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by
G. B. Kyle, L. E. White, and J. P. Koenings

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ABSTRACT

Spiridon Lake, is the third largest lake on Kodiak Island, but does not support anadromous fish due to a series of cascading falls on the lake outlet preventing access. Since the 1970's, there has been interest in enhancing Spiridon Lake with sockeye salmon (*Oncorhynchus nerka*); however, not until the recent completion of Pillar Creek Hatchery has the potential existed to consider a stocking project. Lake investigations began in the fall of 1987 to determine the rearing potential for sockeye salmon in Spiridon Lake. In addition, sampling was conducted to determine the mortality of smolts negotiating the falls on the lake outlet, and site surveys were conducted to determine the possibility of bypassing smolts around the falls area. The results of these investigations indicate that Spiridon Lake could support an estimated 11 million sockeye salmon fry, and that a smolt bypass system on the lake outlet is feasible. Although this lake is capable of supporting 11 million fry, a gradual approach to stocking is recommended to ensure maintenance of a macro-zooplankton community capable of supporting a long-term stocking project.

INTRODUCTION

Spiridon Lake, located 74 km southwest of the city of Kodiak (Figure 1), is the third largest lake on Kodiak Island, and does not support anadromous fish due to a series of cascading falls on the lake outlet. The lake has been under investigation by the Alaska Department of Fish and Game (ADF&G) as a potential sockeye salmon (*Oncorhynchus nerka*) enhancement project since the 1970's. In 1971, Blackett[1] (personal communication) concluded that although the lake had a large rearing area, spawning area along the lake shore and in the tributaries was limited. However, without a suitable hatchery fry delivery system in the 1970's, the initial plan was limited to either building a fish ladder on the lake outlet, or diverting the lake discharge into Little River to provide access for adult salmon into the lake. For various reasons, neither enhancement

[1]Aquatech, P.O. Box 593, Kodiak, AK. 99615.

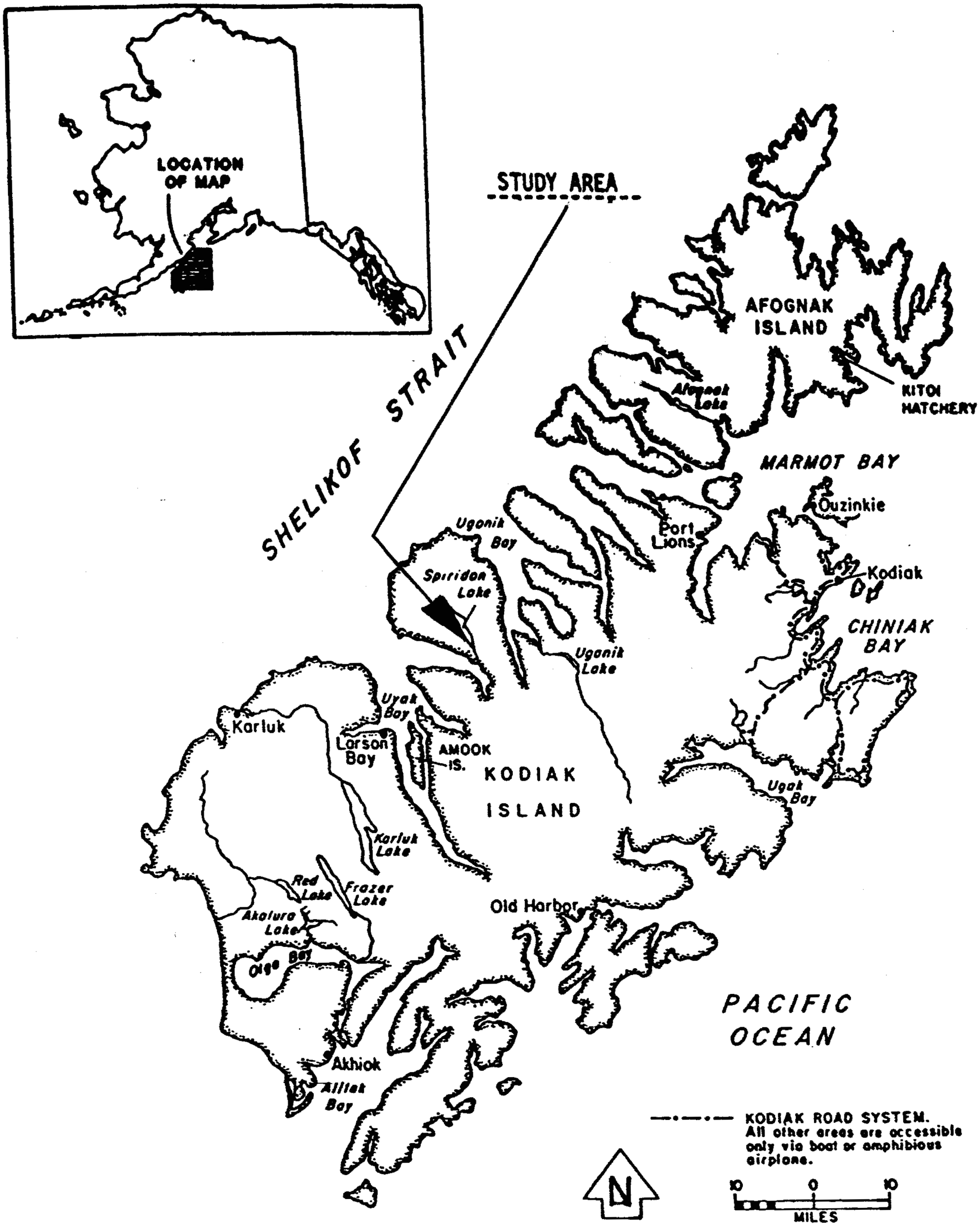

Figure 1. Area map of Kodiak and Afognak Islands showing location of Spiridon Lake.

technique was implemented.

Recently, with the completion of Pillar Creek Hatchery on Kodiak Island, the stocking of Spiridon Lake with hatchery-produced sockeye salmon fry is possible, and the potential to provide more adult fish for the common-property fishery now exists. To address the rearing capacity of Spiridon Lake, fisheries and limnological investigations were initiated in the fall of 1987. Specifically, water quality and zooplankton samples were collected, assessment of the resident (limnetic) fish stock was conducted, and morphometric features were determined. In addition, sockeye salmon smolts were released above the outlet falls to determine the extent of mortality, and approximately 250,000 sockeye salmon fry (from a stock known to smolt as age-0) were planted in Spiridon Lake to determine whether these fry would continue to migrate as age-0 smolts, or holdover and migrate as age-1 smolts.

The purpose of this report is to summarize fisheries and limnological investigations relative to assessing sockeye salmon production, the enhancement potential, and the appropriate type of enhancement relevant to the productivity status of Spiridon Lake.

Description of Study Area

Spiridon Lake (57° 40' N, 153° 39' W) lies at an elevation of 136 m, is 9.6 km long, up to 1.6 km wide, and has a surface area of 9.2×10^6 m^2 (Figure 2). This lake has a mean depth of 34.7 m, a maximum depth of 82 m, and is characterized as an oligotrophic system. Because of the relative deepness and elevation of this lake, ice usually remains until the first of May and water temperatures are colder than other Kodiak lakes. The watershed drains over an area of 60 km^2, and with a mean annual precipitation of 101.5 cm, the lake-water residence time is 7.1 years. Resident fish in Spiridon Lake include: rainbow trout (*O. mykiss*), Dolly Varden char (*Salvelinus malma*), three spine stickleback (*Gasterosteus aculeatus*), and freshwater sculpin (*Cottus aleuticus*). In addition, pink salmon (*O. gorbuscha*) have been observed in the intertidal area of the lake's outlet.

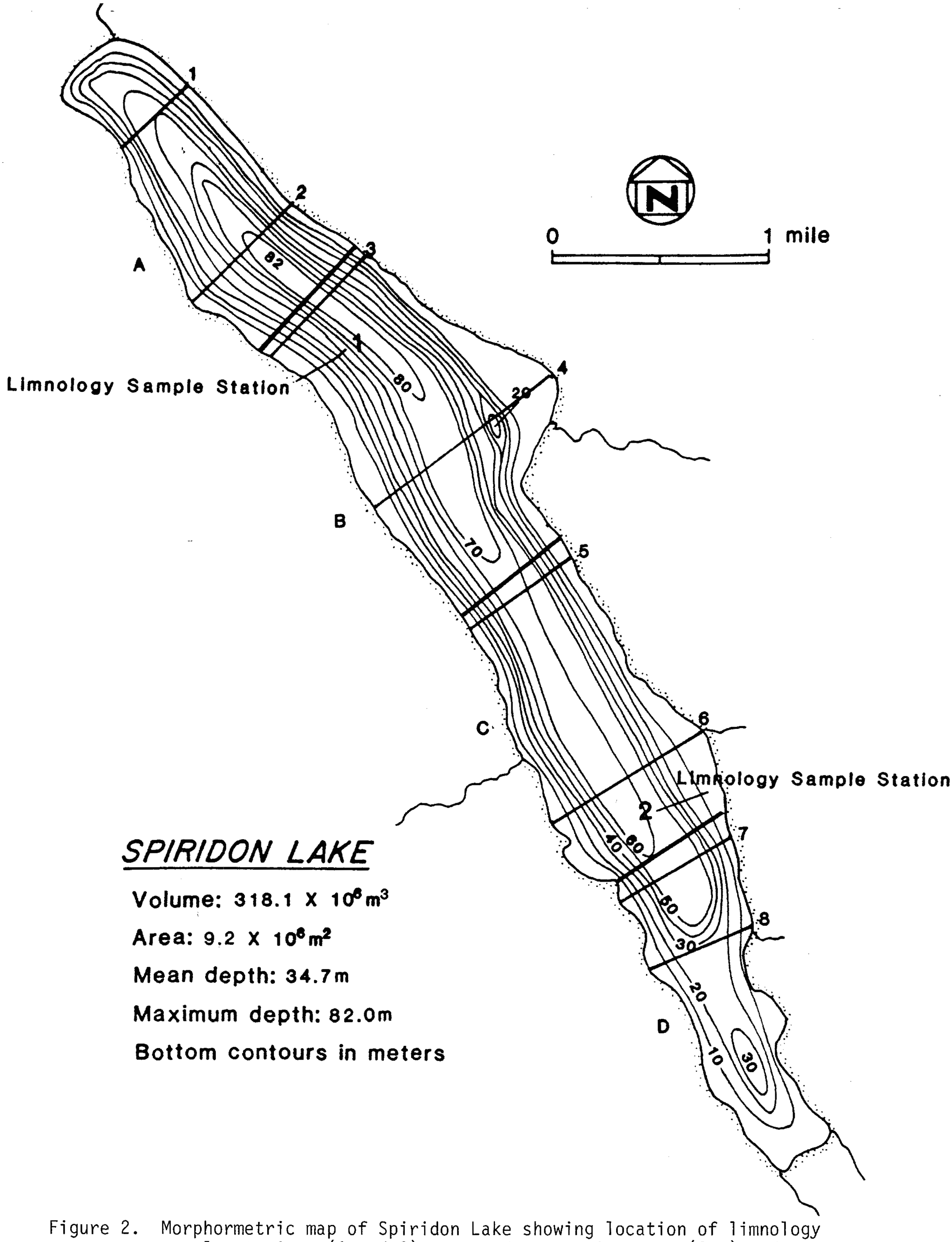

Figure 2. Morphormetric map of Spiridon Lake showing location of limnology sample stations (1 and 2), and hydroacoustic areas (A-D) and transects 1-8).

METHODS AND MATERIALS

Juvenile Salmon Assessment

Hydroacoustic Survey-- A fall (September) hydroacoustic survey was conducted in 1988 to estimate the number and distribution of limnetically-rearing fish in Spiridon Lake. The survey comprised of recording data along eight transects perpendicular to the longitudinal axis of the lake (Figure 2). Recording of down-looking acoustic data along the transects was done at night because fish are more evenly dispersed. Flashing strobe lights were placed at both ends of each transect to assist in maintaining transect course. A BioSonics® model-105 echosounder system with 6/15° dual-beam transducer was used for data collection. Fish signals were recorded electronically using a Sony digital video recording system and on chart paper using a BioSonics model-115 recorder.

Analysis of the recorded hydroacoustic data was conducted by Dr. Richard Thorne of BioSonics, Inc. Fish densities were low enough during the September survey that echo counting techniques (Thorne 1983) could be used. The number of echoes from fish targets were counted in 1-min increments along the 8 transects for 9 depth intervals. Sampling volumes were estimated by the duration-in-beam technique (Nunnallee and Mathisen 1972; Nunnallee 1980; Thorne 1988). For each depth interval and 1-min increment, fish densities (no./m^3) were summed to determine the total areal fish density (no./m^2) for each transect. Mean transect fish densities were weighted by time, since end-of-transect increments were usually less than 1 min. A weighted mean fish density and an associated variance were computed for paired transect areas (Kyle 1990). The total fish population estimate was obtained by summing the products of the weighted mean fish density and respective lake areas. Transect variances were summed and a 95% confidence interval for the total fish population estimate was calculated.

®Mention of commercial products and trade names does not constitute endorsement by ADF&G, FRED Division.

Smolt Migration Mortality-- To evaluate the potential mortality that sockeye salmon smolts may incur as they negotiate the falls, a bioassay was conducted by releasing smolts upstream of the upper falls in 1989. On May 26, approximately 1,400 sockeye salmon smolts averaging 105 mm in length and 8 g in weight from Karluk River were collected and held in a live box until being transported by helicopter to the falls on the outlet of Spiridon Lake on May 30 (poor weather delayed transportation). The flight to Spiridon Lake was only 20 minutes, and the initial transport stress was minimal as only 10 fish died during the flight. However, after being held in a live-box for 10 hours, a total of 114 fish died or were showing signs of stress, and were not used to evaluate mortality in negotiating the falls. Two fyke nets were set downstream of the uppermost falls; the first net (net 1) was set approximately 600 m above saltwater and covered 25% of the stream, while a second net (net 2) was set at saltwater and covered 90% of the stream at low- to mid-tide conditions.

Fry Stocking and Smolt Production-- Evaluation of stocked sockeye salmon fry in Spiridon Lake was conducted in 1990 to determine whether an age-0 stock of sockeye salmon (Upper Station Lake) released into Spiridon Lake would migrate as underyearlings or hold-over an additional year (or two) before migrating. This evaluation was done as an initial investigation in determining if the production of age-0 smolts is related to the rearing environment or is a genetic trait. A total of 249,000 Upper Station Lake sockeye salmon fry (that were incubated at the Kitoi Bay Hatchery) were stocked at the north end of Spiridon Lake on 25 May 1990. The fry were transported in two 190-L tanks mounted in an amphibious-equipped Beaver aircraft, and no mortality occurred during the transport. A winged fyke net (18 m wide by 2.5 m long) connected to a live box (1.7 m^2) was placed at the lake outlet during 28 June-23 July to capture all fish migrating downstream.

Limnological Assessment

Morphometry and Water Residence Time-- Lake-bottom profiles were recorded with a fathometer along numerous lake transects to develop a bathymetric map. The area of each depth strata was determined with a polar planimeter, and the lake volume (V) was computed by summation of successive strata (Hutchinson 1957), and mean lake depth determined from:

$$z = V/A_L$$

Where: z = lake mean depth (m)
V = lake volume ($\cdot 10^6 m^3$)
A_L = lake surface area ($\cdot 10^6 m^2$).

The theoretical water residence time was calculated using the following formula (Koenings et al. 1987):

$$T_w \text{ (yr)} = V/TLO$$

Where: T_w = theoretical water residence time (years)
V = total lake volume ($\cdot 10^6 m^3$)
TLO = total lake outflow ($\cdot 10^6 m^3/yr$).

Physical Features-- The collection of physical data included the measurement of lake temperatures, dissolved oxygen, and light penetration at both Stations 1 and 2. Lake temperature/dissolved oxygen profiles were measured using a YSI model-57 meter. These profiles were taken at 1-m increments from the surface to 5 m, and at 2-m increments from 6 m to the bottom of the lake. The algal light compensation point was defined as the depth at which 1% of the subsurface light (photosynthetically available radiation [400-700 mm]) penetrated (Schindler 1971), and was measured using a Protomatic submersible photometer. Recordings were taken every 0.5 m to 5 m, and every 1 m down to the light compensation depth. Water clarity was also measured with a 20-cm Secchi disk by recording the depth at which the disk disappeared from view.

Water Sampling-- Lake assessment surveys were initiated in the fall of 1987. Transportation to and from Spiridon Lake was provided by a float-equipped aircraft; limnological samples were collected after mooring to two permanent sampling stations

(Figure 2). The frequency of sampling was designed to characterize the lake from ice-off in the spring to ice-on in the winter. Lake water was sampled at the 1 m (epilimnion) and 50 m (hypolimnion) zones for algal nutrients (nitrogen, phosphorus, silicon, and carbon) as well as general water quality parameters. Water samples from multiple casts with a non-metallic Van Dorn sampler were pooled, stored in 8-10 L translucent carboys, and immediately transported to Kodiak for filtering and preservation. Subsequent filtered and unfiltered water samples were stored either refrigerated or frozen in acid-cleaned, pre-rinsed polybottles. The pre-processed water samples were then sent to the ADF&G Limnology Laboratory in Soldotna for analysis.

General Water Quality Parameters-- Water samples were analyzed for the following parameters as detailed by Koenings et al. (1987). Conductivity (μmhos/cm) was measured with a YSI model-32 conductance meter. Alkalinity levels (mg/L) were determined by acid titration (0.02 N H_2SO_4) to pH 4.5, using a Corning model-399A specific ion meter. Calcium and magnesium (mg/L) were determined from separate EDTA (0.01 N) titrations after Golterman (1969), turbidity (NTU) was measured with a HF model-DRT100 turbidimeter, and color (Pt units) was determined with a spectrophotometer. Total iron (μg/L) was analyzed by reduction of ferric iron with hydroxylamine during hydrochloric acid digestion after Strickland and Parsons (1972).

Nutrients-- All nutrients were reported in μg/L and were analyzed by detailed methods described by Koenings et al. (1987). Filterable reactive phosphorus (FRP) was analyzed by the molybdate-blue/ascorbic-acid method of Murphy and Riley (1962), as modified by Eisenreich et al. (1975). Total phosphorus (TP) was determined by FRP procedure, after persulfate digestion. Nitrate and nitrite (NO_3 + NO_2) were determined as nitrite, following Stainton et al. (1977), after cadmium reduction of nitrate. Total Kjeldahl nitrogen (TKN) was determined as total ammonia following sulfuric acid block digestion (Crowther et al. 1980). Total nitrogen was calculated as the sum of TKN and NO_3 + NO_2. Reactive silicon (Si) was determined using the method of ascorbic acid reduction to molybdenum-blue after Stainton et al. (1977).

Chlorophyll a-- Algal standing crop was estimated by chlorophyll a (chl a) analysis, after the fluorometric procedure of Strickland and Parsons (1972). The low-strength acid addition recommended by Riemann (1978) was used to estimate phaeophytin. Water samples (1-2 L) were filtered through 4.25-cm GF/F filters to which 1-2 mls of a saturated $MgCO_3$ solution were added just prior to the completion of filtration. The filters were then stored frozen in individual plexislides for later analysis.

Zooplankton-- Zooplankton were enumerated from duplicate 50-m vertical tows using a 0.2-m diameter (153-μm mesh) conical net. The net was pulled at a constant 1 m/s, and all organisms were preserved in a 10% neutralized formalin solution. Identification of *Daphnia* followed Brooks (1957), *Bosmina* after Pennak (1978), and the copepods after both Wilson (1959) and Yeatman (1959). Enumeration consisted of counting triplicate 1-ml subsamples taken with a Hansen-Stempel pipette in a 1-ml Sedgewick-Rafter cell. Finally, zooplankton body sizes were obtained by measuring the length to the nearest 0.01 mm of at least 10 individuals along a transect in each 1-ml subsample (Koenings et al. 1987). Zooplankter biomass was estimated from an empirical regression between zooplankter body-length and dry weight, and was weighted by organism density (Koenings et al. 1987).

RESULTS AND DISCUSSION

Juvenile Salmon Assessment

Limnetic Fish Population Estimate and Distribution-- The hydroacoustic survey conducted on 12 September 1988 revealed a population estimate of 310,365 $\pm$ 98,840 fish (Table 1). Transects 3-5, located approximately in the middle of the lake (Figure 2), had the highest density of fish; however, in comparison to other lakes, fish densities in Spiridon Lake are very low, indicating a trivial population of resident fish. There appeared to be at least two distinct (different size) groups of fish as many of the fish concentrated nearshore, and in schools of the limnetic area had lower echo strengths compared to the scattered individual targets in the limnetic area. There was no

Table 1. Fish population estimates and variances for paired transect areas of Spiridon Lake, 12 September 1988.

Area	Transect	Mean fish density (no./1000 m^2)	Area (x 1000 m^2) transect	Area (x 1000 m^2) total	Weighted mean fish density (no./1000 m^2)	Variance (X 1000)	Fish pop.	Variance
	1	2.7	750					
A				1,750	5.3	6.5	9,325	2.0E+07
	2	7.3	1,000					
	3	84.5	1,600					
B				2,600	72.0	265.4	187,200	1.8E+09
	4	52.0	1,000					
	5	61.1	1,100					
C				1,800	48.7	208.9	87,720	6.8E+08
	6	29.3	700					
	7	34.4	550					
D				1,050	24.9	47.5	26,120	5.2E+07
	8	14.4	500					
							310,365	2.5E+09
					95% confidence interval (+/−)			98,840

preferred location within the water column, as the greatest density of fish (~20 fish/ 1000 m^3) was observed near the surface (2-5 m depth strata) and at mid-depth (18-23 m depth strata). Due to the very low number of fish targets during the survey, no net tows were conducted to determine species composition.

Smolt Migration Mortality-- On the evening of 30 May (2100 h), a total of 1,225 healthy smolts were released above the upper falls in the outlet of Spiridon Lake. The first smolt was caught 32 minutes later in net 1, and mortality occurred within the first two hours of observation. Mortality was directly due to negotiating the falls as the smolts had missing eyes and lacerations on the head and back area. A total of 26 smolts were captured in net 1, of which 4 were alive and 22 were dead. In the second net, located at saltwater, a total of 22 smolts were caught of which 3 were alive and 19 were dead.

A major problem encountered in the assessment of smolts negotiating the falls was the mortality due to the fyke nets. To estimate this mortality, 48 smolts were released into the face of net 1, and after one hour and 40 minutes only 8 smolts had safely found there way into the live box. In contrast, a total of 24 smolts were trapped inside net 1 due to the velocity of water pinning the fish against the net, indicating a net mortality factor of 75% (24/32). The remaining 16 smolts were never recovered and were assumed to have avoided capture. Thus, even considering all the smolts captured in net 1 survived and a net mortality factor of 75%, the survival of smolts negotiating the falls would approximate only 8.5% (26/.25 = 104; 104/1,225).

Due to the very low survival of smolts migrating through the falls, a lake outlet bypass system will be necessary to transport migrating smolts around the falls. On 13 November 1989 and 19 July 1990, site surveys were conducted on the outlet of Spiridon Lake to determine the feasibility and location of a smolt bypass system. The results of those surveys indicate that a smolt bypass system is possible and would involve use of a 21-m wide aluminum weir and an 850-m long plastic pipe (10 cm in diameter), located at the uppermost falls (Figure 3). The weir would be operated from mid-May (ice off) to the end of the smolt migration (late-June).

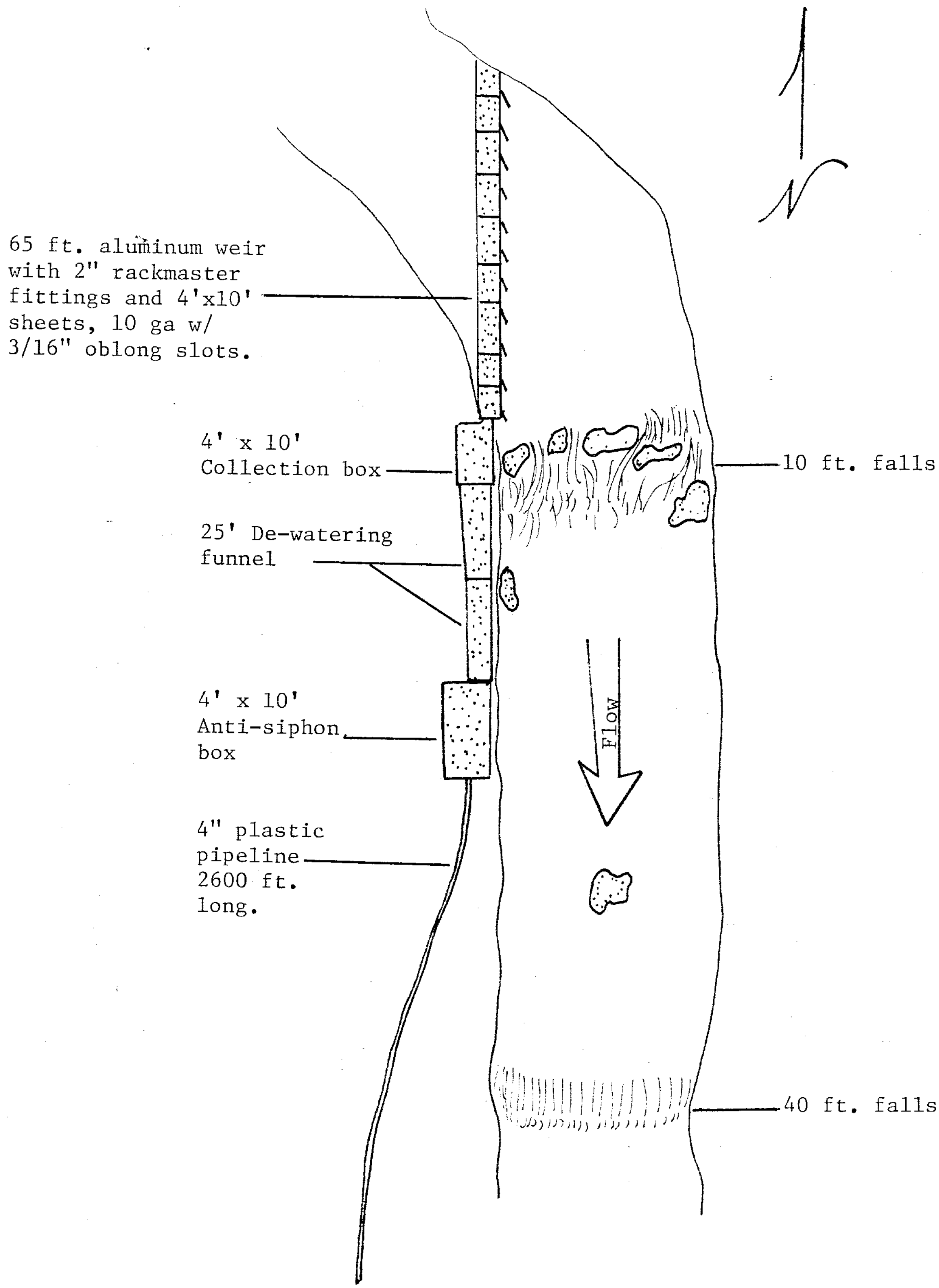

Figure 3. Schematic design of the proposed weir and structure to bypass smolts around the falls in the outlet of Spiridon Lake.

Fry Stocking and Smolt Production-- No smolts emigrated from the lake during sampling (28 June to 23 July 1990), indicating that stocked sockeye salmon fry (Upper Station broodstock) did not gain the growth or undergo the physiological changes necessary to migrate as underyearling smolts in Spiridon Lake. Other studies of underyearling smolts indicate that the fish need to reach approximately 50 mm in length and 1.5 g in weight to tolerate seawater (Rice and Moles 1988; Murphy et al. 1988). In Upper Station Lake, it is believed that the production of age-0 smolts is achieved by rapid growth in the May-July period due to warm lake temperatures and high lake productivity (i.e. an environmental consequence rather than a genetic trait). Thus, producing age-0 smolts in Spiridon Lake is doubtful, but the result of this initial stocking alleviates the concern that the smolts would migrate as under-size (due to slower growth) age-0 fish due to a genetic attribute.

Limnological Assessment

Light Penetration-- During 1988-1990, photosynthetically active radiation (sunlight) penetrated to a seasonal depth ranging from 20.5-25.1 m (Table 2). This depth defines the compensation depth (euphotic zone depth [EZD]) for algal photosynthesis. In addition, the Secchi disk depth ranged from 6.3-12.2 m, and averaged ~9 m during 1988-1990. The seasonal EZD in Spiridon Lake averaged ~23 m, and thus, the euphotic volume (EV) equals 212 x 10^6 m^3 or 212 EV units.

Temperature and Dissolved Oxygen Regimes-- Temperature profiles for the two stations were combined to characterize the whole-lake heating and cooling periods in 1989 and 1990 (Figures 4 and 5). Lake temperatures were cool (3-8° C) during May and June, warmed (≥10° C) during July and August but warming was restricted to less than 20 m, and by October the lake was beginning to cool (≤10° C). The thermocline was restricted to a depth of less than 10 m in July and August, below which temperatures generally dropped to less than 10°C. Thus, because of the relative shallowness of the thermocline, a large volume of water during the summer was not substantially heated. Finally, for the entire season and for all depths, dissolved oxygen concentrations ranged between

Table 2. Euphotic zone depth (one percent light level) and secchi disk readings by month for stations 1 and 2 in Spiridon Lake, 1987–1990.

Sample month/year	Secchi disk (m) Station 1	Secchi disk (m) Station 2	1% light level (m) Station 1	1% light level (m) Station 2
Aug/87	7.5	ND	17.0	ND
Jun/88	10.3	9.8	22.5	25.0
Aug/88	6.8	9.3	ND	ND
Sep/88	10.5	10.0	18.0	20.0
Oct/88	9.0	12.2	21.0	19.5
Seasonal mean	9.1	10.3	20.5	21.5
May/89	ND	7.5	28.0	30.5
Jun/89	11.0	8.5	19.0	15.5
Jul/89	11.8	10.8	26.0	26.5
Aug/89	ND	10.5	28.0	22.5
Oct/89	6.5	7.5	24.5	22.5
Seasonal mean	9.8	9.0	25.1	23.5
May/90	9.5	9.5	24.0	26.0
Jun/90	10.5	7.5	22.5	ND
Jul/90	7.5	8.3	21.5	23.5
Aug/90	10.3	7.3	20.5	21.0
Oct/90	6.3	5.3	29.5	29.5
Seasonal mean	8.8	7.6	23.6	25.0

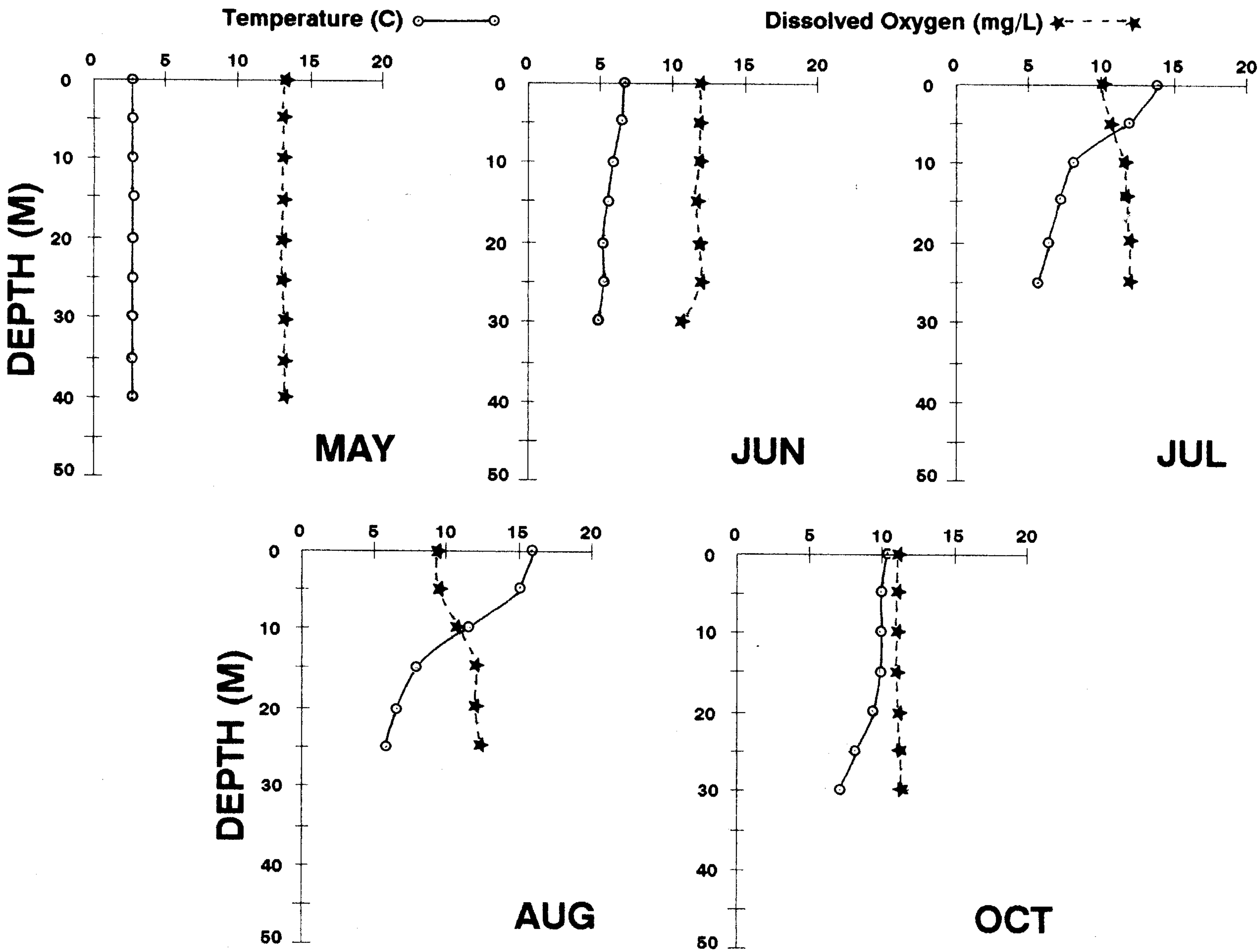

Figure 4. Seasonal mean (stations 1 and 2) temperature and dissolved oxygen profiles for Spiridon Lake, 1989.

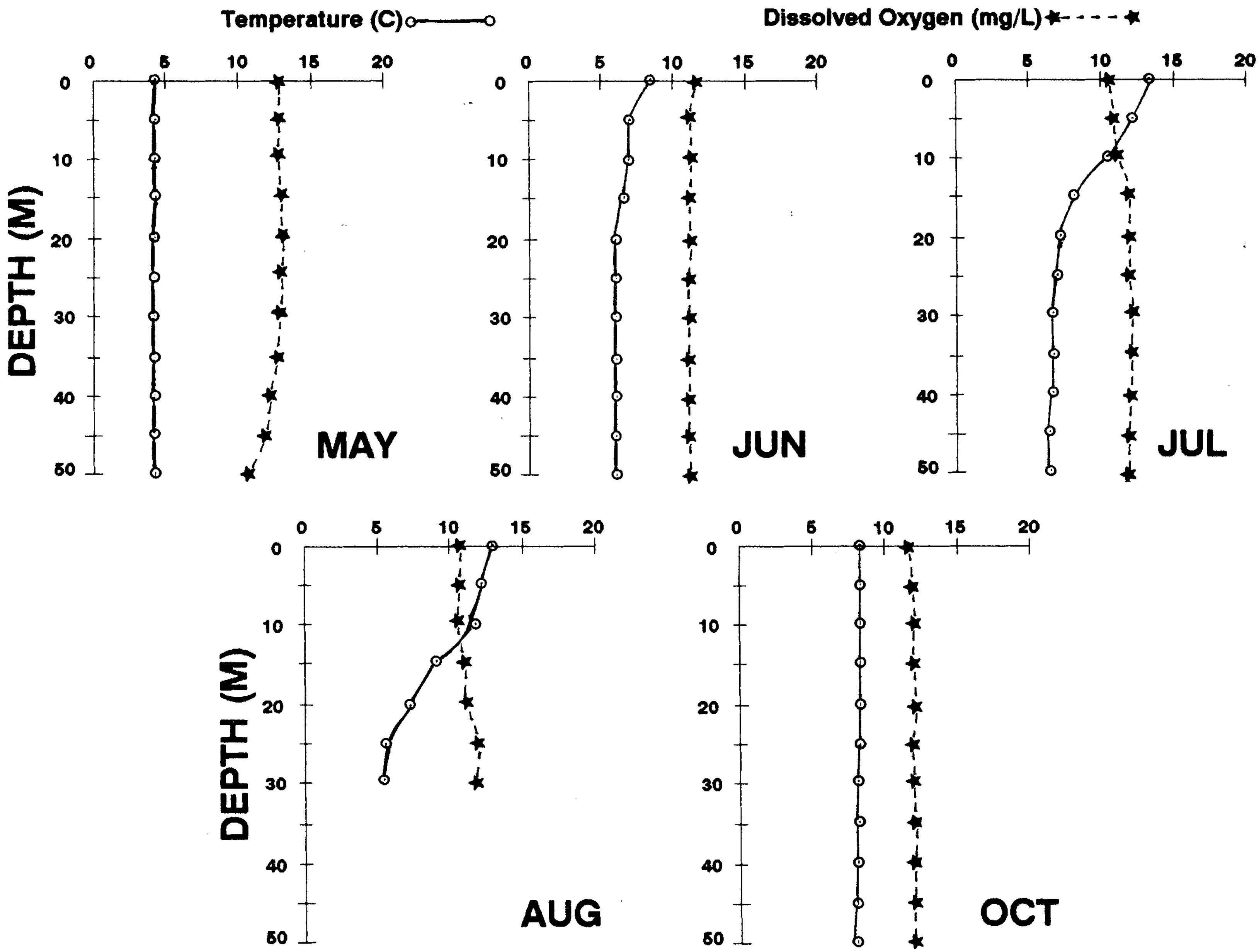

Figure 5. Seasonal mean (stations 1 and 2) temperature and dissolved oxygen profiles for Spiridon Lake, 1990.

~10-12 mg/L which indicated a saturation level of 90-100%.

General Water Quality Parameters-- All water quality information collected during 1987-1990 (including nutrients and chlorophyll concentrations) are summarized by month, depth, and station in Table 3. Turbidity levels were quite low, ranging between 0.2 and 2.3 NTUs and averaged 0.5 NTU in the epilimnion and the hypolimnion. Color usually ranged between 4 and 10 Pt units, except in the fall of 1989 when color measurements were consistently high (>15 Pt units). Conductivities ranged between 70 and 92 μmhos/cm, and averaged 73 μmhos/cm, while Ph values varied between 6.8 and 7.6 units, and alkalinity averaged 22 mg/L (as $CaCO_3$). Except for the July 1989 sample taken at 50 m, iron concentrations generally ranged between <3 and 25 μg/L. The July 1989 iron concentration was relatively high (342 μg/L) and possibly reflects sample contamination, as the total phosphorus concentration for this sample was also high. The concentrations of both calcium (4.4-9.6 mg/L) and magnesium (<0.2-4.5 mg/L) were within the general range for Alaska lakes.

Nutrients-- Reactive silicon (Si) ranged between 1,992 and 2,903 μg/L during 1987-1990, and the average concentration at 1 m (2,157 μg/L) was slightly less than at 50 m (2,225 μg/L), and seasonal trends were not evident. Such consistency is not surprising given the deep euphotic depth (66% of the mean depth) and the oligotrophic nature of Spiridon lake.

Nitrogen (1 m) in Spiridon Lake is divided among organic (30%), ammonium (2%), and nitrate + nitrite (70%). The seasonal mean total Kjeldahl nitrogen (TKN) at 1 m was 98 μg/L and was 93 μg/L at the 50 m depth, and with the exception of higher concentrations in August of 1988 and 1989, there was no apparent seasonal cycle. Nitrate + nitrite (1 m) varied between 53 and 267 μg/L, averaged 206 μg/L, and showed no trends during the sampling period. Ammonium ranged from 2.8 to 18 μg/L in the epilimnion (1 m), averaged 7.4 μg/L, and like TKN, was lower in 1990.

Table 3. General water quality parameters, nutrient concentrations, and chlorophyll concentrations within the epilimnion (1 m) and hypolimnion (50 m) by month for stations 1 and 2 in Spiridon Lake, 1987–1990.

Year	1987		1988											
Month	Aug		Jun				Aug				Sep			
Station	1		1		2		1		2		1		2	
Depth	1m	50m	1m	50m	1m	50m	1m	50m	1m	50m	1m	50m	1m	50m
Conductivity (umhos/cm)	72	72	73	72	72	72	71	71	72	71	71	72	71	72
pH	7.1	7.1	7.0	6.9	7.1	7.0	7.2	7.0	7.0	6.8	7.2	7.1	7.3	7.2
Alkalinity (mg/L)	22	21	21	22	19	19	23	21	21	21	20	20	20	19
Turbidity (NTU)	1.4	0.6	0.5	0.4	0.4	0.4	0.3	0.3	0.3	0.2	0.4	0.3	0.4	0.5
Color (Pt)	5.3	NA	5.3	6.4	7.5	5.3	8.7	6.4	7.5	6.4	8.7	6.4	7.5	12.1
Calcium (mg/L)	6.4	6.0	NA	NA	NA	NA	5.2	5.7	5.7	5.2	7.1	7.1	9.6	5.3
Magnesium (mg/L)	1.4	1.4	NA	NA	NA	NA	2.4	2.4	2.4	2.1	1.8	1.4	<0.2	2.8
Iron (ug/L)	14	7	20	16	23	14	14	8	14	7	14	12	12	25
TP (ug/L)	3.7	5.8	5.8	3.6	3.5	3.0	3.4	4.6	3.4	3.9	2.7	3.3	3.6	4.4
TFP (ug/L)	1.8	2.3	2.8	2.4	2.5	1.8	3.4	3.0	2.0	2.3	4.1	1.9	1.4	2.6
FRP (ug/L)	1.3	0.8	1.6	1.5	2.0	1.3	2.9	2.4	1.8	2.0	4.0	1.4	1.5	2.5
TKN (ug/L)	104.3	99.5	98.9	84.3	87.5	77.0	119.3	105.4	107.9	85.1	99.7	91.6	106.2	98.9
Ammonium (ug/L)	4.0	7.3	7.7	5.6	2.8	4.3	13.1	18.1	15.2	15.2	11.1	12.9	5.3	9.8
Nitrate + Nitrite (ug/L)	246.4	278.5	235.9	248.5	233.7	206.3	218.1	267.8	218.1	267.0	184.8	261.9	212.2	207.7
Reactive Si (ug/L)	2,565	2,645	2,363	2,434	2,434	2,399	2,227	2,414	2,315	2,414	1,992	2,181	2,099	2,160
Chl a (ug/L)	1.11	0.82	0.31	0.15	0.29	0.25	0.52	0.11	0.44	0.14	0.48	0.12	0.47	0.32
Phaeo a (ug/L)	0.10	0.15	0.17	0.28	0.09	0.30	0.26	0.20	0.22	0.19	0.17	0.12	0.22	0.34

--continued--

Table 3 continued. General water quality parameters, nutrient concentrations, and chlorophyll concentrations within the epilimnion (1 m) and hypolimnion (50 m) by month for stations 1 and 2 in Spiridon Lake, 1987–1990.

Year	1988				1989											
Month	Oct				May				Jun				Jul			
Station	1		2		1		2		1		2		1		2	
Depth	1m	50m	1m	50m	1m	50m	1m	50m	1m	50m	1m	50m	1m	25m	1m	50m
Conductivity (umhos/cm)	71	71	71	72	72	72	72	73	72	72	73	72	72	73	76	74
pH	6.9	6.9	6.9	7.0	7.1	7.2	7.2	7.2	7.3	7.3	7.2	7.3	7.2	7.3	7.3	7.2
Alkalinity (mg/L)	19	19	19	19	20	22	21	13	22	21	20	22	21	21	22	22
Turbidity (NTU)	1.0	1.2	1.0	1.3	0.4	0.4	0.3	0.4	0.2	0.3	0.5	0.4	0.4	0.3	0.6	2.3
Color (Pt)	5.3	5.3	6.4	7.5	18.8	7.5	8.7	6.4	6.4	8.7	7.5	9.8	8.7	13.2	12.0	16.6
Calcium (mg/L)	6.1	5.6	5.6	5.6	4.9	6.1	6.1	4.9	5.6	6.0	5.6	5.6	5.4	6.1	5.4	5.9
Magnesium (mg/L)	2.7	2.7	4.5	3.4	1.6	1.6	2.4	2.4	2.3	3.5	2.7	3.5	2.1	2.4	2.1	1.7
Iron (ug/L)	18	12	17	12	6	7	4	18	11	28	27	38	4	7	<3	342
TP (ug/L)	3.4	3.7	4.4	4.3	3.1	4.5	4.3	3.4	4.9	3.7	4.1	4.5	3.3	3.5	7.2	21.3
TFP (ug/L)	1.5	1.5	1.2	1.5	6.7	3.0	2.3	1.9	2.8	2.0	3.2	2.3	4.2	5.1	4.2	3.5
FRP (ug/L)	1.6	1.4	1.4	1.7	7.0	2.7	2.0	2.0	2.3	2.0	3.0	2.1	1.9	2.1	2.8	3.5
TKN (ug/L)	93.2	98.1	98.9	97.3	99.9	120.2	85.8	85.4	102.2	81.2	83.5	76.8	109.7	100.7	192.7	172.4
Ammonium (ug/L)	7.7	8.2	8.7	4.8	6.5	5.4	4.6	4.0	5.8	6.0	6.5	6.0	9.3	8.8	10.5	10.8
Nitrate + Nitrite (ug/L)	247.0	249.2	250.7	249.2	208.4	238.3	246.4	211.4	192.0	222.7	241.3	238.3	178.6	178.6	99.4	124.0
Reactive Si (ug/L)	2,100	2,088	2,123	2,088	2,027	2,038	2,038	2,038	2,038	2,142	2,142	2,168	2,181	2,168	2,148	2,227
Chl a (ug/L)	0.48	0.25	0.46	0.26	0.20	0.30	0.20	0.30	0.20	0.40	0.40	0.40	0.10	0.50	0.10	0.80
Phaeo a (ug/L)	0.31	0.27	0.39	0.26	0.20	0.20	0.20	0.30	0.20	0.20	0.20	0.40	0.10	0.30	0.10	1.30

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Table 3 continued. General water quality parameters, nutrient concentrations, and chlorophyll concentrations within the epilimnion (1 m) and hypolimnion (50 m) by month for stations 1 and 2 in Spiridon Lake, 1987–1990.

Year	1989								1990							
Month	Aug				Oct				May				Jun			
Station	1		2		1		2		1		2		1		2	
Depth	1m	50m	1m	50m	1m	50m	1m	50m	1m	50m	1m	50m	1m	50m	1m	50m
Conductivity (umhos/cm)	86	92	73	74	73	75	74	70	89	76	74	73	74	74	74	74
pH	7.6	7.6	7.6	7.4	7.3	7.2	7.3	7.2	7.8	7.6	7.6	7.6	7.5	7.4	7.4	7.4
Alkalinity (mg/L)	27	29	22	23	21	21	22	21	28	26	25	25	24	23	23	24
Turbidity (NTU)	0.5	0.5	1.7	0.5	0.2	0.2	0.2	0.2	1.2	1.1	1.0	1.1	0.4	0.4	0.5	0.4
Color (Pt)	14.3	16.6	13.2	17.7	21.1	15.4	17.7	21.1	8.0	6.0	5.0	5.0	5.0	5.0	4.0	4.0
Calcium (mg/L)	7.4	7.4	6.5	6.5	5.4	5.9	5.9	5.9	5.9	5.9	5.9	5.9	4.4	6.2	6.2	4.4
Magnesium (mg/L)	2.3	2.3	2.7	2.3	1.9	1.9	1.9	1.9	1.5	1.5	1.5	3.2	2.8	2.8	2.1	2.8
Iron (ug/L)	9	8	86	8	13	10	6	16	20	22	20	22	22	19	16	22
TP (ug/L)	3.3	5.8	12.0	4.3	3.6	3.6	2.8	3.1	4.6	3.8	2.1	2.6	3.8	3.4	2.8	2.2
TFP (ug/L)	2.2	3.5	1.7	3.2	2.5	2.5	2.3	2.8	2.4	2.6	2.5	2.6	3.2	3.2	2.8	2.7
FRP (ug/L)	1.9	3.0	2.3	3.3	2.1	2.2	2.2	2.6	0.8	1.1	1.4	1.3	1.9	1.9	2.2	2.2
TKN (ug/L)	111.9	110.4	118.7	107.4	93.2	76.8	93.2	78.2	85.6	91.7	87.7	92.8	105.9	86.7	79.6	83.6
Ammonium (ug/L)	8.8	14.3	7.8	10.3	12.0	23.0	18.0	31.5	5.4	4.4	4.2	4.4	3.4	3.9	3.4	2.9
Nitrate + Nitrite (ug/L)	267.4	329.4	227.4	252.4	189.0	244.3	174.8	222.7	232.1	239.6	239.6	241.5	235.8	239.6	241.5	237.7
Reactive Si (ug/L)	2,523	2,903	2,310	2,322	1,994	2,136	2,007	2,110	2,016	2,039	2,039	2,039	2,215	2,202	2,215	2,236
Chl a (ug/L)	0.10	0.40	0.10	0.30	0.03	2.00	1.39	4.25	0.34	0.41	0.35	0.37	0.27	0.60	0.27	0.36
Phaeo a (ug/L)	0.10	0.30	0.10	0.20	0.08	1.45	0.98	2.72	0.14	0.10	0.24	0.26	0.18	0.22	0.06	0.19

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Table 3 continued. General water quality parameters, nutrient concentrations, and chlorophyll concentrations within the epilimnion (1 m) and hypolimnion (50 m) by month for stations 1 and 2 in Spiridon Lake, 1987–1990.

Year	1990											
Month	Jul				Aug				Oct			
Station	1		2		1		2		1		2	
Depth	1m	50m	1m	50m	1m	50m	1m	50m	1m	50m	1m	50m
Conductivity (umhos/cm)	73	71	71	72	72	72	73	73	73	73	73	74
pH	7.3	7.2	7.4	7.3	7.4	7.3	7.4	7.3	7.2	7.2	7.3	7.1
Alkalinity (mg/L)	23	23	24	23	23	22	22	22	21	23	22	21
Turbidity (NTU)	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.4	0.4	0.6	0.6
Color (Pt)	4.0	4.0	9.0	11.0	5.0	5.0	9.0	4.0	3.0	4.0	3.0	5.0
Calcium (mg/L)	7.0	7.0	7.0	6.0	5.6	5.6	5.8	5.8	5.7	5.7	6.6	6.6
Magnesium (mg/L)	2.7	2.7	1.8	2.7	2.0	2.6	2.9	2.0	1.9	1.9	1.9	1.9
Iron (ug/L)	<3	22.0	28.0	4.0	9.0	<3	9.0	<3	18.0	17.0	24.0	29.0
TP (ug/L)	5.7	3.0	3.0	1.9	1.3	1.9	1.5	2.0	4.0	5.5	3.5	4.9
TFP (ug/L)	2.7	2.4	9.7	4.6	2.4	2.4	3.7	2.0	1.4	3.6	1.5	1.6
FRP (ug/L)	2.1	1.9	7.5	6.3	3.0	2.7	3.0	2.6	2.4	2.4	2.4	2.3
TKN (ug/L)	96.8	86.7	74.5	79.5	72.9	66.7	83.8	76.0	89.8	94.6	90.6	106.7
Ammonium (ug/L)	3.4	5.4	3.4	7.3	3.9	8.8	4.9	9.3	8.2	9.2	7.4	8.9
Nitrate + Nitrite (ug/L)	219.0	237.7	222.7	241.5	151.4	241.5	53.4	59.9	178.7	184.2	167.8	155.8
Reactive Si (ug/L)	2,027	2,106	2,058	2,160	2,112	2,252	2,124	2,275	2,201	2,258	2,201	2,315
Chl a (ug/L)	0.08	0.14	0.11	0.21	0.22	0.20	0.24	0.21	NA	NA	0.24	0.07
Phaeo a (ug/L)	0.05	0.12	0.05	0.19	0.18	0.18	0.16	0.20	NA	NA	0.16	0.06

In 1988, seasonal total phosphorus (TP) concentrations (1 m) ranged between 2.7 and 5.8 μg/L and averaged 3.8 μg/L, while in 1989 TP ranged from 3.1 to 5.8 μg/L and averaged 4.9 μg/L, and in 1990 epilimnetic TP levels ranged between 1.3 and 4.6 μg/L and averaged 3.2 μg/L. Except for 1989, epilimnetic TP concentrations were lowest in the fall. Reactive or (inorganic) phosphorus (FRP) ranged between 0.8 and 7.5 μg/L and averaged 2.5 μg/L in the epilimnion, and comprised a high percentage (64%) of the total phosphorus present in the epilimnion.

Finally, nutrient ratios (by atoms) in the epilimnion during the sampling period averaged 198:1 for TN:TP, 592:169:1 for Si:N:P, and 3.5:1 for Si:N. The desired Si:N:P for phytoplankton growth is 17:16:1. Thus, phosphorus concentrations were extremely low relative to the supply of nitrogen, as were the nitrogen concentrations relative to reactive silicon.

Chlorophyll a-- The algal standing crop (chl a) is exceptionally low in Spiridon Lake (Table 3). In the epilimnion (1 m), chl a ranged between 0.03 and 1.39 μg/L, and the seasonal concentration of chl a in the epilimnion averaged 0.3 μg/L. In the hypolimnion (50 m), chl a concentrations ranged between 0.07 and 4.25 μg/L and averaged 0.5 μg/L. Epilimnetic chl a concentrations in 1988 were somewhat higher (>.03), and no seasonal trends were evident, as the lowest concentration in 1988 was in June and during 1989 and 1990 was in October and July, respectively.

Zooplankton Abundance and Size-- The macro-zooplankton community consisted primarily of three cladocerans (*Daphnia longiremus*, *Daphnia rosea*, and *Bosmina longirostris*) and two copepods (*Cyclops columbianus*, and *Diaptomus pribilofensis*) (Table 4). Seasonal mean densities for the cladocerans ranged from a low of 1,698/m^2 for *Daphnia longiremus* (1989 Station 2) to a high of 41,110/m^2 for *Bosmina longirostris* (1989 Station 1), while copepod densities ranged between 51,685/m^2 (*Cyclops columbianus*; 1988 Station 2) and 327,760/m^2 (*Cyclops columbianus*; 1989 Station 2). The seasonal mean density of macro-zooplankton for both stations ranged from 255,543/m^2 (1988) to 465,738/m^2 (1989). The macro-zooplankton community was

Table 4. Macro-zooplankton density (no./m^2) for each taxa by month and the seasonal mean for stations 1 and 2 in Spiridon Lake, 1987-1990.

Station/ Zooplankton taxa		Density (no./m^2) May	Jun	Jul	Aug	Sep	Oct	Seasonal mean (no./m^2)
					1987			
Station 1								
Bosmina longirostris		ND	ND	ND	65,287	ND	ND	ND
Daphnia rosea		ND	ND	ND	54,140	ND	ND	ND
Cyclops columbianus		ND	ND	ND	225,318	ND	ND	ND
Diaptomus pribilofensis		ND	ND	ND	131,369	ND	ND	ND
	Subtotal	ND	ND	ND	476,114	ND	ND	ND
Station 2								
Bosmina longirostris		ND	ND	ND	ND	ND	ND	ND
Daphnia rosea		ND	ND	ND	ND	ND	ND	ND
Cyclops columbianus		ND	ND	ND	ND	ND	ND	ND
Diaptomus pribilofensis		ND	ND	ND	ND	ND	ND	ND
	Subtotal	ND	ND	ND	ND	ND	ND	ND
	Mean station 1&2	ND	ND	ND	ND	ND	ND	ND
					1988			
Station 1								
Bosmina longirostris		ND	3,715	ND	72,983	78,822	3,185	39,676
Daphnia rosea		ND	18,577	ND	35,828	18,312	3,981	19,175
Cyclops columbianus		ND	147,028	ND	161,890	167,197	132,962	152,269
Diaptomus pribilofensis		ND	30,255	ND	78,291	54,936	56,529	55,003
	Subtotal	ND	199,575	ND	348,992	319,267	196,657	266,123
Station 2								
Bosmina longirostris		ND	2,123	ND	56,274	66,083	6,369	32,712
Daphnia rosea		ND	7,431	ND	32,389	27,070	8,758	18,912
Cyclops columbianus		ND	84,926	ND	162,420	160,828	158,439	141,653
Diaptomus pribilofensis		ND	22,558	ND	90,234	54,936	39,013	51,685
	Subtotal	ND	117,038	ND	341,317	308,917	212,579	244,963
	Mean station 1&2	ND	158,307	ND	345,155	314,092	204,618	255,543
					1989			
Station 1								
Bosmina longirostris		8,493	13,270	31,184	115,446	ND	37,155	41,110
Daphnia rosea		0	5,308	15,260	62,367	ND	30,786	22,744
Daphnia longiremus		1,327	2,654	3,317	3,981	ND	4,246	3,105
Cyclops columbianus		101,380	656,847	218,286	408,705	ND	153,928	307,829
Diaptomus pribilofensis		39,278	207,006	74,310	141,985	ND	70,064	106,529
	Subtotal	150,478	885,085	342,357	732,484	ND	296,179	481,317

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Table 4 continued. Macro-zooplanton density (no./m^2) for each taxa by month and the seasonal mean for stations 1 and 2 in Spiridon Lake, 1987-1990.

Station/ Zooplankton taxa	Density (no./m^2) May	Jun	Jul	Aug	Sep	Oct	Seasonal mean (no./m^2)
1989							
Station 2							
Bosmina longirostris	4,777	6,635	12,739	57,059	ND	48,832	26,008
Daphnia rosea	0	13,270	6,369	27,866	ND	4,246	10,350
Daphnia longiremus	1,592	1,327	1,592	3,981	ND	0	1,698
Cyclops columbianus	98,992	400,743	417,197	440,552	ND	281,316	327,760
Diaptomus pribilofensis	49,628	138,004	70,860	99,522	ND	63,694	84,342
Subtotal	154,989	559,979	508,757	628,980	ND	398,088	450,159
Mean station 1&2	152,734	722,532	425,557	680,732	ND	347,134	465,738
1990							
Station 1							
Bosmina longirostris	531	1,062	2,123	34,501	ND	112,261	30,096
Daphnia rosea	0	12,208	5,308	89,172	ND	28,662	27,070
Daphnia longiremus	2,389	4,777	15,924	28,662	ND	3,185	10,987
Cyclops columbianus	144,374	171,975	346,603	208,599	ND	216,561	217,622
Diaptomus pribilofensis	30,520	167,728	153,397	170,913	ND	156,847	135,881
Subtotal	177,814	357,750	523,355	531,847	ND	517,516	421,656
Station 2							
Bosmina longirostris	531	531	3,450	16,985	ND	39,809	12,261
Daphnia rosea	0	3,450	7,431	39,278	ND	14,862	13,004
Daphnia longiremus	2,123	3,450	16,720	21,231	ND	1,858	9,076
Cyclops columbianus	111,200	162,951	283,174	280,255	ND	141,189	195,754
Diaptomus pribilofensis	71,125	32,643	106,953	173,567	ND	50,159	86,889
Subtotal	184,979	203,025	417,728	531,316	ND	247,877	316,985
Mean station 1&2	181,397	280,388	470,542	531,582	ND	382,697	369,321

characterized by the dominance of *Cyclops columbianus* followed by *Diaptomus pribilofensis*, and during most years both peaked before August. In contrast, densities of *Daphnia* and *Bosmina* were usually low during the early season and generally peaked in August. Over the season, copepods accounted for 85% of the total density of macro-zooplankton during 1988-1990. The cladoceran-to-copepod ratio averaged 0.17:1 during 1988-1990, which is not surprising low for an oligotrophic lake (Kyle et al. 1988).

Body sizes of the smallest macro-zooplankton (*Bosmina*) averaged >0.55 mm (Table 5), which substantially exceeded the 0.40 mm threshold size considered for elective consumption by sockeye salmon fry (Koenings and McDaniel 1983), and indicates an insignificant food item of resident, plankton-eating fish. Similarly, seasonal average sizes of *Daphnia* were relatively large, ranging between 0.73 and 1.50 mm, as were *Cyclops* which ranged in body size from 0.59 to 0.82 mm, and *Diaptomus* ranging between 0.88 and 1.11 mm. Finally, the seasonal weighted biomass of macro-zooplankton ranged from 857 to 1,125 mg/m^2 during 1988-1990 (Table 6).

EVALUATION

Potential Sockeye Salmon Production-- From experimental results of stocking and nutrient enrichment in Leisure Lake, located in lower Cook Inlet, an empirical model based on euphotic volume (Koenings and Burkett 1987) was developed to predict the maximum and optimum number of sockeye salmon fry that nursery lakes could support. Maximum stocking density (minimum size smolts) was found to be 110,000 fry per euphotic volume (EV) unit, and the optimum stocking density (relative to smolt size and marine survival) was defined as 54,000 fry per EV unit. Using this rearing capacity model, Spiridon Lake, which has 212 EV units, would support between 11 and 23 million sockeye salmon fry. However, considering a goal of producing optimum size smolts (80-90 mm; ~5 g) for maximum marine survival, the ultimate annual stocking level should be ~11 million sockeye salmon fry. From this annual stocking level, a total of 2.2 million smolts should be produced, which in turn, should result in a total return of ~450,000 adult sockeye salmon. Since no adult sockeye salmon can enter Spiridon Lake

Table 5. Macro-zooplankton length (mm) for each taxa by month and the seasonal weighted mean for stations 1 and 2 in Spiridon Lake, 1987-1990.

Station/ Zooplankton taxa	Body length (mm) May	Jun	Jul	Aug	Sep	Oct	Seasonal weighted mean (mm)
				1987			
Station 1							
Bosmina longirostris	ND	ND	ND	0.57	ND	ND	ND
Daphnia rosea	ND	ND	ND	0.75	ND	ND	ND
Cyclops columbianus	ND	ND	ND	0.74	ND	ND	ND
Diaptomus pribilofensis	ND	ND	ND	0.96	ND	ND	ND
Station 2							
Bosmina longirostris	ND	ND	ND	ND	ND	ND	ND
Daphnia rosea	ND	ND	ND	ND	ND	ND	ND
Cyclops columbianus	ND	ND	ND	ND	ND	ND	ND
Diaptomus pribilofensis	ND	ND	ND	ND	ND	ND	ND
				1988			
Station 1							
Bosmina longirostris	ND	0.58	ND	0.64	0.61	0.58	0.62
Daphnia rosea	ND	0.88	ND	1.21	1.28	1.43	1.16
Cyclops columbianus	ND	0.80	ND	0.92	0.73	0.78	0.81
Diaptomus pribilofensis	ND	0.94	ND	0.97	1.04	1.16	1.03
Station 2							
Bosmina longirostris	ND	0.47	ND	0.62	0.57	0.58	0.59
Daphnia rosea	ND	0.71	ND	1.25	1.31	1.41	1.24
Cyclops columbianus	ND	1.06	ND	0.77	0.82	0.75	0.82
Diaptomus pribilofensis	ND	0.86	ND	0.98	1.02	1.14	1.01
				1989			
Station 1							
Bosmina longirostris	0.60	0.54	0.55	0.56	ND	0.59	0.56
Daphnia rosea	ND	0.86	0.82	0.94	ND	1.33	1.03
Daphnia longiremus	0.85	0.82	0.72	0.81	ND	0.87	0.81
Cyclops columbianus	0.73	0.59	0.57	0.58	ND	0.80	0.61
Diaptomus pribilofensis	1.04	0.72	0.82	0.98	ND	1.10	0.88
Station 2							
Bosmina longirostris	0.57	0.48	0.52	0.53	ND	0.61	0.56
Daphnia rosea	ND	0.83	1.01	0.93	ND	1.33	0.95
Daphnia longiremus	0.76	0.76	0.74	0.71	ND	ND	0.73
Cyclops columbianus	0.76	0.51	0.60	0.57	ND	0.66	0.59
Diaptomus pribilofensis	0.97	0.72	0.95	0.96	ND	1.08	0.90

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Table 5 continued. Macro-zooplankton length (mm) for each taxa by month and the seasonal weighted mean for stations 1 and 2 in Spiridon Lake, 1987-1990.

Station/ Zooplankton taxa	Body length (mm) May	Jun	Jul	Aug	Sep	Oct	Seasonal weighted mean (mm)
				1990			
Station 1							
Bosmina longirostris	0.62	0.61	0.43	0.59	ND	0.57	0.57
Daphnia rosea	ND	0.71	1.06	1.12	ND	1.39	1.20
Daphnia longiremus	0.77	0.80	0.88	0.83	ND	0.91	0.84
Cyclops columbianus	0.71	0.83	0.78	0.74	ND	0.82	0.78
Diaptomus pribilofensis	1.11	0.65	0.97	1.01	ND	1.10	0.94
Station 2							
Bosmina longirostris	0.56	ND	0.57	0.61	ND	0.60	0.60
Daphnia rosea	ND	0.69	0.92	1.33	ND	1.50	1.29
Daphnia longiremus	0.89	0.67	0.72	0.93	ND	0.94	0.83
Cyclops columbianus	0.72	0.74	0.77	0.71	ND	0.76	0.74
Diaptomus pribilofensis	1.13	0.79	1.05	1.06	ND	1.11	1.05

Table 6. Seasonal weighted biomass (mg/m^2) of macro-zooplankton for stations 1 and 2 in Spiridon Lake, 1987-1990.

Sample month/year	Seasonal weighted biomass (mg/m^2)		
	Station 1	Station 2	Mean
Aug/87	1,378	ND	ND
Jun-Oct/88	890	823	857
May-Oct/89	991	821	906
May-Oct/90	1,259	990	1,125

and spawn due to the barrier falls, all returning adults would be available for harvest.

Zooplankton Community and Production-- Changes in the zooplankton community resulting from the affect of vertebrate planktivores (e.g. juvenile sockeye salmon) is well documented (Stenson 1972, 1976; Kerfoot 1980; Vanni 1986; Kyle et al. 1988). In Spiridon Lake, the composition of the macro-zooplankton population is dominated (85%) by copepods. Even though copepods have adapted to cold environments by devoting much of their energy intake into lipid reserves, their mode of reproduction is considered a detriment to the yearly rearing potential of lakes. That is, unlike cladocerans, copepods reproduce sexually which reduces the regeneration time and causes delays in their response to changes in lake productivity and/or abundance of predators. For example, heavy predation on copepods can lead to a drastic reduction in the recruitment of nauplii the following year. In addition, because of their size and egg clusters, copepods are more conspicuous to visual predators but their greater physiological agility ameliorates their vulnerability to predation. Thus, the natural capacity of Spiridon Lake to rear juvenile sockeye salmon will depend in large part on balancing introduced numbers of fry with a zooplankton community that is relatively sensitive to predation.

Spiridon Bay Harvest Management Plan-- The purpose of the Spiridon Bay harvest management plan is to allow for the harvest of sockeye salmon returning to Spiridon Lake (Telrod Cove) which will potentially be produced from the Spiridon Lake enhancement project. In addition, adequate safeguards are needed to protect the escapements of natural salmonid stocks returning to the various streams in this bay. A fairly large proportion of the sockeye salmon produced from the Spiridon Lake enhancement project will be harvested in the traditional fishing areas of the Northwest Kodiak District, during openings that are directed toward harvesting of Karluk Lake sockeye salmon and west-side pink and chum salmon stocks.

A special terminal-harvest area will be required to provide an orderly harvest of sockeye salmon produced from stocking Spiridon Lake that will escape the traditional commercial fishing areas. The special harvest area will be defined as that area of Spiridon Bay west of a line drawn from 153° 37' 21" W longitude and 57° 38' 54" N latitude, to the opposite shore at 153° 38' 27" W longitude and 57° 38' N latitude to 153° 42' 24" W longitude. By regulation, the legal gear within the special harvest area will be seine only.

When a harvestable number of sockeye salmon return to the Spiridon Bay special harvest area, fishery openings will be limited to six hours (during daylight hours), and will start no earlier than three hours before high tide (daylight series). When possible, this fishery would be coordinated with openings of fishing periods scheduled for management areas within the Northwestern Kodiak District. Any openings within the Spiridon Bay special harvest area will commence by a flare launched from a representative of ADF&G.

Finally, there is a possibility that natural stocks will be incidentally harvested in the terminal-harvest area specifically designed to harvest only sockeye salmon produced from the enhancement project at Spiridon Lake. If it appears that other salmon-producing systems in the area are not receiving adequate escapements, either the special harvest area will be limited in size (in an attempt to further restrict the catch to only Spiridon Lake sockeye salmon), the fishery will be limited in duration, or no fishery will take place.

RECOMMENDATIONS

Stocking Spiridon Lake with sockeye salmon fry is recommended based on the following:

1. The ultimate stocking level should approximate 11 million fry with a goal of producing age-1 smolts ≥85 mm/5 g.

2. Stocking should proceed in a gradual manner such that the response of macro-zooplankton to predation by sockeye salmon fry can be closely

monitored and evaluated. An incremental stocking plan worth considering is a 5 million plant for two years followed by two years of stocking 8 million, and finally, after four years of evaluation proceed to the 11 million level.

3. Limnological and fishery sampling should continue. Specifically, the once per month collection of zooplankton and water samples should be continued at both stations from May-October. In addition, hydroacoustic/townet surveys should be done to determine the fall population estimate (survival) and mean rearing temperatures of juvenile sockeye salmon, and smolt sampling should be done to determine out-migration, age, length, and weight.

4. A smolt bypass system is needed (by the spring of 1992) to route migrating smolts around the falls on the outlet of Spiridon Lake.

5. The present North West Kodiak District Management Plan, as detailed in the 1988 Kodiak Commercial Salmon Harvest Strategy, should not be compromised or changed by this proposed enhancement project. A high proportion of the sockeye salmon returning to Spiridon Lake are expected to be harvested in the interception fishery of the NW District during the July openings. This fishery will continue to be operated by in-season emergency openings based on escapements of major salmon-producing systems within the district. As an unknown number of returning adults from this project will not be harvested in the traditional fisheries, a special terminal-harvest area must be established in the Spiridon Bay area. A barrier net should be placed in front of the outlet of Spiridon Lake to prevent sockeye salmon from entering. Finally, the escapement of chum salmon (both early and late runs) into Spiridon River, which is adjacent to the outlet of Spiridon Lake, should be monitored during the commercial fishery to ensure achieving the escapement goals.

6. Sockeye salmon captured in the proposed fishery of Telrod Cove, should be sampled for age and length. In addition, the contribution of Spiridon Lake sockeye salmon caught in the west-side (Kodiak Island) fishery should be determined through scale pattern analysis.

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