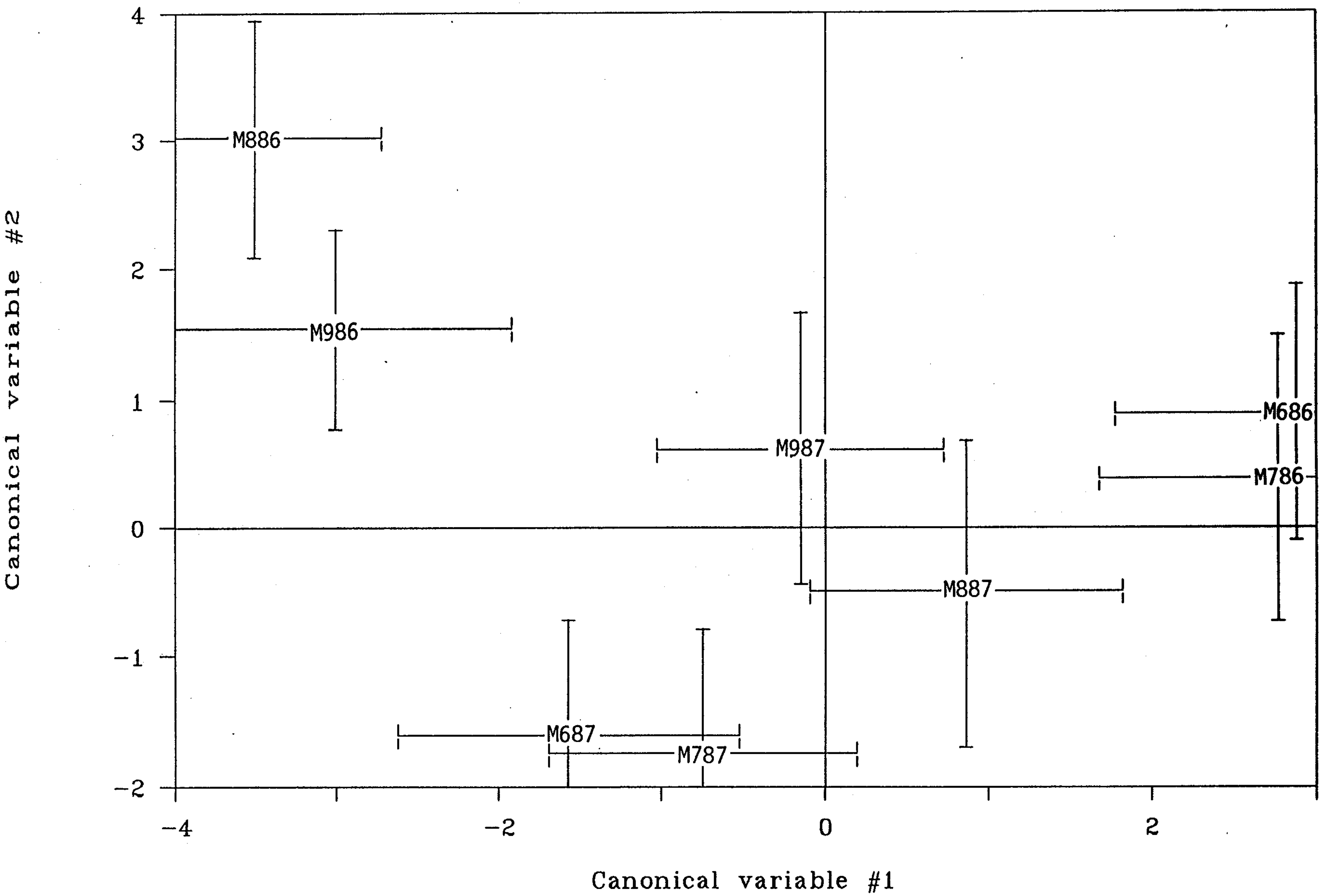
M986 - Missi Falls, September, 1986 sample.

M687 - Missi Falls, June, 1986 sample.

M787 - Missi Falls, July, 1987 sample.

M887 - Missi Falls, August, 1987 sample.

M987 - Missi Falls, September, 1987 sample.



Canonical variable #2
Canonical variable #1
4
3
2
1
0
−1
−2
−4
−2
0
2
M886
M986
M987
M686
M786
M887
M687
M787

the June, 1986 and July, 1986 samples. These two samples had significantly larger (P<0.0001) mean values for the first canonical variable, than all other samples. The August, 1987 and September, 1987 samples had mean values for the first canonical variable which were closest in magnitude to those from the June, 1986 and July, 1986 samples. There was no significant difference (P<0.0001) between the mean values of the August, 1986 sample and the September, 1986 sample for the first canonical variable. The mean values for the August, 1986 and September,1986 samples were significantly smaller (P<0.0001) than all other samples for this variable. There was no significant difference (P<0.0001) between the mean values of the June, 1987 and the July, 1987 samples. These two samples had significantly smaller (P<0.0001) mean values than all other samples for the second canonical variable and mean values for the first canonical variable that were between those for the August, 1986 and September, 1986 samples, and the August, 1987 and September, 1987 samples. The August 1987 sample had significantly different (P<0.0001) mean values from all other samples for both the first and second canonical variable. However, the September, 1987 sample had the next most similar mean value to this sample. The August, 1987 sample had a mean value which was between those for the July, 1987 and September, 1987 samples, for the second canonical variable and a mean value between the September, 1987 sample and the June, 1986 and

July, 1986 samples for the first canonical variable. The September, 1987 sample had a mean value for the first canonical variable that was not significantly different ($P<0.0001$) from that of the June, 1986 and July, 1986 samples and had a mean value for the second canonical variable that was not significantly different ($P<0.0001$) from that of the July, 1987 sample. The mean value for the September, 1987 sample was between the mean value for the August, 1987 sample and the September, 1986 sample for both the first and second canonical variable.

Mean values for any given month in 1986 were significantly different ($P<0.0001$) from the same sample month of 1987 and trends in morphology over the 1986 sample period appeared to be quite diferent from trends in the 1987 sample period.

In a plot of the first and second canonical variables using the ratio-adjusted data (Appendix G, Figure 1), the trends were similar to those observed when the residual-adjusted data was used. The August, 1986 and September, 1986 samples had significantly smaller ($P<0.0001$) mean values from all other samples for both the first and second canonical variables. The mean values of the June, 1986 and the July, 1986 samples appeared to be closer in magnitude to those of the August and September, 1987 samples for the second canonical variable, but were significantly larger ($P<0.0001$) than all other samples for the first canonical variable. The June, 1987, July, 1987 and August, 1987 samples all had mean values that were significantly smaller (P<0.0001) than the July, 1986 and August 1986 samples for the second canonical variable. The September, 1987 sample had a mean value that was between those for the June, 1986 and July, 1986 samples and that for the September, 1986 sample.

c) Principal Components Analysis

In general, although somewhat more obscure, results from plots of principal components analyses reflected those from canonical discriminant functions analyses. The first two principal components accounted for 21.4% of the total variation when the residual-adjusted data was used in analysis. When the ratio-adjusted data was used, the first two principal components accounted for 22.5% of the total variation. Although the first two principal components did not account for most of the variation in the analyses, principal components analyses were used only to substantiate results based on other analyses. Therefore, this was not considered a serious problem.

In a plot of the first and second principal component using the residual-adjusted data (Appendix G, Figure 2), there was no significant difference (P<0.0001) between the mean values of the June, 1986 and the July, 1986 samples. These two samples had significantly smaller (P<0.0001) mean values for the second principal component than all other samples. However, there were no significant differences ($P<0.0001$) among the mean values of all other samples for the second principal component. The August, 1986 and September, 1986 samples had significantly smaller ($P<0.0001$) mean values for the first principal component than all other samples. There was a gradual increase in mean values for the first principal component from the July, 1987 and the June, 1987 samples to the August, 1987 and September, 1987 samples with the June,1986 and July, 1986 samples having larger mean values for the first principal component.

The plot of the first and second principal components using the ratio-adjusted data (Appendix G, Figure 3) also displayed these trends. There were no significant differences ($P<0.0001$) among the mean values of the June, 1986, July, 1986, August, 1987 and September, 1987 samples. There were large differences observed when the mean values of these four samples were compared to that of the September, 1986 sample. The remaining samples had mean values between that of the September, 1986 sample and those of the June, 1986, July, 1986, August, 1987 and September, 1987 samples. The mean value of the September, 1986 sample was most different to that of the August, 1987 sample.

In general, results from principal components analyses confirmed those from canonical discriminant functions analyses. It appeared that there were changes in morphology of the Missi Falls whitefish population over time. The

September, 1986 and August, 1987 samples appeared to be the most morphologically different. The gradual changes in morphology between these two extremes over time, which was observed in other analyses, was also somewhat apparent with principal components results. The different trends over time observed in comparisons of each study season were also apparent in the principal components results.

3. Statistical Comparisons of the Missi Falls Samples with the total data set.

In general, most of the analyses concluded that the Missi Falls fish caught in the autumn of 1986 most resembled the closest upstream samples, whereas the Missi Falls fish caught in the summer of 1987 most resembled the closest downstream samples. Gradual changes between those two extremes over time was also observed. Trends in morphology during the 1986 sampling period were quite different from trends observed in the 1987 sampling period.

a) Discriminant Function Analysis

The examination of the total data set without the Missi Falls samples indicated that fish from upstream and downstream areas were quite morphologically different from one another. However, there were slight morphological similarities between the upstream Strawberry Island sample (obtained in June, 1986) and the downstream Partidge Breast Lake sample (obtained in October, 1987). The differences were most obvious when the residual-adjusted data was used.

Only five downstream fish were reclassified to the Area 4 sample from SIL (Table 7) and no downstream fish were reclassified to the Strawberry Island sample from SIL. A total of only six fish from Area 4 were reclassified to the downstream samples (from Partridge Breast and Fidler lakes) and only five fish from the Strawberry Island sample were reclassified to downstream samples (Partridge Breast). Most samples had a very high percentage of correct reclassifications. The use of ratio-adjusted data confirmed these results (Appendix H, Table 1).

Samples from each month from the Missi Falls data were then reclassified into the total (Missi-free) data set. Since the various study months at Missi Falls were kept separate, temporal trends at Missi Falls were uncovered.

When the residual-adjusted data set was used, most of the June, 1986 and July, 1986 fish from Missi Falls were reclassified into the Partridge Breast Lake sample, with some fish from these months being reclassified into the Gauer Lake sample, and only a small number being reclassified into the Area 4 sample (Table 8). Fewer Missi Falls fish from the August and September samples of 1986 were reclassified to the Partridge Breast sample than in the earlier months of that year. Only two fish from the September, 1986 sample from Missi Falls were reclassified to the Partridge Breast Lake sample. The vast majority of the September, 1986 Missi Falls fish were reclassified to the

Table 7. Summary of reclassification table examining total (Missi-free) data set using the residual-adjusted data. Values are number (and percentage) of observations classified into sample.

Sampling site	Partridge Breast Lake	Northern Indian Lake	Area 4	Fidler Lake	Gauer Lake	Coffer dam	Strawberry Island	Total
Partridge Breast L.	60 (92.3)	1 (1.5)	3 (4.6)	1 (1.5)	0 (0.0)	0 (0.0)	0 (0.0)	65 (100.0)
Northern Indian L.	2 (5.4)	34 (91.9)	0 (0.0)	0 (0.0)	0 (0.0)	1 (2.7)	0 (0.0)	37 (100.0)
Area 4	4 (14.8)	0 (0.0)	21 (77.8)	2 (7.4)	0 (0.0)	0 (0.0)	0 (0.0)	27 (100.0)
Fidler L.	0 (0.0)	0 (0.0)	1 (8.3)	11 (91.7)	0 (0.0)	0 (0.0)	0 (0.0)	12 (100.0)
Gauer L.	0 (0.0)	0 (0.0)	1 (4.8)	0 (0.0)	20 (95.2)	0 (0.0)	0 (0.0)	21 (100.0)
Coffer dam	0 (0.0)	2 (22.2)	0 (0.0)	1 (11.1)	0 (0.0)	6 (66.7)	0 (0.0)	9 (100.0)
Strawberry I.	5 (10.9)	0 (0.0)	1 (2.2)	0 (0.0)	0 (0.0)	0 (0.0)	40 (87.0)	46 (100.0)
Total	71 (32.7)	37 (17.1)	27 (12.4)	15 (6.9)	20 (9.2)	7 (3.2)	40 (18.4)	217 (100.0)

Table 8. Summary of reclassification table of Missi Falls samples into the total (Missi-free) data set using the residual-adjusted data. Values are number (and percentage) of observations classified into sample.

Missi Falls sampling period	Partridge Breast Lake	Northern Indian Lake	Area 4	Fidler Lake	Gauer Lake	Coffer dam	Strawberry Island	Total
June, 1986	30 (66.7)	0 (0.0)	7 (15.6)	0 (0.0)	8 (17.8)	0 (0.0)	0 (0.0)	45 (100.0)
July, 1986	35 (87.5)	1 (2.5)	2 (5.0)	0 (0.0)	2 (5.0)	0 (0.0)	0 (0.0)	40 (100.0)
Aug, 1986	3 (13.6)	0 (0.0)	15 (68.2)	0 (0.0)	4 (18.2)	0 (0.0)	0 (0.0)	22 (100.0)
Sept, 1986	2 (9.1)	0 (0.0)	16 (72.7)	0 (0.0)	1 (4.6)	0 (0.0)	3 (13.6)	22 (100.0)
June, 1987	16 (30.2)	0 (0.0)	16 (30.2)	0 (0.0)	0 (0.0)	3 (5.7)	18 (34.0)	53 (100.0)
July, 1987	8 (17.0)	0 (0.0)	4 (8.5)	0 (0.0)	0 (0.0)	0 (0.0)	35 (74.5)	47 (100.0)
Aug, 1987	15 (45.5)	0 (0.0)	3 (9.1)	0 (0.0)	3 (9.1)	0 (0.0)	12 (36.4)	33 (100.0)
Sept, 1987	39 (88.6)	1 (2.3)	1 (2.3)	0 (0.0)	2 (4.6)	0 (0.0)	1 (2.3)	44 (100.0)
Total	148 (48.4)	2 (0.7)	64 (20.9)	0 (0.0)	20 (6.5)	3 (1.0)	69 (22.6)	306 (100.0)

Area 4 sample, (almost 73%) with some being reclassified to the Strawberry Island sample.

Use of the ratio-adjusted data set (Appendix 4, Table 2) also resulted in fewer Missi Falls fish from the autumn samples being reclassified to the downstream samples than the spring and summer samples of 1986, and a corresponding increase in reclassification of Missi Falls fish from the autumn, 1986 samples to upstream samples. However, results were somewhat more obscure, with more fluctuations, and more fish from all months were reclassified to the Strawberry Island sample.

Trends in 1987 were apparently almost the inverse of those in 1986 when the residual-adjusted data was used. Most of the June and July, 1987 samples from Missi Falls were reclassified into the upstream samples of Area 4 and Strawberry Island (Table 8). The majority of Missi Falls fish from the August and September samples of that year were reclassified into the downstream Partridge Breast sample, with almost no fish being reclassified to either upstream sample. Use of ratio-adjusted data (Appendix H, Table 2) gave somewhat obscure results but similar trends were observed. There was a gradual increase in reclassification of the Missi Falls fish to the downstream samples over the study period, and a corresponding decrease in reclassification to the upstream samples from the autumn of 1986 to the summer of 1987. However, as with the 1986 results, there were more fluctuations over time and more Missi Falls fish were reclassified to the Strawberry Island sample. An exception to this was the autumn results from both years, which reflected those when the residual-adjusted data was used.

b) Canonical Discriminant Functions Analysis

When the mean values of the Missi Falls samples for the canonical variables were plotted together with the mean values for the other locations, the morphological changes observed over time in the Missi Falls plots were found to relate to similarities between upstream or downstream samples. The first two canonical variables accounted for most of the total variation when either the residual-adjusted data or the ratio-adjusted data were used in analyses. when the residual adjusted data was used, the first two canonical variables accounted for 70.2% of the total variation. When the ratio-adjusted data was used, the first two canonical variables accounted for 78.2% of the total variation.

In most comparisons, mean values for upstream samples were significantly different ($P<0.0001$) from mean values for near-downstream samples. Downstream samples sometimes had mean values which were not significantly different ($P<0.0001$) from the upstream samples. Although this violated an assumption that upstream and downstream samples were significantly different, these downstream samples were consistently significantly different from all upstream samples for at least one of the canonical variables in all comparisons. Therefore, this was not considered to be a serious violation.

In a plot of the group means for first and second canonical variables using the residual-adjusted data (Figure 5) the upstream Strawberry Island sample had a mean value which was significantly smaller ($P<0.0001$) than those of all other samples for the first canonical variable. The mean value for the upstream Area 4 sample was significantly different ($P<0.0001$) from that of the downstream Northern Indian Lake sample for both the first and second canonical variable and significantly smaller ($P<0.0001$) than the downstream Partridge Breast Lake sample for the second canonical variable. The Gauer Lake sample had a mean value which was significantly different ($P<0.0001$) from all other samples for both the first and second canonical variable. The Fidler Lake sample had a mean value which was significantly smaller ($P<0.0001$) than all other samples for the second canonical variable.

The groupings of pairs of sample months based on overlapping standard deviations and statistical comparisons, which were present in the plots of the Missi Falls samples (Section 2b) were also noted in plots using the total data set. As in the Missi Falls analyses, trends observed at Missi Falls over time in the 1986 results were quite

Figure 5. Plot of the first and second canonical variables for the total data set using the residual-adjusted data.

Legend:

M686 - Missi Falls, June, 1986 sample.

M786 - Missi Falls, July, 1986 sample.

M886 - Missi Falls, August, 1986 sample.

M986 - Missi Falls, September, 1986 sample.

M687 - Missi Falls, June, 1987 sample.

M787 - Missi Falls, July, 1987 sample.

M887 - Missi Falls, August, 1987 sample.

SI - Strawberry Island sample from SIL.

A4 - Area 4 sample from SIL.

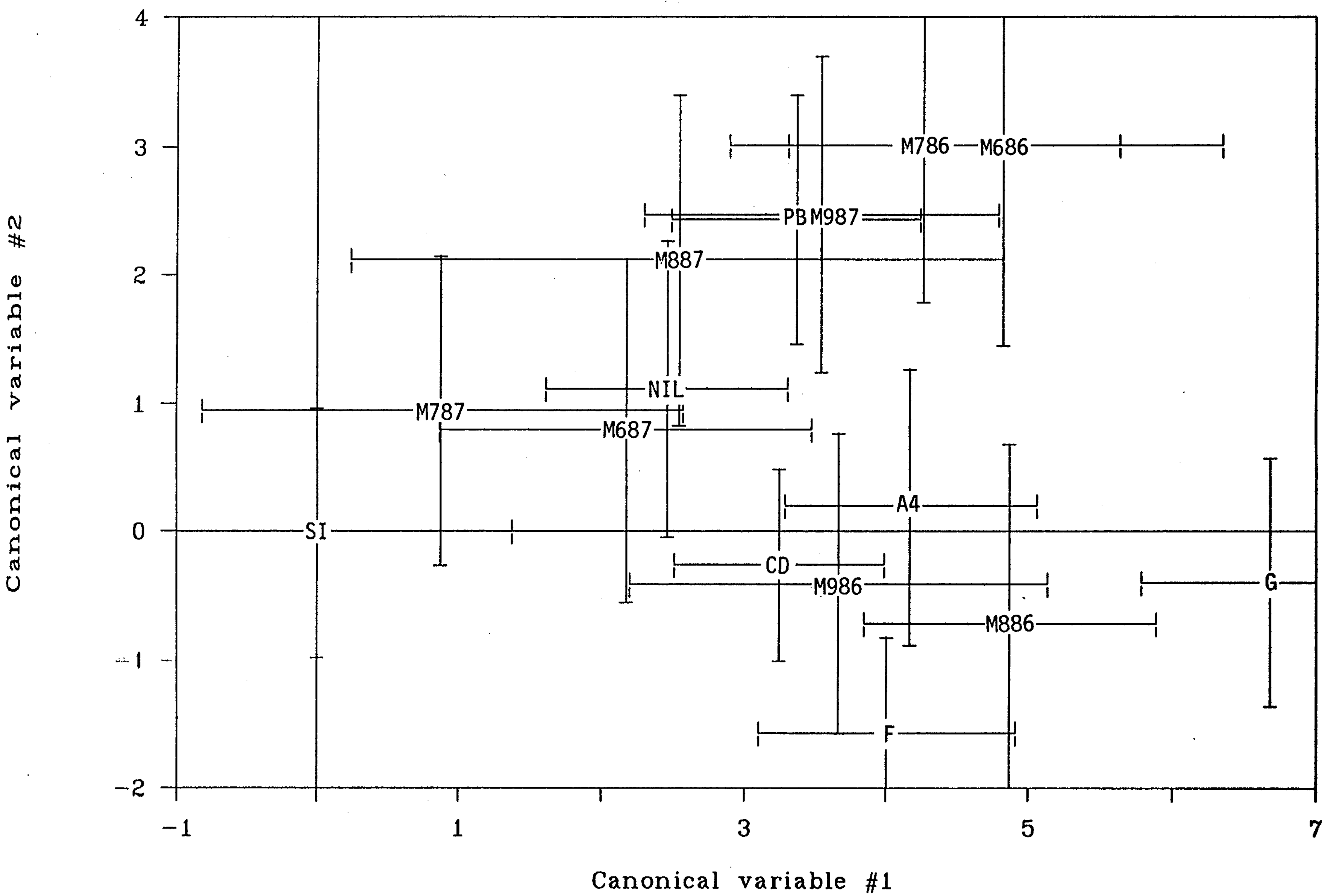
CD - Coffer dam sample.

PB - Partridge Breast Lake sample.

NIL - Northern Indian Lake sample.

F - Fidler Lake sample.

G - Gauer Lake sample.



Canonical variable #2
Canonical variable #1
4
3
2
1
0
−1
−2
−1
1
3
5
7
M786
M686
PB
M987
M887
NIL
M787
M687
A4
SI
CD
M986
G
M886
F

different from those observed in 1987 results.

There were no significant differences (P<0.0001) among the mean values of the Missi Falls samples from June, 1986 and July, 1986 and those for the Area 4 and Coffer dam samples for the first canonical variable. However, mean values for these two Missi Falls samples were not significantly different (P<0.0001) from those of the Partridge Breast Lake sample and the Missi Falls sample from September, 1987, for the second canonical variable. There were no significant differences (P<0.0001) among the mean values of the Missi Falls samples from August and September of 1986 and those for the Coffer dam and Area 4 samples, for the first canonical variable. There was no significant difference (P<0.0001) among the mean values of these two samples from Missi Falls and those from the Coffer dam, Area 4 and Strawberry Island samples for the second canonical variable. There were no significant differences (P<0.0001) among the mean values of the Missi Falls sample from June, 1987, the Northern Indian Lake sample and the Missi Falls samples from August 1987, for the first canonical variable. However the standard deviations of the Missi Falls samples from June, 1987 and July, 1987 overlapped the Northern Indian Lake sample and also the Area 4, Coffer dam and Missi Falls samples from September, 1986 for the second canonical variable. There were no significant differences (P<0.0001) among the mean values of the Missi Falls samples from

August, 1987 , September, 1987 and from the Partridge Breast Lake sample for the second canonical variable. The Missi Falls samples from June, 1986 and July, 1986 also had mean values for the second canonical variable which were not significantly different (P<0.0001) from those of the Partridge Breast Lake samples and the Missi Falls samples from September, 1987 and August, 1987.

Plots of the first two canonical variables using the ratio-adjusted data (Appendix M, figure 1) gave results which were somewhat more obscure than those from the residual adjusted data. Other than the Coffer dam sample, most downstream samples were, in general, significantly different (P<0.0001) from the upstream samples for the second canonical variable. The mean value of the Partridge Breast Lake sample was not significantly different (P<0.0001) from the mean value of the Missi Falls sample from August 1987 for both the first and second canonical variable. These two samples had significantly larger (P<0.0001) mean values than all other samples for the second canonical variable. The Area 4 sample had a mean value which was not significantly different (P<0.0001) from the mean value of the Missi Falls samples from August, 1986 and September, 1986 for the first and second canonical variable. The Gauer Lake sample had a significantly larger (P<0.0001) mean value than all other samples, for the first canonical variable. There were no other obvious trends in results.

In general, results based on canonical discriminant functions analysis were not quite as clear as those from discriminant functions analysis. However, significant differences were usually established between upstream and downstream samples. In some comparisons, the Gauer Lake and Fidler Lake samples were not significantly different from upstream samples for one canonical variable, but were usually significant for the other canonical variable. The apparent changes in morphology of the Missi Falls samples over time reflected similarities to either upstream or downstream samples. In most analyses, the August, 1986 and September, 1986 samples from Missi Falls had mean values which were similar to those of the Area 4 sample. In most analyses, the August, 1987 sample from Missi Falls had a mean value which was similar to that of the Partridge Breast Lake sample. Many of the plots indicated that there were gradual changes in the morphology of the Missi Falls population, from resembling downstream fish in June and July of 1986, to resembling upstream fish in August and September of 1986 and then a gradual shift over June and July of 1987 to fish in August, 1987 and September, 1987 which resembled downstream fish. Trends observed at Missi Falls in 1986 results were quite different to those observed in 1987 results, with trends in morphology over time in 1986 being virualy the inverse of those in 1987.

c) Principal Components Analysis

The principal components analyses were not constructed in the same way as the canonical discriminant functions analyses in that samples from all locations (including the Missi Falls samples) were analyzed simultaneously. The discriminant function was constructed from a data set which did not contain the Missi Falls samples. The results based on principal components analyses were not as clear as those based on the canonical discriminant functions analyses. There was less separation between group means when the principal components analyses were used.

There was a very gradual increase in the total amount of variation accounted for as each principal component was included. At least 10 components were required to account for a substantial portion of the total variation. However, since this analysis was used only to substantiate results from other analyses, only the first two principal components were examined. These accounted for 20.9% of the total variation when the residual-adjusted data was used and 23.0% of the total variation when the ratio-adjusted data was used.

In some plots, the mean values of upstream and downstream samples were not significantly ($P<0.0001$) different. However, some of the trends observed in other analyses were apparent in principal components analyses. In plots of the first two principal components using both the residual-adjusted data (Appendix H, Figure 2) and the ratio-adjusted data (Appendix H, Figure 3), there were no significant differences (P<0.0001) among the mean values of the Partridge Breast Lake sample and those for the Missi Falls samples from August, 1987 and September, 1987 and June, 1986 and July, 1986 for the first principal component. The Missi Falls samples from August, 1986 and September, 1986 had mean values which were not significantly different (P<0.0001) from the mean value of the Area 4 sample, for the first principal component when the residual-adjusted data was used. The mean values for the Missi Falls samples from June, 1987 and July, 1987 were between those of the Area 4, Partridge Breast Lake, and Strawberry Island samples for both the first and second principal component when the residual-adjusted data was used.

In general, results from principal components analyses indicated that there were morphological similarities between the Missi Falls samples from the autumn of 1986 and the upstream Area 4 sample, and morphological similarities between the Missi Falls samples from the summer of 1987 and the near-downstream samples. There were no noticable similarities in morphological trends in between-years comparisons. However, as previously mentioned, the trends were somewhat obscure.

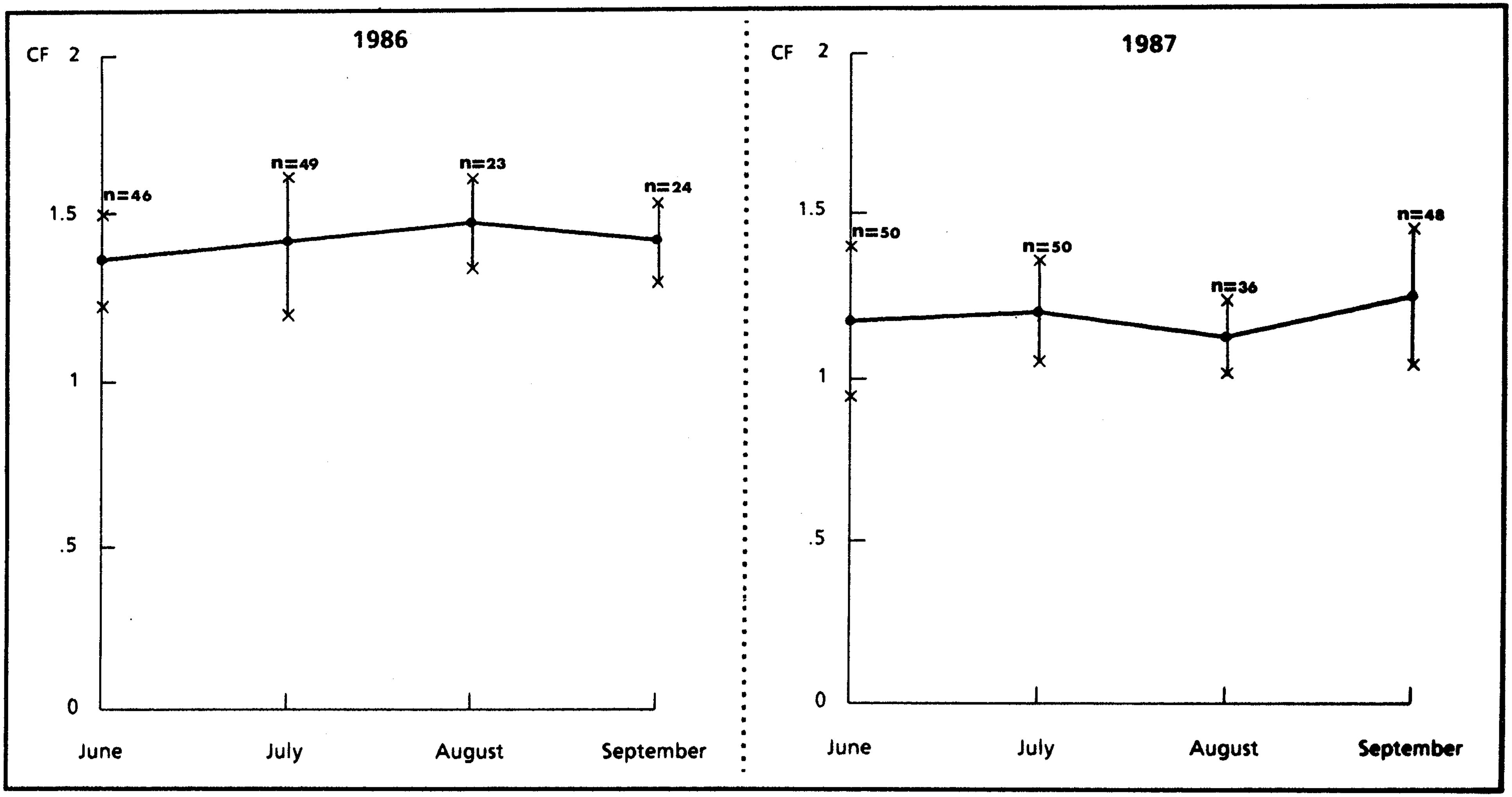
C. BIOLOGICAL EXAMINATIONS OF MISSI FALLS FISH

In general, Missi Falls fish caught in 1986 were healthier than those caught at Missi Falls in 1987. The condition of Missi Falls fish improved over the summer of 1986 and was poorest in the summer of 1987. The fish caught in 1986 also had, on average, fuller digestive tracts and larger gonads than did the 1987 samples from Missi Falls, and an increase in liver size in females toward the autumn, which was not observed in fish caught in 1987.

1. Condition Factor

The fish caught in 1986 were in significantly ($P<0.0001$) better condition than fish caught in 1987. Mean condition factors for 1986 were 1.42 $g.cm^{-3}$ while the 1987 value was only 1.19 $g.cm^{-3}$. Condition factors increased from 1.37 ($\pm$0.13) to 1.47 ($\pm$0.14) $g.cm^{-3}$ over the spring and summer of 1986, with the August fish being in the best condition (Figure 6). The fish caught in the autumn of 1986 were in slightly poorer condition than fish caught in other months of that year and had a condition factor of 1.42 ($\pm$0.12) $g.cm^{-3}$. The 1987 results were virtually the inverse of those for 1986. Condition factors in 1987 decreased from 1.17 ($\pm$0.23) $g.cm^{-3}$ to a low of 1.13 ($\pm$0.02) $g.cm^{-3}$ in August of that year, with an increase in the autumn to 1.24 ($\pm$0.201) $g.cm^{-3}$. Results for male and female fish were also compared (Appendix I) and found to be too similar to warrant separate discussion.

Figure 6. Monthly condition factors ($g.cm^{-3}$) for lake whitefish caught at the Missi Falls control structure: June 1986 to September 1987. (Vertical bars represent $\pm$ 1 standard deviations about the mean).

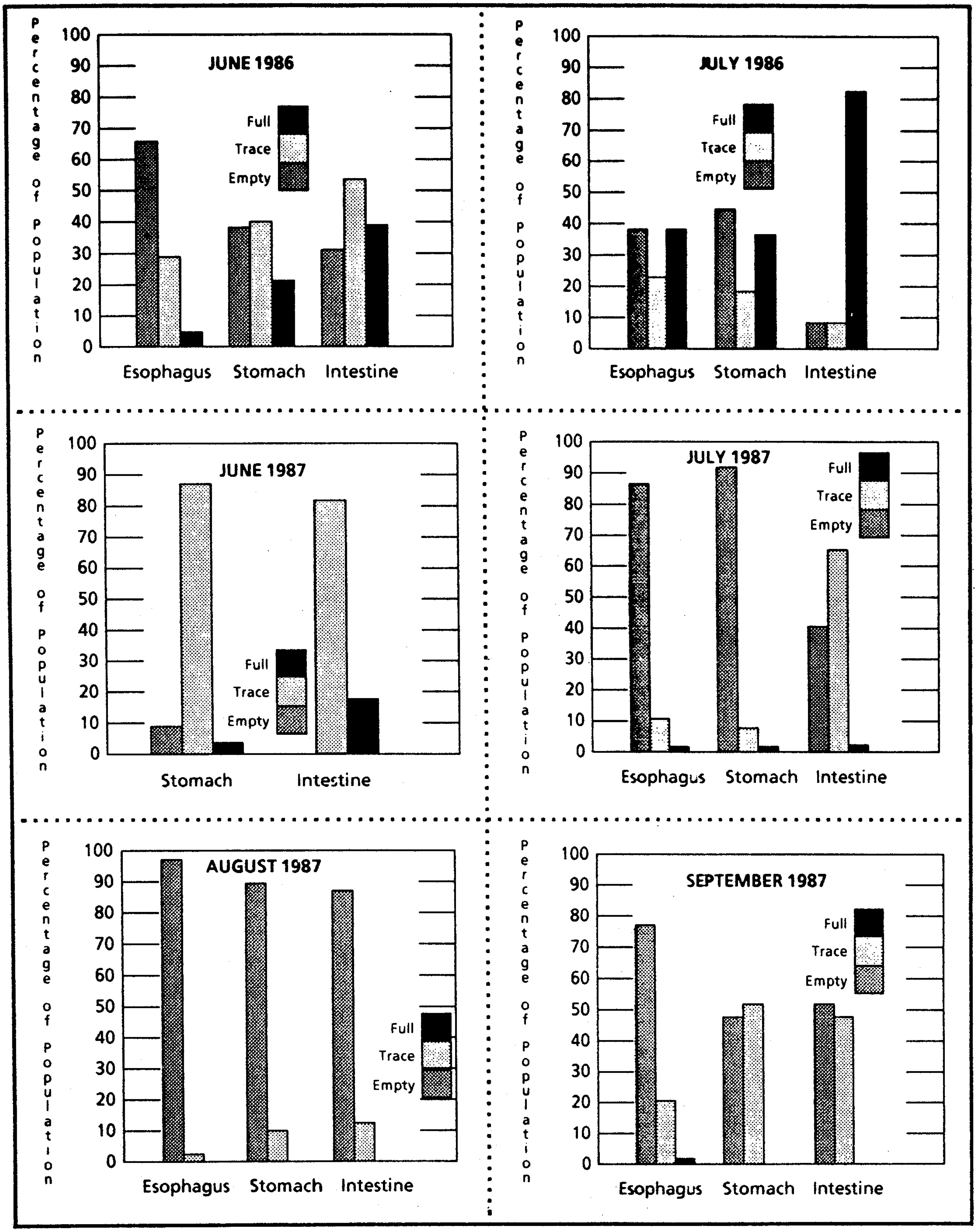

1986
CF
2
1.5
1
.5
0
n=46
n=49
n=23
n=24
June
July
August
September
1987
CF
2
1.5
1
.5
0
n=50
n=50
n=36
n=48
June
July
August
September

2. Digestive Tract Fullness

Although a complete data set for 1986 was not available, fish clearly had more food in their digestive tracts in 1986 compared to 1987 (Figure 7). The esophagus and intestine levels were significantly higher ($P<0.0001$) in fish caught in July of 1986 and these fish and had fuller digestive tracts than those caught in 1987. Contents of the digestive tracts of Missi Falls fish increased from June to July of 1986, with more fish having a full, rather than an empty esophagus, stomach and intestine. The most dramatic increase was in intestine fullness over this time period.

Digestive tract fullness decreased over the 1987 sampling period, with a slight increase in fish caught in September 1987 as compared to fish caught in previous months of that year. There was a large decrease in the number of fish having trace amounts of food in their digestive tract and a corresponding increase in the number with empty digestive tracts from the June 1987 to the July 1987 samples. No values were obtained for esophagus fullness for the June 1987 sample. Although no areas of the digestive tract were full, there were more fish with trace amounts of food in their digestive tracts in the September 1987 sample, than in samples obtained at earlier times in that year.

Figure 7. Indices of fullness of esophagus, stomach and intestine of lake whitefish from Missi Falls: June 1986 to September 1987. (Numbers represent percentage of population with a given index of fullness).


JUNE 1986
JULY 1986
JUNE 1987
JULY 1987
AUGUST 1987
SEPTEMBER 1987
Full
Trace
Empty
Percentage of Population
0
10
20
30
40
50
60
70
80
90
100
Esophagus
Stomach
Intestine

3. Liver Somatic Index (LSI)

The LSI for female whitefish was somewhat higher in 1986 than in 1987 (Figure 8). In 1986, there was a gradual increase over the season, with a total increase of 0.49 units, and an average value of 1.46. In 1987, there was an overall decrease of 0.60 units, with an average value of 1.33.

The LSI for males was relatively constant over both years (Figure 9) with no overall increases and an average value of 1.09. The exception to this was the September, 1987 sample of males, which had a noticeable decrease in LSI in 1987.

4. Gonad Somatic Index (GSI)

The GSI of female fish was substantially higher in 1986 than in 1987 for most months (Figure 10). Mean values were 7.25 units in 1986 and increased almost exponentially toward the autumn months. Mean values in 1987 were only 3.36 and there was a decrease over the summer months and then a slight increase in the autumn of that year.

The changes in GSI over the study period for male fish were similar to those for female fish (Figure 11). Average values in 1986 were 2.45 units, and also increased over the 1986 sampling period. Mean values in 1987 were only 1.07 and decreased over the 1987 sampling period with a slight increase in the September 1987 sample over previous values for that year.

Figure 8. Temporal changes in Liver Somatic Index (LSI) for female lake whitefish caught at the Missi Falls control structure: June 1986 to September 1987. (Vertical bars represent ± 1 standard deviations about the mean).

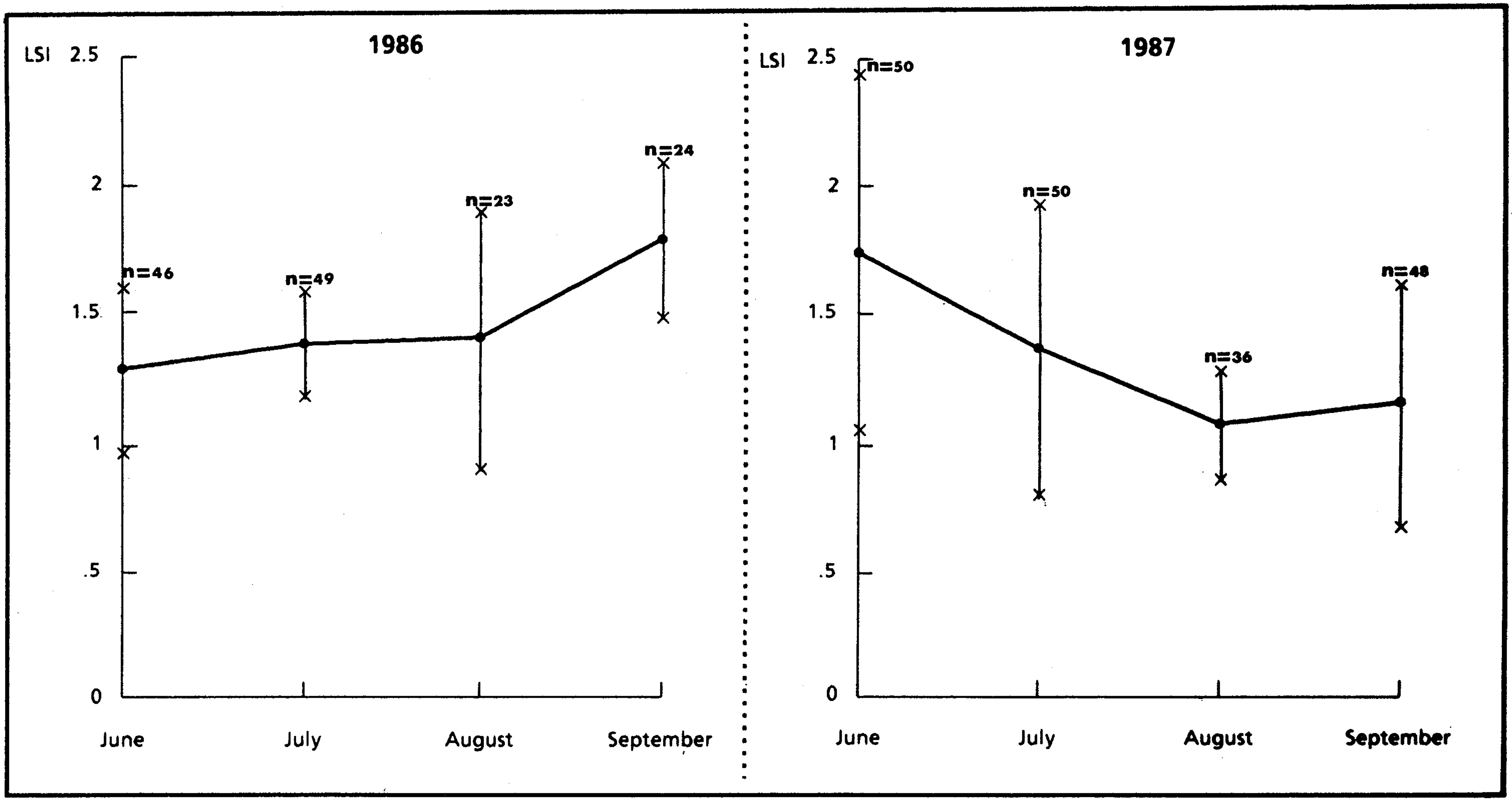

1986
LSI
2.5
2
1.5
1
.5
0
n=46
n=49
n=23
n=24
June
July
August
September
1987
LSI
2.5
2
1.5
1
.5
0
n=50
n=50
n=36
n=48
June
July
August
September

Figure 9. Temporal changes in Liver Somatic Index (LSI) for male lake whitefish caught at the Missi Falls control structure: June 1986 to September, 1987. (Vertical bars represent ± 1 standard deviations about the mean).

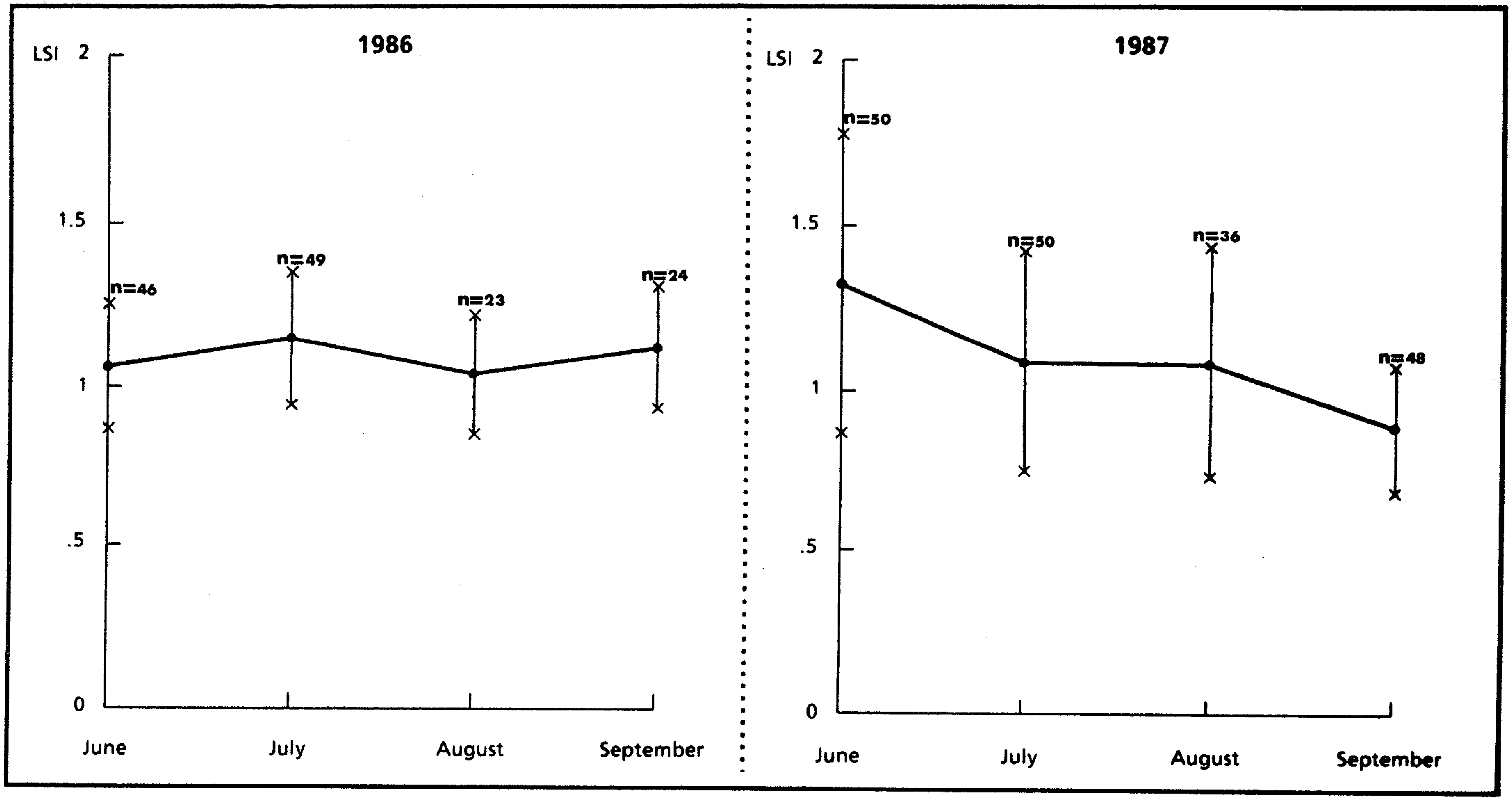

1986
LSI
2
1.5
1
.5
0
n=46
n=49
n=23
n=24
June
July
August
September
1987
LSI
2
1.5
1
.5
0
n=50
n=50
n=36
n=48
June
July
August
September

Figure 10. Temporal changes in Gonad somatic Index (GSI) for female lake whitefish caught at the Missi Falls control structure: June 1986 to September 1986. (Vertical bars represent ± 1 standard deviations about the mean).

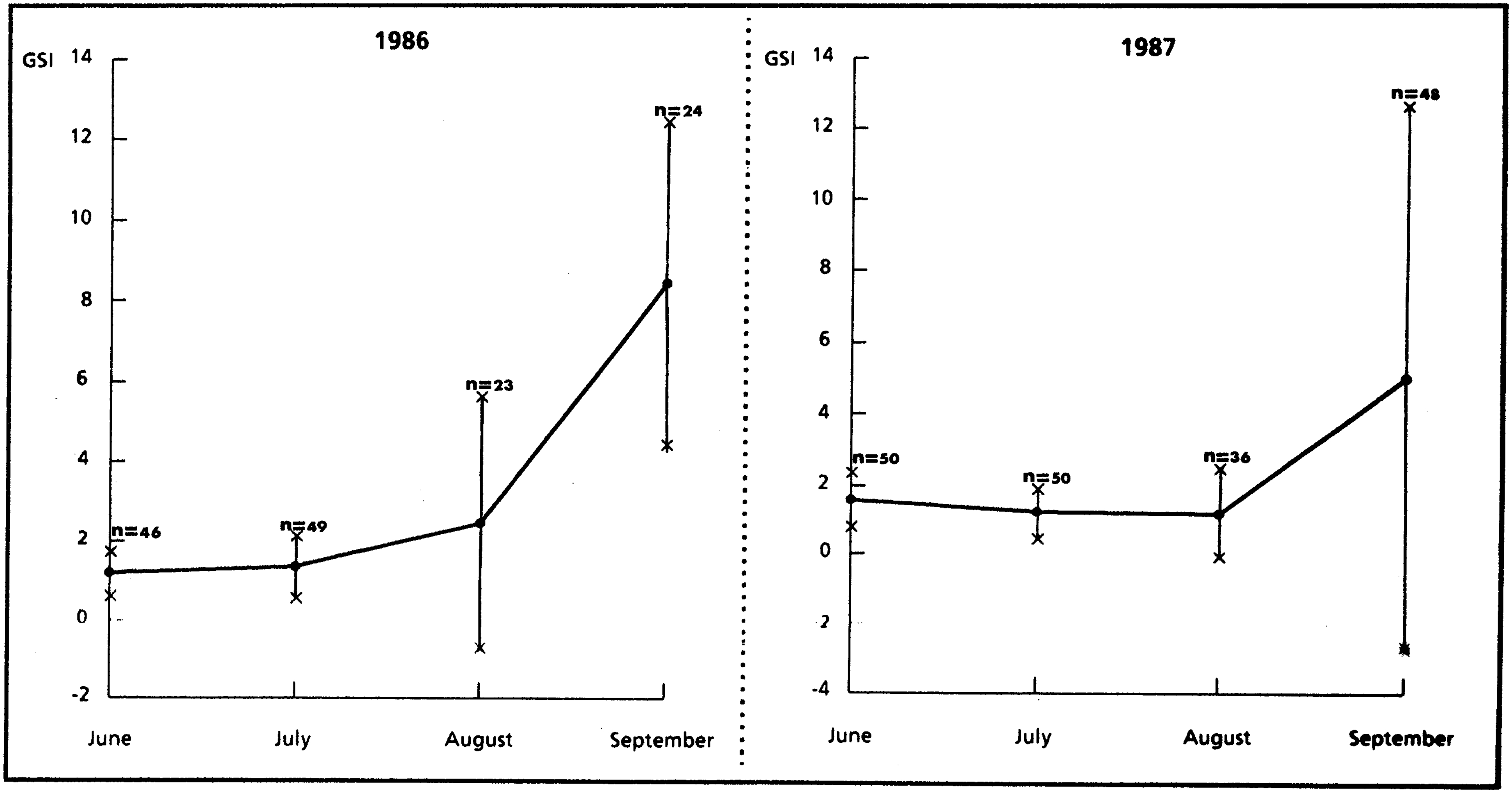
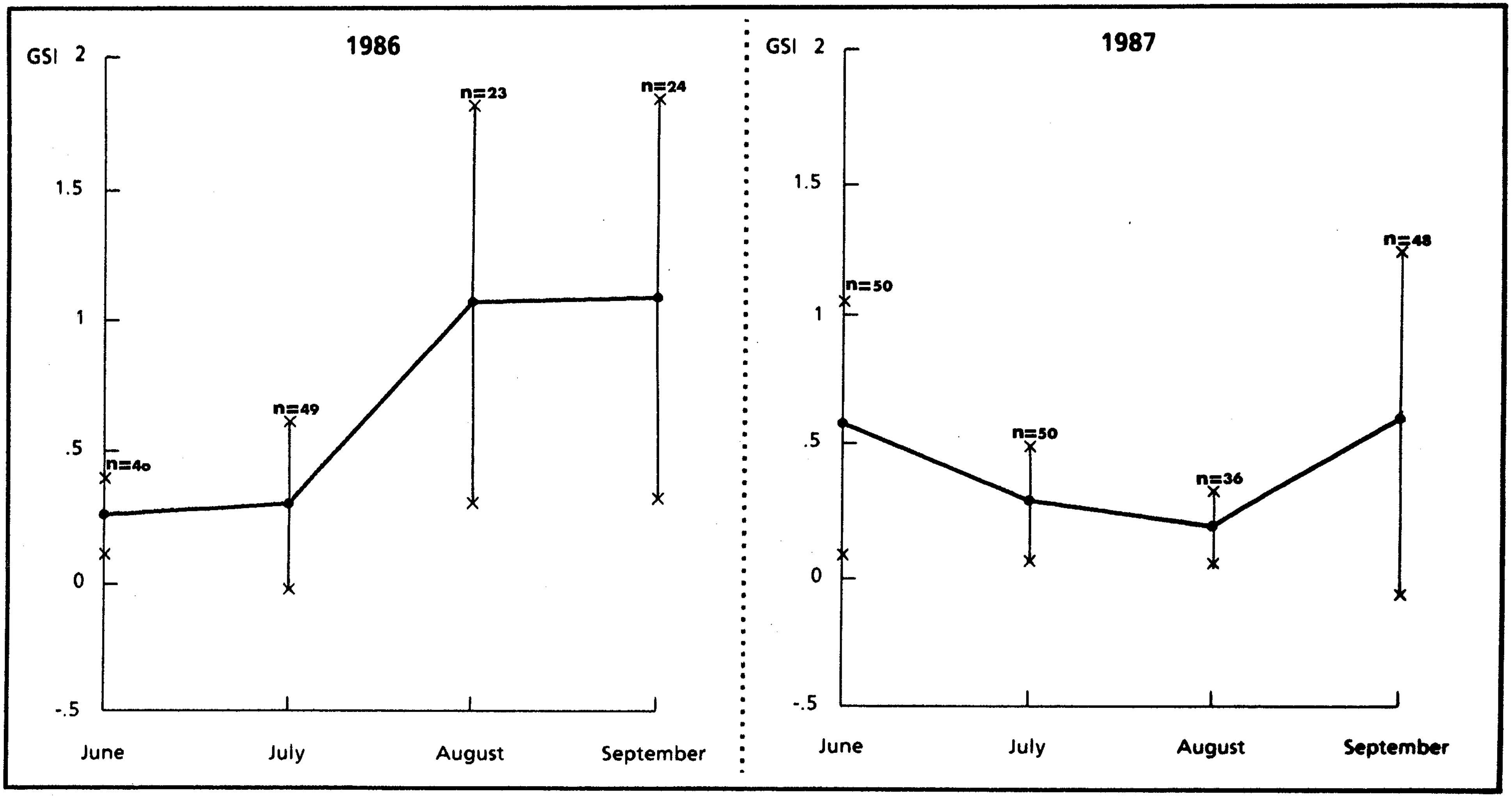

1986
GSI
14
12
10
8
6
4
2
0
-2
n=46
n=49
n=23
n=24
June
July
August
September
1987
GSI
14
12
10
8
6
4
2
0
-2
-4
n=50
n=50
n=36
n=48
June
July
August
September

Figure 11. Temporal changes in Gonad Somatic Index (GSI) for male lake whitefish caught at the Missi Falls control structure: June 1986 to September 1987. (Vertical bars represent ± 1 standard deviations about the mean).


1986
GSI
2
1.5
1
.5
0
-.5
n=4o
n=49
n=23
n=24
June
July
August
September
1987
GSI
2
1.5
1
.5
0
-.5
n=50
n=50
n=36
n=48
June
July
August
September

D. TEMPERATURE AND DISCHARGE COMPARISONS

Temperature data was obtained in 1987 from 11 locations in the study area (Figure 1), as part of a study of the lower Churchill lakes (Rosenberg and Weins, unpublished data). In all years for which temperature were available, there were noticeable differences in water temperatures between Missi Falls and lakes downstream of Missi Falls. Unfortunately, data was only available for June 1979, 1981 and 1987 (Table 9). In these years, there was a gradual increase in water temperatures with distance from Missi Falls. Plots of June, 1987 temperatures (Figure 12), showed a dramatic increase in water temperature from Missi Falls to the nearest downstream lakes.

Water temperatures at Missi Falls increased earlier in 1987, as compared to 1986 (Figure 13). In July of 1987, water temperatures were as high as 15^0C, whereas in July of 1986, water temperatures were only nine degrees celsius. Also, summer temperatures were somewhat higher in 1987 as compared to 1986.

Discharge over Missi Falls was much higher in 1986 than in 1987 (Figure 13). Discharge in 1986 peaked in July of 1986 at $1{,}417 m^3s^{-1}$. Discharge during most of the 1987 study period was only $14.2 m^3s^{-1}$.

In 1986, long-term mean discharges in June, July and August were all greater than 5.30 km^3/month, which approximated that of pre-impoundment conditions (McCullough,

Table 9. June water temperatures (degrees Celsius) for 1979, 1981 and 1987, Missi Falls to Fidler Lake.

Year	Depth	Missi Falls	Partridge Breast Lake			Northern Indian Lake						Fidler Lake
		site 1	site 2	site 3	site 4	site 5	site 6	site 7	site 8	site 9	site 10	site 11
1979	surface	-	5.9	6.0	8.0	8.6	10.5	11.0	10.0	9.0	8.0	8.6
	Middle	-	5.9	6.0	8.0	8.6	10.5	11.0	10.0	9.0	7.8	8.6
	Bottom	-	5.9	6.0	8.0	8.6	10.5	10.5	9.9	9.0	7.5	8.6
1981	surface	-	14.0	15.1	16.8	13.2	15.0	16.0	13.0	15.5	10.3	18.0
	Middle	-	12.0	10.1	12.0	11.0	11.2	11.0	11.0	11.0	9.4	18.0
	Bottom	-	8.0	7.2	10.7	10.2	9.2	9.0	10.1	9.3	9.2	18.0
1987	surface	6.0	-	-	16.0	17.2	16.2	14.9	15.0	-	-	-
	Middle	6.0	-	-	15.8	16.5	15.0	14.9	14.5	-	-	-
	Bottom	6.0	-	-	15.0	10.0	11.0	13.0	13.0	-	-	-

Figure 12. Water temperatures for June, 1987:
Missi Falls to Northern Indian Lake.
(See Figure 1 for sites).

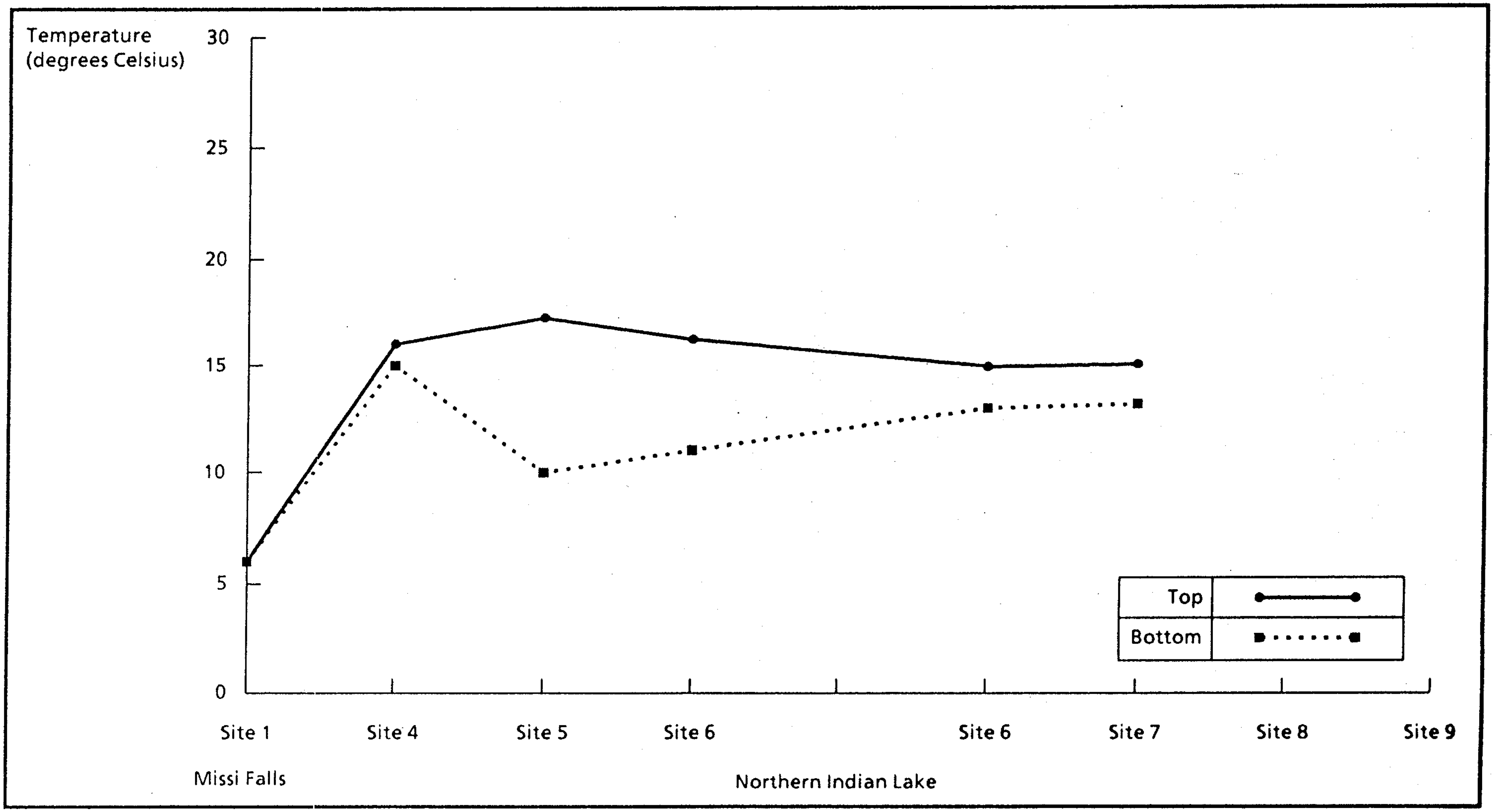
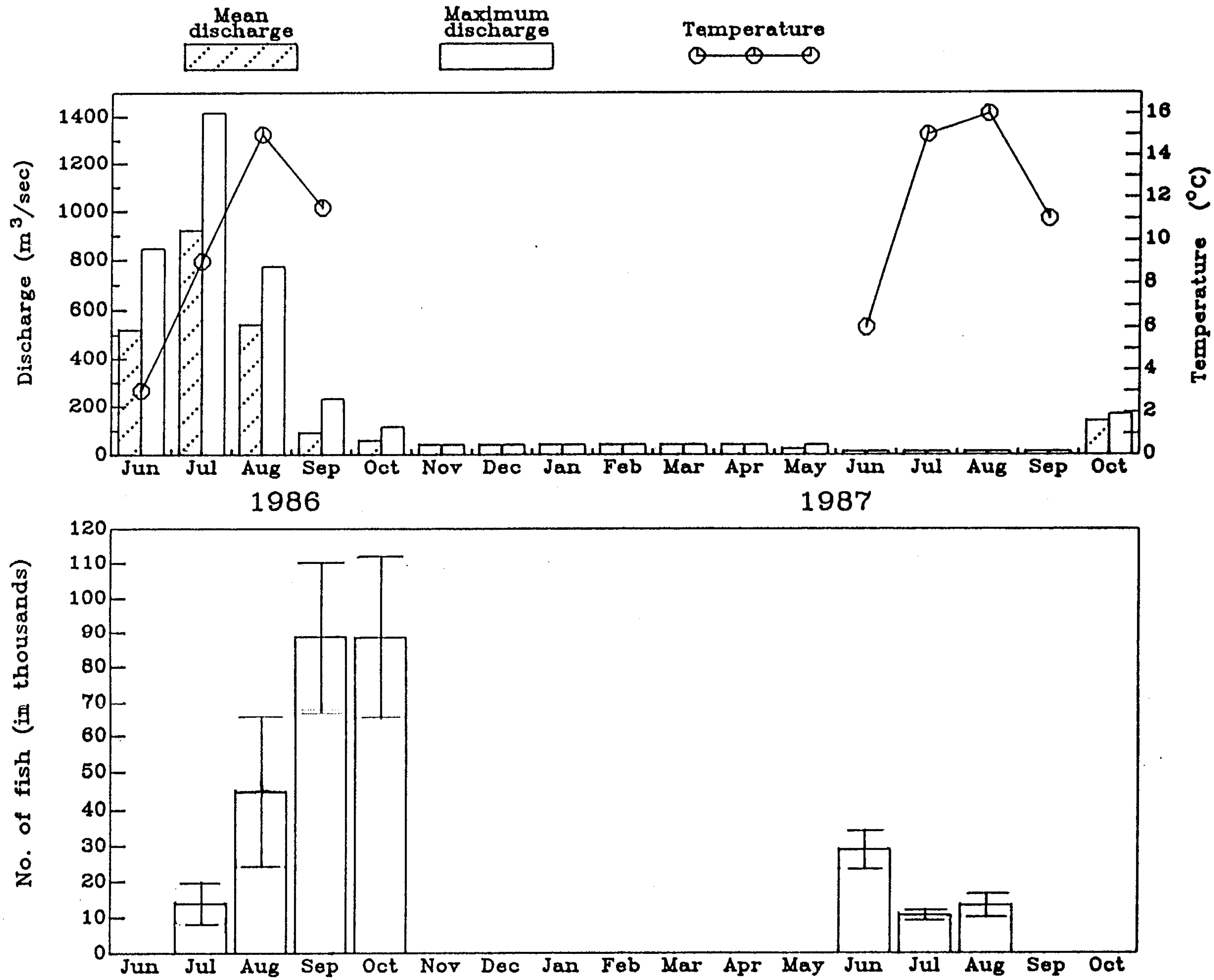

Temperature
(degrees Celsius)
30
25
20
15
10
5
0
Site 1
Site 4
Site 5
Site 6
Site 6
Site 7
Site 8
Site 9
Missi Falls
Northern Indian Lake
Top
Bottom

Figure 13. Plots of discharge, temperature and number of fish (with standard deviations) at Missi Falls during the 1986-1987 study period.



Mean discharge
Maximum discharge
Temperature
Discharge (m3/sec)
Temperature (°C)
0
200
400
600
800
1000
1200
1400
0
2
4
6
8
10
12
14
16
Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct
1986
1987
No. of fish (in thousands)
0
10
20
30
40
50
60
70
80
90
100
110
120
Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct

pers. comm.). In 1987, long term mean discharge was only 0.12 km^3/month. Local drainage and rainfall on the lake, minus evaporation, was approximately 0.48 km^3/month for both years. In 1986, almost 92% of the flow over Missi Falls was from the Churchill River, and conditions in Area 4 and in the downstream lakes were similar to long term pre-impoundment conditions. In 1987, however, 80% of the flow over Missi Falls and through Area 4 was from local inflow, and most of the incoming Churchill River flow was diverted south toward the outlet at Notigi (Figure 1).

F. SUBJECTIVE OBSERVATIONS

Several observations were made during the sample periods which were not quantified, but rather, were left as subjective observations. These are outlined below.

- Fish were actually seen being washed out of the open gate(s) on the dam, and were also observed making attempts to swim into the open gate(s).
- Fish caught at the dam had an abnormally large number of abrasions. This was especially true of those fish caught in 1986 when water flows were higher.
- There seemed to be a large number of fish with copepod parasites in 1986.
- There were large numbers of pike below the dam in 1987 when discharge was low and temperatures were high. Pike made up approximately 20% of the catch at this time, as compared to only 2% in the summer of 1986.
- Areas 200 to 300 meters downstream were sampled in:
    - 1986 when flow was highest and a calm bay was created which could be gillnetted; and,
    - 1987 when flows were low enough that beach setting could be performed.

Both techniques caught fish which had been tagged at the control structure, indicating that fish did not remain in close proximity to the dam at all times.

IV. DISCUSSION

A. INTRODUCTION

The null hypothesis being tested in this study was that all fish found below the Missi Falls control dam originated from downstream areas. The reason for the movement of fish upstream toward the Missi Falls dam could relate to water temperature. If the downstream water temperatures were above preferred temperatures, lake whitefish could have moved upstream toward the cooler water coming from SIL. Research on temperature preference of whitefish indicates that this hypothesis is reasonable.

A compilation of data from several researchers was presented by Wismer and Christie (1987) and indicated that adult lake whitefish in the Great Lakes preferred temperatures of less than 9^0C. Ferguson (1958) stated that two year old lake whitefish preferred temperatures of 7^0C to 12^0C. Furthermore, it may be that because these studies were undertaken in a warmer environment than the study area of the present research populations in Northern Manitoba could prefer slightly cooler temperatures. Therefore, if temperatures in the downstream lakes became greater than those present at Missi Falls, there would be a temperature gradient from the cooler water at Missi Falls to the warmer water in the downstream areas. This could induce fish to move upstream to Missi Falls. An hypothesis of movement based on temperature preferences leads to the following predictions regarding fish congregating below the Missi Falls control dam:

1. When a temperature gradient from Missi Falls to the downstream lakes is present and temperatures in downstream lakes are above those preferred by lake whitefish, there would be congregations of lake whitefish below the Missi Falls dam.
2. These fish would resemble downstream fish morphologically.
3. The number of fish would increase as the downstream water temperatures increased.
4. The warmer water temperatures in the downstream lakes would place physiological stress on the fish. If fish spent the summer months at the Missi Falls dam, where food was probably scarce, they would have empty digestive tracts and would be in poor condition, due to a lack of food in this area.

The alternate hypothesis being tested in this study was that fish from Southern Indian Lake were present below the Missi Falls control dam. The primary mechanism involved in causing lake whitefish from upstream locations to be present below the Missi Falls dam was thought to be the migratory behavior of the fish to response to cues from the Churchill River. These cues could include flow, temperature and olfaction (Leggett, 1977). If a stock of lake whitefish traditionally made an annual migration over Missi Falls, the presence of the control structure at Missi Falls would block the return migration back to SIL. Since the dam allows fish to pass downstream but blocks upstream movements, fish would congregate on the downstream side of the dam.

Although lake whitefish are not generally regarded as a migratory species, migration has been shown to occur both within lakes (Budd, 1956; Machniak, 1975), between lakes and rivers (Bajkov, 1930; Machniak, 1975; McCart et al, 1982) and probably between rivers and estuaries (Gudderly et al, 1976; Morin et al, 1981). Local hydrographic conditions are a major factor in determining movements of migratory fish species (Budd, 1956). Factors such as spawning and feeding can initiate movement. Documentation of migrations between lakes and rivers seems to be limited to populations which feed in lakes and utilize rivers for spawning (Bajkov, 1930; Machniak, 1975; McCart et al, 1982). If one accepts the alternate hypothesis one must assume that a migration between SIL and the lower Churchill took place in the opposite direction; that is, back to a large lake for spawning. This could be possible, due to the particular conditions in the lakes involved. The lower Churchill lakes were shallower and had much higher standing crops of benthic invertebrates (especially Partridge Breast Lake), than the northern basins of SIL (Hamilton, 1974; Hamilton and McCrae, 1974), whereas SIL Area 4 had an abundance of shallow, rocky shoals for spawning. Ayles and Koshinsky (1974) noted that prior to the impoundment of SIL, abundance of lake whitefish in Area 4 increased in the autumn. If fish were migrating between SIL and downstream waters at this time this could account for those increases in abundance. Migrations to the lower Churchill would have been energy effective because of the relatively short distances involved.

Morin et al (1981) studied lake whitefish and cisco migration in the James Bay area. This study concluded that members from both study species undertook long range movements between the rivers and the estuaries with whitefish appearing to move downstream in the summer. They could not clearly define causal mechanisms, but discuss food distribution and quote Valtonen's (1970) work on preferred temperatures as possible explanations. Ikonen (1982) studied river spawning whitefish in the Gulf of Finland. He concluded that Coregonus lavaretus, a species closely related to lake whitefish, begin a downstream feeding migration in May. By June or July most fish are in the feeding areas and in late July to early August the fish begin the upstream spawning run.

If there is a stock of lake whitefish which undergoes migration from SIL to downstream areas, it is therefore probable that these fish spawned and overwintered in SIL and in the spring and early summer passed downstream over Missi Falls to feed in downstream areas. These fish would then return to SIL in the late summer and autumn months. These fish would follow environmental cues present in the Churchill River.

An hypothesis of movement based on feeding and spawning migration leads to the following predictions regarding fish congregating below the Missi Falls control dam:

1. When a significant flow of the Churchill River water was being discharged at Missi Falls, there would be congregations of lake whitefish below the Missi Falls dam.
2. These fish would resemble upstream SIL fish.
3. The numbers of fish would increase toward the late summer and autumn.
4. In the autumn, if the lake whitefish were in the process of returning to SIL to spawn after a summer of feeding in downstream lakes, the fish would be in good condition with full digestive tracts and would show few signs of physiological stress.

During the study period, discharges in 1987 were much lower than those in 1986 and environmental conditions existed which enabled the testing of both hypotheses.

Mean annual discharges over the Missi Falls control structure decreased from 1,010 to $22m^3s^{-1}$ after impoundment (McCullough, 1981) and water levels dropped dramatically in Partridge Breast, Northern Indian and Fidler Lakes (Figure

1). Water levels in downstream lakes now fluctuate two to three meters; this fluctuation is much greater than the natural range of one meter, which occurred before impoundment (Brown, 1974).

Discharges over Missi Falls in the 1987 study period were as low as $14 m^3 s^{-1}$ (Figure 13) which was much lower than pre-impoundment mean levels. In 1987, as in most post-impoundment years, if lake whitefish were following navigational cues from the Churchill River, they would have followed the diverted Churchill River, out of the south basin of SIL, rather than over Missi Falls. These environmental conditions existed not only in 1987, but in 1985, 1984, 1983 and in 1981 (Appendix J). At these times, the only flow over the Missi Falls control structure would have been from local inflows from small streams immediately upstream of the dam, rather than the Churchill River. Congregations of lake whitefish were also observed below the Missi Falls dam in the summer of 1981 (Bodaly, pers. comm.).

Spring temperatures were higher at Missi and temperatures appeared to peak earlier in 1987. The lower discharge over Missi Falls in 1987 as compared to 1986 (Figure 13), resulted in shallower downstream lakes. Unfortunately, extensive data on downstream water temperatures was not available for 1986, since surveys of the lower Churchill are usually undertaken in June of every second year (Weins, pers. comm.). As early as June, 1987 there was a noticeable difference in water temperature between Missi Falls and downstream lakes. One might expect the difference to be even greater in the midsummer months. Bottom temperatures for June, 1987 in Partridge Breast Lake were at least 15^0C, while the water temperature at Missi Falls was only six degrees celsius at this time. This represents a nine degree change in water temperatures in only a few kilometers. Bottom temperatures in Northern Indian Lake ranged from four degrees celsius to seven degrees celsius warmer than those at Missi Falls. In the midsummer months, one would expect a much more pronounced difference, since the shallower lower Churchill lakes are much more susceptible to increases in temperature than SIL.

In 1986, discharge over the Missi Falls dam was much higher than in 1987 (Figure 13) and most of the Churchill River was passing downstream into the lower Churchill. If lake whitefish historically undertook a migration over Missi Falls they would have passed over the Missi Falls dam at this time, as they had over Missi Falls prior to impoundment. Summers with high discharge occurred not only in 1986, but in 1980, 1978 and 1976 (Appendix J). From 1972 to impoundment, discharge ranged from $900m^3s^{-1}$ to $1600m^3s^{-1}$ with peaks usually occurring in the midsummer months (Newbury et al, 1984). The historical range was probably even greater. This trend was maintained in most post-impoundment years; however, discharges were greatly reduced and were well below pre-impoundment means. In the years after impoundment when flows were high, the mean levels of pre-impoundment years were never attained (Newbury et al, 1984). However, in those years the conditions were similar to those before diversion and incentives for lake whitefish to move over Missi Falls must have been similar.

In order to test the two hypotheses, the four predictions for each hypothesis were investigated. The estimates of abundance and trends in the population at Missi Falls established the presence of lake whitefish during periods of warmer downstream water temperatures and also during the spawning period. Morphological comparisons examined the resemblances of the Missi Falls lake whitefish to upstream or downstream fish. Biological examinations determined whether or not the Missi Falls lake whitefish were showing signs of physiological stress.

B. ABUNDANCE

Population estimates indicated that there were significantly more fish present at Missi Falls in 1986 than in 1987. The gradual increase in numbers towards the autumn of 1986 is evidence to suggest a return migration to SIL to spawn and overwinter and fish caught at this time were in obvious spawning condition. The summer peak in 1987 is consistent with the theory that fish were moving upstream in response to the warmer downstream temperatures at that time. An October sample trip was planned in 1987 but not taken, since population estimates were sufficiently precise without the time and expenditure of another trip. Hindsight suggested that an October trip would have uncovered further trends in 1987 abundance. The only conclusions that can be drawn in this year were that numbers probably peaked in the summer months.

There appeared to be a proportional increase in the number of fish moving into the Missi Falls area as the temperature of the downstream lakes increased in the summer of 1987. In 1986, the number of entries increased as the autumn approached, suggesting an autumn migration. Survival rate also differed between years. In 1987 when temperatures at Missi Falls and in the downstream lakes were quite warm, the survival rate of the Missi population was less than 25%/month. In 1986 it was almost 77%/month; fish were surviving longer and were in better condition. Missi Falls fish caught in 1987 had significantly thinner ($P<0.0001$) bodies than 1986 fish, were in poorer condition, and more fish had empty digestive tracts than the 1986 fish. These facts suggest a longer residence time at the dam, perhaps due to an earlier arrival in 1987, and also illustrate that the fish were under more stress in 1987, possibly due to the warmer downstream water temperatures.

The POPAN model used to estimate the population parameters utilizes the adaptability of the Jolly-Seber mark-recapture model for an open population of animals (Jolly, 1965; Seber, 1965). Pollock and Mann (1983) list some assumptions for open population mark-recapture models:

- Mark/tag loss is minimal or zero since it can cause serious negative bias on survival rates. (However, in open population models, population size estimates are unaffected).
- Marked fish become randomly mixed with unmarked fish (or the distribution of fishing effort in subsequent sampling is proportional to the number of fish present).
- All marks are recognized and reported on recovery.
- The marking and handling procedures do not affect the fish (i.e. behavior, catchability etc.).
- The probability of recapture and survival is homogeneous within the population.

Fish previously sampled may not react to sampling gear in the same was as naive fish (Ricker, 1975; White et al, 1982). Gear avoidance by marked fish will cause positive bias in population estimates, whereas increased susceptibility to capture will cause negative bias. Damaged fish can be ultimately lost and will cause positive bias.

Since survival rates are based only on marked fish, the above problems do not apply. However, reduced survival due to marking, if applied to the entire population, will seriously underestimate survival. The assumptions of the model were tested and found to be acceptable.

A study on a related species (c. albula) indicated that temperatures of less than 10^0C were optimal for capture and marking (Pasonen et al, 1919). Autumn was the least desirable time to sample, when glycogen reserves in the liver are negligible and female fish have the greatest risk of dying. The study concluded that the total holding time for marking should be less than two hours in duration. Missi Falls fish were captured and marked in much less than two hours and any fish that appeared to be adversely affected from the procedure was removed from the population. The hole punch technique used in 1987 would not be appropriate for long term studies since the hole tended to scar over after approximately three months and recognition became difficult.

C. MORPHOLOGICAL COMPARISONS

Whitefish are known to exhibit great morphological variability among the various species and stocks. This morphological variability has often been attributed to environmental influences (Hall, 1925; Svardson, 1951, 1952; Loch, 1974). Although morphometric and meristic data are influenced by environmental differences, they can be as valuable in indicating stock discreteness as other, more heritable features (Casselman et al, 1981). Differences uncovered by morphological comparisons could be due to either genetic differences or environmental effects, or a combination of the two.

In a review comparing organismal and molecular evolution, Clayton (1981) stated that, in some species of fish, phenotypic divergence is extremely rapid, often occurring in a period of time too short to have allowed the accumulation of significant genotypic changes. With this in mind, it appeared logical to invest more time in a morphological comparison of the Missi Falls fish, rather than a biochemical comparison. Also, some genetic comparisons had already been performed on lake whitefish in the Missi Falls area (Bodaly et al, 1984b) and no significant differences were discovered. Therefore, although perhaps not as conclusive as genetic comparisons, morphological comparisons were thought to have been more sensitive to any differences which might occur between several populations of the same species which are in close proximity to one another.

Morphological comparisons indicated that there were changes in the origin of the Missi Falls lake whitefish population over time. Most of the fish present in the spring and early summer of 1986 appeared to originate from near-downstream areas. There was apparently a gradual change over the summer so that most fish present in the late summer and autumn of 1986 appeared to originate from the near-upstream locations in SIL. In the spring and early summer of 1987 the Missi Falls fish still appeared to originate from SIL with a gradual shift in morphology over the summer of 1987 to fish which resembled those from downstream area. This change in origin over time is evidence to suggest a return migration of SIL fish which were attempting to spawn and overwater in SIL in 1986 when most of the Churchill River was flowing over Missi Falls. It also suggests the movement of downstream fish toward Missi Falls in the summer of 1987 when downstream water temperatures exceeded the preferred temperature of lake whitefish.

Attempts were made to obtain samples from the locations surrounding Missi Falls in the autumn when the lake whitefish were most likely to be near their respective spawning areas. At this time any potential stocks would have naturally been separated into their respective genetic or population groupings. However, this was not possible for some samples, such as those obtained from Area 4. Sampling of Area 4 presented problems because of the difficulty in obtaining large samples in any one sample period. Barnes (1981) also noted that the numbers of lake whitefish caught upstream of the Lobstick control structure in Labrador were very low and the area had to be intensely sampled to obtain a substantial sample. The pooling of samples from several time periods in Area 4 had to be tested to ensure than there were no temporal differences in morphology. When compared with the Strawberry Island sample, which was the closest and only other upstream sample, most of the analyses suggested that there were no significant differences between the two largest samples from Area 4 and these could therefore be pooled.

There was less concern with obtaining autumn-only samples from the upstream locations, since the upstream samples could not contain any downstream fish, and potential problems associated with the mixing of several stocks was considerably less. However, there was still a potential problem of temporal differences in morphology obscuring spatial differences in morphology. Some of the upstream samples were obtained in June and July of 1986 and most of the downstream samples were obtained in October of 1987. Therefore, there were some difficulties in proving that changes in morphology among locations were related to spatial separation of different populations, or merely seasonal changes in morphology within a single population. The fact that the changes observed over time at Missi Falls in 1986 were quite different from those observed in 1987 (actually the inverse) suggested that these morphological changes probably represented changes in the origin of the Missi Falls fish, rather than changes in each fish which occurred on a seasonal basis each year. If the changes in morphology over time in the Missi Falls population as a whole were largely due to seasonal changes in each fish, then the changes observed over time at Missi Falls in 1986 would be reflected in the changes during the 1987 period; this was certainly not the case.

Interpretations from some analyses suggested that there were slight morphological similarities between the upstream Strawberry Island sample obtained in June of 1986 and the downstream Partridge Breast Lake sample which was obtained in October of 1987. This is evidence to suggest that morphological changes among locations did not represent regular seasonal changes within a single population. If this were the case, these morphological similarities between two temporally distinct samples (June, 1986 and October, 1987) would not occur; rather, fish caught in June of 1986 would resemble fish caught in June of 1987 and fish caught in October of 1987 would resemble fish caught in October of 1986; these relationships were usually not observed.

Although the morphological similarities between the August, 1986 and August, 1987 samples from Area 4 were close enough that they could be pooled, the trends observed at Area 4 over time in 1986 results were quite different from those observed in the 1987 sampling period results (given that samples were not available from many time periods at this location). As with the Missi Falls results, the trends in Area 4 results also suggested that regular seasonal changes in the morphological parameters used in this study were not occurring. Therefore, although it is realised that the results based on the morphological comparisons between Missi Falls Fish and those caught in upstream and downstream locations should be viewed with some caution, one can be reasonably confident that there are morphological differences between upstream and downstream locations which are based on spatial, rather than temporal differences and that the origin of the lake whitefish caught at Missi Falls changes as the environmental conditions change.

D. BIOLOGICAL ANALYSES

The hypothesis of movement based on feeding and spawning migrations lead to the prediction which suggested that fish caught at Missi Falls in the autumn would show no signs of physiological stress. This situation was observed in 1986. The hypothesis based on temperature preferences lead to the prediction that fish caught at Missi Falls when downstream temperatures were very warm would show signs of physiological stress. This situation was observed in 1987.

Missi Falls fish caught in 1987 had significantly thinner bodies ($P<0.0001$) than 1986 fish, were in poorer condition and also had more empty digestive tracts than 1986 fish. Barnes (1981) suggested that if fish below a control structure had lower condition factors than at surrounding locations, a proportion of the fish below the structure represented a resident population, since length and weight do not vary significantly over short periods of time. This long residence time is consistent with the theory that 1987 fish move upstream from the lower Churchill in the late spring and early summer and remain at Missi Falls while warm temperatures persist. In 1986, fish congregated below Missi Falls in the autumn, presumably on a return migration to SIL after feeding in downstream areas. Fish caught at this time were in good condition and had full digestive tracts.

Liver somatic indices (LSI) fluctuated in 1986 with no noticeable trends, but decreased gradually over the 1987 sample season. Barnes (1981) suggested that fish must expend considerable amounts of energy to maintain their position below the dam, and can deplete energy reserves stored in the liver. This could have been the case with fish that spent the summer of 1987 below the Missi Falls dam. Although the flows were lower in 1987 than in 1986, the decreases in LSI could also have been related to the fact that water temperatures were higher in 1987 than 1986. Fish at Missi Falls in 1987 were already under temperature stress and maintaining their position below the dam was probably physiologically demanding.

Gonad somatic indices (GSI) increased almost exponentially in 1986 for both males and females, but decreased over the 1987 sample season until autumn. This is further evidence that 1986 fish were trying to return to Missi Falls to spawn, whereas 1987 fish were merely avoiding the warm downstream lakes. In 1987 fish at Missi Falls were probably more stressed by water temperatures and also, as Barnes (1981) suggests, increased flows could flush more food items over the dam. With little flow, the large number of fish were competing for what little food was already present below the control structure, and energy levels could become depleted. This theory was somewhat supported by the examination of the digestive tracts which seemed to be fuller, at Missi Falls, in 1986 and in 1987, although 1986 data was incomplete. The digestive tract analyses were subdivided into esophagus, stomach and intestine. Barnes (1981) noted that the amount of post-death digestion was unknown. By examining all three areas, a better grasp of fullness over time was expected.

The biological analyses of the Missi Falls fish also suggested that there were gradual changes in the origin of the Missi Falls fish over the study period. In 1986 it would appear that well-fed fish in good condition were attempting to move into SIL from downstream areas to spawn in the autumn of that year. In 1987 it would appear that underfed fish in poor condition were attempting to move into SIL during the summer periods when downstream water temperatures became too warm.

V. SUMMARY

The null hypothesis being tested in this study was that all fish below the Missi Falls control dam originated from downstream areas. The alternate hypothesis stated that fish from SIL were present below the Missi Falls control dam. Based on results from 1986, the null hypothesis was rejected in favour of the alternate hypothesis since it was apparent that there were fish from SIL present below the dam. However, the situation appears to be more complex than anticipated, since in the summer of 1987 the population at Missi Falls appeared to be dominated by fish originating from downstream areas.

The four predictions constructed for each hypothesis were investigated and found to differ based on the different environmental conditions present in each of the study years.

In 1986 most of the Churchill River passed over Missi Falls which could have resulted in a resumption of traditional migratory patterns for a stock of whitefish in SIL. This would have resulted in the congregations of SIL fish below the Missi falls dam which dramatically increased in the autumn of 1986. These fish had presumably spent the summer feeding in downstream areas and were attempting to return upstream to spawn and overwinter in SIL.

In 1987 discharge over Missi Falls was from local inflows only. The morphological composition of the population below Missi Falls in 1987 changed in the midsummer months to fish which resembled those caught in near downstream lakes. At this time, water temperatures in the downstream lakes exceeded those preferred by the species and it would appear that these fish moved upstream toward the cooler waters at Missi Falls. These fish, having spent the midsummer period below the Missi Falls dam, were in much poorer condition than those in 1986.

The number of lake whitefish estimated to be trapped below Missi Falls in the autumn of 1986 represented over 61% of the total lake whitefish commercial catch in SIL in that year. The majority of those fish below Missi Falls appeared to have originated from SIL. At the same time, commercial catches in all of the downstream lakes under study was less than 10% of the estimated population at Missi Falls. Thus, the number of fish congregating downstream of the dam is significant when compared to both upstream and downstream commercial catches. Fish will be unavailable to commercial fishermen not only in high flow years, when the SIL stock will be trapped below Missi Falls in the autumn, but from Partridge Breast Lake and perhaps Northern Indian Lake in low flow years, when fish move out of these areas in the midsummer months. The diversion channel may also have contributed to the decline in abundance in SIL.

Understanding the mechanisms involved in the fishery could aid in its management. Coordinating fishing intensity to discharge patterns over Missi Falls could improve efficiency. It should still be possible to improve the fish productivity of SIL. Mitigating measures could involve a seining program at Missi Falls to transport fish upstream over the dam at critical periods when fish are attempting to move upstream. Construction of a fish ladder is still an option although this is now an expensive alternative to the seining program.

Previous studies have shown that the large numbers of fish once caught in commercial nets, both in SIL and the downstream lakes, have been drastically reduced. It would appear that this reduction has been greatly influenced by the construction of the Missi Falls control structure. This study suggests that after almost ten years since the impoundment of SIL, there are still significant numbers of lake whitefish attempting to complete the traditional migration. It should be possible to re-establish this migratory stock. The genetic variability and overall fish productivity of SIL would be adversely affected by the permanent loss of the migratory component of this SIL stock.

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VII APPENDICES

APPENDIX A - STATISTICAL ANALYSES OF MORPHOLOGICAL COMPARISONS

An analysis of variance was performed to test whether the sample means of each location could have been obtained from fish groups with the same parameter means with respect to each given variable (considered separately). Even though the allometric factor was suppressed, an analysis of covariance (ANCOVA) was also performed on the raw morphometric data. ANCOVA fits regression lines with a common slope to the groups and tests whether there is significant heterogeneity among the adjusted means, where the adjustment is along the regression line to a common covariate value. ANCOVA can increase the precision in an experiment and can also adjust for unwanted sources of mean difference, such as the effect of different mean sizes of fish among groups. ANCOVA was used to test the effect of standard length, as the covariate, on the variables for each location. The ANCOVA procedure assumes that the regression slopes are parallel and results such as tests of paralellism, slopes and intercepts were analysed.

In univariate analyses, the group comparisons are based on the means and distributions (measured by the variance or standard deviation). Multivariate techniques include not only the mean and variance comparison, but also the covariance values which measure the interactions of the variables. Multivariate techniques included discriminant functions analysis, canonical discriminant functions analysis and principal components analysis.

Discriminant functions analysis compares groups by creating artificial variables which are a linear function of each pair of original variables, for each group. These are produced in such a way that the F-Ratio is maximized (i.e. to maximize the variation among group means related to the pooled-within group variation).

The procedure involves three steps: the first tests the null hypothesis that the mean vectors (centroids) of the populations sampled are equal. This is accomplished by a multivariate analysis of variance which includes a test of the null hypothesis of equality of population covariance matrices. If the test accepts the null hypothesis, there is no need to continue. Rejecting the hypothesis of equality of centroids is necessary to establish differences between populations prior to studying these differences (Colgan, 1978). As mentioned earlier, once the difference is established, each individual is classified to the group it most closely resembles in form. Each group is assigned either to its own group or to another group. The relationships between the groups and individuals in discriminant space are examined by rotating the orthogonal axes in euclidean space, and then performing the discriminant vector analysis. If this becomes too complex, canonical discrimination is better (Colgan, 1978).

The canonical discriminant functions analysis yields a coefficient for each variable which, in effect, ranks its importance in discriminating the groups. Given that the means do differ, the procedure attempts to determine the degree of difference. Comparisons with the univariate analysis of variance can be made; if only one variable from the univariate analysis is significantly different, the multivariate analysis will yield a significantly different result. The eigenvalue is a measure of overall variation; statistics, such as Wilk's Lambda, test whether the difference in the population centroids is significantly different, and finally, a chart can be made of the canonical coefficients for each group and the amount of overlap visualized. Univariate statistics further calibrate the chart.

The morphometric and meristic variables were analyzed together in the study. Thorpe (1976) suggests that since the transformed data is unitless, comparisons between different types of measurements could be made. It was realized that there are potential problems associated with combining meristic and transformed morphometric data. However, the purpose of the study was not to determine why the various groups differed, but only to establish that differences occurred.

Where discriminant analysis creates imaginary test variables to compare actual data, principal component analysis uses the actual data to estimate multivariate coefficients as the components of the first principal component of the covariance matrix. The procedure examines clouds of observations describing hyper-ellipsoids in multi-dimensional space. To simplify the description of these clouds of points, principal axes are calculated through them. Eigenvalues representing the variance along the principal axis, the second major axis and so forth of the hyper-ellipsoid, successively removing the greatest, second greatest and successively smaller sources of variation (Sokal & Rohlf, 1969). The procedure assumes linearity and a multivariate normality, and can inefficiently summarize non-linear patterns. Also, the results are data specific where the inclusion of odd characters are ones that contrast the general patterns in the data and greatly influence the results. Finally, plots are made of the first few, most important, components and a univariate analysis obtains the statistics for the factors such as means and standard deviations, for a visualization of the group separations.

If the principal component analyses, which is more descriptive of the "real world" and the discriminant analysis, with more inherent assumptions, are similar in the type of results, the hypothesis testing has been successful. Any differences are not due to violations in assumptions, but actual differences in the groups being compared.

APPENDIX B.

Morphometric and meristic character states used for statistical comparisons and analyses of covariance.

Table B1. Mean values for variables used in the total analyses. (S.I.L.= Southern Indian Lake). Morphometric measurements are in mm.

Count/measurement	Partridge Breast Lake	Northern Indian Lake	S.I.L. Area 4	Fidler Lake	Gauer Lake	Coffer dam	S.I.L. Strawberry Island
Meristic variables:							
Lateral line scale count	81.4	83.1	81.1	81.0	82.2	83.2	80.5
Supra pelvic scale count	9.8	9.7	9.8	9.9	9.3	9.7	9.4
Scales above lateral line	10.3	10.4	10.3	10.3	10.4	10.2	10.0
Dorsal fin ray count	11.9	11.5	11.6	11.6	11.9	11.5	11.8
Anal fin ray count	12.4	12.0	11.7	11.9	12.3	11.8	12.1
Pectoral fin ray count	15.7	15.5	15.6	15.8	16.2	16.1	15.8
Pelvic fin ray count	11.6	11.5	11.7	11.8	11.7	11.6	11.4
Upper gill raker count	9.9	9.6	9.7	9.7	9.7	10.0	9.9
Lower gill raker count	16.9	16.6	16.4	16.7	16.4	16.5	16.6
Morphometric variables:							
Fork length	385.7	385.0	386.1	385.1	385.5	385.5	393.2
Pre-orbital length	20.6	19.8	21.2	19.4	20.2	20.9	21.6
Orbital diameter	13.5	12.7	12.9	12.3	13.1	13.2	13.6
Trunk length	89.3	91.7	86.8	88.5	89.4	84.2	83.4
Caudal peduncle length	37.0	36.0	37.2	35.7	33.5	36.1	38.1
Middle gill raker length	7.9	7.5	7.2	7.8	7.8	7.7	7.1
Post-orbital length	42.6	42.1	43.3	42.1	44.0	43.4	42.2
Dorsal fin base length	46.2	46.0	45.9	44.6	45.8	45.8	47.2
Lumbar length	74.6	74.7	77.0	78.8	71.6	73.3	78.8
Anal fin length	40.7	38.3	37.0	35.9	38.0	37.3	37.4
Caudal peduncle depth	32.8	32.2	33.0	32.8	34.1	32.5	31.8
Head depth	33.1	32.7	32.1	32.6	33.0	32.4	34.3
Body depth	98.8	100.0	103.2	100.9	99.4	95.9	109.7
Inter-orbital width	20.8	20.3	20.2	19.4	19.7	19.7	20.4
Maxilla width	8.1	7.9	8.0	7.5	8.1	8.2	8.2
Maxilla length	20.6	20.6	20.1	19.5	20.6	20.2	19.5
Pectoral fin length	71.1	68.8	69.9	67.0	71.5	68.7	68.5
Pelvic fin length	65.0	63.4	65.6	64.7	65.6	63.8	64.1
Adipose fin length	18.9	19.2	18.8	18.0	17.5	18.1	18.6
Lower gill arch length	26.3	25.6	25.0	25.6	26.3	26.5	25.9

Table B2. Mean values for variables used in the Missi Falls analyses. Morphometric measurements are in mm.

Count/measurement	1986				1987			
	June	July	Aug	Sept	June	July	Aug	Sept
Meristic variables:								
Lateral line scale count	81.0	80.6	79.9	81.3	80.5	80.4	80.7	81.2
Supra pelvic scale count	9.4	8.9	8.9	8.7	9.5	9.3	9.1	9.4
Scales above lateral line	10.5	10.5	10.1	9.9	10.0	10.0	9.9	10.2
Dorsal fin ray count	11.5	11.8	12.0	12.0	11.7	11.6	11.6	11.9
Anal fin ray count	12.0	12.0	12.0	12.0	11.9	12.0	11.9	12.2
Pectoral fin ray count	15.7	15.9	15.1	16.0	15.7	15.6	15.3	15.8
Pelvic fin ray count	11.5	11.6	11.5	11.5	11.5	11.6	11.4	11.6
Upper gill raker count	12.0	9.6	9.7	9.6	9.7	9.7	9.6	9.9
Lower gill raker count	17.6	17.8	16.5	16.3	16.6	16.7	16.5	16.7
Morphometric variables:								
Fork length	384.0	383.2	388.4	388.1	383.7	388.1	388.9	387.0
Pre-orbital length	20.5	21.4	20.1	21.6	23.3	22.6	2.7	21.3
Orbital diameter	14.1	13.1	12.6	12.9	13.2	13.8	14.3	13.5
Trunk length	84.2	88.2	83.4	88.5	86.9	84.3	86.2	83.7
Caudal peduncle length	38.4	37.9	39.2	38.5	39.3	39.8	38.1	37.1
Middle gill raker length	8.5	8.0	8.0	7.4	6.8	7.0	7.0	7.8
Post-orbital length	42.7	43.2	42.1	42.9	43.2	42.9	43.4	44.4
Dorsal fin base length	45.7	46.9	45.2	44.1	46.5	45.4	47.1	45.9
Lumbar length	69.4	71.3	75.3	76.1	74.6	74.0	73.9	69.3
Anal fin length	38.8	39.2	36.9	35.9	38.0	38.2	39.0	39.5
Caudal peduncle depth	32.7	33.6	32.0	32.0	32.6	31.4	32.2	32.0
Head depth	34.6	34.3	31.2	30.9	32.0	33.3	34.7	33.2
Body depth	98.7	99.5	99.3	101.8	95.1	91.2	88.9	93.3
Inter-orbital width	21.6	22.2	19.2	19.9	20.8	20.7	21.1	21.1
Maxilla width	8.1	7.9	8.1	8.5	8.6	8.2	8.2	8.2
Maxilla length	20.1	19.7	20.0	20.5	20.3	20.0	20.7	20.5
Pectoral fin length	71.2	70.1	70.7	69.7	69.6	68.6	71.1	71.2
Pelvic fin length	67.8	67.2	66.8	66.3	64.9	64.7	66.5	66.1
Adipose fin length	17.1	18.6	19.3	18.9	18.7	17.6	18.4	20.0
Lower gill arch length	25.6	26.0	26.3	25.2	25.8	25.5	28.9	27.0

Table B3. Univariate significance tests of morphometric data.

Morphometric variable	All sites			All but Missi Falls sites			Missi Falls sites only		
	Covariate effect (slope)	Intercept	Parallelism	Covariate effect (slope)	Intercept	Parallelism	Covariate effect (slope)	Intercept	Parallelism
Fork length	0.0001	0.0525	0.0642	0.0001	0.0487	0.0894	0.0001	0.7005	0.5175
Pre-orbital length	0.0001	0.3015	0.2441	0.0001	0.1465	0.2111	0.0001	0.5345	0.2612
Orbital diameter	0.0001	0.2401	0.3278	0.0001	0.7642	0.7403	0.0001	0.5786	0.4177
Post-orbital length	0.0001	0.0951	0.0579	0.0001	0.4469	0.2912	0.0001	0.0883	0.0600
Trunk length	0.0001	0.3519	0.3512	0.0001	0.1443	0.1097	0.0001	0.8030	0.8096
Dorsal fin base length	0.0001	0.0443	0.0410	0.0001	0.0186	0.0204	0.0001	0.2713	0.2354
Lumbar length	0.0001	0.0930	0.0930	0.0001	0.2187	0.1400	0.0001	0.5304	0.2361
Anal fin length	0.0001	0.1930	0.2764	0.0001	0.0316	0.0660	0.0001	0.5738	0.5684
Caudal peduncle length	0.0001	0.0001	0.0001	0.0001	0.0248	0.0326	0.0001	0.0002	0.0003
Head depth	0.0001	0.3103	0.2580	0.0001	0.2522	0.4332	0.0001	0.3426	0.1279
Body depth	0.0001	0.0006	0.0001	0.0001	0.0015	0.0004	0.0001	0.4880	0.5118
Caudal peduncle depth	0.0001	0.3403	0.2882	0.0001	0.0983	0.0800	0.0001	0.8536	0.8440
Inter-orbital width	0.0001	0.2716	0.2853	0.0001	0.1093	0.0887	0.0001	0.7698	0.7693
Maxilla length	0.0001	0.0156	0.0174	0.0001	0.2660	0.1860	0.0001	0.0699	0.1119
Maxilla width	0.0001	0.0122	0.0260	0.0001	0.0234	0.0445	0.0001	0.1183	0.0999
Pectoral fin length	0.0001	0.0131	0.0304	0.0001	0.0415	0.0598	0.0001	0.9346	0.9531
Pelvic fin length	0.0001	0.0516	0.0738	0.0001	0.0748	0.0478	0.0001	0.8535	0.8469
Adipose fin length	0.0001	0.3286	0.2627	0.0001	0.4153	0.3126	0.0001	0.3099	0.2832
Middle gill raker length	0.0001	0.7875	0.8936	0.0001	0.4911	0.5904	0.0001	0.7549	0.8822
Lower gill arch length	0.0001	0.0822	0.0534	0.0001	0.0316	0.0306	0.0001	0.3336	0.2466

APPENDIX C

Table of mark-recapture data used to generate estimates of abundance

Table C1. Mark-recapture dataused to generate population parameters. Numbers in parentheses represent fish caught more than once in a time period.

Sampling period	No tagged and released	No kept plus mortalities	No of new fish caught	1986 Jun [1]	1986 Jul [2]	1986 Aug [3]	1986 early Sep [4]	1986 late Sep [5]	1987 Jun [6]	1987 Jul [7]	1987 Aug [8]	1987 Sep [9]	[1&2]	[3&4]	[1&3]	[1&4]	[2&4]	[4&5]	[1&6]	[5&6]	[6&7]	[5&7]	[7&8]	[6&8]	[1&8]	[4&7]	[8&9]	[3&6]	Total no of new recaptures
June '86	257	49	306	(49)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
July '86	493	50	543	10	(55)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10
Aug '86	447	78	525	5	1	(85)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6
Early Sept '86	2364	80	2444	3	9	19	(385)	-	-	-	-	-	1	(7)	-	(2)	(3)	-	-	-	-	-	-	-	-	-	-	-	33
Late Sept '86	1459	59	1518	2	6	7	62	(59)	-	-	-	-	-	1	-	-	-	(1)	-	-	-	-	-	-	-	-	-	-	78
June '87	3029	50	3079	1	3	5	24	16	(153)	-	-	-	-	-	-	-	-	-	(2)	(1)	-	-	-	-	-	-	-	-	49
July '87	2265	65	2330	3	6	-	9	4	255	(186)	-	-	-	-	-	-	-	-	-	-	(10)	(2)	-	-	-	(1)	-	-	277
Aug '87	1624	72	1696	2	2	2	1	2	12	94	(145)	-	-	-	-	-	-	-	-	-	1	-	(13)	(1)	(1)	-	-	-	116
Sept '87	859	78	936	1	-	-	2	1	5	10	43	84	-	-	-	-	-	-	-	-	-	-	-	-	-	-	(1)	1	147

APPENDIX D

Missi population analyses using the Jolly-Seber full (birth and death) model. Results using the total data set and results with pooling of July and August 1986 data.

SELECT
PARAGRAPH # 1

NICK BARNES...SIL...MISSI FALLS...1986-87
SELECTING ALL ANIMALS AND TIMES...

SELECTED DATASET NUMBER = 12

FILE IS STORED UNDER FORMAT(A8, A2,2A1,(200A2,200A2,112A2))

ORIGINAL FILE CREATED USING FORMAT(F14.5,8X,I3,1X,A1,1X,12I4/100(28X,12I4/))

IDENTIFIER TYPE	# ATTRIBUTES	BEGIN	END	LSEL	# HISTORIES	ACHECKS DONE	TCHECKS DONE	FILE ORDERED
NUMERIC	0	1	8	8	12434	NO	ORDER & RANGE	YES

MAP OF NEW NUMBERING FOR SAMPLE TIMES

	OLD NUMBER				NEW NUMBER			
I	OX(I)	SDES(I)	ABS. TIMES	WEIGHTS	NX(I)	NEW SDES(I)	ABS. TIMES	WEIGHTS
1	1	JUN-86	1.0000	1	1	JUN-86	1.0000	1
2	2	JUL-86	4.0000	1	2	JUL-86	4.0000	1
3	3	AUG-86	9.0000	1	3	AUG-86	9.0000	1
4	4	SEP-86	12.0000	1	4	SEP-86	12.0000	1
5	5	OCT-86	15.0000	1	5	OCT-86	15.0000	1
6	6	JUN-87	48.0000	1	6	JUN-87	48.0000	1
7	7	JUL-87	50.0000	1	7	JUL-87	50.0000	1
8	8	AUG-87	54.0000	1	8	AUG-87	54.0000	1

OLD LSEL (ORIGINAL DATA) = 8

NEW LSEL (REDUCED DATA) = 8

ATTRIBUTE SELECTION CONDITION WAS:

AT =ALL

```
************************
*                      *
*  ANALYSIS            *
*  PARAGRAPH #    1    *
*                      *
************************
```

NICK BARNES...SIL...MISSI FALLS...1986-87
SELECTING ALL ANIMALS AND TIMES...
FIRST ANALYSIS USING ...
JOLLY-SEBER FULL (BIRTH & DEATH) MODEL

STATISTICS TABLE DEFINITION

NAME	DESCRIPTION (AND DEFINING PHRASE)
N(I)	SAMPLE SIZE AT TIME I, EXCLUDING INJECTED ANIMALS SEEN AT (I) AND NOT INJECTED AT (I)
M(I)	SIZE OF MARKED SUBSET OF N(I) SEEN AT (I) AND SEEN BEFORE (I)
L(I)	LOSSES ON CAPTURE LOST AT (I)
S(I)	NUMBER RETURNED TO POPULATION (EXCLUDING LOSSES, INCLUDING INJECTIONS) SEEN AT (I) AND NOT LOST AT (I)
R(I)	NUMBER OF RECAPTURES OUT OF S(I) SEEN AT (I) AND SEEN AFTER (I)
Z(I)	NUMBER SEEN BEFORE I, AFTER I, AND NOT AT I SEEN BEFORE (I) AND SEEN AFTER (I) AND NOT SEEN AT (I)

```
*********************
*                   *
* ANALYSIS          *
* PARAGRAPH #   1   *
*                   *
*********************
```

NICK BARNES...SIL...MISSI FALLS...1986-87
SELECTING ALL ANIMALS AND TIMES...
FIRST ANALYSIS USING ...
JOLLY-SEBER FULL (BIRTH & DEATH) MODEL

STATISTICS TABLE
================

I	N(I)	M(I)	L(I)	S(I)	R(I)	Z(I)
1	306	0	49	257	28	0
2	553	10	50	503	33	18
3	531	6	78	453	34	45
4	2476	32	80	2396	97	47
5	1596	79	59	1537	22	65
6	3129	52	50	3079	267	35
7	2607	277	65	2542	95	25
8	1812	120	72	1740	0	0

HISTORIES SCANNED USING EFFICIENT SCAN = 12434

HISTORIES REJECTED ON ATTRIBUTES = 0

HISTORIES REJECTED FOR NO CAPTURES IN (BEGIN,END) = 0

STATISTICS TABLE NOT SAVED...EXECUTION CONTINUING

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*********************
*                   *
*  ANALYSIS         *
*  PARAGRAPH #   1  *
*                   *
*********************
```

NICK BARNES...SIL...MISSI FALLS...1986-87
SELECTING ALL ANIMALS AND TIMES...
FIRST ANALYSIS USING ...
JOLLY-SEBER FULL (BIRTH & DEATH) MODEL

ESTIMATE TABLE

ESTIMATE DEFINITIONS

NAME	DESCRIPTION
AH(I)	PROPORTION OF MARKS IN THE POPULATION (BIAS CORRECTED)
MH(I)	ESTIMATED NUMBER OF MARKS IN POPULATION (BIAS CORRECTED)
NH(I)	ESTIMATED POPULATION SIZE AT TIME I
NH(I)!N)	CONDITIONAL STANDARD ERROR OF ESTIMATE OF POPULATION SIZE
PHI(I)	ESTIMATE OF SURVIVAL RATE BETWEEN I,I+1
S(PHI(I))	STANDARD ERROR OF ESTIMATE OF SURVIVAL RATE
BH(I)	ESTIMATE OF BIRTHS ENTERING BETWEEN I AND I+1
S(BH(I))	STANDARD ERROR OF THE ESTIMATE OF BIRTHS

VALIDITY FLAGS
(LOCATED TO THE IMMEDIATE RIGHT OF ANY ESTIMATE)

CHAR.	MEANING
' '	ESTIMATE AS CALCULATED IS VALID
'G'	ESTIMATE OF A PROPORTION IS > 1 -- ESTIMATE WAS RESET TO 1
'L'	ESTIMATE OF A POSITIVE QTY < 0 -- ESTIMATE WAS RESET TO 0
'Z'	ESTIMATE NOT FORMED DUE TO 0 IN DENOMINATOR
'U'	ESTIMATE UNAVAILABLE FOR ESTIMATES NEAR BEGINNING/END OF SAMPLE CHAIN
'R'	NO UNMARKED ANIMALS -- ESTIMATE MAY BE INVALID IF SAMPLE IS 'RECAPTURES ONLY'
N	SAMPLE SIZE = 0 -- ESTIMATE SET TO 0 -- OTHERS IN THIS ROW MAY BE INVALID
	INVALID DUE TO 0 SAMPLE SIZE AT NEXT SAMPLE TIME
	GENERAL FAILURE -- E.G. CONVERGENCE FAILURE OR MATRIX INVERSION ERROR

ANALYSIS
PARAGRAPH # 1

NICK BARNES...SIL...MISSI FALLS...1986-87
SELECTING ALL ANIMALS AND TIMES...
FIRST ANALYSIS USING ...
JOLLY-SEBER FULL (BIRTH & DEATH) MODEL

ESTIMATE TABLE

I	AH(I)	MH(I)	NH(I)	S(NH(I)!N)	PHI(I)	S(PHI(I))	BH(I)	S(BH(I))
1	0.0000 U	0.0 U	0.0 U	0.0 U	1.0000 G	0.2755	0.0 U	0.0 U
2	0.0199	276.8	13941.8	5744.1	0.7660	0.1838	34176.6	19901.8
3	0.0132	589.7	44818.3	20527.7	1.0000 G	0.2102	43949.9	25212.9
4	0.0133	1181.6	88690.2	21511.2	1.0000 G	0.2484	0.0 L	20710.0
5	0.0501	4425.5	88344.5	23423.0	0.0772	0.0186	20009.7	4702.9
6	0.0169	454.2	26825.8	5355.6	0.2698	0.0431	1587.2	1437.7
7	0.1066	939.2	8811.3	1437.4	0.0000 U	0.0000 U	0.0 U	0.0 U
8	0.0667	0.0 U	0.0 U	0.0 U	0.0000 U	0.0000 U	0.0 U	0.0 U

*** ESTIMATE TABLE NOT SAVED...EXECUTION CONTINUING

```
**********************
*                    *
*  SELECT            *      NICK BARNES...SIL...MISSI FALLS...1986-87
*  PARAGRAPH #    2  *      POOLING 86 DATA INTO 2 SAMPLES...
*                    *
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SELECTED DATASET NUMBER = 12

FILE IS STORED UNDER FORMAT(A8, A2,2A1,(200A2,200A2,112A2))

ORIGINAL FILE CREATED USING FORMAT(F14.5,8X,I3,1X,A1,1X,12I4/100(28X,12I4/))

IDENTIFIER TYPE	# ATTRIBUTES	BEGIN	END	LSEL	# HISTORIES	ACHECKS DONE	TCHECKS DONE	FILE ORDERED
NUMERIC	0	1	8	8	12434	NO	ORDER & RANGE	YES

MAP OF NEW NUMBERING FOR SAMPLE TIMES

	OLD NUMBER				NEW NUMBER			
I	OX(I)	SDES(I)	ABS. TIMES	WEIGHTS	NX(I)	NEW SDES(I)	ABS. TIMES	WEIGHTS
1	1	JUN-86	1.0000	1	1	JUN-86	4.6667	3
2	2	JUL-86	4.0000	1	0	GROUP AS 1	0.0000	0
3	3	AUG-86	9.0000	1	0	GROUP AS 1	0.0000	0
4	4	SEP-86	12.0000	1	2	SEP-86	12.0000	1
5	5	OCT-86	15.0000	1	3	OCT-86	15.0000	1
6	6	JUN-87	48.0000	1	4	JUN-87	48.0000	1
7	7	JUL-87	50.0000	1	5	JUL-87	50.0000	1
8	8	AUG-87	54.0000	1	6	AUG-87	54.0000	1

OLD LSEL (ORIGINAL DATA) = 8

NEW LSEL (REDUCED DATA) = 6

ATTRIBUTE SELECTION CONDITION WAS:

AT =ALL

```
**********************
*                    *
*  ANALYSIS          *     NICK BARNES...SIL...MISSI FALLS...1986-87
*  PARAGRAPH #   2   *     POOLING 86 DATA INTO 2 SAMPLES...
*                    *     SECOND ANALYSIS USING...
**********************     JOLLY-SEBER FULL (BIRTH & DEATH) MODEL
```

STATISTICS TABLE DEFINITION
===========================

NAME	DESCRIPTION (AND DEFINING PHRASE)
N(I)	SAMPLE SIZE AT TIME I, EXCLUDING INJECTED ANIMALS SEEN AT (I) AND NOT INJECTED AT (I)
M(I)	SIZE OF MARKED SUBSET OF N(I) SEEN AT (I) AND SEEN BEFORE (I)
L(I)	LOSSES ON CAPTURE LOST AT (I)
S(I)	NUMBER RETURNED TO POPULATION (EXCLUDING LOSSES, INCLUDING INJECTIONS) SEEN AT (I) AND NOT LOST AT (I)
R(I)	NUMBER OF RECAPTURES OUT OF S(I) SEEN AT (I) AND SEEN AFTER (I)
Z(I)	NUMBER SEEN BEFORE I, AFTER I, AND NOT AT I SEEN BEFORE (I) AND SEEN AFTER (I) AND NOT SEEN AT (I)

```
**********************
*                    *
*  ANALYSIS          *
*  PARAGRAPH #   2   *
*                    *
**********************
```

NICK BARNES...SIL...MISSI FALLS...1986-87
POOLING 86 DATA INTO 2 SAMPLES...
SECOND ANALYSIS USING...
JOLLY-SEBER FULL (BIRTH & DEATH) MODEL

STATISTICS TABLE
================

I	N(I)	M(I)	L(I)	S(I)	R(I)	Z(I)
1	1374	0	177	1197	79	0
2	2476	32	80	2396	97	47
3	1596	79	59	1537	22	65
4	3129	52	50	3079	267	35
5	2607	277	65	2542	95	25
6	1812	120	72	1740	0	0

HISTORIES SCANNED USING EFFICIENT SCAN = 12434

HISTORIES REJECTED ON ATTRIBUTES = 0

HISTORIES REJECTED FOR NO CAPTURES IN (BEGIN,END) = 0

STATISTICS TABLE NOT SAVED...EXECUTION CONTINUING

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*********************
*                   *
*  ANALYSIS         *      NICK BARNES...SIL...MISSI FALLS...1986-87
*  PARAGRAPH #   2  *      POOLING 86 DATA INTO 2 SAMPLES...
*                   *      SECOND ANALYSIS USING...
*********************      JOLLY-SEBER FULL (BIRTH & DEATH) MODEL
```

ESTIMATE TABLE

ESTIMATE DEFINITIONS

NAME	DESCRIPTION
AH(I)	PROPORTION OF MARKS IN THE POPULATION (BIAS CORRECTED)
MH(I)	ESTIMATED NUMBER OF MARKS IN POPULATION (BIAS CORRECTED)
NH(I)	ESTIMATED POPULATION SIZE AT TIME I
S(NH(I)!N)	CONDITIONAL STANDARD ERROR OF ESTIMATE OF POPULATION SIZE
PHI(I)	ESTIMATE OF SURVIVAL RATE BETWEEN I,I+1
S(PHI(I))	STANDARD ERROR OF ESTIMATE OF SURVIVAL RATE
BH(I)	ESTIMATE OF BIRTHS ENTERING BETWEEN I AND I+1
S(BH(I))	STANDARD ERROR OF THE ESTIMATE OF BIRTHS

VALIDITY FLAGS
(LOCATED TO THE IMMEDIATE RIGHT OF ANY ESTIMATE)

CHAR.	MEANING
' '	ESTIMATE AS CALCULATED IS VALID
'G'	ESTIMATE OF A PROPORTION IS > 1 -- ESTIMATE WAS RESET TO 1
'L'	ESTIMATE OF A POSITIVE QTY < 0 -- ESTIMATE WAS RESET TO 0
'Z'	ESTIMATE NOT FORMED DUE TO 0 IN DENOMINATOR
'U'	ESTIMATE UNAVAILABLE FOR ESTIMATES NEAR BEGINNING/END OF SAMPLE CHAIN
'R'	NO UNMARKED ANIMALS -- ESTIMATE MAY BE INVALID IF SAMPLE IS 'RECAPTURES ONLY'
'N'	SAMPLE SIZE = 0 -- ESTIMATE SET TO 0 -- OTHERS IN THIS ROW MAY BE INVALID
'I'	INVALID DUE TO 0 SAMPLE SIZE AT NEXT SAMPLE TIME
F	GENERAL FAILURE -- E.G. CONVERGENCE FAILURE OR MATRIX INVERSION ERROR

```
**********************
*                    *
*  ANALYSIS          *
*  PARAGRAPH #   2   *
*                    *
**********************
```

NICK BARNES...SIL...MISSI FALLS...1986-87
POOLING 86 DATA INTO 2 SAMPLES...
SECOND ANALYSIS USING...
JOLLY-SEBER FULL (BIRTH & DEATH) MODEL

ESTIMATE TABLE
==============

I	AH(I)	MH(I)	NH(I)	S(NH(I)!N)	PHI(I)	S(PHI(I))	BH(I)	S(BH(I))
1	0.0000 U	0.0 U	0.0 U	0.0 U	0.9871	0.1678	0.0 U	0.0 U
2	0.0133	1181.6	88690.2	21511.2	1.0000 G	0.2484	0.0 L	20710.0
3	0.0501	4425.5	88344.5	23423.0	0.0772	0.0186	20009.7	4702.9
4	0.0169	454.2	26825.8	5355.6	0.2698	0.0431	1587.2	1437.7
5	0.1066	939.2	8811.3	1437.4	0.0000 U	0.0000 U	0.0 U	0.0 U
6	0.0667	0.0 U	0.0 U	0.0 U	0.0000 U	0.0000 U	0.0 U	0.0 U

*** ESTIMATE TABLE NOT SAVED...EXECUTION CONTINUING

APPENDIX E

Multivariate examination of Area 4 samples

Figure 1. plot of the first and second canonical variable for the Area 4 samples using the ratio-adjusted data.

Legend:

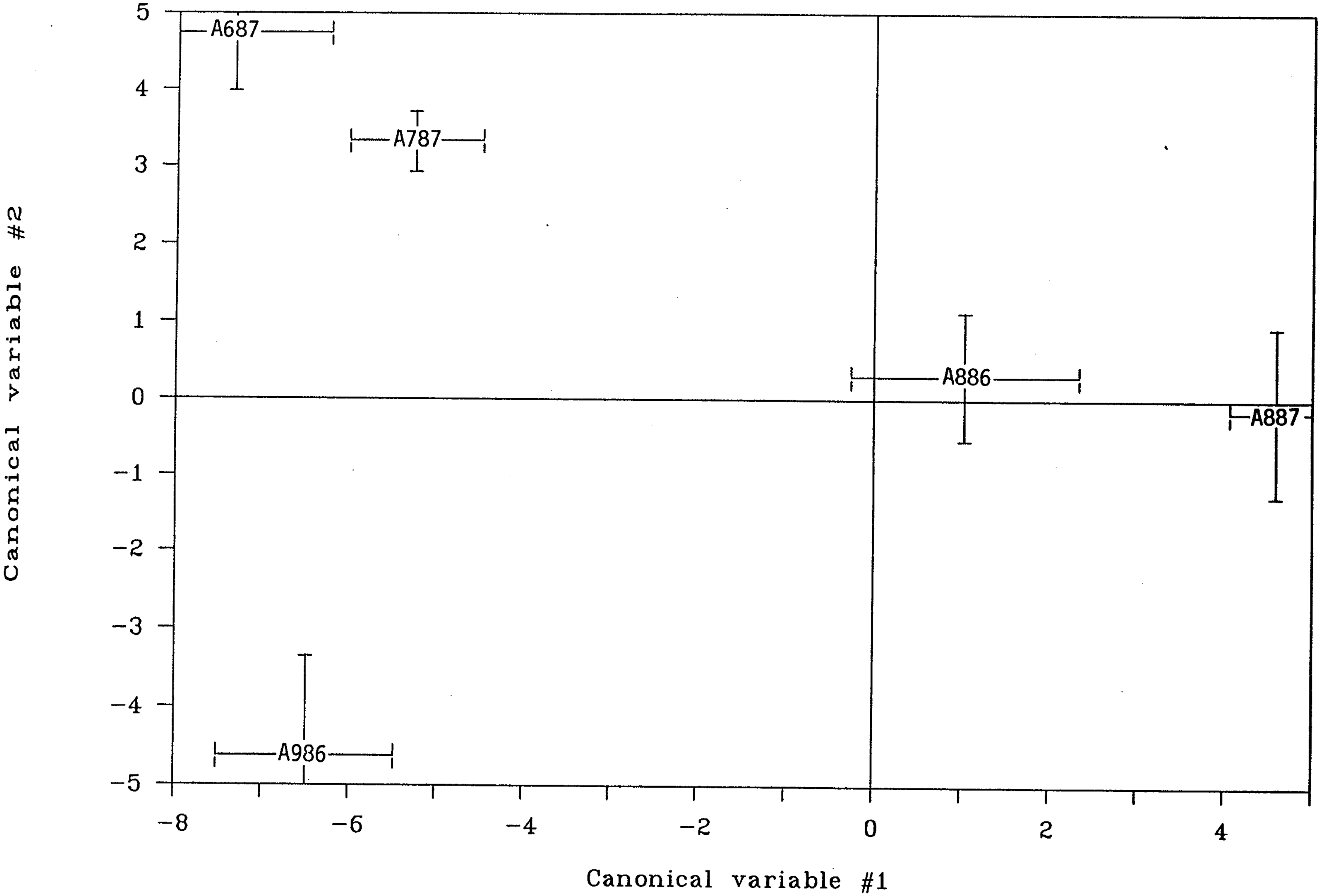
A886 - Area 4, August, 1986 sample.

A986 - Area 4, September, 1986 sample.

A687 - Area 4, June, 1987 sample.

A787 - Area 4, July, 1987 sample.

A887 - Area 4, August, 1987 sample.


A687
A787
A886
A887
A986
Canonical variable #2
Canonical variable #1
5
4
3
2
1
0
−1
−2
−3
−4
−5
−8
−6
−4
−2
0
2
4

APPENDIX F

Multivariate examination of upstream samples.

Table F1. Summary of reclassification table for the upstream samples (Area 4 and Strawberry I.) using the ratio-adjusted data. Values are number (and percentage) of observations classified into sample.

Sample	Strawberry Island July '86	Area 4					Total
		Aug '86	Sept '86	June '87	July '87	Aug '87	
Strawberry I., July '86	47 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	47 (100.0)
Area 4, Aug '86	13 (92.9)	1 (7.1)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	14 (100.0)
Area 4, Sept '86	6 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	6 (100.0)
Area 4, June '87	4 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	4 (100.0)
Area 4, July '87	2 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (100.0)
Area 4, Aug '87	13 (92.9)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (7.1)	14 (100.0)
Total	85 (97.7)	1 (1.2)	0 (0.0)	0 (0.0)	0 (0.0)	1 (1.2)	87 (100.0)

Figure 1. Plot of the first and second canonical variables for the upstream samples using the ratio-adjusted data.

Legend:

A886 - Area 4, August, 1986 sample.

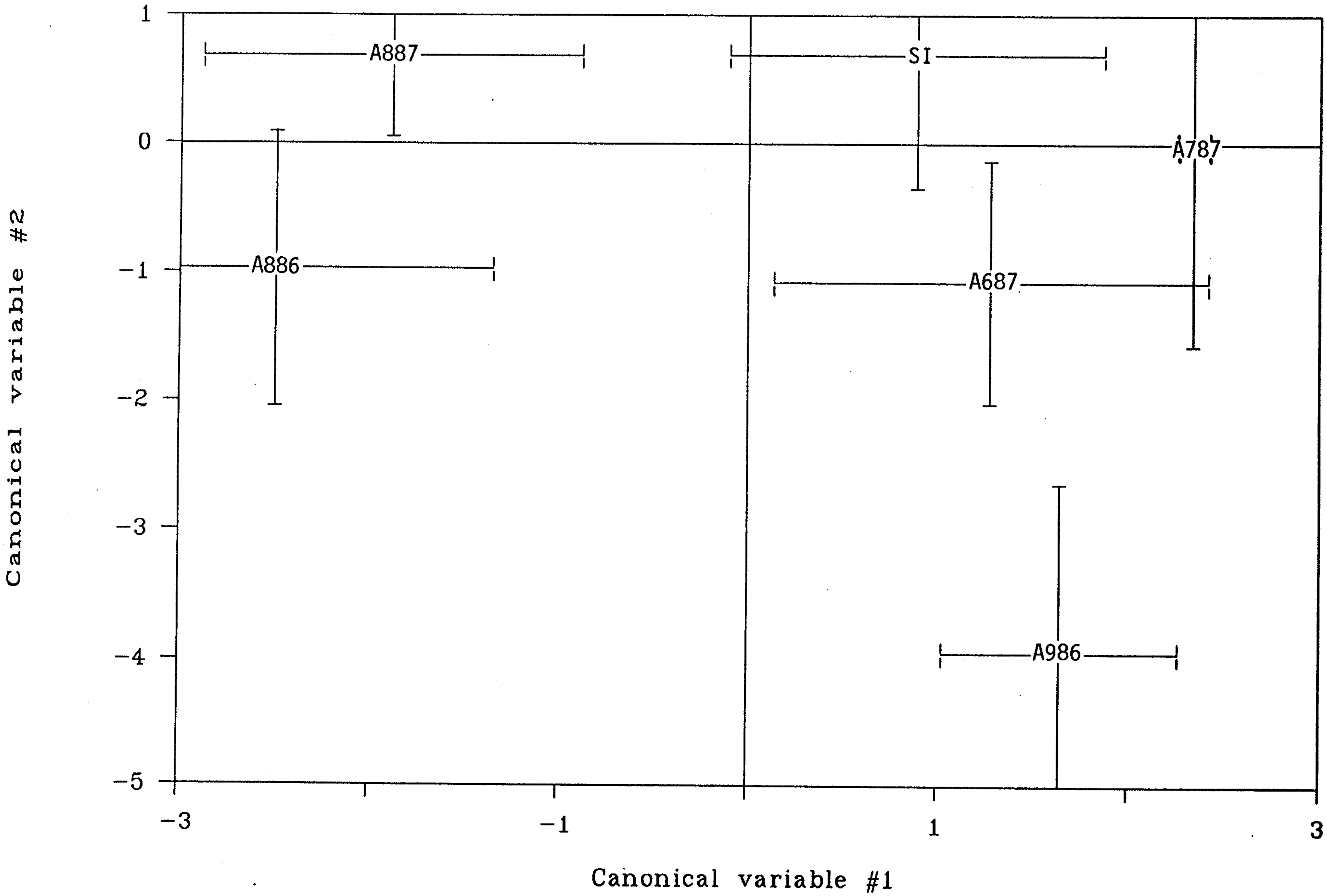
A986 - Area 4, September, 1986 sample.

A687 - Area 4, June, 1987 sample.

A787 - Area 4, July, 1987 sample.

A887 - Area 4, August, 1987 sample.

SI - Strawberry Island (June, 1986) sample.


A887
SI
A787
A886
A687
A986
1
0
−1
−2
−3
−4
−5
−3
−1
1
3
Canonical variable #1
Canonical variable #2

APPENDIX G

Multivariate examination of Missi Falls samples.

Table G1. Summary of reclassification table for the Missi Falls samples using the ratio-adjusted data. Values are number (and percentage) of observations classified into sample.

Site	June '86	July '86	Aug '86	Sept '86	June '87	July '87	Aug '87	Sept '87	Total
June '86	34 (75.6)	5 (11.1)	1 (2.2)	0 (0.0)	0 (0.0)	2 (4.4)	0 (0.0)	3 (6.7)	45 (100.0)
July '86	6 (15.0)	33 (82.5)	0 (0.0)	0 (0.0)	0 (0.0)	1 (2.5)	0 (0.0)	0 (0.0)	40 (100.0)
Aug '86	0 (0.0)	0 (0.0)	15 (68.2)	3 (13.6)	0 (0.0)	1 (4.6)	0 (0.0)	3 (13.6)	22 (100.0)
Sept '86	0 (0.0)	0 (0.0)	2 (9.1)	19 (86.4)	0 (0.0)	0 (0.0)	0 (0.0)	1 (4.6)	22 (100.0)
June '87	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	42 (79.3)	6 (11.3)	4 (7.6)	1 (1.9)	53 (100.0)
July '87	1 (2.1)	1 (2.1)	0 (0.0)	1 (2.1)	1 (2.1)	31 (66.0)	7 (14.9)	5 (10.6)	47 (100.0)
Aug '87	2 (6.1)	0 (0.0)	1 (3.0)	0 (0.0)	2 (8.1)	5 (15.2)	20 (60.1)	3 (9.1)	33 (100.0)
Sept '87	3 (6.8)	0 (0.0)	2 (4.6)	0 (0.0)	1 (2.3)	2 (4.6)	3 (6.8)	33 (75.0)	44 (100.0)
Total	46 (15.0)	39 (12.8)	21 (6.9)	23 (7.5)	46 (15.0)	48 (15.7)	34 (11.1)	49 (16.0)	306 (100.0)

Figure 1. Plot of the first and second canonical variables for the Missi Falls samples using the ratio-adjusted data.

<u>Legend:</u>

M686 - Missi Falls, June, 1986 sample.

M786 - Missi Falls, July, 1986 sample.

M886 - Missi Falls, August, 1986 sample.

M986 - Missi Falls, September, 1986 sample.

M687 - Missi Falls, June, 1987 sample.

M787 - Missi Falls, July, 1987 sample.

M887 - Missi Falls, August, 1987 sample.

M987 - Missi Falls, September, 1987 sample.

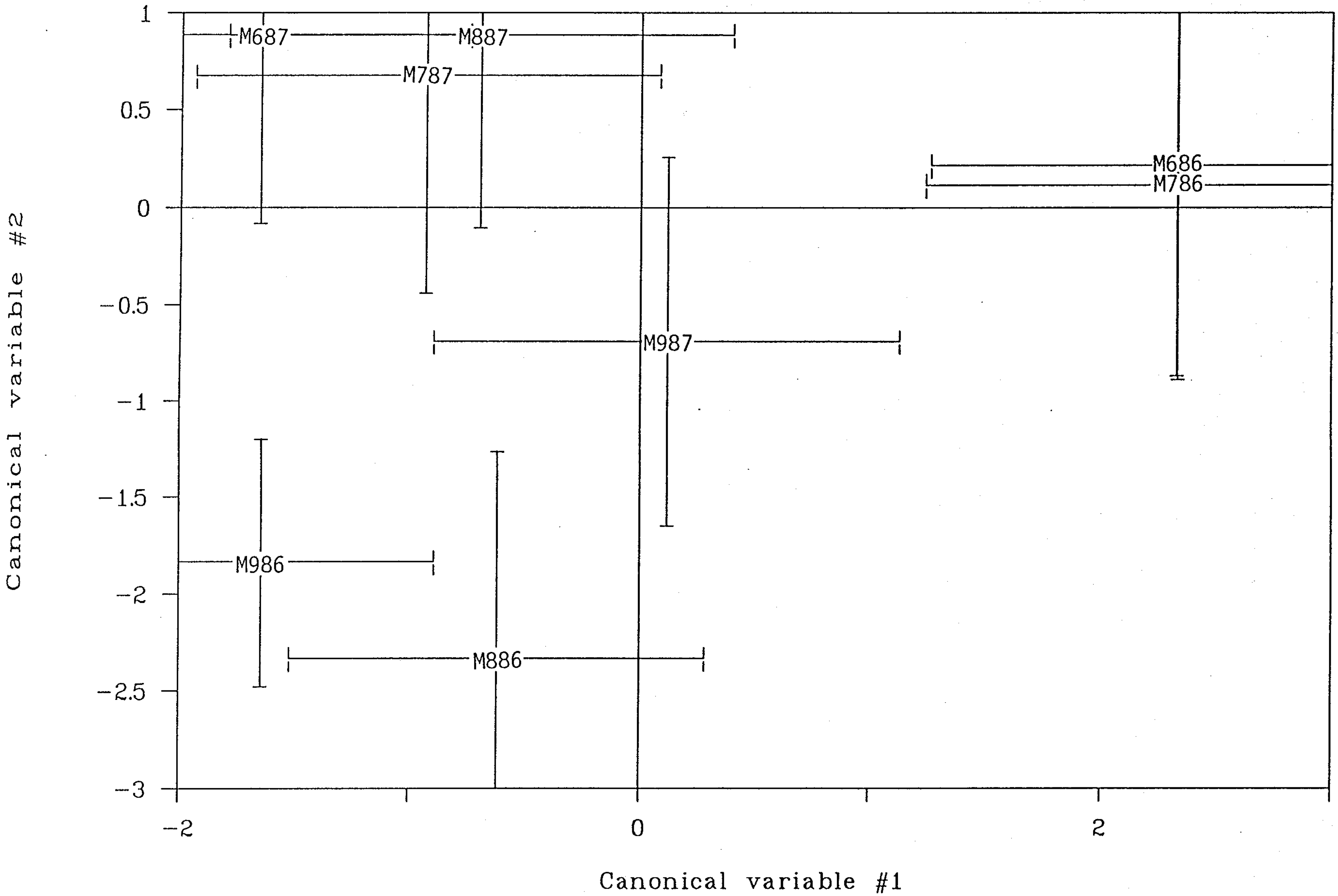
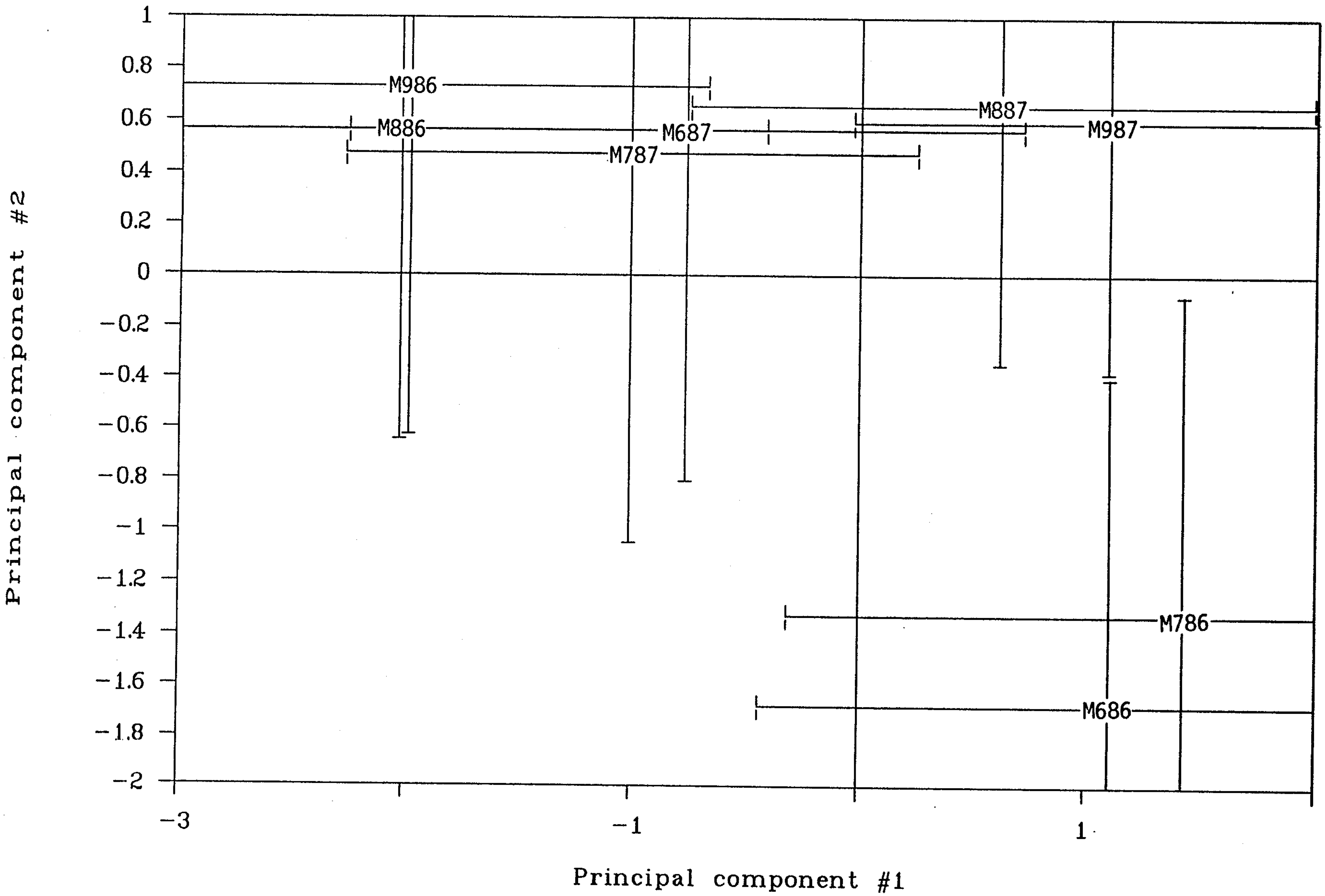

M687
M887
M787
M686
M786
M987
M986
M886
1
0.5
0
−0.5
−1
−1.5
−2
−2.5
−3
−2
0
2
Canonical variable #1
Canonical variable #2

Figure 2. Plot of the first and second principal components for the Missi Falls samples using the residual-adjusted data.

Legend:

M686 - Missi Falls, June, 1986 sample.
M786 - Missi Falls, July, 1986 sample.
M886 - Missi Falls, August, 1986 sample.
M986 - Missi Falls, September, 1986 sample.
M687 - Missi Falls, June, 1987 sample.
M787 - Missi Falls, July, 1987 sample.
M887 - Missi Falls, August, 1987 sample.
M987 - Missi Falls, September, 1987 sample.



1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1
−1.2
−1.4
−1.6
−1.8
−2
−3
−1
1
Principal component #2
Principal component #1
M986
M887
M886
M687
M987
M787
M786
M686

Figure 3. Plot of the first and second principal components for the Missi Falls samples using the ratio-adjusted data.

<u>Legend:</u>

M686 - Missi Falls, June, 1986 samples.

M786 - Missi Falls, July, 1986 samples.

M886 - Missi Falls, August, 1986 samples.

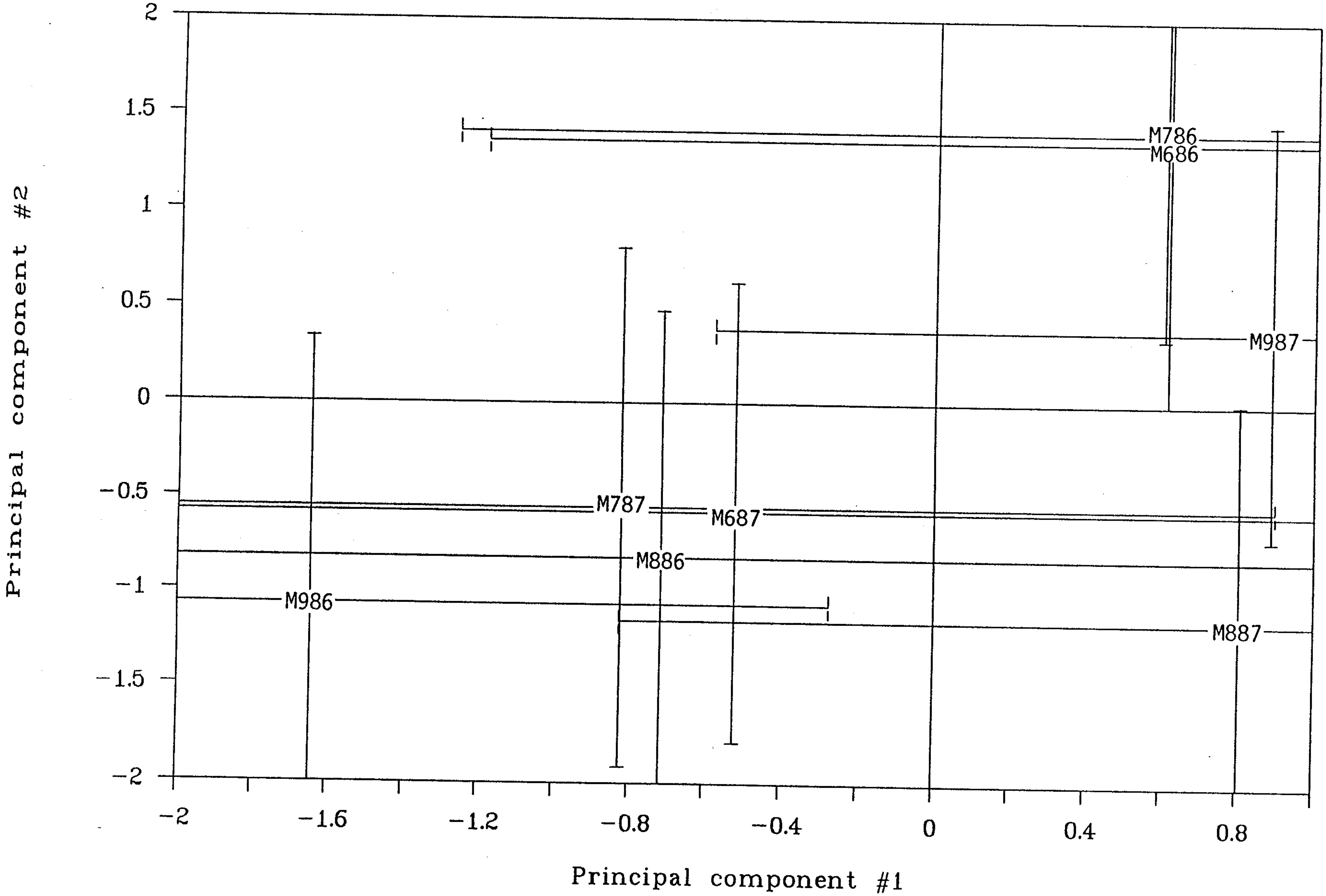
M986 - Missi Falls, September, 1986 samples.

M687 - Missi Falls, June, 1987 samples.

M787 - Missi Falls, July, 1987 samples.

M887 - Missi Falls, August, 1987 samples.

M987 - Missi Falls, September, 1987 samples.


M786
M686
M987
M787
M687
M886
M986
M887
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2
−2
−1.6
−1.2
−0.8
−0.4
0
0.4
0.8
Principal component #1
Principal component #2

APPENDIX H

Multivariate comparison of Missi Falls samples to upstream and downstream samples.

Table H1. Summary of reclassification table examining the complete data set less the Missi sites using the ratio-adjusted data. Values are number (and percentage) of observations classified into sample.

Sampling site	Partridge Breast Lake	Northern Indian Lake	Area 4	Fidler Lake	Gauer Lake	Coffer dam	Strawberry Island	Totals
Partridge Breast L.	48 (73.9)	7 (10.8)	1 (1.5)	1 (1.5)	3 (4.6)	5 (7.7)	0 (0.0)	65 (100.0)
Northern Indian L.	3 (8.1)	28 (75.7)	2 (5.4)	1 (2.7)	1 (2.7)	2 (5.4)	0 (0.0)	37 (100.0)
Area 4	2 (7.4)	0 (0.0)	18 (66.7)	4 (14.8)	1 (3.7)	2 (7.4)	0 (0.0)	27 (100.0)
Fidler L.	0 (0.0)	0 (0.0)	0 (0.0)	12 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	12 (100.0)
Gauer L.	0 (0.0)	0 (0.0)	0 (0.0)	2 (9.5)	17 (81.0)	2 (9.5)	0 (0.0)	21 (100.0)
Coffer dam	0 (0.0)	0 (0.0)	1 (11.1)	1 (11.1)	0 (0.0)	7 (7.8)	0 (0.0)	9 (100.0)
Strawberry I.	5 (10.9)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	41 (89.1)	46 (100.0)
Totals	58 (26.7)	35 (16.1)	22 (10.1)	21 (9.7)	22 (10.1)	18 (18.3)	41 (18.9)	217 (100.0)

Table H2. Summary of reclassification table of Missi Falls samples into the total data set using the ratio-adjusted data. Values are number (and percentage) of observations classified into sample.

Missi Falls sampling period	Partridge Breast Lake	Northern Indian Lake	Area 4	Fidler Lake	Gauer Lake	Coffer dam	Strawberry Island	Total
June, 1986	17 (37.8)	1 (2.2)	7 (15.6)	0 (0.0)	8 (17.8)	0 (0.0)	12 (0.0)	45 (100.0)
July, 1986	7 (17.5)	0 (0.0)	10 (25.0)	3 (7.5)	2 (5.0)	3 (7.5)	15 (7.5)	40 (100.0)
Aug, 1986	6 (27.3)	4 (18.2)	2 (9.1)	2 (9.1)	4 (18.2)	2 (9.1)	2 (9.1)	22 (100.0)
Sept, 1986	0 (0.0)	3 (13.6)	5 (22.7)	0 (0.0)	2 (9.1)	7 (31.8)	5 (22.7)	22 (100.0)
June, 1987	7 (13.2)	2 (3.8)	9 (17.0)	0 (0.0)	0 (0.0)	10 (18.9)	25 (47.2)	53 (100.0)
July, 1987	7 (14.9)	1 (2.1)	1 (2.1)	0 (0.0)	0 (0.0)	3 (6.4)	35 (74.5)	47 (100.0)
Aug, 1987	6 (18.2)	3 (9.1)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	24 (72.7)	33 (100.0)
Sept, 1987	14 (31.8)	1 (2.3)	4 (9.1)	0 (0.0)	7 (15.9)	12 (27.3)	6 (13.6)	44 (100.0)
Total	64 (20.9)	15 (4.9)	38 (12.4)	5 (1.6)	23 (7.5)	37 (12.1)	124 (40.5)	306 (100.0)

Figure 1. Plot of the first and second canonical variables for the total data set using the ratio-adjusted data.

<u>Legend:</u>

M686 - Missi Falls, June, 1986 samples.

M786 - Missi Falls, July, 1986 samples.

M886 - Missi Falls, August, 1986 samples.

M986 - Missi Falls, September, 1986 samples.

M687 - Missi Falls, June, 1987 samples.

M787 - Missi Falls, July, 1987 samples.

M887 - Missi Falls, August, 1987 samples.

M987 - Missi Falls, September, 1987 samples.

SI - SIL-Strawberry Island sample.

A4 - SIL-Area 4 sample.

CD - Coffer dam sample.

PB - Partridge Breast Lake sample.

NIL - Northern Indian Lake sample.

F - Fidler Lake sample.

G - Gauer Lake sample.

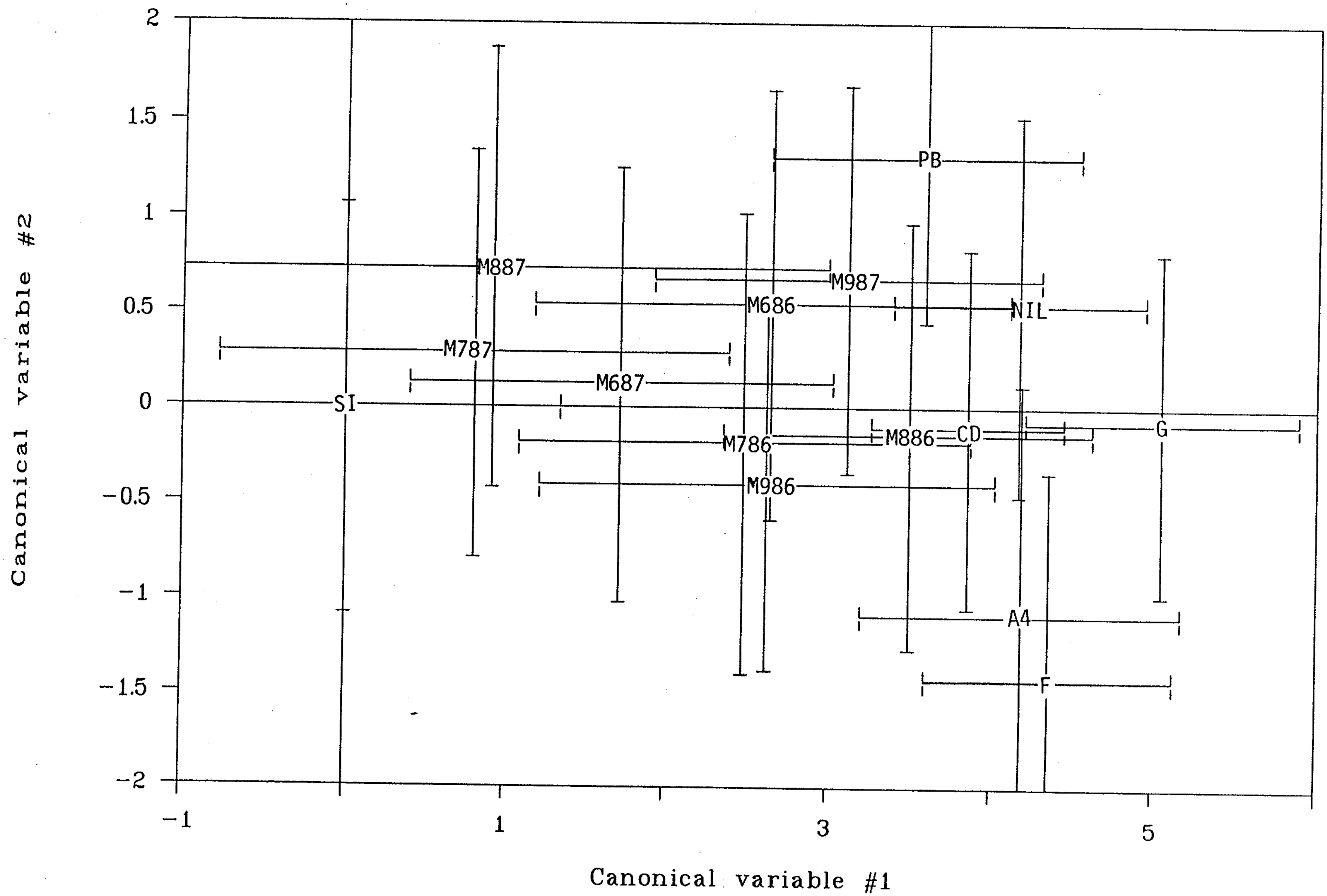

Canonical variable #2
Canonical variable #1
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2
−1
1
3
5
PB
M887
M987
M686
NIL
M787
M687
SI
M886
CD
G
M786
M986
A4
F

Figure 2. Plot of the first and second principal components for the total data set using the residual-adjusted data.

<u>Legend:</u>

M686 - Missi Falls, June, 1986 samples.

M786 - Missi Falls, July, 1986 samples.

M886 - Missi Falls, August, 1986 samples.

M986 - Missi Falls, September, 1986 samples.

M687 - Missi Falls, June, 1987 samples.

M787 - Missi Falls, July, 1987 samples.

M887 - Missi Falls, August, 1987 samples.

M987 - Missi Falls, September, 1987 samples.

SI - SIL-Strawberry Island sample.

A4 - SIL-Area 4 sample.

CD - Coffer dam sample.

PB - Partridge Breast Lake sample.

NIL - Northern Indian Lake sample.

F - Fidler Lake sample.

G - Gauer Lake sample.

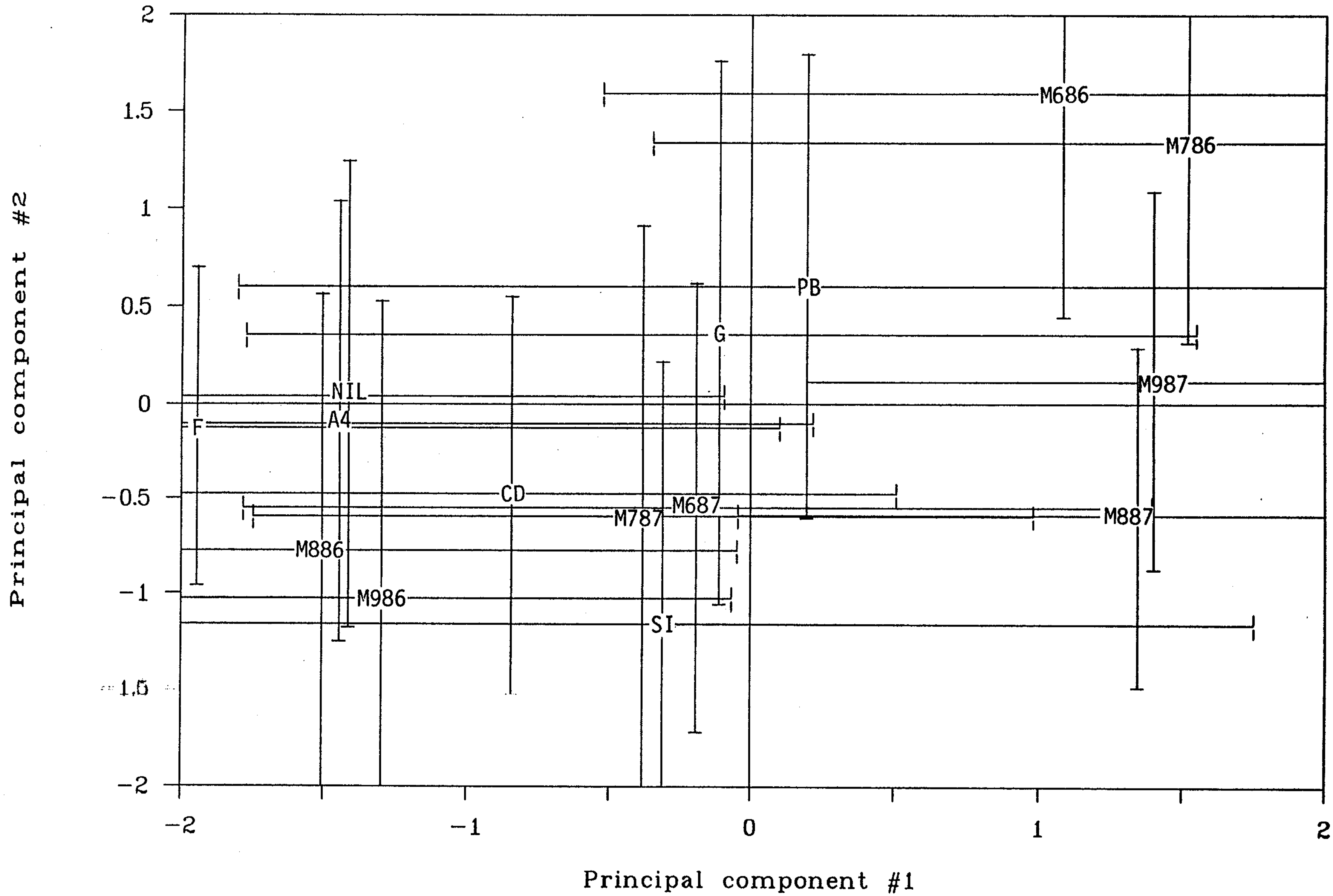

M686
M786
PB
G
NIL
M987
F
A4
CD
M687
M787
M887
M886
M986
SI
Principal component #1
Principal component #2
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2
−2
−1
0
1
2

Figure 3. Plot of the first and second principal components for the total data set using the ratio-adjusted data.

Legend:

M686 - Missi Falls, June, 1986 samples.

M786 - Missi Falls, July, 1986 samples.

M886 - Missi Falls, August, 1986 samples.

M986 - Missi Falls, September, 1986 samples.

M687 - Missi Falls, June, 1987 samples.

M787 - Missi Falls, July, 1987 samples.

M887 - Missi Falls, August, 1987 samples.

M987 - Missi Falls, September, 1987 samples.

SI - SIL-Strawberry Island sample.

A4 - SIL-Area 4 sample.

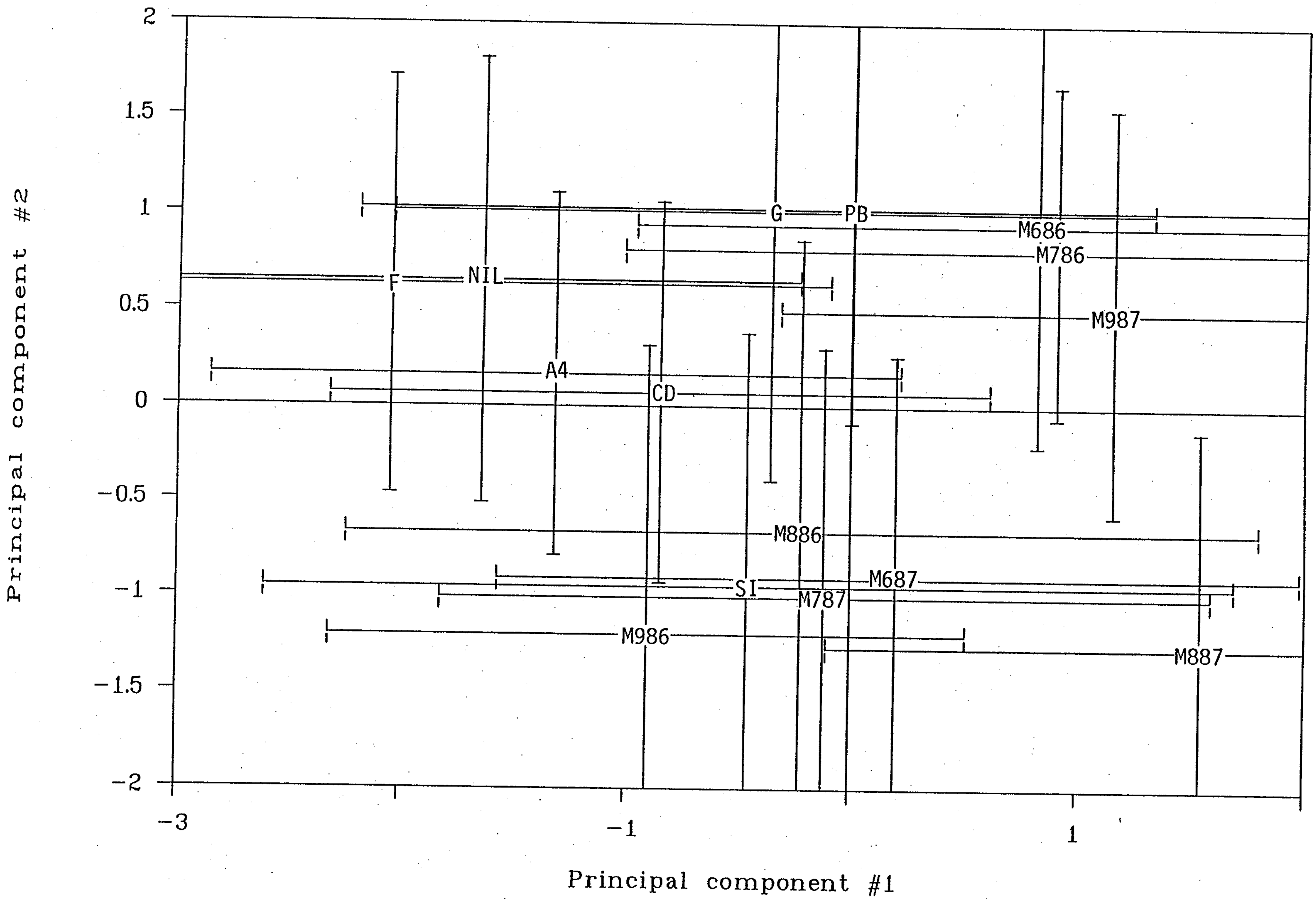
CD - Coffer dam sample.

PB - Partridge Breast Lake sample.

NIL - Northern Indian Lake sample.

F - Fidler Lake sample.

G - Gauer Lake sample.



Principal component #2
Principal component #1
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2
−3
−1
1
G
PB
M686
M786
F
NIL
M987
A4
CD
M886
SI
M687
M787
M986
M887

APPENDIX I

Biological analyses of the Missi Falls data set.

Figure 1. Temporal changes in condition factor (CF) for male and female lake whitefish caught at the Missi Falls control structure: June, 1986 to September 1986. (Vertical bars represent standard deviations).

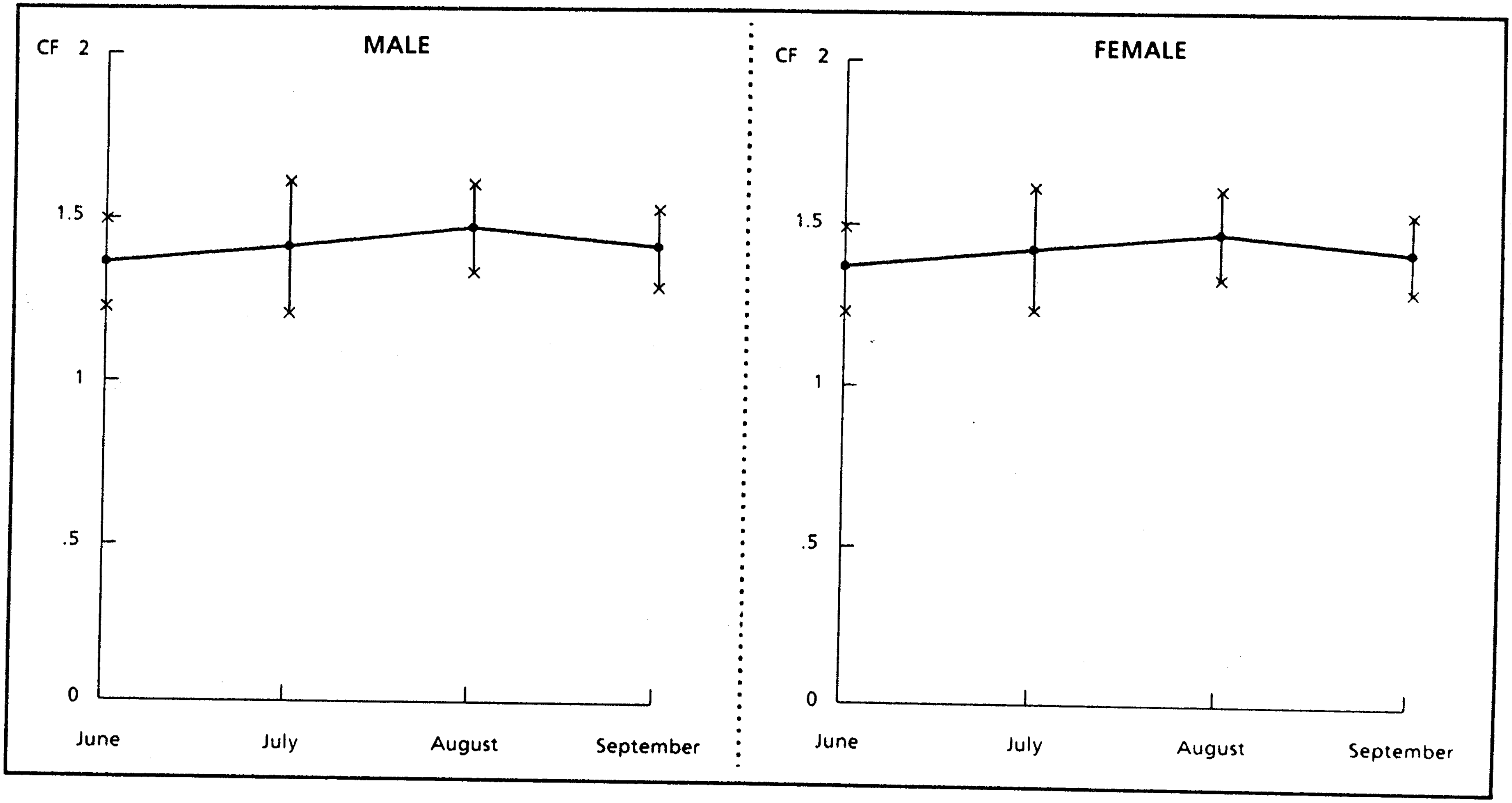
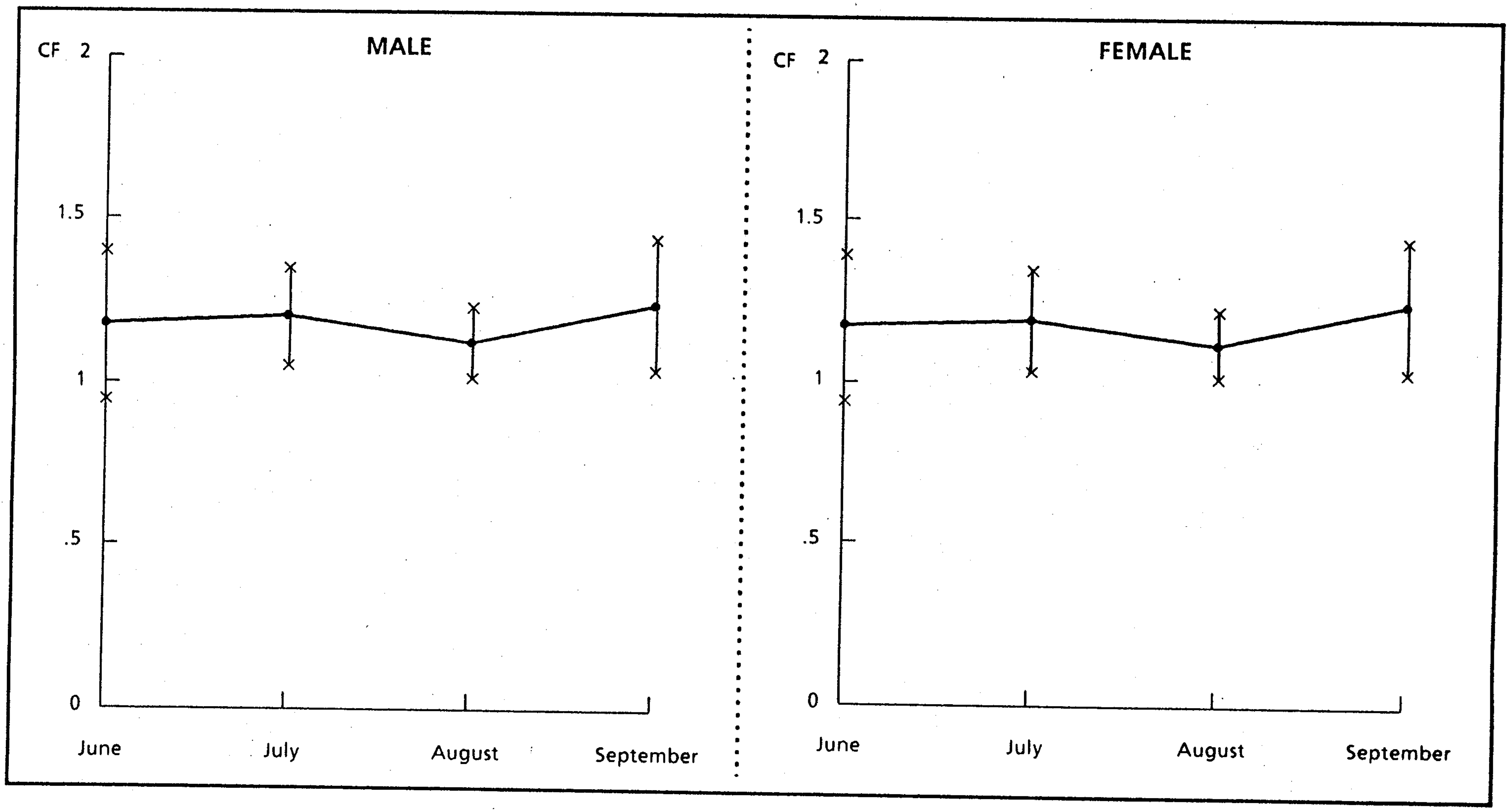

MALE
FEMALE
CF
2
1.5
1
.5
0
June
July
August
September

Figure 2. Temporal changes in condition factor (CF) for male and female lake whitefish caught at the Missi Falls control structure: June, 1987 to September 1987. (Vertical bars represent standard deviations).


MALE
FEMALE
CF
2
1.5
1
.5
0
June
July
August
September

APPENDIX J

Manitoba Hydro historic flow records at Missi Falls.

Manitoba Hydro - SOD/MJD - Daily Hydraulic Information - 11-27-1987
field 209 = Missi Discharge - cfs

FileYYDD	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
209F75 1												35240
209F75 2												35240
209F75 3												35240
209F75 4												35120
209F75 5												35270
209F75 6												35120
209F75 7												35240
209F75 8												35330
209F75 9												35270
209F7510												35330
209F7511												35270
209F7512												35240
209F7513												35180
209F7514												
209F7515												35210
209F7516												
209F7517												
209F7518												
209F7519												
209F7520												
209F7521												
209F7522												
209F7523												
209F7524												
209F7525												
209F7526												
209F7527												
209F7528												
209F7529												
209F7530												
209F7531												
209F76 1	34410	33100	24480		33980	50130	10000	13082	21700	31493	39670	38610
209F76 2	34350	23680	24570		33980	47500	10820	13198	21800	31432	39340	38510
209F76 3	34320	23870	24540		34010	40950	10870	13300	21800	31371	39000	38580
209F76 4	34260	23850	24470		34010	35500	10920	13300	21880	31300	39000	38580
209F76 5	34230	23890	24590		34040	32600	10980	13390	21950	31218	39000	38590
209F76 6	34170	23960	24520		34100	25150	10920	13480	22000	31473	39000	38590
209F76 7	34110	23960	24590		34100	20500	10910	13470	22130	31667	39000	38610
209F76 8	34050	24030	24660		34130	16330	10930	13550	22180	37000	39000	38540
209F76 9	33990	24110	24680		34190	10500	10750	13730	22200	37000	39000	38590
209F7610	33090	23940	24680		34250	10500	10960	13810	22200	37000	39000	38630
209F7611	33870	24110	24790		34310	10500	11120	13760	22180	37000	38950	38300
209F7612	33840	24030	24770		34400	10500	11280	13920	22230	37000	38900	38300
209F7613	33780	24170	24770		34460	10000	11250	13980	22300	37000	38850	38210
209F7614	33750	24150	24840		34550	10000	11000	14050	22918	37000	38800	38300
209F7615	33690	24060	24890		34670	10000	11400	14143	23020	37000	38750	38000
209F7616	33660	24060	24930		34760	10000	11680	14240	23032	37000	38700	31230
209F7617	33480	24240	24890		34880	10000	11620	14330	23068	49000	38650	31390
209F7618	33480	24290	24930		35000	10000	11710	14660	30000	49000	38650	31310
209F7619	33480	24310	25040		35120	10000	11860	14660	31279	49000	38650	31440
209F7620	33630	24340	25100		35270	10000	11840	14600	31188	49000	38650	31430
209F7621	33420	24410	25080		35390	10000	11930	14500	31096	49000	38650	31340
209F7622	33270	24450	25060		35450	10000	11980	14651	31768	49000	38650	31330
209F7623	33540	24500	25100		52320	10000	12060	14700	31524	49000	38650	31300
209F7624	33420	24410	35420		52200	10000	12320	14500	31279	49000	38650	31420
209F7625	33450	24520	35270		51990	10000	12390	14800	31330	49000	38640	31390
209F7626	33480	24520	35300		51790	10000	5790	14300	31345	49000	38640	31410

209F7627	33360	24620	35270		51550	10000	12540	14500	31360	49000	38630	31380
209F7628	33390	24620	35240		51300	10000	12570	15050	31360	49000	38630	31390
209F7629	33120	24590	35210		51020	10000	12680	15160	31310	49000	38620	31360
209F7630	33330		35090		50740	10000	12890	21510	31585	49000	38610	31360
209F7631	33120		35180		50330		12970	21630		49000		31350
209F78 1	6000	6180	6180	6180	8850	21630	10180	18510	45530	15180	19180	19180
209F78 2	6000	6180	6180	6180	9850	22630	10180	20180	26530	15180	19180	19180
209F78 3	6000	6180	6180	6180	10460	23630	10180	20180	15180	15180	19180	19180
209F78 4	6000	6180	6180	6180	11850	24530	10180	20180	15180	15180	19180	19180
209F78 5	6000	6180	6180	6180	12850	25630	10180	20180	15180	15180	19180	19180
209F78 6	6000	6180	6180	6180	13790	26480	10180	20180	15180	15180	19180	19180
209F78 7	6000	6180	6180	6180	14800	27480	10180	20180	15180	15180	19180	19180
209F78 8	6000	6180	6180	6180	15180	28520	10180	20180	15180	15180	19180	19180
209F78 9	6000	6180	6180	6180	15180	29550	10180	20180	15180	15180	19180	19180
209F7810	6000	6180	6180	6180	15180	33790	10180	20180	15180	15180	19180	19180
209F7811	6090	6180	6180	6180	15180	40180	12940	20180	15180	15180	19180	19180
209F7812	6180	6180	6180	6180	15180	40180	15180	20180	15180	15180	19180	19180
209F7813	6180	6180	6180	6180	15180	30080	15180	20180	15180	15180	19180	19180
209F7814	6180	6180	6180	6180	15180	30180	15180	20180	15180	15180	19180	19180
209F7815	6180	6180	6180	6180	15180	30180	15180	20180	15180	15180	19180	17930
209F7816	6180	6180	6180	6180	15180	30180	15180	20180	15180	20060	19180	16180
209F7817	6180	6180	6180	6180	15180	30180	15180	20180	15180	24180	19180	16180
209F7818	6180	6180	6180	6180	15180	30180	15180	20180	15180	27510	19180	16180
209F7819	6180	6180	6180	6180	15180	30180	15180	20180	15180	34180	19180	16180
209F7820	6180	6180	6180	6180	15180	28300	15180	20180	15180	34180	19180	16180
209F7821	6180	6180	6180	6180	15180	25180	15180	20180	15180	34180	19180	16180
209F7822	6180	6180	6180	6180	15180	25180	15180	22010	15180	34180	19180	16180
209F7823	6180	6180	6180	6180	15180	24200	15180	26180	15180	34180	19180	16180
209F7824	6180	6180	6180	6180	15180	20180	15180	29650	15180	34180	19180	16180
209F7825	6180	6180	6180	6180	15180	20180	15180	36180	15180	34180	19180	16180
209F7826	6180	6180	6180	6180	15000	20180	15180	43260	15180	28690	19180	16180
209F7827	6180	6180	6180	6180	16600	20180	15180	53180	15180	24180	19180	16180
209F7828	6180	6180	6180	6180	17600	14560	15180	53180	15180	24180	19180	16180
209F7829	6180		6180	6650	18600	10180	15180	53180	15180	24180	19180	16180
209F7830	6180		6180	7670	19600	10180	15180	53180	15180	24180	19180	16180
209F7831	6180		6180		20600		15180	53180		21890		16180
209F79 1	16180	11160	6180	6180	6180	6180	26180	24180	6180	1130	4000	4000
209F79 2	16180	10180	6180	6180	6180	6180	26180	24180	6180	1130	4000	4000
209F79 3	16180	10180	6180	6180	6180	6180	26180	20740	6180	1070	4000	4000
209F79 4	16180	10180	6180	6180	6180	6760	26850	18180	6180	2330	4000	4000
209F79 5	16180	10180	6180	6180	6180	7180	28180	18180	3620	4000	4000	4000
209F79 6	16180	10180	6180	6180	6180	7760	29350	18180	1130	4000	4000	4000
209F79 7	16180	10180	6180	6180	6180	8180	30180	16055	1130	4000	4000	4000
209F79 8	16180	10180	6180	6180	6180	8760	30180	14180	1130	4000	4000	4000
209F79 9	16180	10180	6180	6180	6180	9180	30180	12100	1130	4000	4000	4000
209F7910	16180	10180	6180	6180	6180	9760	30180	10180	1130	4000	4000	4000
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209F7912	16180	10180	6180	6180	6180	11350	30180	10180	1130	4000	4000	4000
209F7913	16180	10180	6180	6180	6180	12180	29100	10180	1130	4000	4000	4000
209F7914	16180	8652	6180	6180	6180	13402	28180	10180	1130	4000	4000	4000
209F7915	16180	6180	6180	6180	6180	14180	28180	10180	1130	4000	4000	4000
209F7916	16180	6180	6180	6180	6180	15402	28180	10180	1130	4000	4000	4000
209F7917	16180	6180	6180	6180	6180	16180	28180	8720	1130	4000	4000	4000
209F7918	16180	6180	6180	6180	6180	16180	28180	6180	1130	4000	4000	4000
209F7919	16180	6180	6180	6180	6180	16180	28180	6180	1130	4000	4000	4000
209F7920	16180	6180	6180	6180	6180	16180	28180	6180	1130	4000	4000	4000
209F7921	16180	6180	6180	6180	6180	17305	28180	6180	1130	4000	4000	4000
209F7922	16180	6180	6180	6180	6180	19347	28180	6180	1130	4000	4000	4000
209F7923	16180	6180	6180	6180	6180	20180	28180	6180	1130	4000	4000	4000
209F7924	14930	6180	6180	6180	6180	20180	27010	6180	1130	4000	4000	4000

209F7925	14180	6180	6180	6180	6180	20180	26180	6180	1130	4000	4000	4000
209F7926	14180	6180	6180	6180	6180	21347	26180	6180	1130	4000	4000	4000
209F7927	14180	6180	6180	6180	6180	22180	26180	6180	1130	4000	4000	4000
209F7928	14180	6180	6180	6180	6180	23013	26180	6180	1130	4000	4000	4000
209F7929	12930		6180	6180	6180	24180	26180	6180	1130	4000	4000	4000
209F7930	12180		6180	6180	6180	25013	26180	6180	1130	4000	4000	4000
209F7931	12180		6180		6180		25010	6180		4000		4000
209F80 1	4000	4000	4000	4000	7000	4000	13000	1160	49730	6210	6240	8240
209F80 2	4000	4000	4000	4000	5000	4000	13000	1160	49430	10200	6260	8230
209F80 3	4000	4000	4000	4000	4000	4000	13270	1165	49055	13290	6260	8220
209F80 4	4000	4000	4000	4000	4000	4000	15782	1165	48900	13290	6280	8230
209F80 5	4000	4000	4000	4000	4000	5100	17150	1165	38520	13330	6230	8210
209F80 6	4000	4000	4000	4000	4000	7000	17170	1165	30000	13280	6250	8210
209F80 7	4000	4000	4000	4000	4000	7000	17120	1170	30000	13350	6260	8220
209F80 8	4000	4000	4000	4000	4000	7000	17130	1170	30000	13280	6255	8220
209F80 9	4000	4000	4000	4000	4000	8150	17100	1170	25850	13280	6250	8200
209F8010	4000	4000	4000	4000	4000	10000	15030	1170	16010	13270	6250	8230
209F8011	4000	4000	4000	4000	4000	10000	13170	1170	10270	13300	6260	8220
209F8012	4000	4000	4000	4000	4000	10000	13150	1550	10270	13320	6260	8200
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209F8217	4260	3950	3980	3490	1170	710	3400	720	710	4040	4005	3046
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209F8315	2974	2074	1541	1561	1549	762	570	560	596	10128	4194	4272
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209F8319	2623	2075	1521	1535	1560	759	562	587	4144	13507	4195	4269
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209F8624	2959	2082	2087	1623	1691	29779	27167	12053	594	4092	3991	3930
209F8625	2959	2075	2084	1626	1685	26722	27282	12052	608	4092	3983	3926
209F8626	2958	2079	1866	1626	1712	21380	27355	12063	605	4082	3981	3903
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209F87 2	3897	2951	2909	1544	1526	665	532	536	577	684	4102	
209F87 3	3898	2940	2907	1480	1514	663	537	537	589	668	4114	
209F87 4	3890	2940	2903	1516	1512	609	537	533	589	689	4104	
209F87 5	3898	2935	2908	1516	1530	568	528	532	589	690	4136	
209F87 6	3885	2940	2915	1516	1126	545	533	534	589	697	4114	
209F87 7	3887	2930	2905	1514	633	543	538	535	571	698	4108	
209F87 8	3883	2941	2899	1530	642	548	535	538	583	702	4069	
209F87 9	3887	2937	2895	1533	641	543	537	538	584	701	4087	
209F8710	3877	2938	2898	1532	623	541	539	541	584	706	4080	
209F8711	3868	2942	2902	1538	626	547	534	530	600	674	4079	
209F8712	3406	2932	2899	1538	639	552	537	554	587	664	4079	
209F8713	2923	2929	2899	1516	651	541	531	580	563	690	4080	
209F8714	2925	2929	2898	1512	644	544	532	581	584	693	4070	
209F8715	2970	2930	2825	1496	638	542	534	570	507	2219	4076	
209F8716	2991	2926	2335	1504	638	547	536	569	665	4120	4065	

209F8717	2959	2927	1997	1506	630	549	544	566	664	4140	4065
209F8718	2958	2927	1999	1506	648	545	527	571	702	4128	
209F8719	2965	2910	1994	1507	663	548	527	569	702	4087	
209F8720	2977	2917	1994	1504	659	548	537	575	660	4101	
209F8721	2985	2916	1994	1504	640	541	534	594	667	4106	
209F8722	2984	2916	1994	1512	644	550	534	559	679	4094	4063
209F8723	3000	2917	1994	1519	640	545	540	572	677	4101	
209F8724	2962	2909	1986	1519	634	548	534	572	678	4145	
209F8725	2965	2916	1991	1510	622	544	534	574	684	4140	
209F8726	2970	2912	1993	1512	630	550	528	578	674	4130	
209F8727	2968	2941	2002	1508	649	552	534	571	665	4105	
209F8728	2951	2894	2002	1534	638	529	532	592	669	4105	
209F8729	2949		1974	1534	651	539	535	591	685	4106	
209F8730	2963		1987	1517	643	539	535	567	696	4098	
209F8731	2963		1989		644		543	589		4105	