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KOKANEE STOCK STATUS& CONTRIBUTION OF CABINET GORGE HATCHERY, LAKE PEND OREILLE, IDAHO

FINAL REPORT

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TABLE OF CONTENTS

TABLE OF CONTENTS (cont.)

LIST OF TABLES

CONTENTS

LIST OF FIGURES

LIST OF FIGURES (Cont.)

CONTENTS

LIST OF APPENDICES

LIST OF APPENDICES (Cont.)

LIST OF APPENDICES (Cont.)

ABSTRACT

Lake Penal Oreille once provided the most popular kokanee *Oncorhynchus nerka* fishery in northern Idaho. A dramatic decline in the population occurred from the mid-1960s to 1970s. Restoration efforts included construction of the Cabinet Gorge Fish Hatchery to supplement the wild population and restore the fishery. In this study, hatchery-reared age O kokanee were stocked into Lake Penal Oreille from 1986 through 1992. Seven experimental stocking strategies for kokanee were tested using five locations and two time periods (early May through early June or late July).

In 1985, the age 3 and older kokanee totaled about 0.35 million, but rose to 0.78 million in 1986, was stable, was then followed by a decline in 1990 to 0.53 million, then improved to 1.75 million in 1992. Much of the annual variation in total numbers of kokanee, ranging from 4.5 million to 10.2 million, was due to hatchery stockings of age O fish. Standing stocks of kokanee remained stable and ranged from 8 to 10 kg/hectare despite dramatic changes in density due to age O fish. Prior to this study (1985), standing stocks were substantially higher (mean= 13.6 kg/hectare), indicating that the population may be operating below carrying capacity.

We found survival of age O hatchery kokanee by each release season to range from 3% in 1986 to 39% in 1992, while the mean from 1987 through 1992 was 23%. We found significant ($P=0.05$) differences in survival between years, but we could not detect differences between stocking locations ($P>0.71$). Our analysis of survival between time (early vs late) and location was weak and inconclusive because after 1989 we had fewer fish to stock and could not repeat testing of some release strategies. We believe some of the variation in survival between release groups each year was due to the length of time between release in the lake and trawling. But we did not find a significant correlation between time at large and survival ($P=0.12$, $r^2=0.61$ for 1988 and $P=0.15$, $r^2=0.44$ for 1989); as many as 40 days separated some release groups. The best survival of a release group was 43% at Garfield Bay and was recorded in 1992, while the poorest release was 5% for an early release into open water in 1987. We found the combined survival of hatchery fry each year was correlated to mean total zooplankton abundance ($P=0.05$, $r^2=0.65$). Survival of individual release groups was correlated to total zooplankton at time of release ($P=0.01$, $r^2=0.29$). Some of the variation in hatchery fry was also due to the density of two Cladocerans *Diaphnanosoma* ($P=0.05$, $r^2=0.33$), the density of *Daphnia* sp. ($P<0.10$, $r^2=0.20$), and the size of *Daphnia* ($P=0.01$, $r^2=0.69$).

Hatchery releases provided some short-term gains, but low survival of wild fry and poor recruitment of young to the spawning escapement were important limitations to restoration to historic levels.

A creel survey in 1991 provided an estimate of 460,679 angler hours during 87,966 angler days. We estimated anglers harvested 227,140 kokanee in 1991 for a catch rate of 1.45 kokanee/h. Mean size of kokanee in the harvest was 242 mm. The harvest of kokanee was only 30% of the project goal. Anglers caught an estimated 2,939 large Gerrard rainbow trout O. *mykiss* (≥ 610 mm) and harvested 2,157. An additional 14,122 smaller (<610 mm) rainbow trout were caught and released. Mean length of Gerrard rainbow trout in the creel was 735 mm while they averaged 5.7 kg. Anglers also creeled an estimated 1,723 bull trout *Salvelinus confluentus*, 766 cutthroat trout *O. clarki*, and at least 43 lake trout *S. namaycush*.

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INTRODUCTION

Lake Penal Oreille supported the most popular kokanee Oncorhynchus nerka fishery in Idaho from the 1940s until the early 1970s. The sport and commercial harvest provided an average annual harvest of one million kokanee and 360,000 hours of angling effort from 1951 to 1965 (Ellis and Bowler 1979). Sport anglers enjoyed average annual catch rates as high as 3.5 fish/h during the mid-1960s. Kokanee harvest declined from 1965 to 1985, resulting in an annual harvest of less than 100,000 fish, with a mean catch rate of approximately 1.0 kokanee/h (Bowles et al. 1987). A rehabilitation program for the kokanee was designed and included goals of an annual harvest of 750,000 kokanee averaging 250 mm in length with catch rates averaging 2.0 fish/h. In addition to providing an important fishery, kokanee are the primary forage for trophy Gerrard rainbow trout Oncorhynchus mykiss and bull trout Salvelinus confluentus in Lake Penal Oreille.

Several factors have contributed to the decline of kokanee abundance in Lake Penal Oreille. Hydropower development and consequential water level drawdowns adversely impacted spawning success and survival of eggs, as well as kokanee fry in redds. Albeni Falls Dam was completed in 1952 by the Army Corps of Engineers as part of the Bonneville Power Administration (BPA) network. Located on the Penal Oreille River approximately 35 km downstream of Lake Penal Oreille, Albeni Falls Dam raised lake levels by 4 m. Annual winter drawdown, which averaged 1.3 m from 1951 to 1968, increased embryo mortality by exposing redds of lakeshore-spawning kokanee (Bowler et al. 1979; M. Maiolie, Idaho Department of Fish and Game, personal communication). Cabinet Gorge Dam was constructed on the Clark *Fork* River (river km 24) for power generation by Washington Water Power Company (wUP). Completion of this dam in 1952 blocked an important kokanee spawning run into Clark Fork River and its tributaries. The establishment of opossum shrimp Mysis relicta in Lake Penal Oreille may also have adversely affected kokanee. Shrimp were introduced in 1968 and were well established by 1975 (Rieman and Falter 1981). The Idaho Department of Fish and Game (IDFG) introduced them to enhance the kokanee forage base. The expected response of increased kokanee growth did not occur because mysids migrate to depths in excess of 60 m during daylight hours, making them unavailable to feeding kokanee.

Interagency efforts to rehabilitate the kokanee fishery began during its initial decline. In 1967, the Army Corps of Engineers adopted a policy for operation of Albeni Falls Dam to minimize water level fluctuations during kokanee spawning and incubation. IDFG restricted kokanee sport harvest and terminated the commercial fishery in 1973. Hatchery production of kokanee for Lake Penal Oreille was established by 1974 and helped stabilize population numbers. Delayed planting of hatchery fry until mid-summer to avoid early season food deficiencies increased hatchery fry survival up to 13 times over wild fry (Bowler 1981). Hatchery production appears to have stabilized the decline in kokanee abundance, but rearing capacity of existing hatcheries was inadequate to rebuild the fishery. Prior to 1985, hatcheries could provide only 6 to 8 million kokanee fry annually for Lake Penal Oreille. Research indicated that releases of up to 20 million fry annually may be necessary to restore the fishery to historic levels (Rieman 1981).

The Cabinet Gorge Hatchery was built on the Clark Fork River in an effort to restore the Lake Penal Oreille kokanee fishery. It is the largest kokanee hatchery in the world and is 4 km below Cabinet Gorge Dam. The hatchery represented a cooperative effort among EPA, WWP and IDFG. Construction and evaluation of Cabinet Gorse Hatchery is specified by Measure 804(e)(5) of the Columbia River Basin Fish and Wildlife Program (NWPPC 1984). Cabinet Gorge Hatchery was operational by November 1985, and at full capacity, can provide up to 20 million kokanee fry for release into Lake Penal Oreille.

The project goal is rebuilding the kokanee population to attain 750,000 kokanee harvested annually and 300,000 hours of angler effort.

OBJECTIVES

1. Evaluate the contribution of Cabinet Gorge Hatchery to the Lake Penal Oreille kokanee stock and fishery.

2. Describe kokanee population dynamics and carrying capacity in relation to kokanee, zooplankton, and mysid community.

3. Determine optimal fry release strategies to maximize fry recruitment and recruitment-to the fishery, as well as provide adequate adult escapement for egg-take needs.

4. Obtain index information on naturally spawning kokanee to evaluate the contribution of hatchery fish.

STUDY AREA

Lake Penal Oreille is located in the panhandle of Idaho (Figure 1). It is the largest lake in Idaho, with a surface area of 383 km^2, or about 38,300 hectares, mean depth of 164 m, and maximum depth of 351 m. Mean surface elevation of Lake Penal Oreille is 629 m. Deep water habitat used by kokanee is considered to be 22,647 hectares. The Clark Fork River is the largest tributary to Lake Penal Oreille. Outflow from the lake forms the Penal Oreille River.

Lake Penal Oreille is a temperate, oligotrophic lake. Summer temperatures (Mayto October) average approximately 9°C in the upper 45 m (Rieman 1977; Bowles et al. 1987, 1988, 1989). Thermal stratification typically occurs from late June to September. The N:P ratio is typically high (>11) and indicates primary production may be P limited (Rieman and Bowler 1980). Mean chlorophyll "a" concentration during summer is approximately 2 micrograms/L. Summer mean water transparency (Secchi disk) ranges from 5 to 11 m. Operation of Albeni Falls Dam on the Penal Oreille River keeps the lake level stable at 628.4 m during summer (July to September), then reduces the lake level to about 625.3 m during winter.

A wide diversity of fish species are present in Lake Penal Oreille. Kokanee entered the lake in the early 1930s, presumably from Flathead Lake, and were well established by the 19400. Other game fish include Kamloops (Gerrard) rainbow trout, bull trout, rainbow trout *Oncorhynchus mykiss*, westslope cutthroat trout *Oncorhynchus clarki lewisi*, lake whitefish *Coregonus culpeaformis*, mountain whitefish *Prosopium williamsoni*, and several coolwater and warmwater species.

METHODS

Kokanee Population Structure

Kokanee population structure in Lake Penal Oreille was determined by collecting kokanee with a mid-water trawl during the last week in August or first week of September. Fish from each sample were counted, measured, weighed, and checked for maturity. Sagitta otoliths were excised for aging. The mid-water

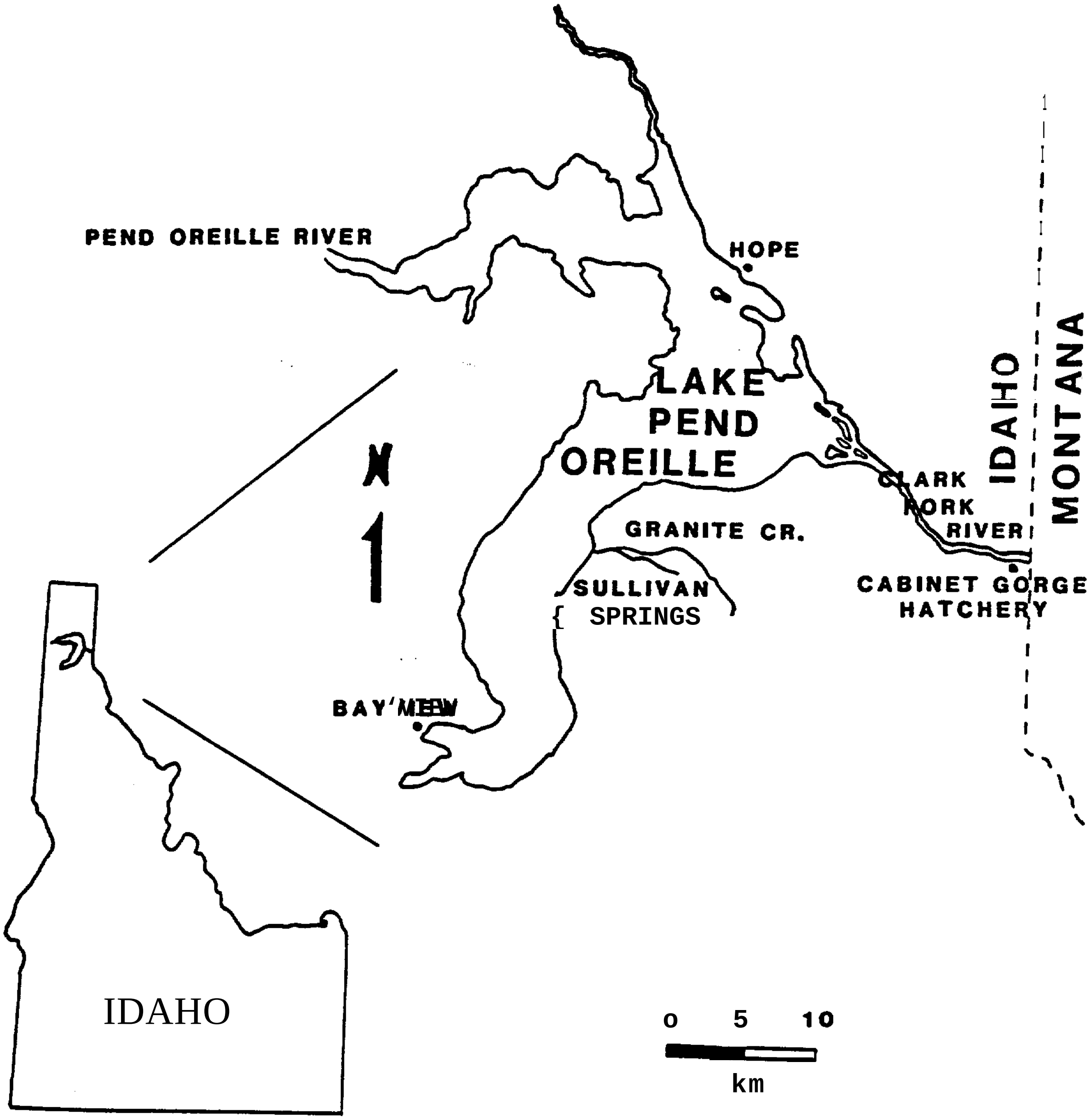

Figure 1. Map of Lake Penal Oreille, Idaho.

trawl and sampling was described by Rieman (1992). The trawl net was towed by an 8.5-m boat powered by a 140-hp diesel engine. The net was 13.7 m long with a 3 x 3 m mouth. Mesh sizes (stretch measure) graduated from 32, 25, 19, and 13 mm in the body of the net to 6 mm in the cod end. All age classes of kokanee were collected. Trawling was done at night during the dark phase of the moon to optimize capture efficiency (Bowler 1979). The trawl was towed at 1.5 m/s at depths calibrated with a depth sounder. Each step-wise oblique haul sampled the entire vertical distribution of kokanee, as determined from echograms produced by a Ross 200 angstrom depth sounder with two hull-mounted transducers (22° and 8° beam angles). The vertical distribution of kokanee was divided into 3.5-m layers; usually 3 to 5 layers encompassed the vertical distribution of kokanee. A standard 3.5-minute tow was made in each layer, sampling 2,832 m^3 of water over a distance of 305 m. Total volume of water sampled for each trawl haul varied from 8,496 to 16,992 m^3, depending on the vertical distribution of kokanee.

A stratified systematic sampling scheme was used to estimate kokanee abundance and density. Lake Penal Oreille was divided into six sections or strata (Figure 2). The area of each section was calculated for the 91.5-m contour; however, Section 6 (the northern end) was calculated from the 36.6-m contour because of shallower water. The 91.5-m contour was used because it represents the pelagic area of the lake where kokanee are found during late summer (Bowler 1978). Six transects were systematically selected within each section and one haul (sample) was made along each transect.

Fish numbers/transect (haul) were divided by transect volume, and the age-specific and total number of kokanee for each stratum and lake total were calculated using standard expansion formulae for stratified sampling designs (Scheaffer et al. 1979). Kokanee population estimates (total and by section) were divided by respective lake surface areas to calculate kokanee densities in number/hectare for each age class. Confidence intervals (90%) were calculated to compare estimates among age classes, lake sections, and years.

Survival

Recruitment and survival of hatchery-reared and wild fry were determined from trawl catches during late August of marked or unmarked fry. Wild fry survival was estimated from potential egg deposition (PED) or the number of fish stocked (in the case of hatchery fish) to the August abundance in Lake Penal Oreille. PED was calculated by multiplying average fecundity at egg collection facilities by estimated mature female kokanee abundance. Hatchery-reared fry were differentiated among release groups and from wild fry by analyzing a date of release mark and daily growth increments on fry otoliths. Annual survival wae estimated for age 1 and older kokanee by comparing trawl-estimated abundance for each year class between years.

Fry Marking

Otolith Coding

Otoliths from kokanee reared at Cabinet Gorge Hatchery exhibit an obvious change in width of daily growth increment at the time of their release (Paragamian et al. 1992). This mark was used from 1988 through 1992 to distinguish hatchery residence from lake residence. Kokanee released on different dates were identified by counting daily growth increment from the release mark to the otolith margin (trawl sampling date). Sagitta otoliths were excised from fry caught during trawling and embedded in a low viscosity medium

Section	Area (hectares)
1	3,166
2	3,220
3	3,739
4	4,036
5	3,373
6	5,011

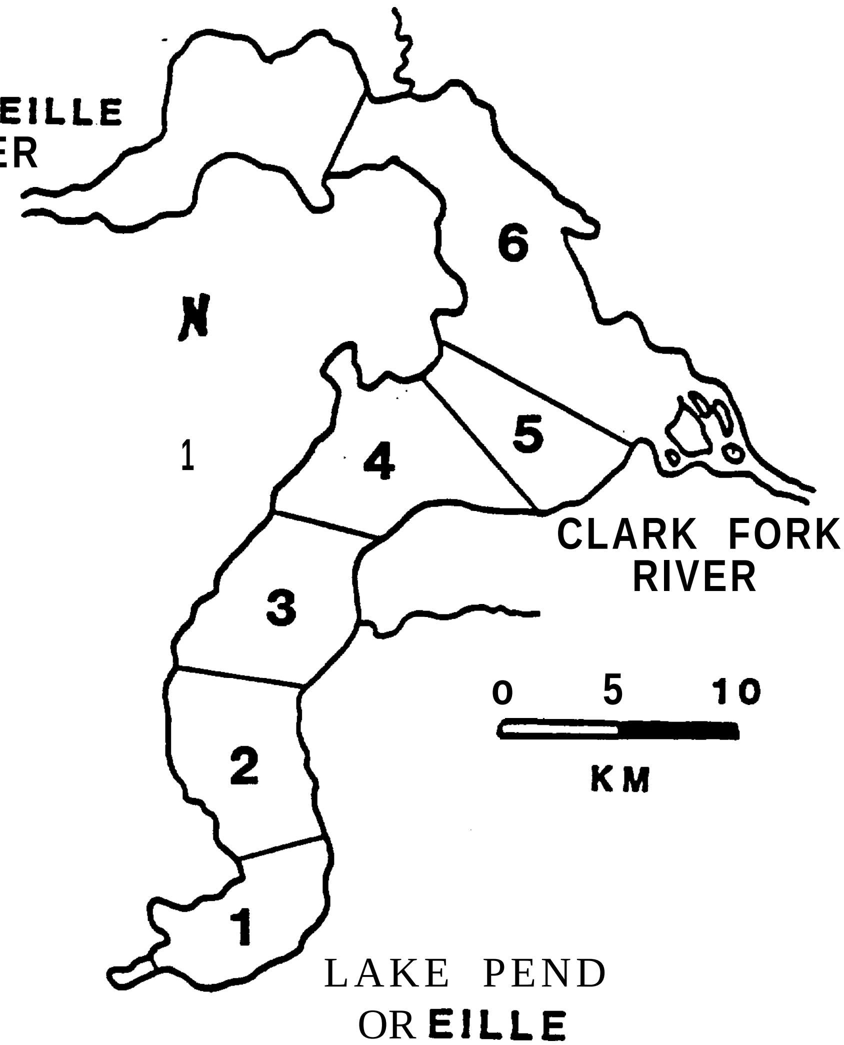

Figure 2. Stratified sampling sections and respective areas of kokanee habitat (hectares) used from 1986 through 1992 for trawling and kokanee abundance estimation on Lake Penal Oreille, Idaho.

(Spurr 1969). The proximal surface was polished (600 grit paper) and otolith microstructure observed (1,000 power) with an oil immersion compound microscope interfaced with a video camera and monitor.

Fin Clip

A fin was clipped from selected groups of kokanee fry from 1988 through 1992 to help evaluate fry-to-adult return ratea to spawning stations at Cabinet Gorge Hatchery and Sullivan Springs Creek. Different fin clips were also used to segregate two length groups of kokanee fry released at Sullivan Springs. This was done in 1991 and 1992. The long range objective was to determine the affect of hatchery growth/size on age at maturity. Fin clips included the adipose fin-clipped kokanee released at Sullivan Springs (large fry of 50 mm), right ventral fin-clipped small kokanee released at Sullivan Springs (37 mm in 1991 and 40 mm in 1992), left pelvic fin-clipped early release group of kokanee in the Clark Fork River, and right pelvic fin-clipped late release group of kokanee in the Clark Fork River. The number of kokanee clipped for each release group and year is in Table 1. Fry were clipped at least one week prior to release and averaged 50 mm total length (1,054 fry/kg), except for small kokanee released at Sullivan Springs in 1991 and 1992. Fry were anesthetized (0.04 g MS-222/L water) prior to handling. Representative samples from each group were retained in the hatchery to evaluate fry mortality and fin regeneration.

Other Marks

Additional marks such as tetracycline and pigmented grit were used in the course of this study. For a detailed description of these marks see the Annual Reports cited earlier in this text.

Fry Release Strategies

We evaluated seven fry release strategies from 1986 through 1992 to compare survival of fry released at two different time periods (early May and late June or July). Releasing fry at these sites also provided adult returns to egg-take stations at Cabinet Gorge Hatchery and Sullivan Springs Creek (Table 1). We released about 5.0 million fry in 1986, although these fry were reared at Cabinet Gorge Fish Hatchery they were only about 33 mm total length (TL) when released.

Clark Fork River

We released 1.0 to 4.6 million fry into the Clark Fork River each year to establish a spawning run to Cabinet Gorge Hatchery (Table 1). Hatchery workers imprinted all fry with morpholine ($5x10^{-5}$ mg/L in hatchery water) for 30 days prior to release from 1988 through completion of this study. Workers also added morpholine to hatchery water flowing from the fish ladder at Cabinet Gorge Hatchery into the Clark Fork River. This was done for 3 days following each release.

<u>Early Season Release</u>-We released about 2.5 to 3.4 million (X=3.2 million) fry through the Cabinet Gorge Hatchery fish ladder into the Clark Fork River (Table 1). The mean TL for these fry ranged from 49.4 mm to 51.0 mm TL. This release was scheduled to coincide with high nighttime river flows resulting from

Table 1. Location, stocking chronology, number released, number fin-clipped, mean length, and standard deviation (SD) of age O kokanee stocked into Lake Penal Oreille, Idaho, 1986-1992.

Stocking Site and Time	Year	Date	Number Released	Number Fin Clipped	Mean Length (mm)	SD
Early Clark Fork River	1988	6/15	3,414,000	50,000	51	..
	1989	6/21	3,513,000	41,000	46	--
	1990	6/21	3,400,000	60,000	50	±2
	1991	6/26	2,610,000	60,000	49	±2
Late Clark Fork River	1986[a]	7/30 to 9/	3,415,500	0	50	--
	1987	7/22 to 7/27	3,013,700	0	52	--
	1988	7/11 to 7/14	1,297,000	40,000	48	--
	1989	7/17 to 7/19	984,000	40,000	49	--
	1992	7/7	1,123,600	60,000	55	--
Sullivan Springs	1986[a]	8/	1,589,700	0	50	--
	1987	7/7 to 7/29	2,847,300	0	52	--
	1988	7/11 to 7/14	5,139,000	40,000	49	--
	1989	7/11 to 7/13	3,538,000	40,000	51	--
	1990	7/10 to 7/12	3,200,000	60,000	50	±2
	1991	7/9 to 7/10	2,570,000	60,000[b]	50	--
	1992	7/14 to 7/15	3,440,000	60,000[b]	60	--
Early Open Water North	1988	6/27	1,607,000	0	46	--
	1989	6/29	1,256,000	0	46	--
Late Open Water South	1988	7/26	1,570,000	0	51	--
	1989	7/26	1,428,000	0	56	--
Late South Shoreline	1989	7/27 to 7/28	1,024,000	0	55	--
	1990	7/24 to 7/25	1,100,000	0	50	±2
Garfield Bay	1992	7/30	970,440	0	51	--

[a]Kokanee fry were released in varying numbers and time intervals during this period.
[b]Approximately 30,000 small kokanee fry (mean length of 37 mm in 1991 and 30 mm in 1992) were marked with a right ventral fin clip.
[c]Confidence intervals were not calculated for all releases.

spring snowmelt, however spring time flows far exceeded the anticipated 990 m^3/s (35,000 ft^3/s) in 1990 and 1991 (Table 2).

Late Season Release-We barged 1.3 million kokanee in 1988 and 3.5 million kokanee in 1989 down the Clark Fork River. We also released 3.0 million kokanee in 1987 and 1.0 million kokanee in 1992 through the hatchery ladder into the river (Table 1). The mean length of these kokanee ranged from 48 mm to 55 mm TL. Barging was used to avoid predation by northern squawfish Ptychocheilus oregonensis by moving them down the river and releasing them near the mouth of the river. An 8.5-m pontoon barge transported two circular tanks that carried 8.8 m^3 of water. The tanks were aerated and plumbed to provide circulating river water. Each tank contained 18 kg of kokanee/m^3.

Open Water

We tested two open water releases in 1988 and 1989; an early release and a late release. The late release corresponded with higher Cladoceran abundance and warmer water. A total of about 3.2 million kokanee were released in 1988 and 2.7 million in 1989, the only two years of testing for the open water release (Table 1). Open water habitat is generally not occupied by the predacious northern squawfish.

south Shoreline

We tested a south shoreline release in 1989 and 1990 as a late season site. Our objective was to test a shallow shoreline site and make use of the abundance of zooplankton food at this time of the year. About 1.0 million kokanee were released each year. They averaged 55 mm and 50 mm TL in 1989 and 1990, respectively (Table 1).

Garfield Bay

We released kokanee in Garfield Bay to test the value of using a rich embayment with warmer water. About 1.0 million kokanee were released into Garfield Bay in 1992, and they averaged 51 mm TL (Table 1).

Sullivan Springs

Approximately 2.57 million to 5.14 million fry (Mean = 3.45) were transported by truck from Cabinet Gorge Hatchery to Sullivan Springs Creek from 1986 through 1992 (Table 1). The fry were transported at a density of 55 to 59 kg/m^3, with a tank temperature of 9°C and a stream of 8°C. The purpose of this release was to insure continued adult returns to the egg-take station on this spring-fed tributary to Lake Penal Oreille (Figure 1). The otolith date-of-release mark was used to distinguish hatchery and wild fry after autumn trawling in Lake Penal Oreille. Approximately 40,000 to 60,000 fry were adipose fin-clipped from 1988 through 1990 (Table 1). We clipped about 30,000 fry (mean = 56.5 mm) with an adipose fin clip in 1991 and 1992 and a second group of 30,000 smaller fry (mean = 43 mm) were marked with a right ventral clip in the same years. Our objective was to evaluate large and small fry and their respective returns as adults spawning from 1994 through 1997 and to evaluate differences in age at maturity.

Table 2. Clark Fork River discharge (Q) during kokanee releases from the Cabinet Gorge Fish Hatchery, 1987 through 1992.

Year	Release group	24 h Q range (m^3/s)	Mean three h Q at release (m^3/s)	Travel time (h)
1987	late	99-694	569	5.0
1988	early late[a]	100-920	809	--
1989	early late[a]	900-1,300	1,024	'7.3
1990	early	1,480-1,842	1,842	7.0
1991	early	99-1,984	1,984	--
1992	late	91-652	634	6.1

'Fry were barged down Clark Fork River.

Egg Collection

Since 1974, IDFG has maintained a permanent weir at the mouth of Sullivan Springs Creek (Figure 1). The collection of eggs at this station by hatchery workers has provided kokanee eggs for Lake Penal Oreille. Additional eggs were collected from kokanee spawners at the Cabinet Gorge Hatchery fish ladder and by purse seining the Clark Fork River during some years.

Naturally-Spawning Kokanee

Research technicians counted mature kokanee along lakeshore and tributary stream spawning areas to provide an index of naturally-spawning kokanee abundance. We counted fish by walking each area once from 0800 to 1500 h during the first week of December; the estimated peak of spawning activity. Predetermined portions of lakeshore spawning areas were surveyed. We surveyed entire spawning areas and tributary streams. An additional 24 historic spawning locations were surveyed during winter of 1992, our purpose was to document re-pioneering of spawning areas by hatchery fish. Trestle Creek was also censused in September to determine use by early run kokanee spawners.

Aae and Lenqth at Maturity

We measured kokanee lengths and extracted otoliths from mature kokanee during the late fall spawning season for spawner age and length determinations. Spawners were collected from early run Trestle Creek, East Hope shoreline, Spring Creek, Clark Fork River, and the weir at Sullivan Springs Creek. Age of maturity was also estimated for kokanee collected during September trawling.

Mysis Shrimp

We sampled shrimp at night during the dark moon phase the first week of June each year, with the exception of 1991 when we sampled in November. Five samples were collected randomly in each of the southern, central, and northern portions of Lake Penal Oreille (Figure 3). We sampled with a Miller high-speed sampler equipped with a General Oceanics flow meter and a 100-micron plankton net and bucket. Stepped oblique tows were made from 46 m to the surface, sampling for 10 s at each 3-m interval. The sampler was towed approximately 1.5 m/s and raised 0.5 m/s with an electric winch. Shrimp from each sample were counted and differentiated by size class into juvenile or adults. Density estimates were based *on volume* of water sampled.

Size and sex data were recorded for shrimp from two samples/lake sections. Shrimp were measured from the tip of the rostrum to the tip of the telson, excluding setae, and classified into five categories according to sex characteristics: juveniles, immature males and females, and mature-males and females (Gregg 1976; Pennak 1978).

Zooplankton

We sampled the zooplankton community in the southern, central,and northern portions of-Lake Penal Oreille (Figure 3). We collected five random samples

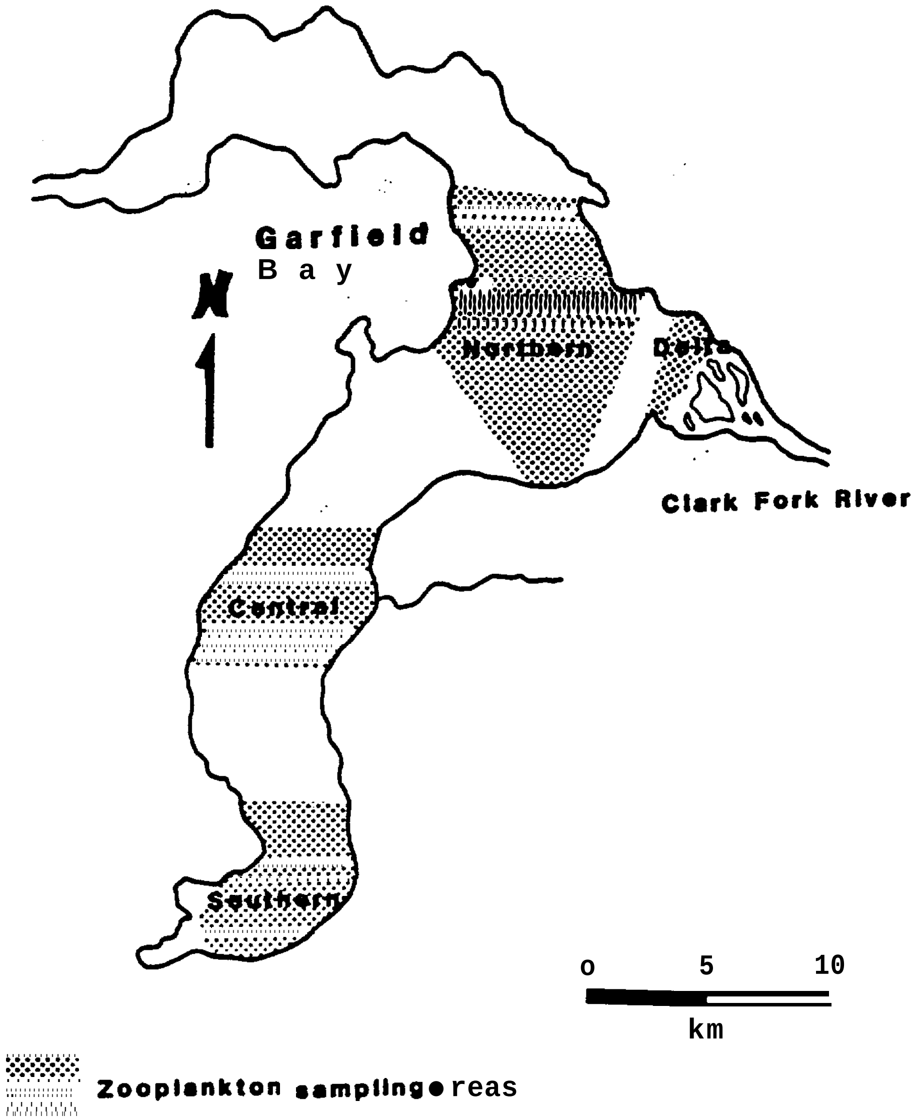

Figure 3. Shrimp and zooplankton sampling areas on Lake Penal Oreille, Idaho.

monthly from each section from May through October in the main body of the lake. We sampled the Clark Fork River delta with five random samples from 1987 through 1989, while two samples were taken from Garfield Bay in 1992. We sampled in the main body of the lake and Garfield Bay with a O.S-m diameter 130-micron plankton net calibrated by a Kahl Scientific flow meter. Vertical hauls from 27.4 m depths to the surface were made by raising the sampler approximately 0.5 m/s with an electric winch. We also sampled a shallow site in Garfield Bay from 18.2 m depth to the surface, and a deeper site of approximately 27.4 m depth. We collected samples from the shallower delta with a Miller high-speed plankton sampler equipped with a flow meter and 130-micron net and bucket. The entire water column was sampled with oblique tows stepped at 1.5-m intervals and towed at 1.5 m/s for a minimum of 40 s/sample. Zooplankters were enumerated by genus using standard dilution and subsampling methods (Edmondson and Winberg 1971). Enumeration data were standardized by volume of water filtered to determine zooplankton densities. Analysis of variance, utilizing a stratified random sampling scheme, was used to compare zooplankton densities, both spatially and temporally.

Water Temperature and Transparency

Thermal stratification of Lake Penal Oreille was monitored by measuring water temperature monthly from May through November at one site in the southern section of the lake. Instantaneous temperatures were measured with a probe from the surface to 60-m depths at l-m intervals for the first 5 m and at 5-m intervals thereafter. When a more dramatic change in temperature was noticed within a 5-m sample, temperatures were measured at l-m intervals to better define the metalimnion.

Water transparencies were monitored temporally and spatially. A Secchi disk reading was taken *in* the southern, central, and northern sections of Lake Penal Oreille each month from May through October.

Angler Effort and Harvest

Creel surveys were conducted during the 1985, 1990, and 1991 fishing seasons to provide estimates of angling effort, catch, and harvest of sport fishes. The data from these creel surveys can be found in annual reports (Bowles et al. 1986; Paragamian et al. 1991; and Paragamian et al. 1992). Some discussion of the findings of those creel surveys is included in the Discussion section of this report.

RESULTS

Kokanee Abundance, Distribution. and Biomass

Estimated total kokanee abundance ranged from 4.26 million fish in 1986 to 10.21 million fish in 1988 (Table 3; Appendix A). Total kokanee age 1 and older ranged from 2.47 million in 1987 to 3.86 million in 1992.

Estimated average kokanee density for the deep water portion of the lake (see Study Area) (all age classes combined) ranged from 189 kokanee/hectare in 1986 to 451 kokanee/hectare in 1988 (Table 4; Appendix A). Population estimates by age group and section for 1992 are recorded in Appendix B. Estimated standing stock of kokanee in Lake Penal Oreille during this study ranged 7.73 kg/hectare

Table 3. Population estimates (by age), total density (N/ha), and standing stocks for kokanee in Lake Penal Oreille, Idaho, 1986 through 1992. The 90% error bound is subtended.

	Population estimate (million) Age								
Year	0	1	2	3	4	5	Total	Density (fish/ha)	Standing Stock
1986	1.65 (0.12)	1.15 (0.30)	0.68 (0.21)	0.54 (0.19)	0.24 (0.23)		4.26	189	8.14
1987	3.55 (0.08)	0.78 (0.38)	0.84 (0.27)	0.43 (0.22)	0.42 (0.25)		6.02	266	8.32
1988	7.31 (0.09)	1.66 (0.24)	0.51 (0.28)	0.38 (0.30)	0.35 (0.27)		10.21	451	8.02
1989	4.50 (0.12)	1.15 (0.33)	1.20 (0.29)	0.45 (0.39)	0.37 (0.27)	0.04 (0.40)	7.71	342	9.71
1990	3.35 (0.11)	1.59 (0.74)	1*45 (0.32)	0.33 (0.33)	0.20 (0.30)		6.93	306	7.73
1991	1.98 (0.20)	0.83 (0.71)	1.77 (0.25)	0.77 (0.32)	0.27 (0.31)		5.62	248	8.93
1992	4.55 (0.14)	1.33 (0.46)	0.78 (0.20)	1.11 (0.25)	0.64 (0.29)		8.41	372	10.63

Table 4. Densities (fish/ha) and standing stocks (Kg/ha) of kokanee in Lake Penal Oreille, Idaho, 1986 through 1992 (standing stock is subtended).

Year	Age						Total
	o	1	2	3	4	5	
1986	73 (0.17)	51 (1.23)	30 (2.50)	24 (2.63)	11 (1.61)	(0;	189 (8.14)
1987	157 (0.25)	34 (0.48)	37 (2.57)	19 (2.23)	19 (2.79)	(0!	266 (8.32)
1988	323 (0.45)	73 (1.50)	23 (1.56)	17 (1.97)	15 (2.54)	(0;	451 (8.02)
1989	198 (0.17)	52 (1.38)	53 (3.42)	20 (1.92)	17 (2.49)	2 (0.33)	342 (9.71)
1990	148 (0.17)	71 (1.43)	64 (3.76)	14 (1.41)	9 (0.96)	(0!	306 (7.73)
1991	87 (0.13)	37 (0.93)	78 (3.69)	34 2.82)	12 (1.36)	(0;	248 (8.93)
1992	201 (0.19)	59 (1.11)	34 (1.78)	49 (4.07)	29 (3.48)	(0;	372 (10.63)

in 1990 to 10.63 kg/hectare in 1992 (Table 4). Mean TL and weights of age O through age 5 kokanee caught trawling, from 1986 through 1992, are shown in Appendix C.

Spawning Escapement

The estimate of mature female kokanee (assuming a 1:1 ratio) *in* the *Lake* Penal Oreille spawning population ranged from 144,082 in 1990 to 411,248 in 1992 (Appendix D). The spawning run to Sullivan Springs Creek from 1976 through 1992 ranged from 10,717 kokanee in 1976 to 177,500 fish in 1981. Total escapement to Sullivan Springs ranged from 17% of the total estimated lake escapement in 1991 to 11% in 1992 (Appendix E). Kokanee counts (December) in tributaries and shorelines ranged from 4,603 spawners in 1989 to 31,925 spawners observed in 1973 (Appendix F). Counts of lakeshore spawning kokanee ranged from only 877 in 1989 to 19,834 in 1973. Counts on tributary streams ranged from O on many streams to 14,000 for Spring Creek in 1986. Surveys at additional historic spawning areas recorded few spawners in 1992. None were recorded at Garfield Bay (other than Harbor Marina), Camp Bay, Camp Bay to Elliot Bay, Ellisport Bay, Bottle Bay, Martin Bay to Glengary Bay, Garfield Bay to Talache, Talache to Maiden Rock, Samowen Bay, West Hope, Button Hook Bay, Maiden Rock to Cape Horn, BlackWell Point to Farragut, Echo Bay, Whetstone Beach, Cement Plant, Lakeview, Mouth of Cedar Creek, Whisky Rock Bay, Granite Creek Bay, bay east of Indian Point, and east of Deadman Point to Johnson Point. One kokanee was *seen* at Kilroy Bay.

Age at Maturity

Mature kokanee, captured during trawling from 1985 through 1992, ranged from 14% mature age 3 in 1989 to 52% in 1990, while age 4 kokanee were almost always mature (Table 5). Age composition of kokanee spawned from Sullivan Springs Creek from 1986 through 1992 averaged 24% age 3 and 76% age 4, while age 2 and age 5 fish were occasionally present but were seldom part of the random sample (Table 6). Samples of kokanee spawners were also collected from several other traditional spawning areas (Table 7).

Potential Egg Deposition and Egg Collection

Estimated total potential egg deposition ranged from 58.6 million eggs in 1990 to 169.0 million eggs in 1992 (Appendix D). Artificial spawning of kokanee at Sullivan Springs yielded from 913,000 eggs in 1976 to over 16.6 million in 1987 (Appendix E). Estimated abundance of mature female kokanee from 1986 through 1992 ranged from 145,390 in 1986 to 411,248 in 1992 determined from late summer trawling. Fecundity ranged from 344 eggs/female in 1991 to 490 eggs/ female in 1988 (Appendix D).

Hatchery personnel collected 7.5 million eggs during 1992. Kokanee spawned at Sullivan Springs provided 6.12 million eggs. An additional 1.37 million eggs were taken at Cabinet Gorge Hatchery from kokanee migrating up Clark Fork River.

Most of the eggs taken at the hatchery and Sullivan Springs in 1992 were from kokanee released during 1988 and 1989. These fish were the first two year classes of kokanee that were imprinted on morpholine prior to release.

Table 5. **Percent mature kokanee by age in trawl samples 1985 through 1992, Lake Penal Oreille, Idaho.**

Year	Percent mature by age .				
	1	2	3	4	5
1985	0	4	85’		
1986	0	0	41[a]		
1987	0	0	39	97	
1988	0	0	29	97	
1989	0	0	14	98	100
1990	0	0	52	100	
1991	0	0	35	100	
1992	0	0	16	100	

[a]Age 3 and 4 combined.

Table 6. Age structure of kokanee spawner escapement at Sullivan Springs, 1985 through 1992.

Year	Percent Contribution by Age			
	2	3	4	5
1985		37	63	
1986	.-	--	--	--
1987		7	93	
1988		20	80	
1989		18	79	3
1990		32	68	
1991	1	46	53	
1992		23	75	2

Table 7. Age composition of kokanee spawners at spawning tributaries to Lake Penal Oreille, 1986 through 1992.

	YEAR													
	1986 Age (%)		1987 Age (%)		1988 Age (%)		1989 Age (%)		1990 Age (%)		1991 Age (%)		1992 Age (%)	
Source	3	4	3	4	3	4	3	4	3	4	3	4	3	4
Spring Creek	14	86	10	90	16	84	--	--	9	91	41	59	20	80
Trestle Creek	--	--	5	95	--	--	--	--	--	--	58	42	--	--
N. Gold Creek	--	--	25	75	--	--	--	--	--	--	46	54	27	73
Hope Shoreline	--	--	--	--	--	--	--	--	--	--	34	66	--	--
Lakeshore	17	83	20	80	14	86	--	--	--	--	--	--	--	--
Cabinet Gorge	--	--	--	--	24	76	--	--	--	--	--	--	--	--
S. Gold Creek	--	--	--	--	24	76	--	--	--	--	--	--	--	--
Cascade Creek	--	100	--	--	--	--	--	--	--	--	--	--	--	--

Survival and Recruitment

Wild kokanee fry survival from potential egg deposition to early September trawl sampling ranged from only 1.3% in 1991 to 4.6% in 1987 (Appendix D). Hatchery fry survival from egg collection to late summer trawl ranged from 9.4% in 1988 to 31.4% in 1992.

Hatchery fry survival from release to late summer trawling ranged from 3% in 1986 to 39% in 1992 (Table 8; Figure 4). Hatchery fry comprised from 8% of total age O recruitment in 1986 to as high as 51% in 1988 (Figure 5). Survival of hatchery fry by release site varied widely and is summarized in Table 9 and graphically illustrated in Figure 6. Survival of hatchery kokanee ranged from 5% for an early open water release in 1989 to 43% for the Garfield Bay release in 1992.

Dispersal of hatchery-reared fry throughout the lake was evident following 1 to 2.25 months of lake residence, but abundance remained highest in lake sections near release sites (Figure 7).

The percent of a year class of kokanee surviving to the next year averaged 38% from age O to age 1, 86% from age 1 to age 2, 51% from age 2 to age 3, and 82% from age 3 to age 4 (Figure 8). Kokanee older than age 4 are uncommon in Lake Penal Oreille. Because survival of younger age groups of kokanee is often estimated to be over 100%, we referred to the values in Figure 8 as an index. For example, population size of age 1 kokanee is often underestimated, and when a cohorts size is estimated at age 2, their numbers are higher and the estimated survival can exceed 100%. At Lake Penal Oreille, age 1 kokanee were caught primarily at the north end of the lake and caught in low numbers to the south. As a result the total population of age 1 kokanee was probably underestimated each year.

Analysis of Release Sites and Time

Regression analysis was used to compare the relationship between survival of age O kokanee for each release group in 1988 ($N=5$) and 1991 ($N=6$) and *number* of days from release to capture date. We did not include other years because of the limited number of release groups, usually two or three. This fact presents some limitation to our analysis. We did not detect a statistical relationship ($P=0.12$, $r^2=0.61$ and $P=0.15$, $r^2=0.44$, respectively) between survival of kokanee and total number of days from release to capture. However, this does not mean time at large was not a factor in differences in survival between release groups.

ANOVA testing and Tukey's statistic were used to compare stocking time (early release vs late), survival between years, and survival between release sites. Late (summer) releases had significantly higher survival ($P<0.02$) than early releases. We calculated a significant difference in survival between years ($P<0.05$) (survival of age O kokanee *in* 1992 and 1988 was higher than 1987, 1989, 1990, and 1991). Additional testing, accounting for a repeated measures design (between years), indicated we could not detect a significant difference in survival between stocking sites ($P>0.71$). Our study design was limited because of the shortage in numbers of fish for stockings after 1989. Also, we did not include 1992 in the analysis of location and time because all releases were late.

Table 8. Brood year, year stocked, total catch in trawl samples, population estimates, 90% confidence interval of the estimate, estimated percent survival, and standard error (SE) of age 0 hatchery kokanee *in* Lake Penal Oreille, Idaho, 1985 through 1992.

Brood year	Year stocked	Total stocked (millions)	Total catch	Population estimate	CI (+/-) (%)	Estimated survival (%)	SE (%)
1985	1986	5.01	16	142,000	--	2.7	--
1986	1987	5.86	107	797,661	15.8	13.6	2
1987	1988	13.13	485	3,682,216	10.9	28.7	3
1988	1989	11.74	289	2,246,064	15	19.1	3
1989	1990	7.70	209	1,562,541	11.9	20.0	5
1990	1991	5.18	137	1,052,029	23.6	20.7	5
1991	1992	5.47	278	2,125,261	17.1	38.5	7

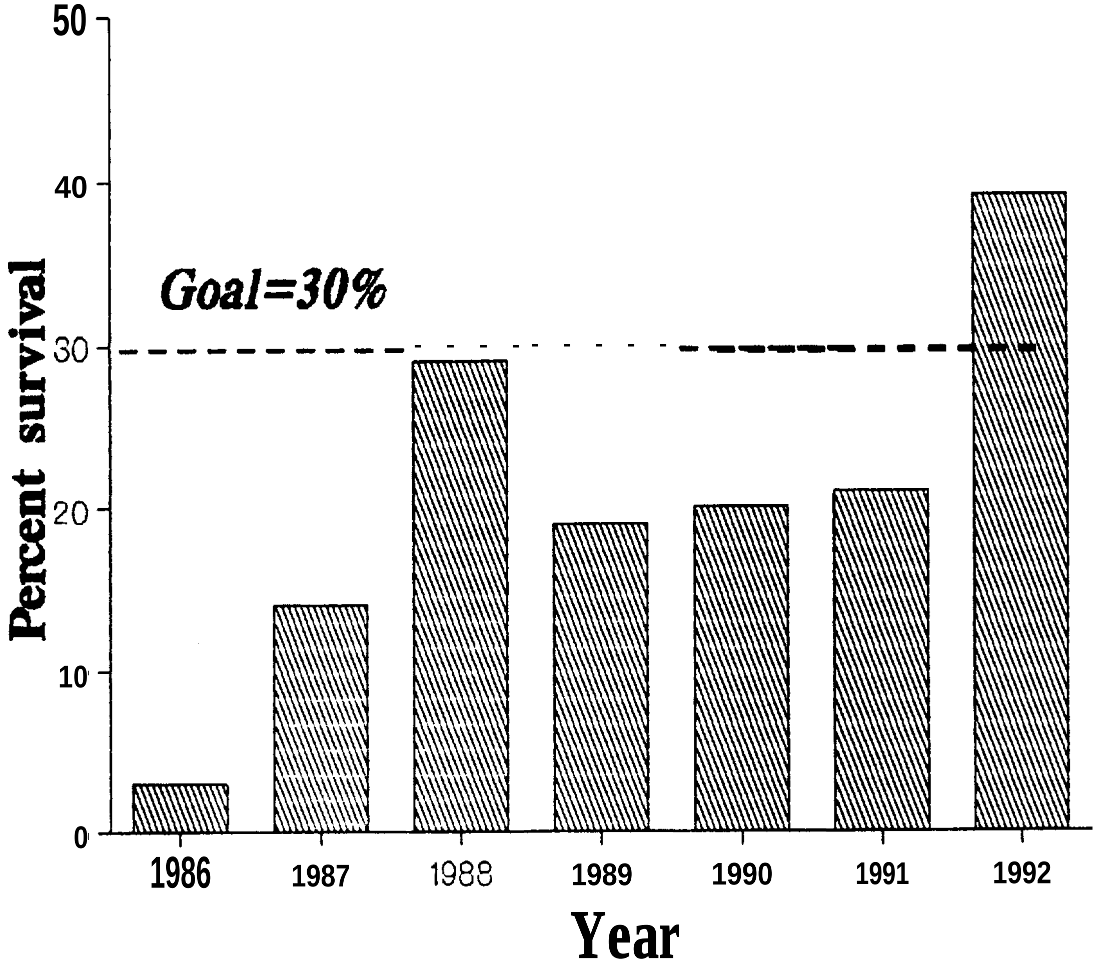

Figure 4. Estimated survival of kokanee fry during their first summer in Lake Penal **Oreille,** Idaho, following release from Cabinet Gorge Hatchery, and survival goal established for the kokanee restoration program 1986 through 1992.

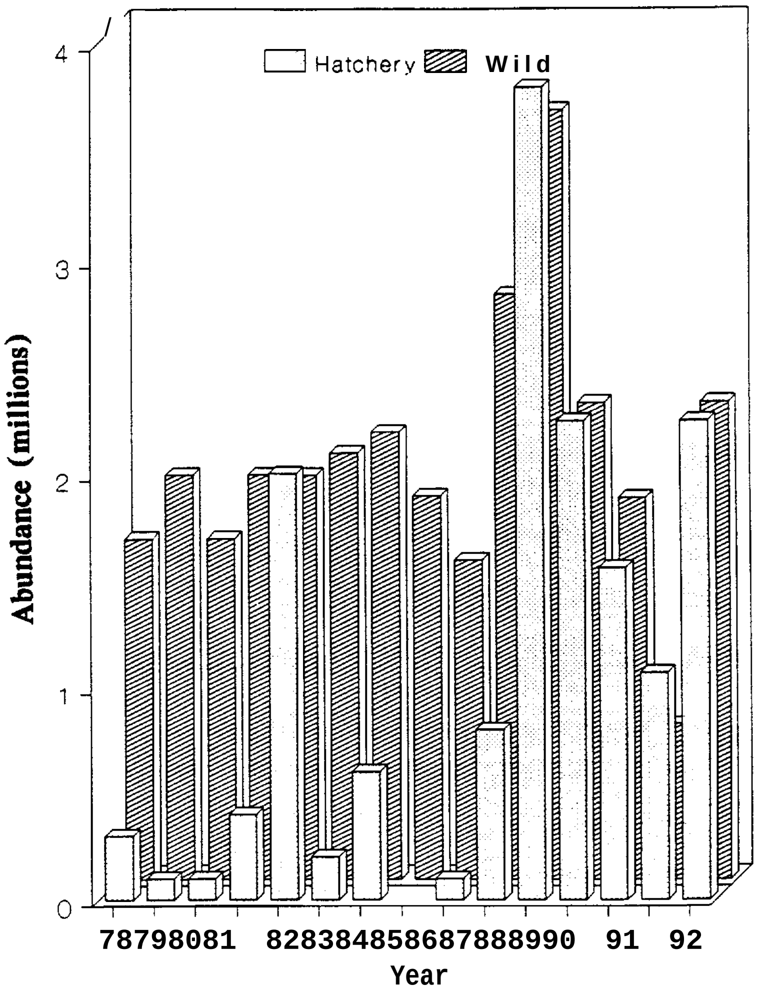

Figure 5. Relative hatchery contribution to total estimated age 0 kokanee abundance in Lake Penal Oreille, Idaho, 1974 through 1992.

Table 9. Location, total catch, autumn population estimate, release to autumn surviva interval (CI) of survival of age O kokanee stocked into Lake Penal **Oreille**, Ida

Stocking site	Year	Total catch	Autumn population estimate	Estimatec survival
Early Clark Fork River	1988	116	921, 781	27
	1989	81	632,340	18
	1990	62	510,000	15
	1991	61	477,630	18
Late Clark Fork River	1986[a]	0	0	0
	1987	0	292,329	10
	1988	50	376,130	29
	1989	19	147,600	16
	1992	43	364,384	32
Sullivan Springs	1986"	0	0	18
	1987	0	512,514	18
	1988	198	1,490,310	29
	1989	102	742,980	21
	1990	99	742,402	23
	1991	78	593,626	23
	1992	179	1,319,135	38
Early Open Water North	1988	38	353,540	22
	1989	7	62,800	5
Late Open Water South	1988	82	565,200	36
	1989	51	357,000	25
Late South Shoreline	1989	39	276,480	27
	1990	48	308,000	28
Garfield Bay	1992	56	412,875	43

'Kokanee release groups could not be distinguished other than hatchery/wild.

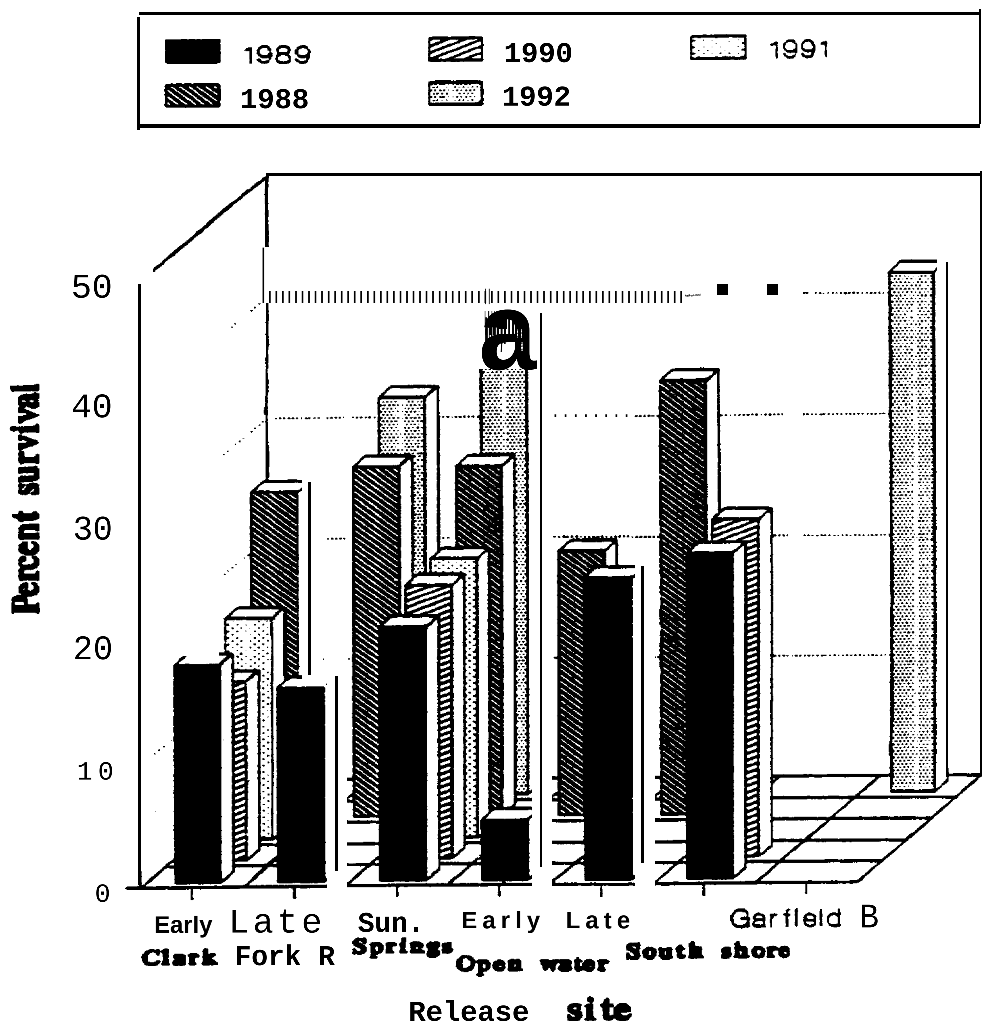

Figure 6. Estimated survival of hatchery fry during their first summer, Lake Penal **Oreille,** Idaho, compared among seven release strategies, 1988 through 1992.

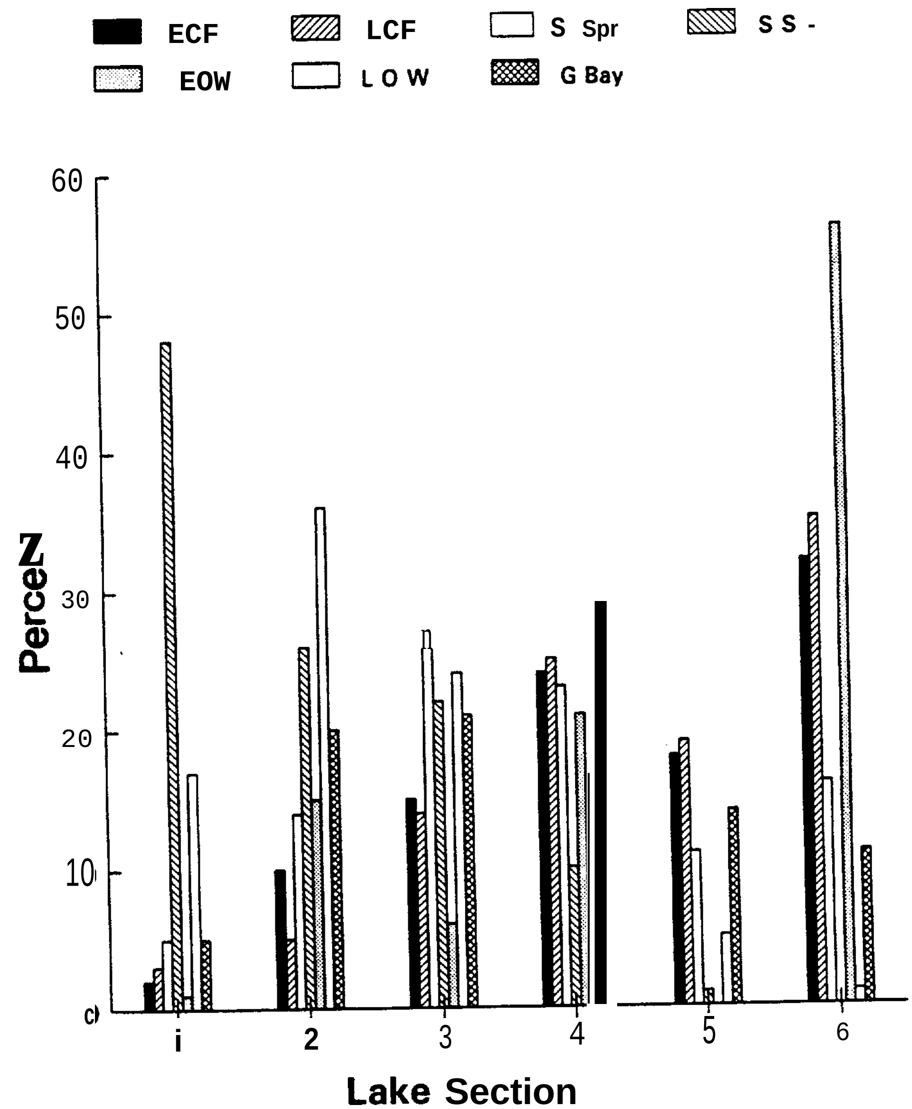

Figure 7. Proportion of trawl catch of age 0 hatchery kokanee, of seven release strategies, by location; E C F - early Clark Fork River, L C F - late Clark Fork River, S Spr - Sullivan Springs, S S - South Shoreline, E O W - early open water, L O W - late open water, G Bay - Garfield Bay, Lake Penal Oreille, Idaho. Samples from 1987 through 1992 were combined.

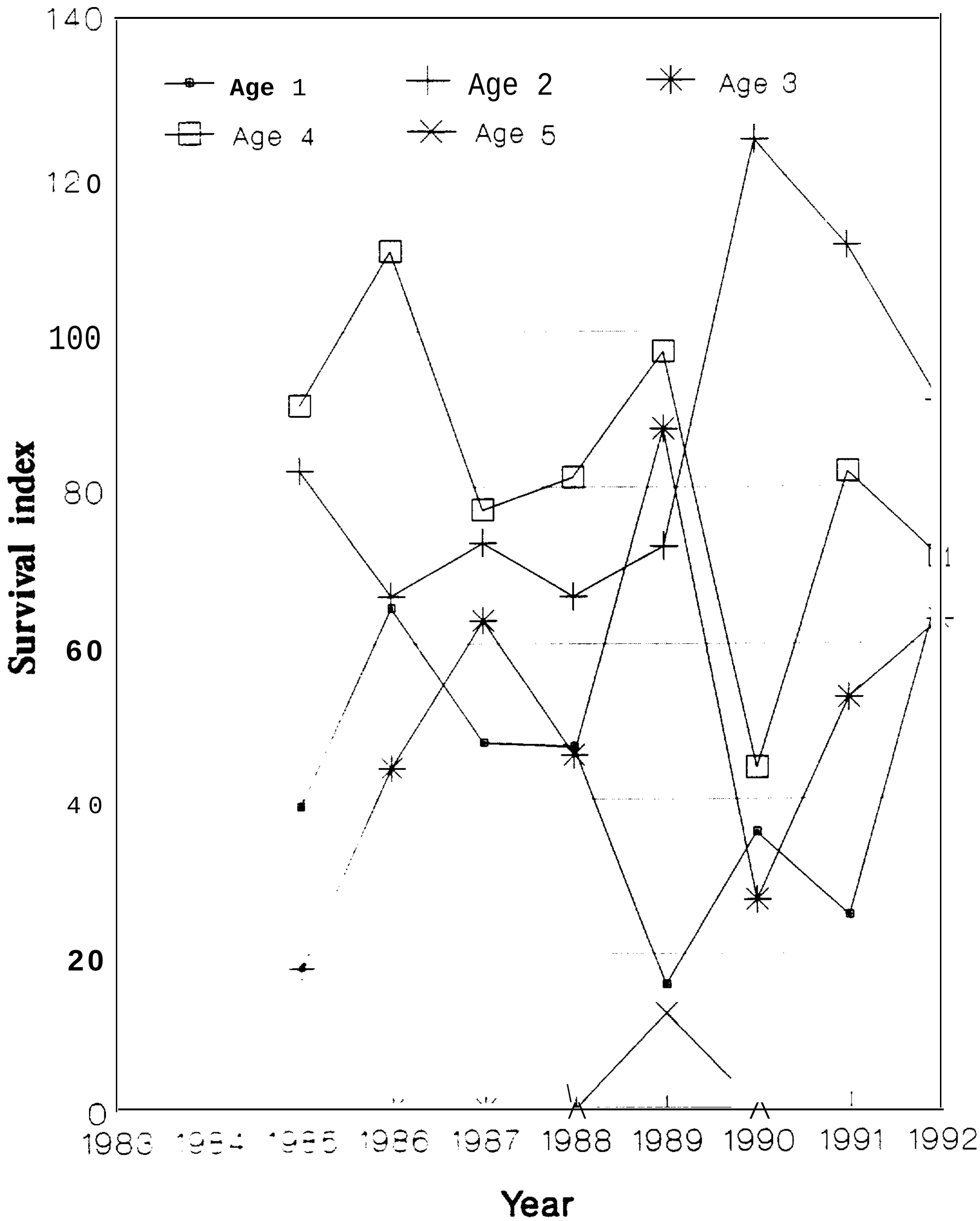

Figure 8. Survival index of five age groups of kokanee from 1985 through 1992, catches by trawling, Lake Penal Oreille, Idaho.

Fry Marking

An obvious mark was evident on kokanee otoliths and formed at time of release. This mark separated hatchery residence from lake residence and enabled us to separate wild from hatchery fry. Number of daily growth increments after the release marks was used to separate fry of various release groups each year (Paragamian et al. 1992).

Returns of Fin-Clipped Kokanee

Hatchery personnel in 1991 and 1992 recaptured a total of 151 and 418 fin-clipped kokanee, respectively. Sullivan Springs accounted for a total of 141 adipose fin-clipped fish (released in Sullivan Springs in 1988), four left ventral fin-clipped fish (early Clark Fork River release in 1988), and one right ventral fin-clipped (late Clark Fork River release by barge in 1988) in 1991. Total spawning escapement to Sullivan Springs in 1991 was about 85,713 kokanee; and of these, 75,624 were spawned and checked for fin clips (88%) (Appendix E). Thus, the estimated total escapement of fin-clipped kokanee at age 3 to Sullivan Springs was 158 adipose, five left ventral, and one right ventral. The estimate of fin-clipped kokanee returning to Sullivan Springs as age 3 is 0.4% of the 40,000 fish clipped at age 0 in 1988. Furthermore, since 0.4% of the marked fish returned, the estimate of the original 5.139 million fish (released as fry at Sullivan Springs in 1988) returning would be 20,299 fish, or about 51% of the age 3 spawners. The remaining 49% would have been from wild stock or strays.

A subsample of 41 adipose-clipped kokanee from Sullivan Springs in 1991 were sexed. About 85% were females, a disproportionate number compared to males.

In 1992, escapement at Sullivan Springs totaled about 84,001 kokanee, of which 73,739 (88%) were spawned. A total of 300 fin-clipped kokanee were collected at Sullivan Springs; 296 adipose-clipped fish, one right ventral, one left ventral, and two kokanee were recaptured with both ventral fins clipped. Therefore, the total estimate of fin-clipped kokanee returning was 336 adipose fin-clipped fish, 1 right ventral, 1 left ventral, and two fish with both ventrals. Analysis of otoliths indicated 32% of the kokanee were age 3 and 68% age 4. The estimate of adipose fin-clipped kokanee returning at age 3 is 0.268% of 40,000 clipped in 1989. Thus, we estimated 9,464 kokanee of the 3.538 million stocked *in* 1989 returned to spawn. The estimate of adipose fin-clipped kokanee returning to spawn at age 4 is 0.573% of 40,000 clipped in 1988. We estimated 29,420 kokanee returned to spawn of the 5.139 million stocked at Sullivan Springs in 1988. Therefore, of the 84,001 kokanee escaping to Sullivan Springs, about 11% were age 3 hatchery fish and 35% were age 4 hatchery kokanee. Random samples of kokanee otoliths indicated 23% were age 3, 75% were age 4, and 2% were age 5. Thus, 49% of the age 3 kokanee were hatchery fish, 47% of the age 4 kokanee were hatchery products, while the majority of the remainder of each group were wild.

Fin-clipped kokanee at Sullivan Springs were comprised of 26% females and 74% males. Age analysis indicated 46% of the females were age 3 and 54% age 4, while 27% of the males were age 3 and 73% were age 4.

Hatchery personnel, at the Cabinet Gorge Fish Hatchery collected five fin-clipped kokanee in 1991 of 5,713 fish that were captured. Of the fin-clipped recaptures, three fish were adipose-clipped strays from Sullivan Springs and two had right ventral fin clips, late Clark Fork River releases of 40,000 clipped in 1988. None of the 50,000 kokanee fry released with the early Clark Fork River group in 1988 were recovered in 1991.

Workers spawning kokanee at the Cabinet Gorge Fish Hatchery in 1992 examined a total of 118 fin-clipped kokanee of 22,875 fish that were spawned. Of the total, 39 kokanee had a right ventral fin clip, 70 had a left ventral fin clip, while the remaining 9 had an adipose clip. Analysis of otoliths from the fin-clipped kokanee indicated 18% of the right ventral clipped fish were age 3 (7 fish) and 82% were age 4 (32 fish). Of the kokanee with left ventral fin clips, 23% (16 fish) were age 3 and 77% (54 fish) age 4, while all of the kokanee with adipose clips were age 4. Estimated contributions of various releases were: 0.018% of 40,000 kokanee with right ventral clips in 1989 and 0.08% of 40,000 released in 1988; 0.039% of the 41,000 kokanee released in 1989 with left ventral fin clips and 0.108% of 50,000 released in 1988; while 0.023% of the kokanee released in 1988 at Sullivan Springs were collected in 1992 as strays. The numerical breakdown of the total catch at Cabinet Gorge Hatchery was as follows: of the right ventral releases, 177 were age 3 and 1,038 were age 4; of the left ventral releases, 1,370 were age 3 and 3,687 were age 4, 1,182 were age 4 strays from Sullivan Springs, and the remaining 15,421 (67%) were wild fish.

Gender of the fin-clipped kokanee collected at Cabinet Gorge Hatchery in 1992 were 36% females and 64% males for the age 3 kokanee, and for the age 4 kokanee they were 9% females and 91% males.

Mysis Shrimp

Our estimates of shrimp densities from a 46-m depth to the surface ranged from 15 organisms/m^3 in 1992 to 47 organisms/m^3 in 1988 and averaged 30 organisms/m^3 (Table 10; Appendix G). The shrimp population was usually comprised of three brood years; juveniles of the year of record, immature shrimp, and adult females. Immature males and females were grouped with the mature females as adults. Analysis of data from 1986 through 1990 and 1992 indicated adult densities during June were not different ($P=0.117$) between lake sections, but juvenile densities were significantly higher ($P<0.001$) in the southern and central sections than the northern section.

Adults comprised about 21% of total shrimp abundance. The November 1991 density of juveniles and adults were not contrasted to other years of this study because they were collected late in the season. Adult density averaged 7 organisms/m^3 from 1986 through 1992 (Table 10). The adult density in 1989 at 16 organisms/m^3 was significantly higher than all other years ($P=0.000$). The second highest density was recorded in 1986 at 8 organisms/m^3 and was significantly higher than 1987 (4 organisms/m^3, $P=0.023$) and 1992 (2 organisms/m^3, $P=0.000$). The third highest density recorded for adult shrimp occurred in 1988 at 6 organisms/m^3, it was significantly higher than 1992 ($P=0.019$).

We estimated the average density of juvenile shrimp to be 24 organisms/m^3 in June from 1986 through 1990 and 1992 (Table 10). The highest density of juvenile shrimp was 42 organisms/m^3 and was significantly higher than all other years ($P<0.06$). Juvenile shrimp were at 31 organisms/m^3 in 1986, the second highest density, and was significantly higher than 1987 (16 organisms/m^3, $P=0.007$), 1990 (16 organisms/m^3, $P=0.008$), and 1992 ($P=0.002$) at 13 organisms/m^3, the lowest June density.

Length of shrimp in Lake Penal Oreille during June sampling from 1986 through 1992 were summarized (Appendix H) and were usually comprised of at least three brood years. The distributions usually ranged in length from 3 mm to 20 nun.

Table 10. Mean adult (over 10 mm), juvenile (10 mm and under) , and total densities (organisms/m^3) of shrimp (standard deviations are subtended) during June in Lake Penal Oreille, Idaho, sampled from 1986 through 1992.

Year	Adult	Juvenile	Total
1986	8 (4)	31 (22)	39 (25)
1987	4 (2)	16 (5)	20 (7)
1988	6 (4)	42 (27)	47 (26)
1989	16 (9)	25 (17)	41 (23)
1990	5 (2)	16 (11)	21 (12)
1991'	1 (1)	5 (3)	5 (3)
1992	2 (1)	13 (6)	15 (7)
Grand mean[b]	6.8	23.8	30.5

[a]Samples taken in November.
bees not include the 1991 sample.

Zooplankton Community

The zooplankton community in Lake Penal Oreille from May through October, 1986 through 1992, included Cvc1oPS, Diaptomus, Epischura, Bosmina, Daphnia, and Diaphanosoma (Table 11). The mean zooplankton density of 12.11 organisms/L (±2.5) in 1991 was the lowest since this study began while the 1992 mean total density of 25.2 organisms/L was the highest (Table 11; Figures 9 and 10). Total zooplankton in 1992 was significantly higher (P=0.000) than 1985, 1987, 1989, and 1990. Total zooplankton density was usually lowest in May and reached a peak by July or August. Copepod densities were higher than cladoceran densities throughout the study sampling periods (Appendices I through N). Cladoceran density was highest during August and September at approximately 10% to 15% of copepod density, respectively (Figure 11). The copepods cvc1oDS and Diaptomus were the most abundant zooplankters.

The average density of Cyclops in 1992 (14.81 organisms/L) was significantly higher (P<0.000) than 1985, 1986 (P=0.032), 1990 (9.17 organisms/L, P=0.051), and 1991 (P=0.000) (Table 11), while the average density of Diaptomus in 1992 (9.24 organisms/L) was significantly higher (P<0.05) than 1985, 1987, and 1990 (P<0.05); a grand mean of 6.23 organisms/L (Table 11). Epischura was the least abundant zooplankter during this study with an estimated average density of 0.02 organisms/L, but their density was highest in 1985 and 1987 at 0.04 organisms/L, respectively. Cladocerans were extremely uncommon in samples early in the season, but became common in August. Bosmina density was highest in 1989 (0.99 organisms/L), was significantly higher than 1985 (P<0.003), 1987 (P<0.022), 1988 (P=0.000), and 1990 (P<0.000). Mean density of Daphnia was highest during 1986 at 1.27 organisms/L and was significantly higher than most years except 1987 and 1992. Diaphanosoma density in 1989 (0.34 organisms/L) was significantly higher (P≤0.003) than all other years. Zooplankton densities were statistically similar (P>0.10) among northern, southern, and central sections of Lake Penal Oreille (Appendix O). Sampling of zooplankton in the Clark Fork River delta was conducted from 1987 through 1989. In general, the zooplankton densities *in* the delta were significantly lower (P<0.10), with the exceptions of Bosmina and Daphnia which were usually higher (P>0.10). Garfield Bay was also sampled, but only during 1992. The mean density of cladocerans in this embayment was twice as high as the deeper sections sampled; Bosmina 0.12 organisms/L; Daphnia 0.50 organisms/L; and Diaphanosoma 0.07 organisms/L. Cyclopods were always lower in Garfield Bay; cvc1oDS 12.02 organisms/L; Epichura <0.01 organisms/L; and Diaptomus was 6.49 organisms/L (Appendix P).

The largest zooplankton in Lake Penal Oreille was Epischura, which averaged about 1.9 mm, followed by Daphnia thorata and D. galeata, which averaged about 1.3 and 1.2 mm, respectively. Diaphanosoma and Diaptomus averaged about 0.9 and 0.8 mm, respectively. Cvc1oDS averaged about 0.7 mm and Bosmina was the smallest zooplankter at 0.4 mm (Appendix Q). Zooplankton were similar in length between lake sections, with the exception of cvc1oDS, which were larger in the Delta, but varied between years (P<0.10) (Appendix O).

Water Temperature and Transparency

Surface temperatures of Lake Penal Oreille from May through November usually ranged from lows of about 5-7°C in May to 21%2 in August. Thermal stratification usually began in July and extended through September, but 1988 and 1992 were exceptions. A thermocline was developed by June of 1988 and 1992 and extended to 22 m in depth by September of 1988 and to 20 m in depth in July of 1992. The year of most rapid thermal stratification was 1992, while 1989 and 1986 were slow to develop and broke down rapidly. The years 1986 and 1992 serve as contrasting

Table 11. Mean mid-day densities of cladocerans and copepods (number/L) above 27.4 m in Lake Penal Oreille, Idaho. Samples collected May through October, 1985 through 1992. Standard deviations are subtended.

	Cladocerans			Copepods			
Year	Bosmina	Daphnia	Diaphanosoma	Cyclops	Epishura	Diaptomus	Total
1992	0.08 (0.26)	1.05 (2.23)	0.13 (0.29)	14.81 (9.27)	0.01 (0.02)	9.24 (7.59)	25.17 (16.23)
1991	0.19 (0.59)	0.35 (0.74)	0.07 (0.19)	6.71 (10.44)	0.02 (0.03)	5.63 (4.15)	12.11 (7.31)
1990	0.27 (0.34)	0.32 .(0.54)	0.12 (0.29)	9.17 (6.36)	0.03 (0.05)	8.06 (5.62)	17.99 (11.48)
1989	0.99 (2.77)	0.71 (1.58)	0.34 (0.76)	11.09 (8.74)	0.02 (0.03)	7.45 (4.43)	20.59 (12.19)
1988	0.15 (0.27)	0.70 (1.51)	0.17 (0.39)	13.23 (8.13)	0.02 (0.03)	7.46 (4.86)	21.72 (12.75)
1987	0.59 (0.76)	1.08 (1.57)	0.04 (0.08)	8.87 (5.19)	0.04 (0.09)	4.36 (2.32)	15.04 (7.18)
1986	0.03 (0.06)	1.27 (2.61)	0.01 (0.04)	6.73 (4.19)	0.01 (0.02)	5.09 (3.45)	13.13 (8.66)
1985	0.37 (0.74)	0.38 (0.57)	0.07 (0.14)	9.12 (6.97)	0.04 (0.10)	6.26 (3.20)	19.30 (11.64)

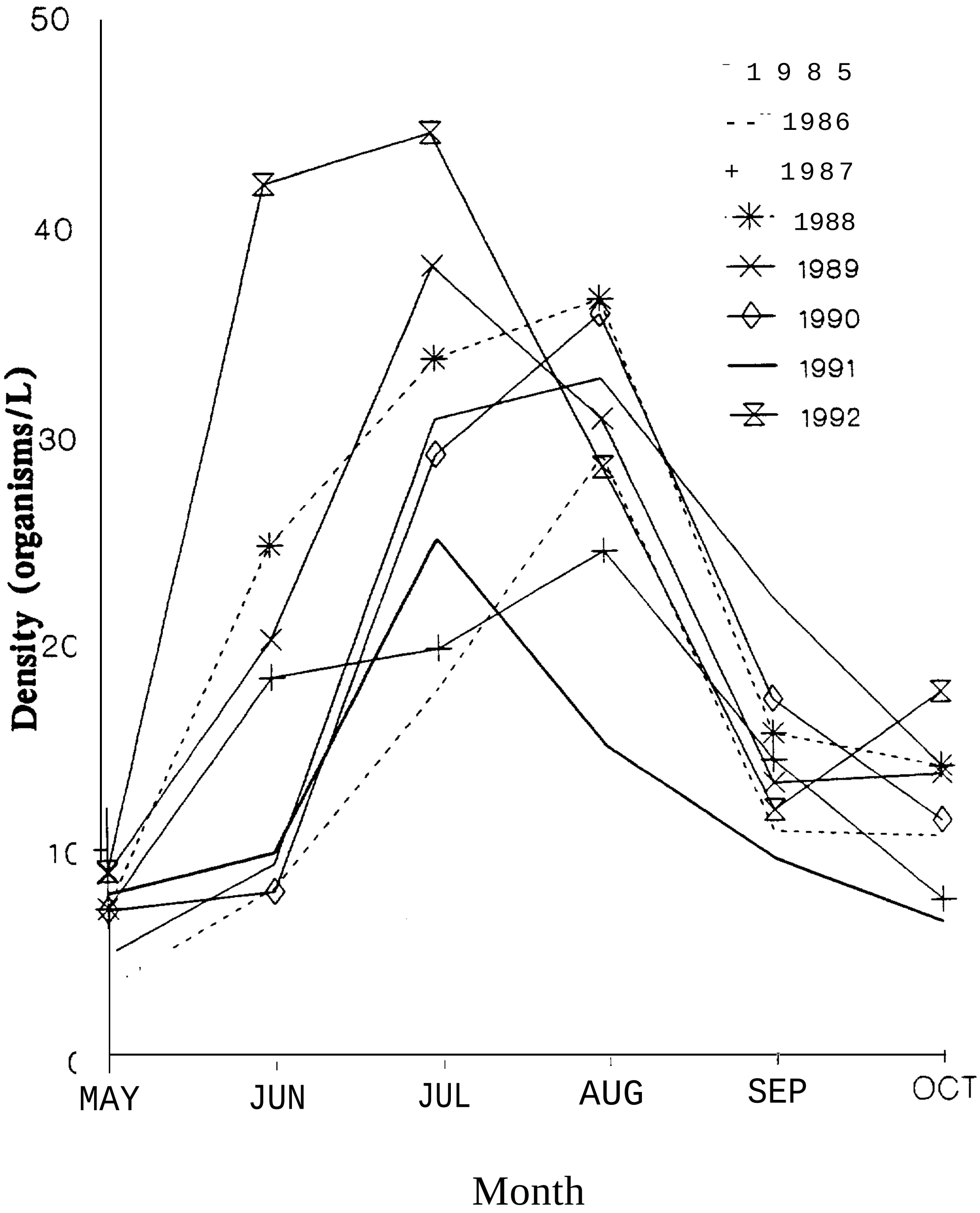

Figure 9. Temporal distribution of mean total zooplankton densities in Lake Penal **Oreille,** Idaho, May through October, 1985 through 1992.

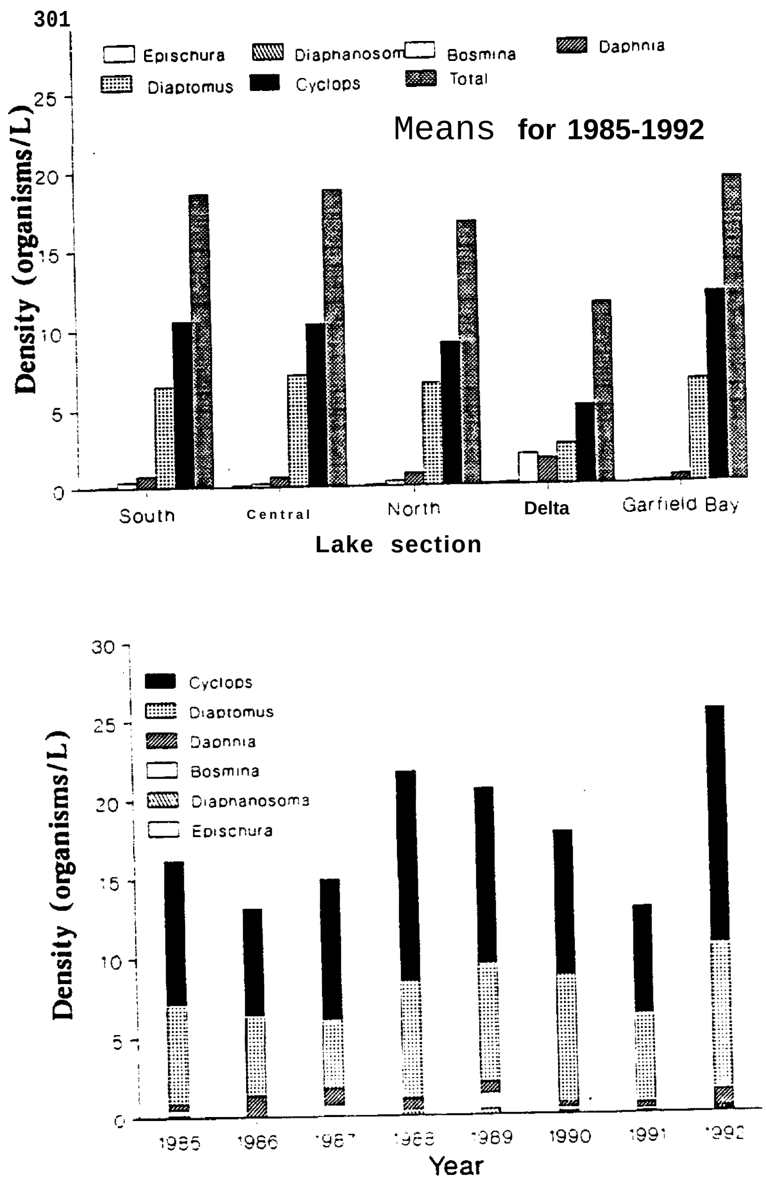

Figure 10. **Mean zooplankton densities in Lake Penal Oreille, Idaho, from 1985 through 1992 compared among lake sections (top figure) and years (bottom figure).**

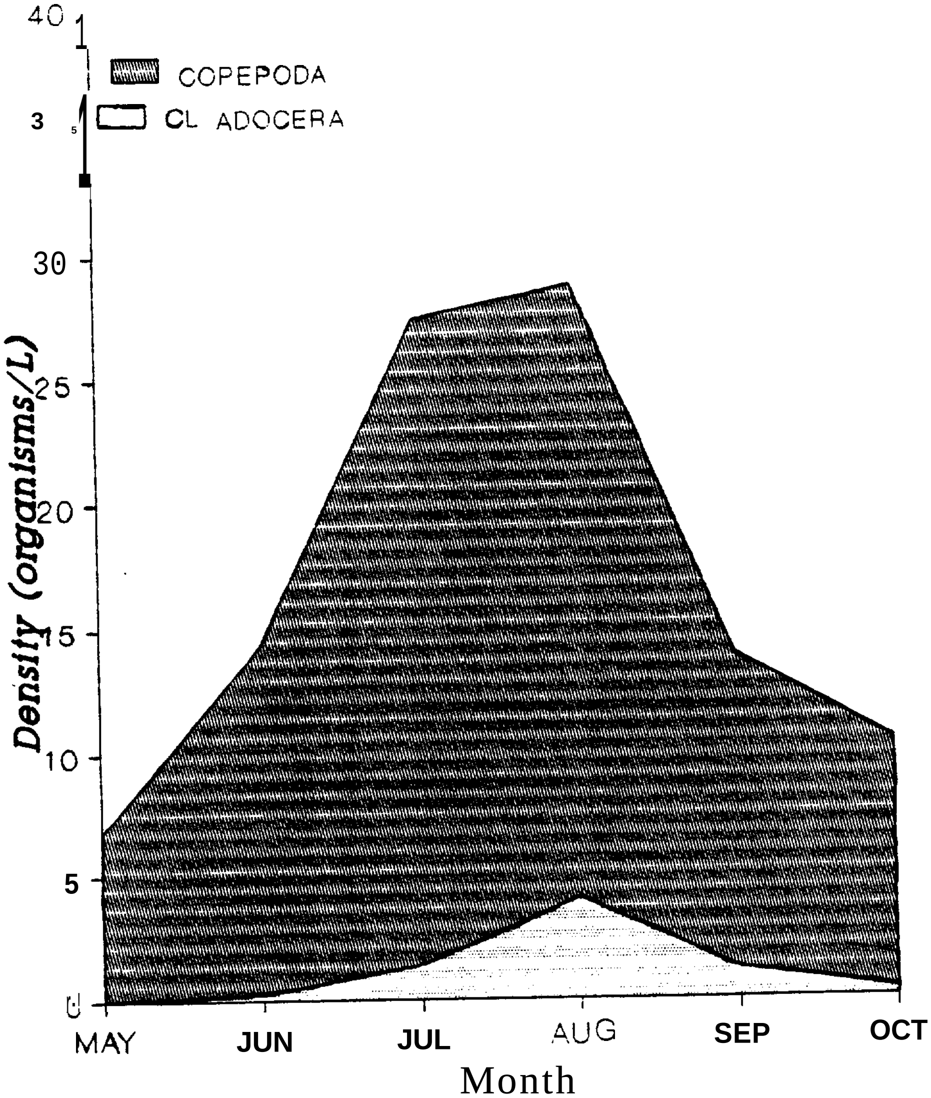

Figure 11. Mean temporal distribution of Copepoda and Cladocera zooplankton in Lake Penal Oreille, Idaho, May through October, 1985 through 1992.

examples of slow thermal development and rapid development respectively (Appendix R). Stratification broke down by October of most years, was gone by September in 1992, but persisted to November in 1985, 1987, and 1988.

Development of a deep 14°C thermal barrier to shrimp (Falter and Rieman 1981) extended to 26 m in 1985, 22 m in 1988, andto 18.5 m in 1992. In each of these years, the maximum depth of the 14°C strata of lake water was achieved in June, but was most rapid in 1992.

Secchi transparencies were always greater in the south end of the lake with grand means ranging from 5.36 m in May to 10.10 m in August (Appendix S). The north end of the lake had the least transparent water because of the inflow from the Clark Fork River and Lightning Creek. Secchi transparencies in the north end of the lake ranged from 3.9 m in May to 8.74 m in August, while the central portion of the lake was usually intermediate between north and south sections (Appendix S).

Analysis of Temperature and Total Zooplankton Abundance

Daily and monthly minimum and maximum means of air temperature at BayView, Idaho, were used to calculate degree days for 1985 through 1992. These data were collected by the State Climatologist, Myron Molnau. A combination of monthly sequences of degree days was compared to mean zooplankton density, regression analysis, and analysis of variance (ANOVA) was used. The best predictor of zooplankton abundance and degree days was the sum of May and June; it provided a weak positive relationship ($P=0.12$, $r^2=0.35$). The addition of precipitation with multiple regression analysis did not provide a better predictor of zooplankton abundance. Greatest depth achieved by the epilimnion was significantly related ($P<0.10$) to May and June thermal sums ($P=0.09$, $r^2=0.40$), while the depth of the 14°C strata was poorly related to the mean density of zooplankton ($P=0.49$, $r^2=0.08$).

DISCUSSION

Kokanee Population Status

The kokanee population in Lake Penal Oreille did not achieve the anticipated recovery from pre-Cabinet Gorge Hatchery years. Initially, the kokanee restoration program, through stockings from the Cabinet Gorge Fish Hatchery, increased the total number of fish from 4.3 million *in* 1986 to 10.2 million in 1988 (Figure 12; Appendix A), but these were primarily age 0 fish (7.3 million in 1988). More importantly, the numbers of adult fish for the creel and spawning escapement (age 3 and older) did not improve sufficiently. At the beginning of this study, age 3 and older kokanee totaled *about* 0.37 million (1985), rose to 0.78 million in 1986, was stable for several years, then declined in 1990 to 0.53 million, then improved to 1.75 million in 1992, a level similar to that of pre-Cabinet Gorge years. From 1989 through 1991, the total population declined to 5.6 million fish, then increased to 8.4 million in 1992. Most of the change in kokanee densities in 1988 and 1989 was due to a substantial increase in the number of stocked fry, while an additional factor in 1988 and 1992 was improved survival of age 0 hatchery and wild kokanee. By 1992, the high total densities of age 0 kokanee precipitated only a small corresponding improvement in the number of adults compared to the historic levels.

Low adult returns, egg collections, and subsequent low fry stockings during most years of this study slowed recovery efforts. From 1990 through 1992, low

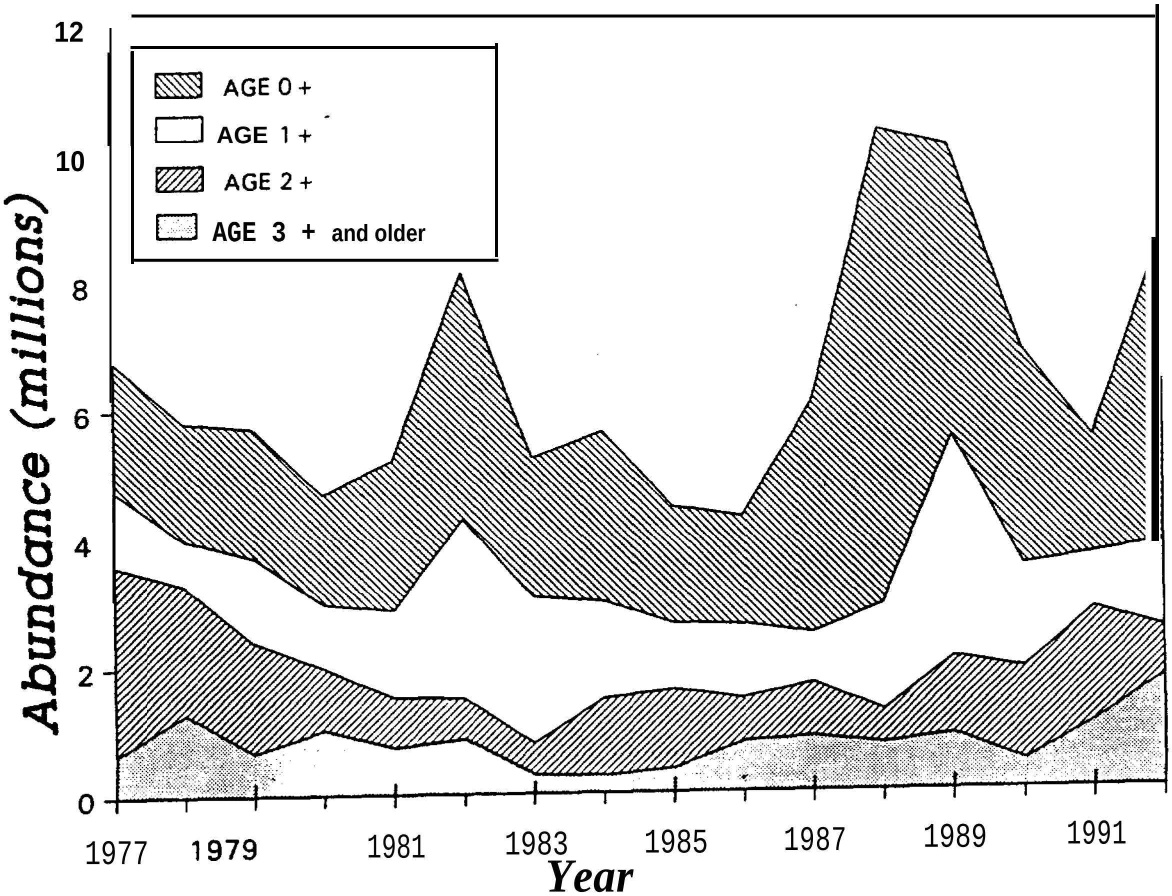

Figure 12. Total estimated abundance of four kokanee age groups in Lake penal Oreille, Idaho, 1977 through 1992.

egg collections lead to reductions in the number of kokanee released; 7.3 million fry in 1990, 5.0 million in 1991, and 5.6 million in 1992, while only about 800,000 were stocked in 1993. Poor returns of adult kokanee to spawning stations is among several problems that will be addressed in this discussion.

There was a modest increase in the total numbers of age 3 and 4 kokanee from 1985 through 1992 (Figure 12). But several weak cohorts from 1989 through 1991 (wild and hatchery) will reduce the total density of the older kokanee in years following 1993.

Standing stocks of kokanee in Lake Penal Oreille declined substantially from 1977 through 1986 (Figure 13). But since 1986, when hatchery supplementation from the cabinet Gorge Fish Hatchery began, it has ranged from about 8 to 10 kg/hectare and appears to have stabilized. However, the fishery may be operating below carrying capacity since standing stock ranged from 10 to 17 kg/hectare from 1977 to 1984. The mechanism primarily responsible for the reduction in standing stock is unknown (Figure 13). Rieman and Bowler (1980) believed that at 13-17 kg/hectare, the kokanee population from 1974 through 1978 was still far below carrying capacity because they saw no significant cropping effect on available zooplankton or changes in kokanee growth.

We found a positive relationship between kokanee growth and zooplankton abundance for age 3 kokanee, but no affect on growth due to density. We used simple regression analysis to compare instantaneous growth of kokanee, by age group for ages 2 through 4, to mean zooplankton density and age group density. Only growth of age 3 kokanee was significantly positively related to mean zooplankton densities, $P<0.05$ ($r^2=0.65$); growth of age 2 and 4 kokanee was not significant ($P>0.10$).

Fry Recruitment and Survival

Size of kokanee released may have been a factor improving survival of hatchery fish over pre-Cabinet Gorge Hatchery years, but this was not tested. Prior to 1986, kokanee were reared at several different hatcheries and released at a length of less than 40 mm into Lake Penal Oreille, and survival was usually less than 3% (Bowles et al. 1987). Kokanee fry released in 1987 were reared at Cabinet Gorge Hatchery, released at about 50 mm in length, and survival increased to 14%. Since 1987, survival has been even higher. Cabinet Gorge Hatchery can produce larger fry because it has warmer water and more space.

The mean survival for hatchery fish was 23% from 1987 through 1992. Survival of hatchery fry is still below the goal of 30% set for restoration of kokanee in Lake Penal Oreille (Bowles et al. 1988). We believe survival can be further improved by discontinuing early fry releases when temperatures are cold and food may be low. The exceptional years of high survival occurred in years with several late releases and temperatures warmer than normal in May and June, like 1988 and 1992. Under normal environmental circumstances, survival will probably fluctuate between 25% and 30%.

Expected higher overwinter survival of large hatchery fry compared to the smaller wild fry did not appear to occur. Analysis of one group of otoliths of age 1 kokanee in 1989 indicated overwinter survival of hatchery fish to be similar to wild fish (Hoelscher et al. 1990); although our sample size was small (n=19). The expectation of higher overwinter survival of the larger hatchery fry may not be correct. A sample of 20 otoliths of age 2 kokanee captured by trawling in 1991 were analyzed using the technique reported by Volket al. (1990). Nine of 19 usable otoliths had a distinct release mark indicating they were hatchery kokanee (Eric Volk, Washington Department of Fisheries, personal communication). These kokanee were age 0 in 1989 and trawl samples indicated

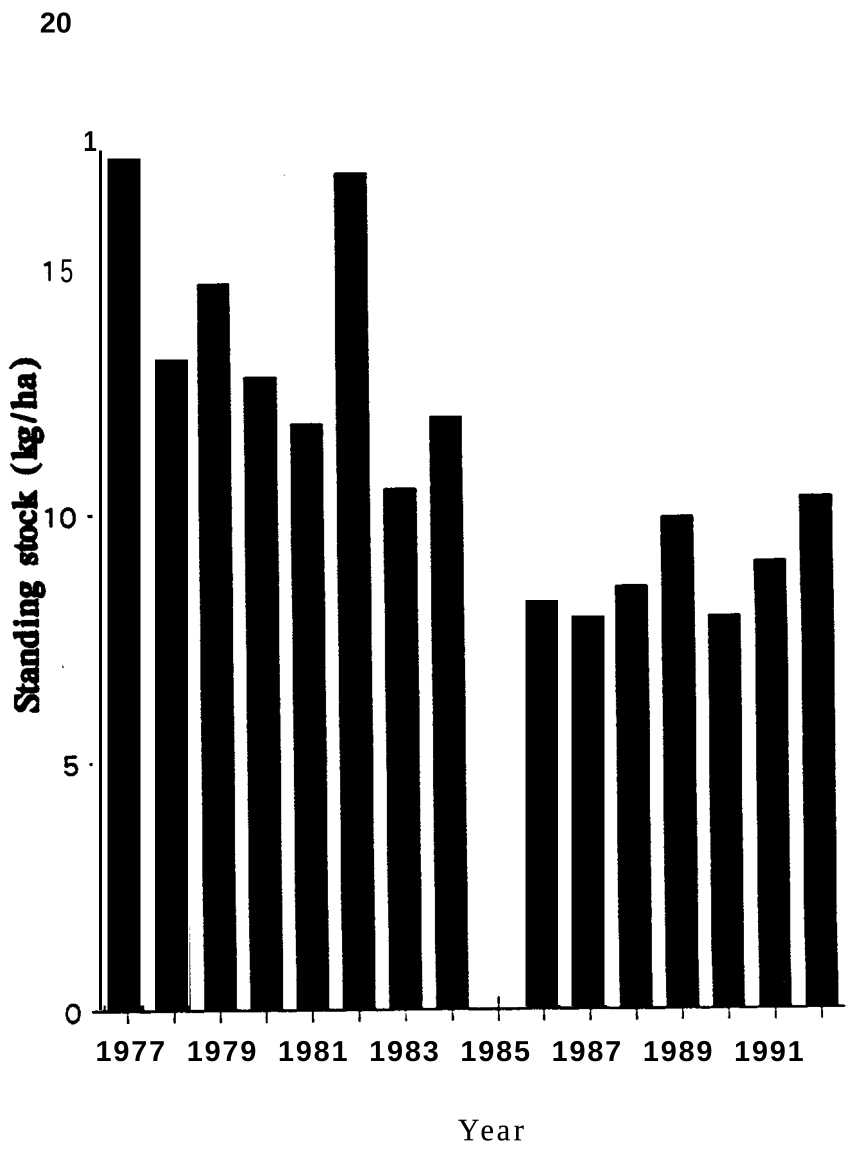

Figure 13. Standing stocks of kokanee in Lake Penal Oreille, Idaho, estimated by mid-water trawling, 1977-1992.

there was about a 1:1 hatchery/wild ratio at that age. Overwinter survival of hatchery kokanee is an important point that needs attention to determine recruitment to the adult stock.

Release Strategies, Food, Temperature and Survival

We believe some of the variation between survival of release groups each year was due to the length of time hatchery kokanee were in the lake prior to trawling. Length of time in the lake covaried with zooplankton composition, and possibly other physical factors. These covariables complicated our analysis of which a single factor may be influencing kokanee survival. The number of release strategies we teated each year ranged from two to six, but depended upon fry availability. Analysis of number of days in the lake and survival of the 1988 and 1989 release demonstrated a weak and inverse relationship, P=0.12 (r^2=0.61) and P=0.15 (r^2=0.44), respectively. This also happened in 1987 when the first release of two late releases had the highest survival. Late release groups had higher survival than early groups (P<0.02). Length of time in the lake is important, but environmental factors at the release time are also thought to play a key role in release to fall survival values for hatchery kokanee.

We found several significant relationships between post release survival of age *0* kokanee and zooplankton densities. Survival of the combined release of all age O kokanee in a given year was significantly related to mean total zooplankton (P=0.05 and r^2=0.65). Survival of individual release groups was statistically related to total zooplankton at the time of release (P=0.01, r^2=0.29). Fry stocked late were introduced into environments that were richer in food. We carried the analysis further by examining the densities of each generation to age O kokanee survival to try to explain come of the variability in survivals. Survival of kokanee was found to be significantly correlated to the density the Cladoceran Diaphanosoma (P=0.05, r^2=0.33) at the release site and weakly associated with the combined density of Daphnia thorata and D. galeata (P=0.096, r^2=0.20). Cladocerans are an important food item of young kokanee *in* Lake Penal Oreille (Rieman and Falter 1980), as well as other waters (Martinez and Bergersen 1991). Cladocerans were seldom encountered until July in zooplankton samples of the open water of Lake Penal Oreille. Rieman and Falter (1981) found Cladocerans only around shorelines and embayments in post Mysis samples of zooplankton. Importance of food abundance and stress to kokanee fry is also supported in part by analysis of the number of daily growth increments of kokanee released in 1988 and 1989. Kokanee released into food poor environments (early open water and early Clark Fork River) had significantly fewer increments (Paragamianet al. 1992). Some fish, when starved, do not produce daily growth increments (Tzeng and Yu 1992).

We found a positive relationship (P=0.01, r^2=0.69) between the survival of fry and the size of Daphnia at the stocking location. *Kerr (1971)* provided theoretical evidence that feeding and growth of planktivores is more efficient on large bodied rather than small prey. Noble (1975) and Mills and Schiavone (19S2) found growth and survival of yellow perch cohorts was directly related to abundance and size of Daphnia. Thus, any combination *of* positive factors may enhance survival of kokanee fry.

High zooplankton densities were associated with warm spring air temperatures and rapid lake stratification. May and June thermal sums were important months to early stratification. The two best years for kokanee fry survival and zooplankton development occurred in 1988 and 1992, the two years of rapid thermal development.

Factors affecting survival of kokanee released into the Clark Fork River were difficult to evaluate. One reason was because release methods of kokanee varied between years, through a ladder system or plumbing directly from the hatchery. Assessment of predation was inconclusive other than to determine some northern squawfish ate kokanee migrating to Lake Penal Oreille. The occurrence of numerous kokanee fry in less than 15% of the northern squawfish suggested most of these predators were not conditioned to feeding on migrating kokanee. Thus, releasing large numbers of kokanee at the same time may provide the benefit that many predators do not take immediate advantage of the available prey.

We experimented with two releases that involved a gradual rise in discharge. The first of these tests occurred in 1987 (Bowles et al. 1988) when it was found that kokanee had significantly higher survival when discharge was increased after fry release vs decreased after fry release.

In 1992, we started from a minimum discharge to 560 m^3/s, controlled by Cabinet Gorge Dam, followed by a release of kokanee with a rise in discharge to 625 m^3/s. The survival of kokanee in 1992 was better than those that were barged past predators in 1988 and 1989.

We evaluated the risk of predation and discharge to survival of kokanee released into the Clark Fork River by using survival at Sullivan Springs as a standard, a quasi control (Figure 14). A diagonal line representing a 1:1 ratio of survival was added as a reference of equal survival. The survival of releases of kokanee in the Clark Fork River and Sullivan Springs were plotted on the figure. Seven points fell below the reference line and one point was on the line indicating lower survival for Clark Fork River releases. The vertical distance from the 1:1 line to a point was a measure in the difference in survival. Barging kokanee in 1988 and 1989 provided little benefit over high spring discharge releases. An additional line connecting survival values of kokanee releases through the ladder in 1987 and 1992 was used to compare this release to barging. The figure infers that barging fish may provide an added benefit of only 6% or 7% to survival. Barging was also an expensive and logistically complicated technique.

Spring flows during early releases may have entrained some kokanee through Lake Penal Oreille to the Penal Oreille River in years of high discharge. The later theory could be due to the configuration of Lake Penal Oreille, a deep southern basin, and a narrow shallow northern basin.

Fry Marking

We used four marks in the progress of this study to differentiate hatchery from wild kokanee and to segregate release groups. Tetracycline marking was used in 1988 and 1989 (Bowles et al. 1989; Hoelscher et al. 1990), fins were clipped on Sullivan Springs and Clark Fork River releases since 1988, and dye and grit were also used (Bowles et al. 1987). Water temperature manipulation in 1988 did not produce a discernible mark on kokanee otoliths, but when an alternate technique (Volk et al. 1990) was used to evaluate this mark in 1992, we found it to be successful. The otolith date of release mark (Paragamian et al. 1992) was used from 1987 through 1992.

The reliability of the date of release mark to this study is important. Thus, a detailed statistical analysis of this mark was made in 1990 to determine its reliability (Paragamian et al. 1992). The analysis indicated the stress mark and daily otolith growth counts are reliable techniques to identify hatchery vs wild fry and segregate release groups. We recommend continued use of these methods and a difference of at least 5 days between release dates.

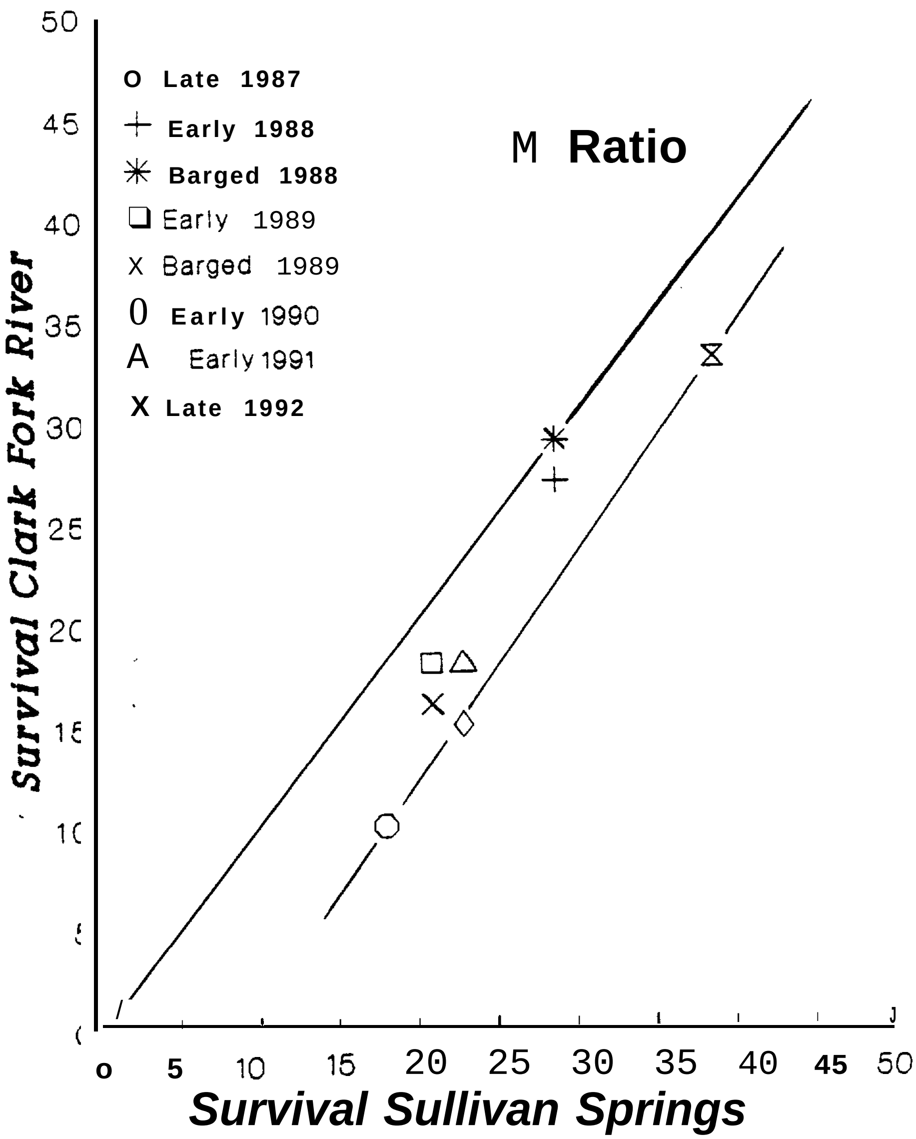

Figure 14. Comparison of age O kokanee fry released into the Clark Fork River by year and release strategy, using survival of kokanee stocked into Sullivan Springs as a standard. The 1:1 ratio line represents equal survival.

Our analysis of otoliths of age 1 kokanee *in* 1989 through 1992 met with only marginal success. A total sample of 45 otoliths of age 1 kokanee caught by trawling was processed following the same procedure as younger fish. Whether these fish were wild or of hatchery origin was unknown. The date of release mark was distinguished on 42% of the fish in 1989 (N=19). But we did not have any success in following years. The method used may be valid but further refinement is necessary. Temperature treatment of hatchery-reared kokanee at the eyed stage or older is a method that will also work (Volk et al. 1990) as previously mentioned.

Spawning

The kokanee spawning escapement of 822,000 adults in 1992 was the highest since 1986, the first year of this investigation. It was only 540,080 in 1991. The increase in the estimated spawning stock was due to several factors: 1) two strong year classes of kokanee (1987 and 1988), and 2) improved survival of fish to age 3 and 4 in 1991 and 1992. The strong 1987 year class (year of egg deposition) was due to the highest contribution of wild and hatchery fish coupled with the second highest hatchery fry survival rate (29%) during this study, while the 1988 year class was comprised of the fourth highest contribution of wild fish in the last decade.

Early maturity of kokanee in Lake Penal Oreille is a factor of concern with hatchery fish because they are a component in the spawning escapement and the egg collection at Sullivan Springs. This concern evolves around two important points. 1) A substantial portion of the kokanee fishery maturing at age 3, or even less desirable age 2, may do so at a size that is not preferred by anglers (<200 mm). They never contribute to the fishery (Rieman and Meyers 1990). 2) Younger kokanee (age 2 and 3) are smaller and less fecund, this has fluctuated substantially at Lake Penal Oreille (Figure 15). At Sullivan Springs, age 4 kokanee comprised about 84% of the spawning escapement from 1987 through 1989 (Table 6). However, this figure changed in 1990 and 1991 with the contribution of mature age 4 fish at 68% and 53%, respectively, but in 1992, the contribution was 75% age 4 (Table 6). In Lake Penal Oreille these changes are often due to year class strength. For example, an age 4 cohort low in numbers can be nearly outnumbered when accompanied by mature age 3 kokanee high in numbers. In 1991, there were only 0.27 million age 4 kokanee, nearly all of which were mature, but there were also 0.77 million age 3 fish of which 35% were mature. There are also differences in age at maturity, but that discussion goes beyond the scope of this study .

The return of disproportionate ratios of male vs female fin-clipped kokanee in 1991 and 1992 suggests an additional problem. About 85% of the known hatchery fish that returned to egg take stations in 1991 were females. The reverse was apparent in 1992 when only 20% of the kokanee were females. Age analysis of mature fin-clipped kokanee collected in 1992 indicated 56% age 3 fish were females, while only 21% of the age 4 fish were female. Speculative information suggests that these may have received a disproportionate ratio of male vs female hormone while in the hatchery (John Thorpe, Idaho Department of Fish and Game, personal communication). Hatchery fry in 1988 and 1989 were fed a brand of food that was comprised of herring meal. Prior to processing, the female herring had ova removed and sold as a byproduct. Thus, the feed probably had a higher proportion of testosterone than progesterone.

The ratio of kokanee stocked to adult returns as spawners to Sullivan Springs has decreased since the mid-1970s (Appendix E). From 1976 through 1979, the proportion of stocked fry to adult returns averaged 11%, dropped to 4.6% in 1980, and thereafter averaged 2.4%. Of the 40,000 fin-clipped kokanee released

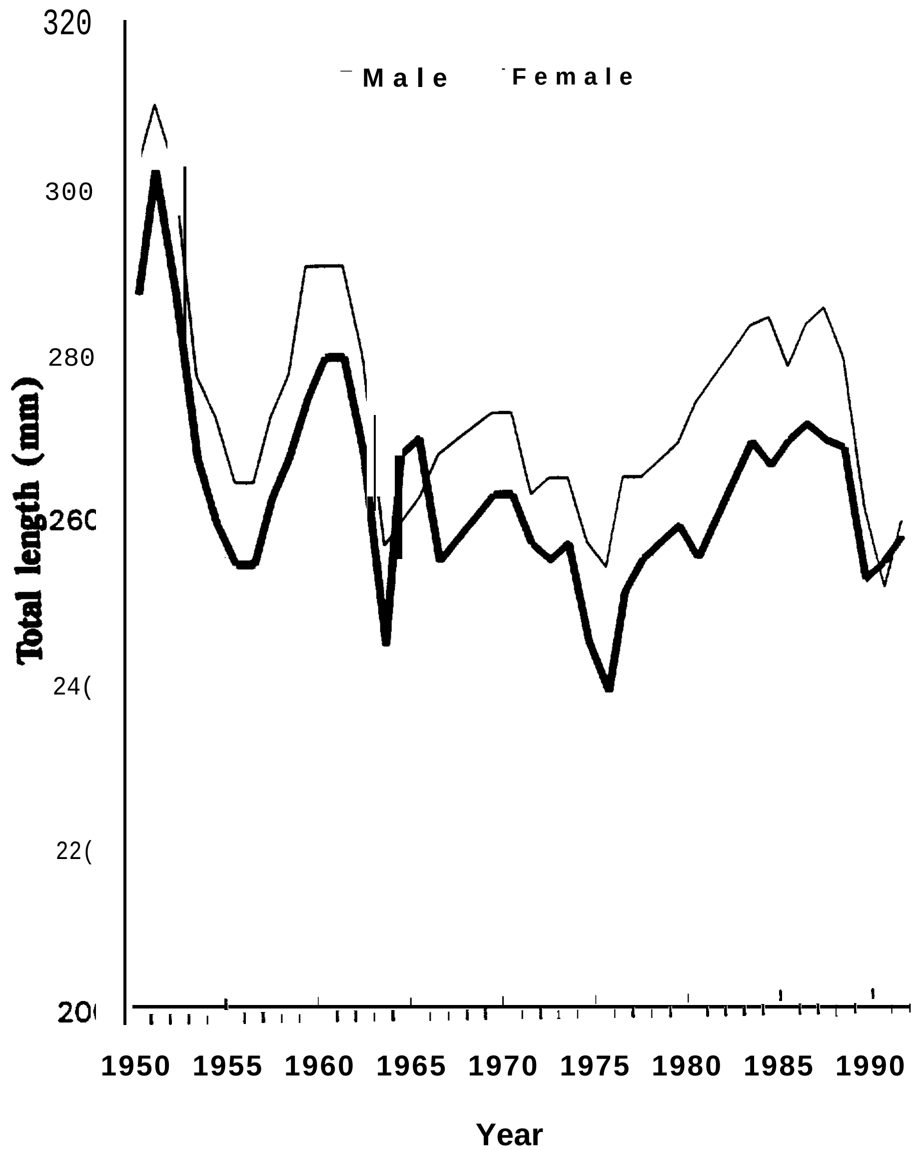

Figure 15. Mean total length of male and female kokanee spawners from Lake Penal **Oreille,** Idaho.

at Sullivan Springs in 1988, <1% have returned as mature adults at age 3 and 4. Straying from Sullivan Springs was demonstrated by recaptures of three fish from Sullivan Springs at the Cabinet Gorge Hatchery ladder in 1991 and nine in 1992. But the extent of straying is unknown. Almost identical declines in percent adults returning to hatcheries was documented for nearly all hatcheries rearing Pacific salmon (Hilborn 1992). It would appear that this trend is common *among* hatcheries introducing fish into wild populations. Based on this trend, Hilborn questioned the validity of hatchery programs in general. The exact reason for this decline is unknown but it could be due to reduced survival of stocked kokanee, differences in imprinting of kokanee because of size of fry stocked, or an unknown factor (prior to 1991 the contribution of wild vs hatchery kokanee at Sullivan Springs could not be estimated). As for the Cabinet Gorge Hatchery, straying and improving the return are important questions that need to be addressed as objectives in themselves in future work.

The Lake Penal Oreille Fishery

Creel surveys for this study were conducted in 1985 (Bowles et al. 1986) and 1991 (Paragamian et al. 1992). Limited creel checks in 1990 (Paragamian et al. 1991) were carried out to determine angler catch effort and mean length of important sport fish. Lake Penal Oreille sport anglers fished an estimated 179,229 hours in 1985 (36,446 angler-days) and 460,679 hours in 1991 (87,966 angler-days).

The kokanee harvest in Lake Penal Oreille is approximately one-third of the management goal of 750,000 (IDFG 1991). An estimated 227,140 kokanee were caught during the 1991 fishing season (Figure 16). However, substantially more kokanee were caught in 1991 than 1985 when the harvest was 71,000 fish (Bowles et al. 1986) . The harvest of kokanee in 1991 is similar to that of 1975. The Cabinet Gorge kokanee program has improved the fishery to that of the 1980s (Figure 16). The hatchery-supported fishery will decline even more in the next three years (1994-1996). Two reasons are the lower *number* of kokanee stocked since 1989 (only about 800,000 in 1993) and the low survival of wild fry *from* PED to autumn sampling in 1990 and 1991.

Catch success of large Gerrard rainbow trout in 1991 was better than it was in 1985, priorto imposition of a 610 mm minimum length limit. Catch success for rainbow over 610 mm in 1985 was 232 h/fish, but improved to 84 h/fish in 1990 and was 78 h/fish in 1991. Imposition of the length limit and a 37% voluntary release rate for large fish in 1990 (Paragamian et al. 1991) and 36% in 1991 accounted for the improved fishery. The improved fishing success for large rainbow trout in 1990 may have stimulated greater fishing effort in 1991. An estimated 460,000 hours of fishing effort was expended in 1991 compared to about 178,000 in 1985 (Bowles et al. 1987).

Harvest of rainbow trout with the more restrictive regulation has decreased 65% from 1985 through 1991. The harvest was about 6,100 rainbow trout in 1985, with a harvest of 3,456 that were over 432 mm. The total catch in 1991 with a 610 mm length limit was about 17,165 rainbow trout. The catch of fish 610 mm or larger was 2,939, while 2,157 were harvested (Paragamian et al. 1992). The peak harvest was 1979 when approximately 10,000 fish were taken (Bowles et al. 1986) . Fishing regulations were liberalized in 1992 with a 510 mm minimum length limit and a two fish per day possession limit.

The harvest of bull trout since 1985 has increased 88% with a doubling of effort (Paragamian et al. 1992). About 915 bull trout were taken by anglers in 1985, while 1,723 were taken in 1991. The catch rate for bull trout in 1985 was 12.5 h/fish, 7.6 h/fish in 1990, and 7 h/fish in 1991. From 1985 to 1991, the effort expended toward bull trout doubled with 5,275 h compared to 11,960 h,

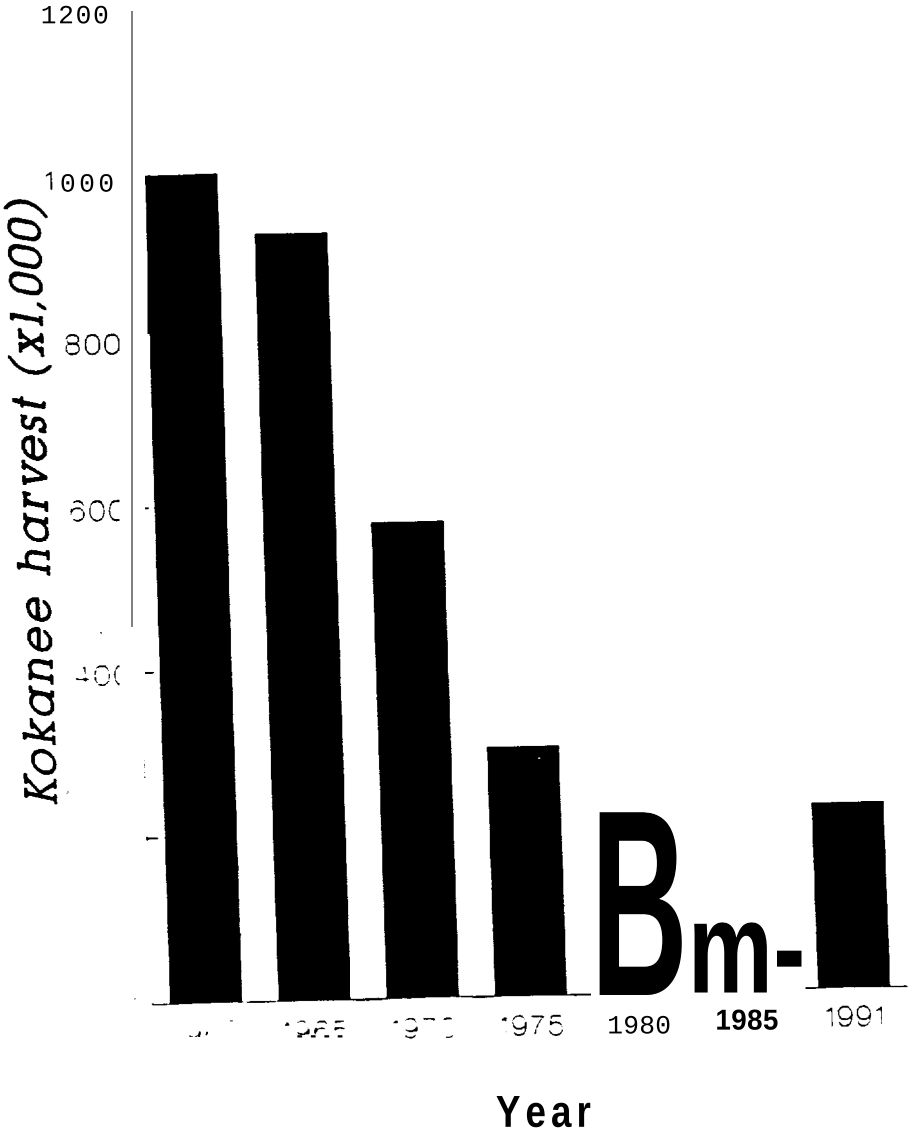

Figure 16. Mean (3-5 years) kokanee harvest in hundreds of thousands from 1960-1980 in Lake Penal Oreille; 1985 and 1991 are point estimates.

respectively. The status of bull trout has declined since the 1950s. Management measures implemented in 1992 (510 mm length limit) should reduce the harvest because 50% of the fish creeled by anglers in previous years were smaller than this length. This length limit should improve the stock density and size structure. While harvest is important, the most rapid decline in the harvest of bull trout occurred after closure of the Cabinet Gorge Dam and fish were prevented from returning to spawning areas above the dam (Paragamian et al. 1991).

The harvest of lake trout and cutthroat trout has improved since 1985. Lake trout were not reported in the creel of 1985, but 25 were reported in 1990 (Paragamian et al. 1991) and 43 were observedby creel clerks in 1991 (Paragamian et al. 1992) (an expanded harvest estimate was not made for lake trout in 1991). Many more lake trout not recorded in the creel survey were reported by anglers targeting this species. The harvest of cutthroat trout from Lake Penal Oreille had a 90% decline from over 8,000 fish in the 1950s to about 800 fish in 1967 (Bowles et al. 1987). Since the late 1960s, the catch of cutthroat trout has been stable with a harvest of 664 fish in 1985 and about 760 cutthroat trout in 1991. It is not known at this time what role the net pen rearing program of supplementation of cutthroat trout may have.

Kokanee Population Diagram

Prior to the development of the Cabinet Gorge Hatchery program a kokanee population diagram was constructed to provide insight to the necessary components of successful hatchery supplementation (Anonymous 1983). This diagram was an important feature in the development of objectives and goals for the Cabinet Gorge mitigation program (Figure 17). The outstanding variables of the diagram included annual releases of 20 million kokanee fry and 30% release to fall fry survival. The diagram also incorporated a recruitment of 4.0 million wild fry annually to the age O component of the stock. In addition, it assumed equal exploitation of 20% to ages 2, 3, and 4 kokanee. The resulting projected harvest of kokanee from Lake Penal Oreille was 744,000 fish. Thus, the Cabinet Gorge Fish Hatchery was designed to provide kokanee for a harvest goal of 750,000 fish.

The kokanee population diagram was adjusted at the conclusion of this investigation. The diagram incorporates the prevailing estimates of the mean PED from 1987-1992, mean number of hatchery releases per year, survivals of various aged kokanee, and exploitation calculated from data from this study (exploitation for ages 2, 3, and 4 was calculated in 1991, and harvest in 1991) (Figure 18). The new diagram indicated the expected annual harvest of kokanee in Lake Penal Oreille could be about 260,000 fish. But this diagram also has some limitations. For example, the survival rates of various age groups of kokanee varied widely during this study, and the use of exploitation for 1991 could be misleading since it will vary with fishing pressure and kokanee densities.

The original diagram was optimistic and suggested increases in the number of age O kokanee would increase the harvest by a comparable proportion. Failure of the original diagram to take into account density dependent factors and assumptions that neglected environmental constraints to the population were shortcomings. The new diagram captured a period in time, it did not identify factors limiting the development of a rebounding stock but highlighted some reasons why it did not. Hatchery supplementation failed to generate a *response in* the improvement of the stock through wild and hatchery fry production, i.e. increased spawner escapement, egg collection at the two stations *was* poor, and wild *fry* survival from PED to late summer fry was poor.

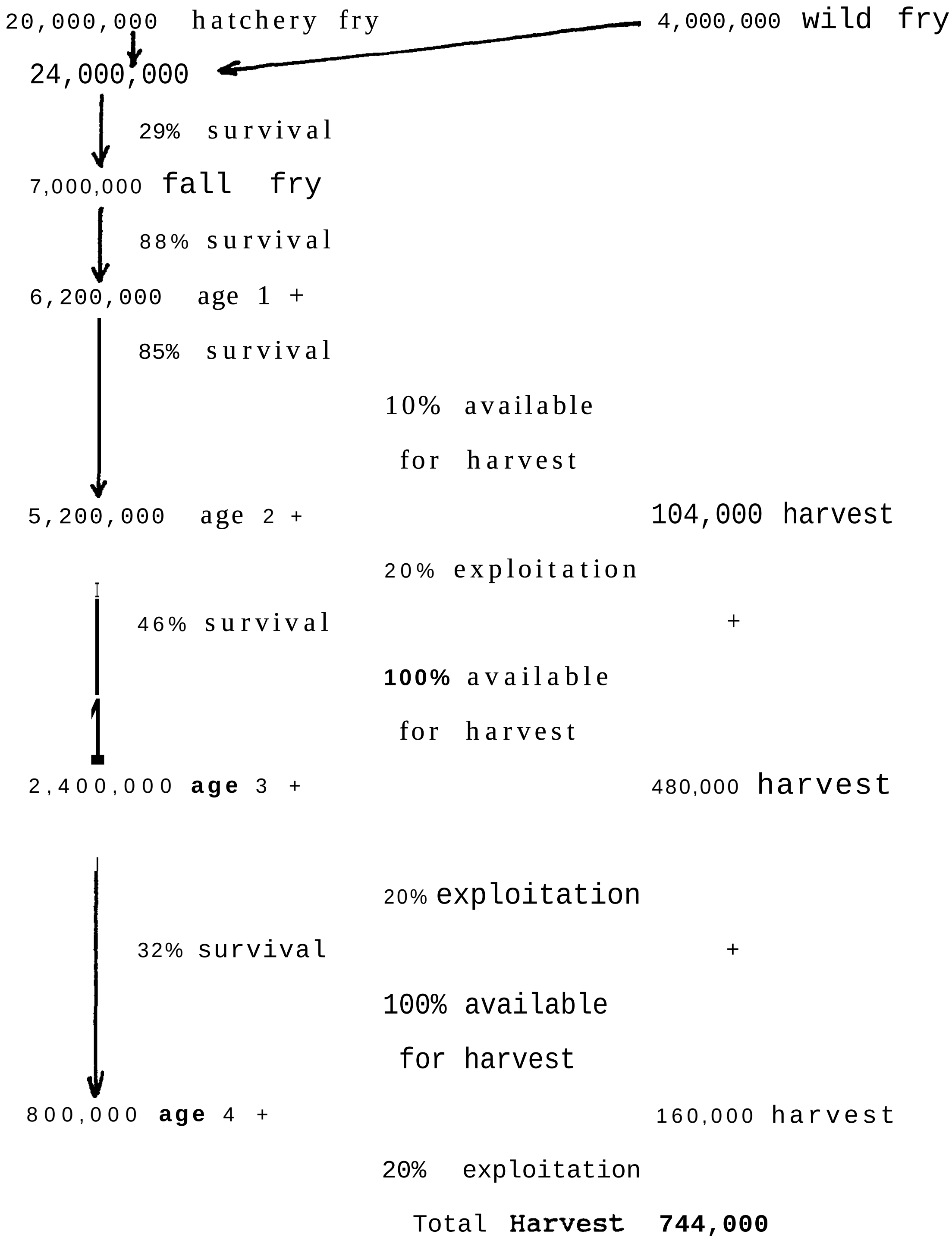

Figure 17. Kokanee population diagram for Lake Pend Oreille (Anonymous 1983).

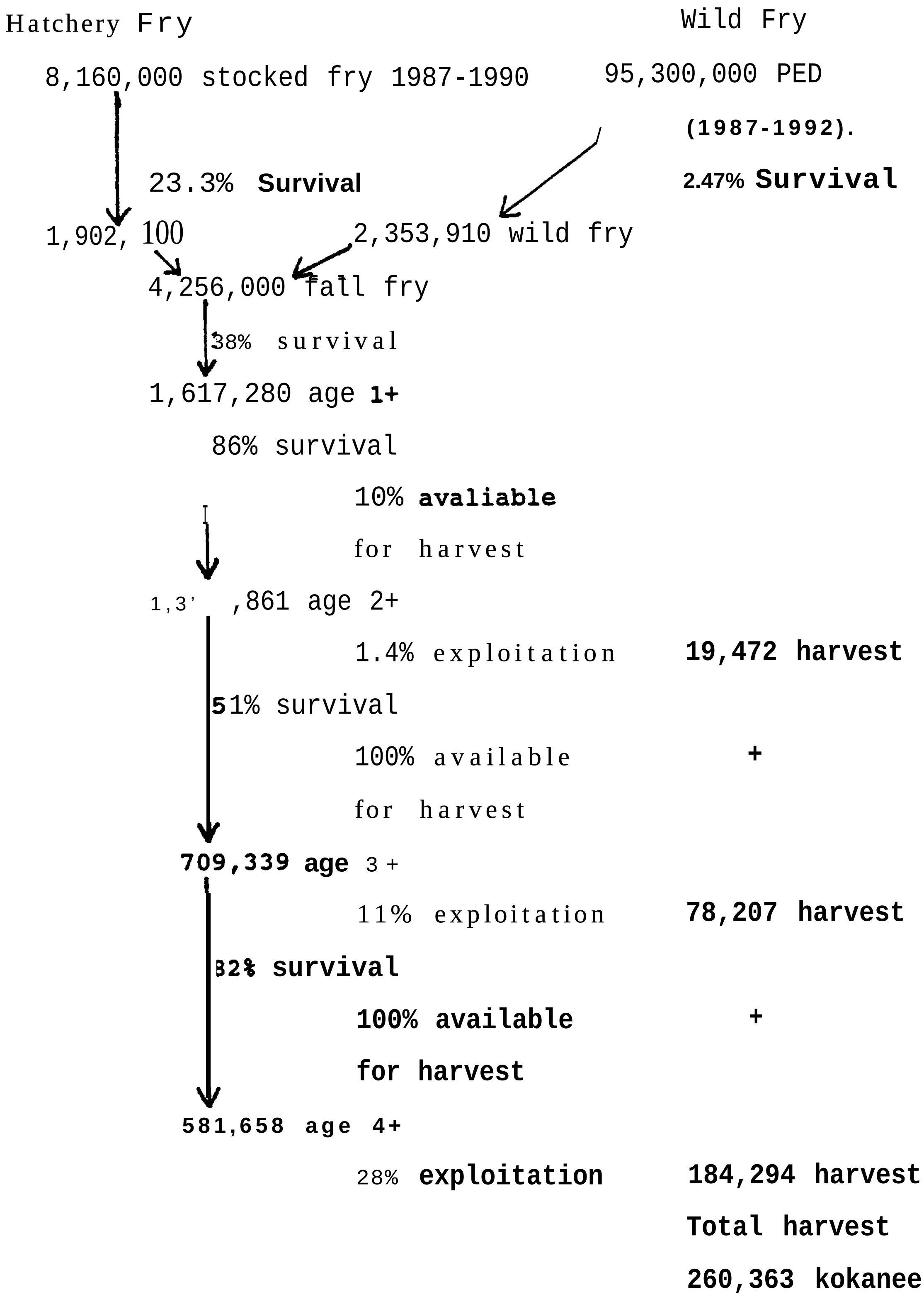

Figure 18. The restructured kokanee population diagram for Lake Penal Oreille using prevailing survivals, PED, and hatchery stockings. Data tabulated from 1987 through 1992.

Stockings of hatchery fish provided short-term gains, but habitat remains a critical issue to kokanee *recovery.* Recovery efforts for the Lake Penal Oreille kokanee population should be redirected from symptoms to causes of limiting factors of the population.

RECOMMENDATIONS

1. Release 1.0 million kokanee fry into the Clark Fork River each year in July. This will increase survival to fall trawling over earlier releases.

2. Release 3.5 million fry into Sullivan Springs Creek each year to maintain an egg supply. Release fry in Sullivan Springs Creek after thermal stratification *of* Lake Penal Oreille (typically mid-July) to provide higher survival to fall trawling.

3. Imprint fry released at Cabinet Gorge Hatchery and Sullivan Springs Creek with morpholine to use as an adult attractant. Fin clip a representative portion of fry (≥60,000 fish) released in Clark Fork River and Sullivan Springs Creek to evaluate adult return rates.

4* Test small (40 mm) vs large fry (50 mm) to determine differences in imprinting, return rates, and maturation at Sullivan Springs with differential fin clipping 30,000 fish from each group each year.

5. If rainbows are again stocked, a mark and recapture program with hatchery and wild fish could provide direction for the Gerrard rainbow trout stocking program.

6. Improve wild egg to fry survival to achieve management goals. Determine if water level management can improve egg to fry survival. Wild kokanee continue to decline with an egg to fry mortality rate of 97.8%, and will be lost from the lake entirely if the decline continues.

ACKNOWLEDGEMENTS

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A P P E N D I C E S

Appendix A. Estimated year class (year eggs were deposited) abundance (millions) of kokanee made by midwater trawl in Lake Penal Oreille, Idaho, 1979 through 1992. The two oldest age classes were combined for estimates from 1979 through 1985.

Year class	Year estimated													
	1992	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979
1991	4.55													
1990	1.33	1.98												
1989	0.78	0.83	3.35											
1988	1.11	1.77	1.59	4.50										
1987	0.64	0.77	1.45	1.15	7.31									
1986		0.27	0.33	1.20	1.66	3.55								
1985			0.20	0.45	0.51	0.78	1.65							
1984				0.37	0.38	0.84	1.15	1.79						
1983				0.04	0.35	0.43	0.68	1.03	2.63					
1982						0.42	0.54	1.24	1.51	2.14				
1981							0.24	0.37	1.21	2.28	3.84			
1980									0.2”7	0.50	2.77	2.31		
1979										0.29	0.64	1.36	1.69	
1978											0.87	0.79	1.00	2.01
1977												0.74	0.96	1.31
1976													1.03	1.70
1975														0.67
Total	8.41	5.62	6.93	7.71	10.21	6.02	4.26	4.47	5.62	5.21	8.12	5.20	4.68	5.69
Density (No./hectare)	372	241	306	342	451	266	189	198	249	230	358	230	207	251

Appendix B. Kokanee age class density (fish/ha) in Lake Penal **Oreille** during late summer, 1992. A **90%** error bound is subtended each estimate.

Age class	Origin	Lake section 1	2	3	4	5	6	Average
0+	Hatchery (total)	26.7(5.8)	72.4(18.6)	119.1(15.9)	104.0(44.9)	65.9(12.3)	142.4(65.3)	93.8(17.1)
	Clark Fork River							
	Late Summer[a]	4.0(0.8)	0	13.3(1.8)	2.2.(0.8)	15.3(2.7)	48.3(20.0)	16.1(4.9)
	Sullivan Springs[b]	17.1(3.9)	51.5(13.2)	75.1(29.6)	77.5(10.0)	78.5(33.9	75.0(38.2)	58.2(10.8)
	Garfield	5.6(1.1)	20.9(5.4)	30.3(4.1)	26.1(11.4)	15.3(2.7)	11.1(5.0)	18.2(2.6)
	Wild	169.1(38.0)	155.0(40.1)	132.7(17.9)	127.7(54.9)	56.2(10.7	35.1(16.0)	107.2(13.5)
	Wild & Hatchery	195.8(43.8)	227.3(58.6)	251.8(33.8)	231.6(99.8)	123.9(23.0	177.5(81.3)	201.0(28.2)
1+	Wild & Hatchery	5.8(4.1)	3.2(5.1)	18.1(18.7)	11.4(7.7)	20.4(7.7)	222.8(122.1)	58.6(27.3)
2+	Wild & Hatchery	66.0(35.7)	11.7’ 5.0)	21.0(12.9	14.7(4.8)	32.5(16.5)	56.1(15.8)	34.3(7.0)
3+	Wild & Hatchery	159.1(60.7)	51.3 52.4)	38.2(15.1	27.7(11.9	33.4(21.3)	14.4(7.1)	49.2(28.5)
4+	Wild & Hatchery	106.9(39.7)	37.9 35.5)	13.7(8.8)	17.0(12.3	15.0(7.7)	2.0(3.2)	28.5(8.2)
5+	Wild & Hatchery	0	0	0	0	0	0	0
Total All Age Classes								309.3(45.9)

[a] Hatchery-reared kokanee fry released into Clark Fork River.
[b] Hatchery-reared kokanee fry released into Sullivan Springs Creek.

Appendix C. Mean total (TL) length (mm) and weight (g) of kokanee caught trawling from 1986 through 1992.

	1986		1987		1988		1989		1990		1991		1992	
Age Class	TL	Wt	TL	Wt	TL	Wt	TL	Wt	TL	Wt	TL	Wt	TL	Wt
Age 0+														
Hatchery	40.8	0.6	60	1.8	62	2.0	55	1.4	63	2.1	67	2.5	65.5	2.3
Wild	39.7	0.5	37	0.4	45	0.8	34	0.3	35	0.4	32	0.3	32.1	0.3
Combined	39.9	0.5	44.3	0.7	54	1.4	45	0.9	48	1.0	49	1.0	46.9	0.9
Age 1+	147	23.6	128	13.8	138	21	154	27	145	20	150	26	142	19.0
Age 2+	214	83.2	206	68.6	205	69	199	65	196	59	193	47	192.1	51.7
Age 3+	233	108.9	252	118	242	116	224	97	229	98	218	83	225.2	83.1
Age 4+	259	150	262	149.5	270	166	260	151	249	111	241	115	252.3	119.9
Age 5+	0	0	0	0	0	0	276	176	0	0	0	0	0	0

Appendix D. Estimated number of adult female kokanee, mean fecundity, potential egg deposition, population estimate of wild and natural age 0 kokanee year following PED, and estimated survival (egg deposition to autumn populations following year) for Lake Pend Oreille, Idaho, 1986 through 1992.

Year	Estimated number adult females	Mean fecundity (eggs/female) (95% C.I.)	PED (million)	estimate age-0 wild and natural kokanee	Wild Age 0 survival (%)	Survival of hatchery fry %
1986	145,390	410	59.6	1,439,859	1.5	12.4
1987	241,800	446 (±32)	107.9	2,750,365	4.6	10.1
1988	209,390	430 (±22)	102.1	3,567,261	3.3	9.4
1989	25[illegible],910	426 (±26)	107.1	2,295,959	2.2	11.3
1990	144,082	392 (±18)	55.0	1,793,795	1.5	11.3
1991	249,900	344 (±19)	86.0	917,90[illegible]	1.3	20.9
1992	411,248	411 (±14)	169.0	2,427,929	2.8	91

Appendix E. Kokanee spawned from Sullivan springs Creek from 1976 through 1991, number o
subsequent fry released into Sullivan Springs and adult return rate.

year	Total escapement	Kokanee spawned	Eggs Coilected	Fry released following year	Estimated retur adults from hat releases and y returned	
1976	10,717	10,200	913,000	757,700	55,500 42,200	((1
1977	20,075	17,650	2,400,000	1,830,000	135,300 29,000	(1 (
1978	0	16,875	1,532,382	1,745,734	118,000 58,000	(1 (
1979	0	12,005	1,389,250	1,081,400	42,000 75,660	(1 (
1980	55,500	48,760	4,186,664	2,219,796	54,340 46,810	(1 (1
1981	177,500	112,820	11,653,036	2,487,804	27,935 20,060	(1 (1
1982	147,000	115,850	11,432,900	3,077,711	22,170 77,773	(1 (1
1983	100,000	79,850	6,328,924	3,214,512	5,854 54,500	(1 (
1984	130,000	122,000	14,973,029	3,428,279	13,600 61,976	((1
1985	75,500	75,500	10,590,579	1,594,731	14,121 39,062	((
1986	42,230	42,230	7,337,000[b]	2,847,345	18,385 45,425 1,764	(1 (1 (1

Appendix E. Continued.

Year	Total escapement	Kokanee spawned	Eggs collected	Fry released following year	Estimated retur adults from hatc releases and y returned	
1987	83,627	83,627	16,600,000[c]	5,138,800	39,428 63,001	(1 (1
1988	68,100	60,555	14,058,000[d]	3,538,000	857 19,236	(1 (1
1989	79,450	70,600	9,372,000[e]	3,190,700		
1990	57,445	51,445	5,686,000[f]	2,570,264		
1991	85,713	75,624	6,364,209[g]	3,440,000		
1992	84,001	73,739	6,125,000[h]			

[a]Additional fry were released in other areas.
[b]An additional 1.76 million eggs were collected from Spring Creek and the Clark Fork Rive bringing the total egg take to 9.1 million.
[c]An additional 0.61 million eggs were collected from Clark Fork River, bringing the total to 17.22 million.
[d]An additional 0.10 million eggs were collected from Clark Fork River, bringing the total 14.16 million.
[e]An additional 0.21 million eggs were collected from Clark Fork River, bringing the total 9.58 million.
[f]An additional 0.30 million eggs were collected from Clark Fork River,bringing the total 5.6 million.
[g]An additional 0.23 million eggs were collected from Clark Fork River, bringing the total 6.59 million.
[h]An additional 1.37 million eggs were collected from Clark Fork River, bringing the total 7.50 million.

Appendix F. Maximum single late run (early run included for Trestle Creek) kokanee coun the 1973-1978 and 1985-1991 spawning seasons on Lake Penal **Oreille** and its excluding the Granite Creek drainage.

	Maximum single counts												
Area	1972	1973	1974	1975	1976	1977	1978	1985	1986	1987	1988	1989	1990
Lakeshore													
BayView	2,626	17,156	3,588	9,231	1,525	3,390	798	2,915	1,720	1,377′	2,100	875	2,036
Farragut	25	0	0	0	0	0	0	0	10	0	4	0	0
Idlewild Bay	13	0	25	0	0	0	0	0	0	0	0	0	0
Lakeview	4	200	18	0	0	25	0	4	127	59	0	0	75
Ellisport Bay /Hope	1	436	975	0	0	0	0	0	0	0	0	0	0
Trestle Creek	0	1,000	2,250	0	115	75	138	2	350	2	2	0	80
Sunnys ide	0	25	0	0	0	0	0	0	0	0	0	0	0
Fisherman 1s1.	0	0	75	0	0	0	0	0	0	0	0	0	0
Andereon Point	0	0	50	0	0	0	0	0	0	0	0	0	0
Camp Bay	0	617	0	0	0	0	0	0	0	0	0	0	0
Garfield Bay	0	400	20	0	0	0	0	0	6	0	35	0	0
Subtotal	2,669	19,834	7,001	9,231	1,640	3,490	936	2,921	1,898	1, 786	2,141	877	2,111
% of Total	29%	62%	25%	64%	33%	40%	19%	32%	10%	20%	14%	19%	25%
Tributaries													
South Gold Crk	1,030	1,875	1,050	440	0	30	0	235	1,550	2,761	2,390	830	834
North Gold Creek	744	1,383	1,068	663	130	426	0	696	1,200	2,750	880	448	458
Cedar Creek	0	267	44	16	11	0	0	0	0	0	0	0	0
Johnson Creek	0	0	1	0	0	0	0	0	182	0	0	0	0
Twin Creek	0	0	135	1	0	0	0	5	0	0	0	0	0
Mosquito Creek	0	503	0	0	0	0	0	0	0	0	0	0	0
Clark Fork River	539	3,520	6,180	0	0	0	0	0	0	0	00	0	0
Lightning Creek (Lower)	350	500	2,350	995	2,240	1,300	44	127	165	75	6	0	0
Spring **Creek**	2,610	4,025	9,450	3,055	910	3,390	4,020	5,284	14,000	1, 500[d]	9,000	2,400	4,400
Cascade Creek	0	00	0	0	0	0	0	0	0	0	119	48	45
Trestle Creek	1,293	18	1,210	15	0	40	0	0	0	0	0	0	0
Trestle[a]	0	1, 100	217	14,555	1,486	865	1,589	208	1,034	410	422	466	525
Garfield Creek	0	0	25	0	0	0	0	0	1	0	0	0	0
Subtotal	6,566	12,091	21,513	5,185	3,291	5,186	4,046	6,347	17, 098	7, 086	12,698	3,726	6,262
Percent of Total[b]	71%	38%	75%	36%	67%	60%	81%	68%	90%	80%	86%	81%	75%
Total[b]	9,235	31,925	28,514	14,416	4,931	8,676	5,000	9,268	18,996	8,872	14,839	4,603	8,373

[a] Maximum single early-run count of kokanee spawners.
[b] Excluding early-run kokanee spawners in Trestle Creek.
[c] Represents a partial count only because heavy wave action kept spawners offshore and uncountable.
[d] Count made third week of December because low flows in Lightning Creek resulted in a complete passage barrier durin

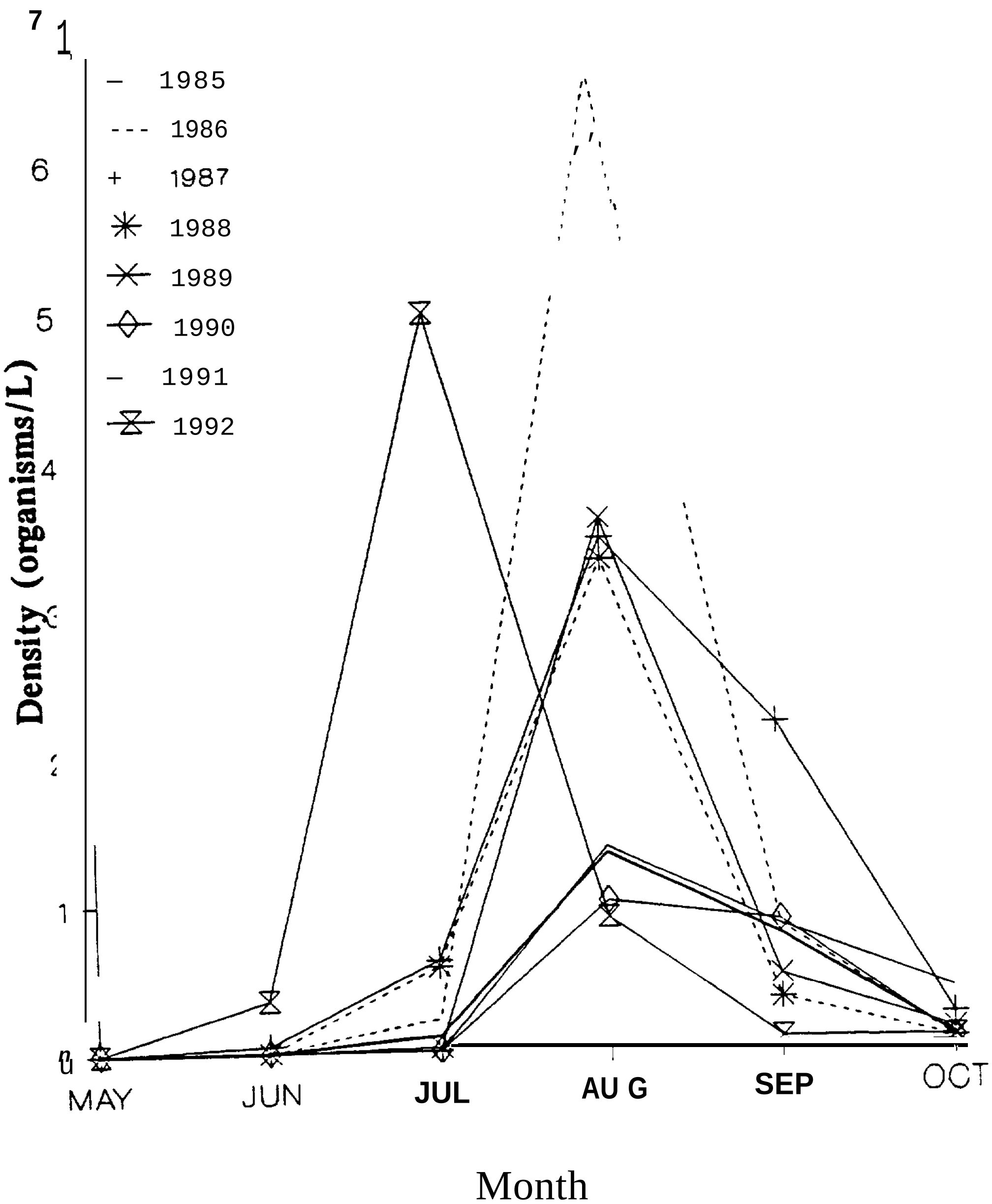
Appendix G. Adult, juvenile and total densities (organisrns/m^3) of shrimp by Section south (s) , central (C) and north (N) Sections of Lake Pend Orielle, 1986 through 1992.

Year	Adult			Juvenile			Total		
	S	C	N	S	C	N	S	C	N
1986	8	11	4	39	46	7	47	57	12
1987	2	4	6	13	18	17	15	22	23
1988	3	6	8	55	54	16	58	60	23
1989	20	20	8	30	30	7	50	58	15
1990	6	6	4	14	27	7	19	33	11
1991	1	1	1	3	5	6	4	5	7
1992	1	2	2	20	13	7	21	15	8

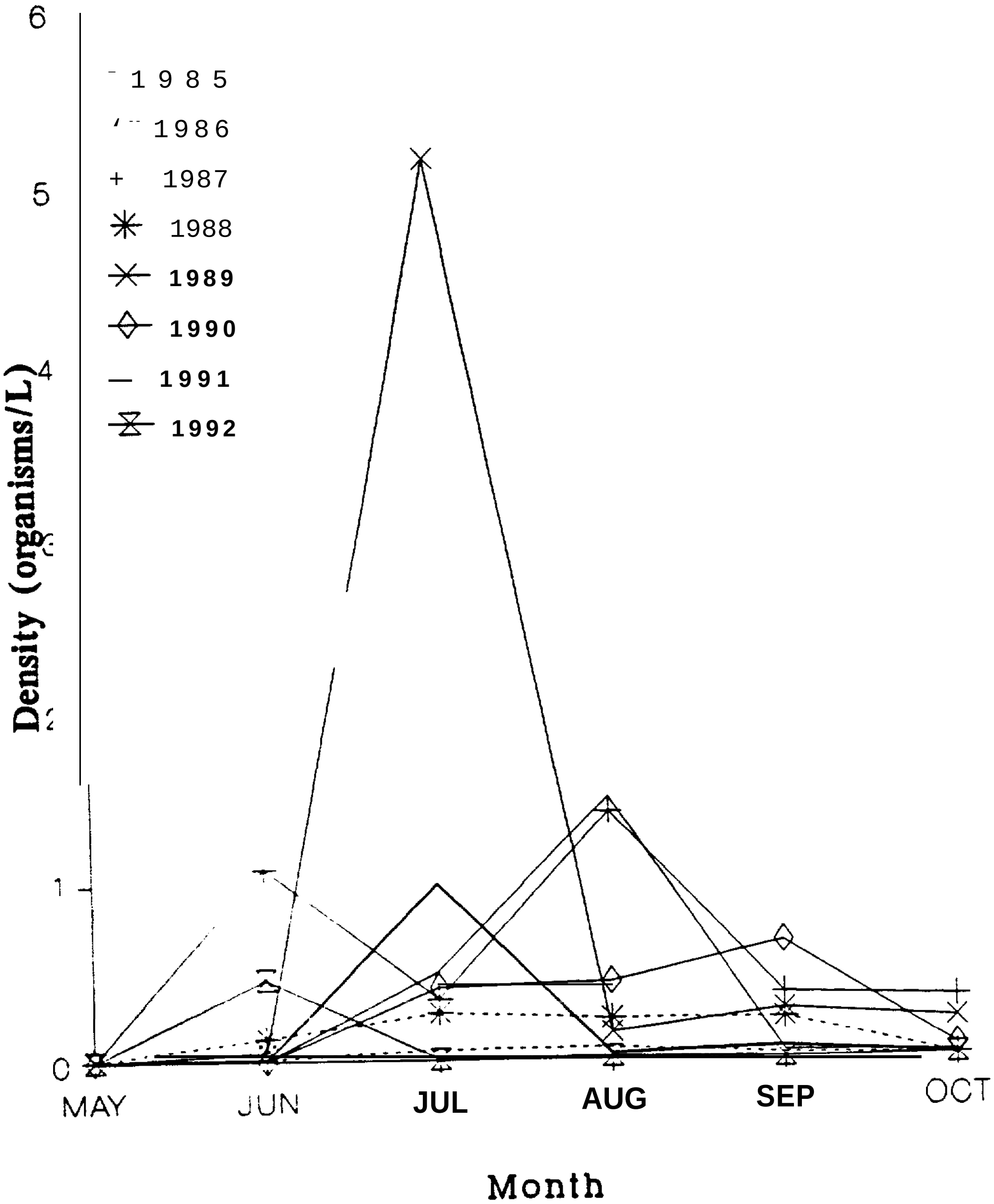
Appendix H. Range and mean lengths (mm) of mature female, immature female, immature male and juvenile shrimp captured in June, Lake Penal Oreille, Idaho, 1989 through 1992.

Year	Mature female		Immature female		Immature male		Juvenile	
	range	mean	range	mean	range	mean	range	mean
1989	16-20	18.4	10-18	13.5	10-17	13.1	3-1o	5.1
1990	17-20	18.6	12-18	15.1	13-18	14.7	3-9	5.9
1991	16-18	17.1	12-15	13.2	14-19	15.8	1-10	7.0
1992	17-22	19.8	13-22	17.8	13-18	16.0	1-10	3.7

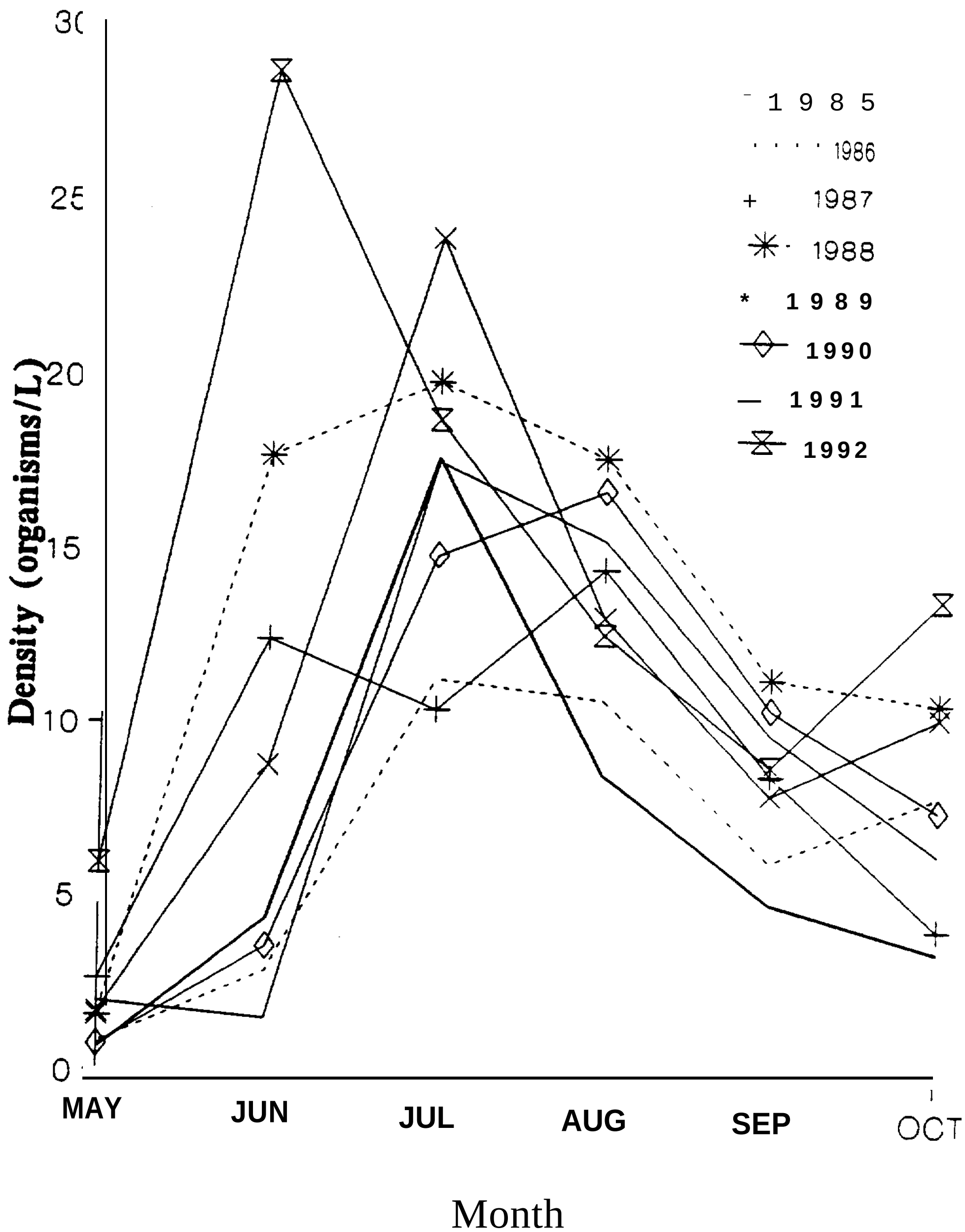
Appendix I. Temporal distribution of mean Daphnia densities in Lake Penal **Oreille,** Idaho, May through October, 1985 through 1992.



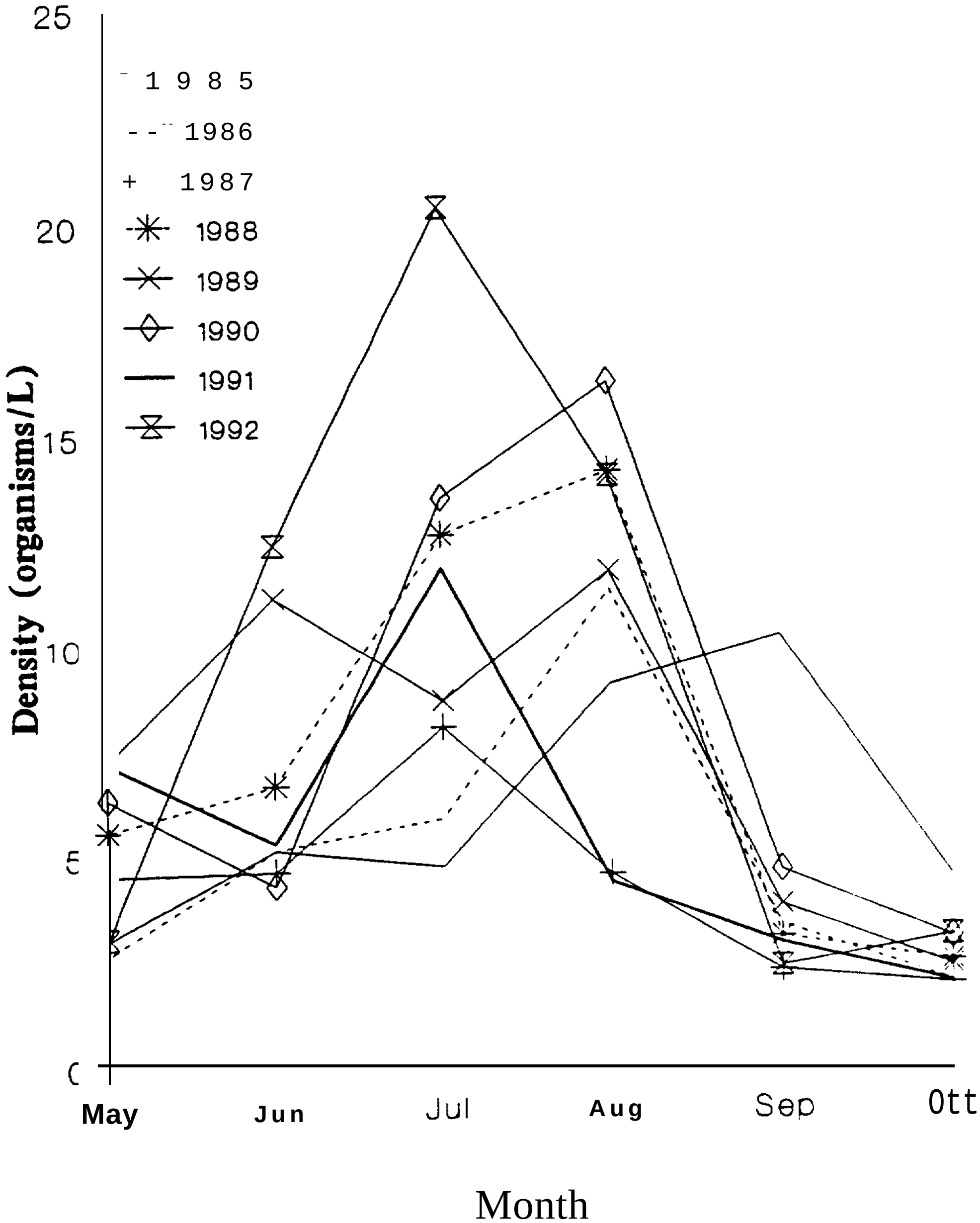
Appendix J. Temporal distribution of mean Bosmina densities in Lake Penal Oreille, Idaho, May through October, 1985 through 1992.



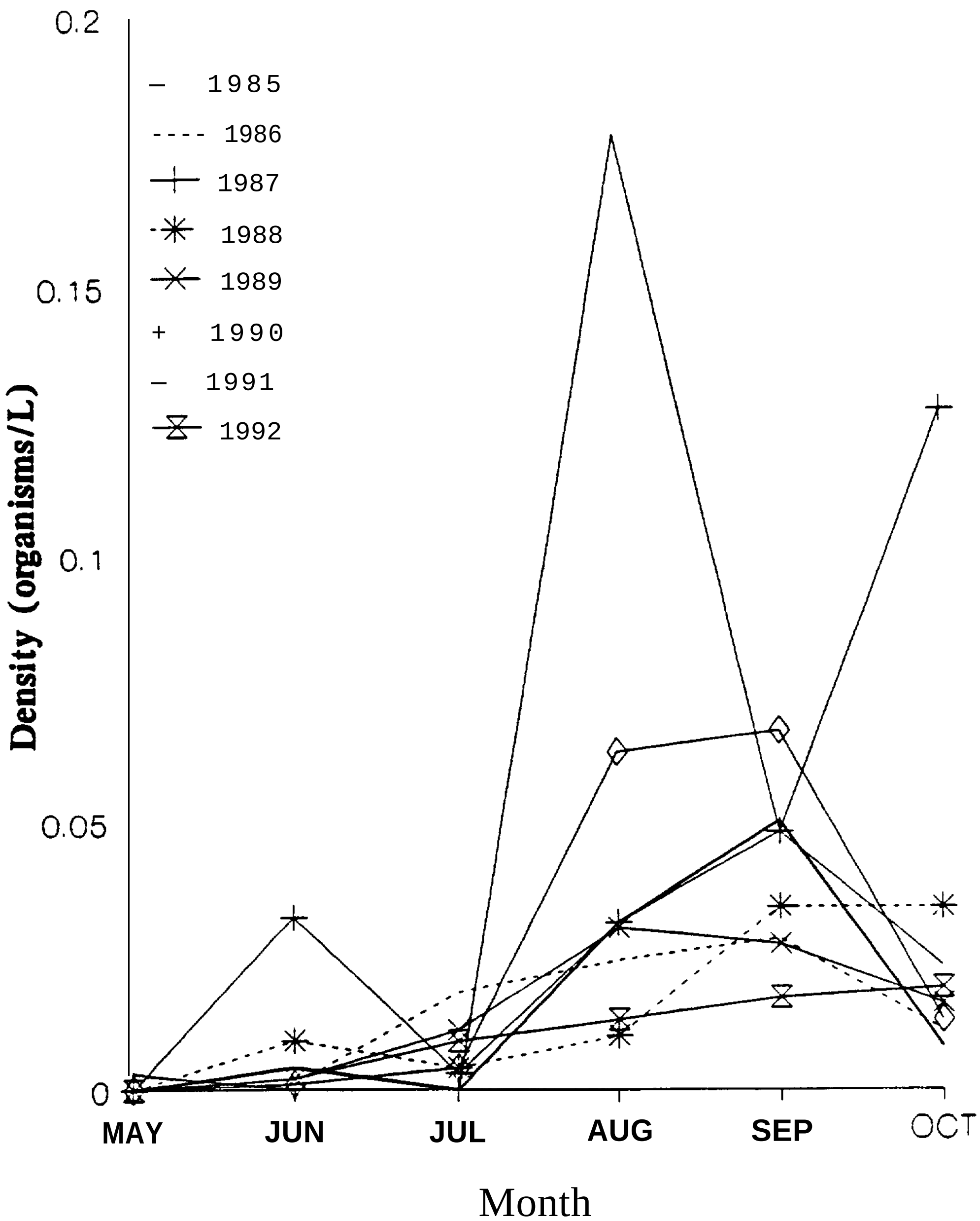
Appendix K. Temporal distribution of mean Cyclops densities in Lake Penal **Oreille,** Idaho, May through October, 1985 through 1992.



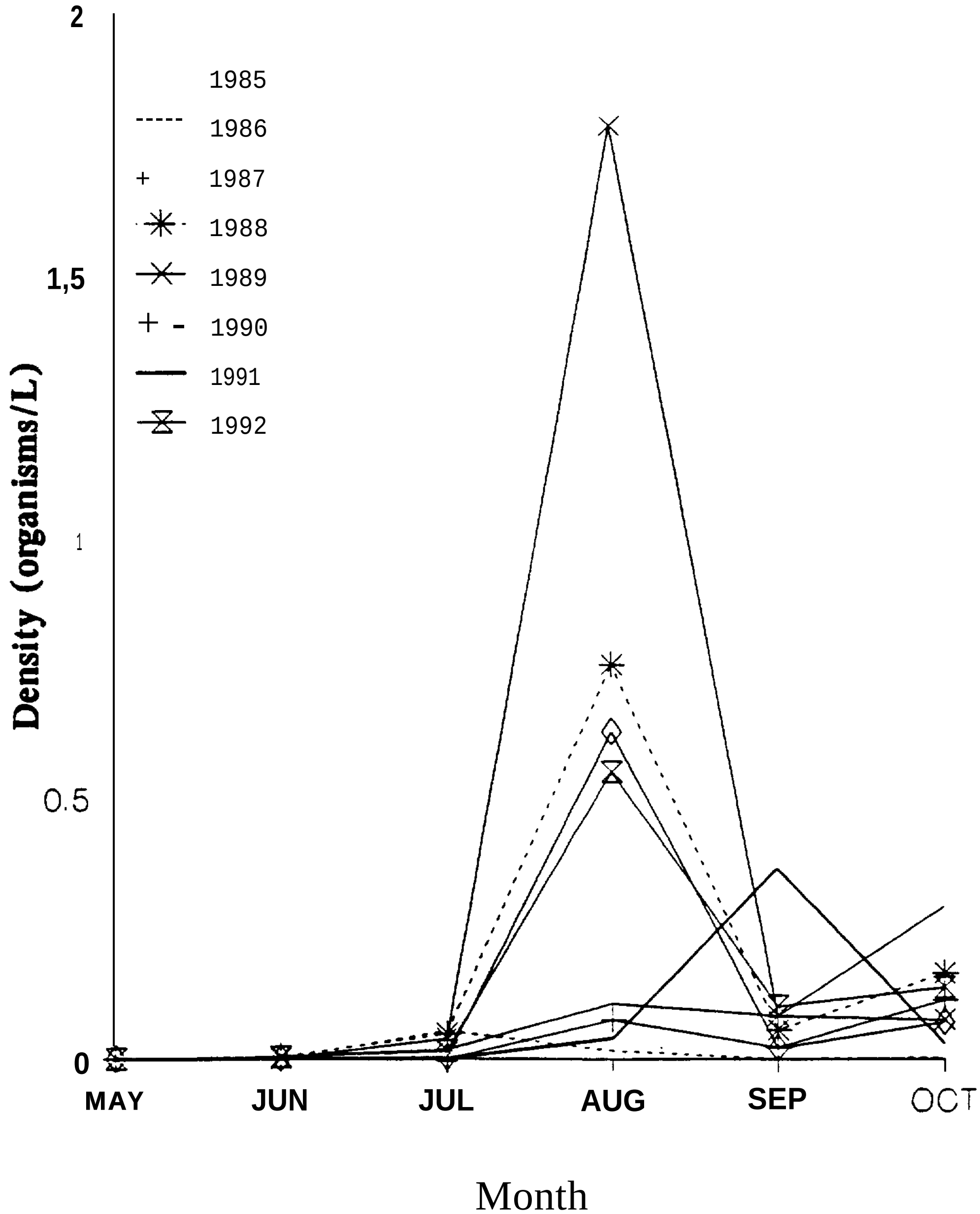
Appendix L. Temporal distribution of mean Diaptomus densities in Lake Penal **Oreille,** Idaho, May through October, 1985 through 1992.



Appendix M. Temporal distribution of mean Epischura densities in Lake Penal Oreille, Idaho, May through October, 1985 through 1992.



Appendix N. Temporal distribution of mean Diaphanosoma densities in Lake Penal Oreille, Idaho, May through October, 1985 through 1992.



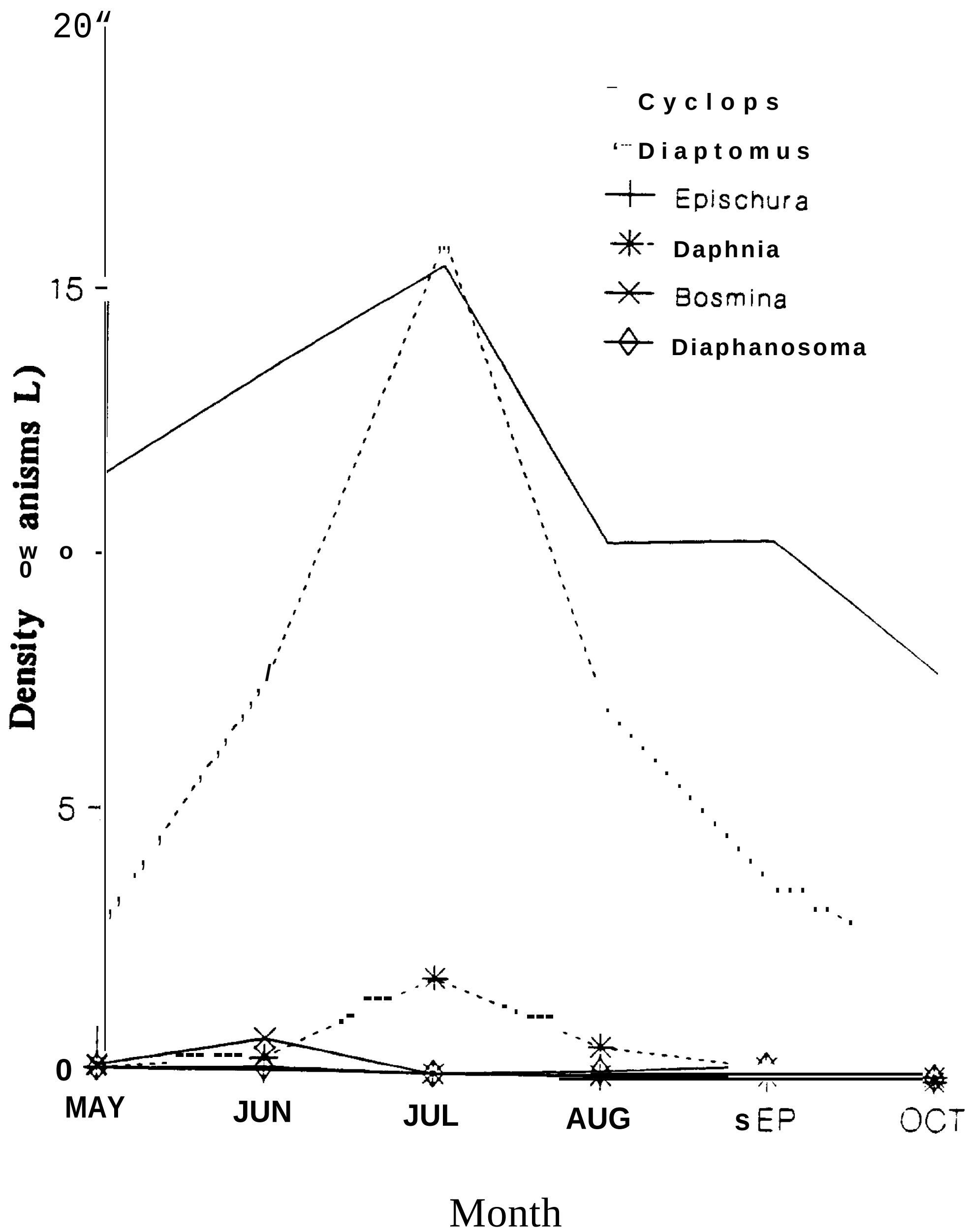
Appendix [illegible] Statistical comparisons (ANOVA) of zooplankton densities from 1985 to 1992 among lake [illegible]ections and years, Lake Pend Oreille, Idaho. Lake section abbreviations are: Southern = S,. Central = C· and Northern = N. Nonsignificant (P>0.10) contrasts are delineated by a common line under each contrast. Estimated density and length increase from left to right for lake sections and years.

Density											
Cyclops	0 111	0 000	N [illegible] S	87	90	85	89	88	91	86	92
Diaptomus	0 [illegible]95	0 000	N S C	[illegible]7	86	[illegible]5	[illegible]1	[illegible]	[illegible]	[illegible]	[illegible]
Epischura	0 [illegible]28	0 [illegible]1	N < S	[illegible]	[illegible]1	[illegible]2	8[illegible]	[illegible]	8[illegible]	87	[illegible]5
Bosmina	0 3[illegible]	0 000	C N S	91	[illegible]6	8[illegible]	[illegible]	[illegible]5	87	[illegible]	[illegible]
[illegible]iaphon[illegible]oma	0 8[illegible]	0 000	S N C	[illegible]1	[illegible]7	85	[illegible]	[illegible]8	[illegible]	[illegible]	
Daphnia	0.[illegible]4	0 [illegible]28	C S N	[illegible]	[illegible]	91	[illegible]	[illegible]	[illegible]7	[illegible]	[illegible]
Total	0.1[illegible]	0 000	N < S	[illegible]1	[illegible]6	[illegible]7	[illegible]	[illegible]5	[illegible]	[illegible]	[illegible]

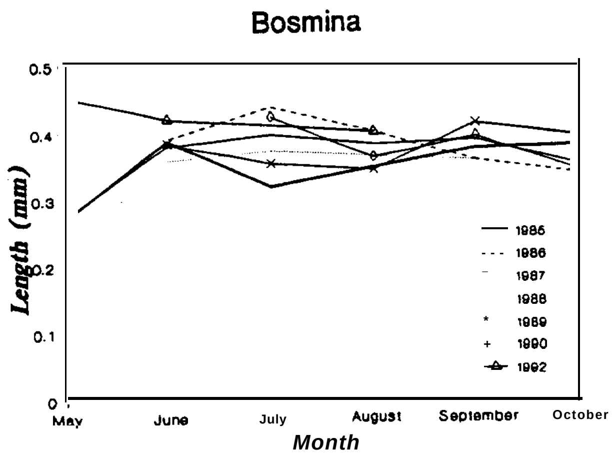
(Continued)
Appendix O. Statistical comparisons (ANOVA) of zooplankton densities from 1985 through 1992 am
years, Lake Penal Oreille, Idaho. Lake section abbreviations are: Southern = S,. Cen
= N., Clark Fork River delta = D. Nonsignificant (P>0.10) contrasts are delineated b
each contrast. Estimated density and length increase from left to right for lake se

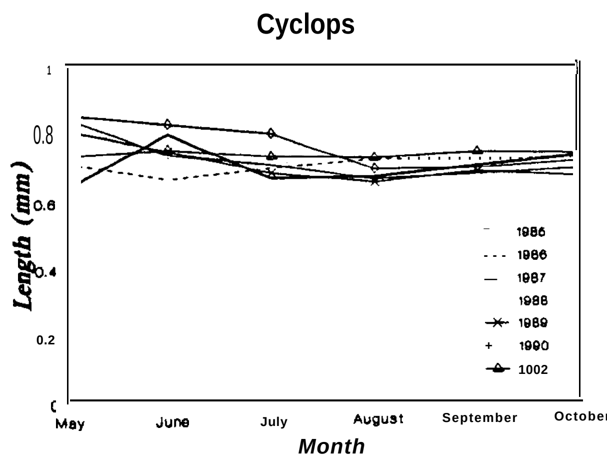
Zooplankton	P level for main effect: Lake section	P level for main effect: Year	Main effect contrasts (P>0.10): Lake section	Main effect contrasts (P>0.10): Year
		Length		
Cyclops	0.838	0.586	N S C D	87 86 89 88
Diaptomus	0.602	0.000	S C N D	89 86 86 92
Epischura	0.617	0.000	C S N D	86 92 87 89
Bosmina	0.246	0.002	S N C D	87 88 90 85
Diaphonosoma	0.328	0.002	S C N.D	86 89 88 85
Daphnia galeata	0.448	0.000	N S C D	87 86 92 85
D. thorata	0.777	0.024	N C S D	86 88 87 85

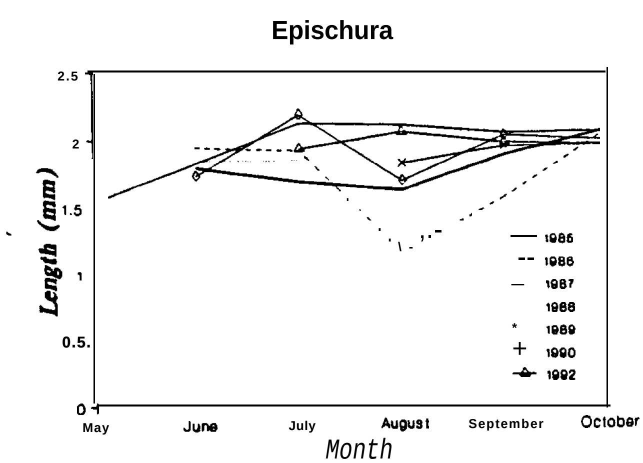
Appendix P. Temporal distribution of mean densities of six genera of zooplankton at Garfield Bay in Lake Penal Oreille, Idaho, May through October, 1992.

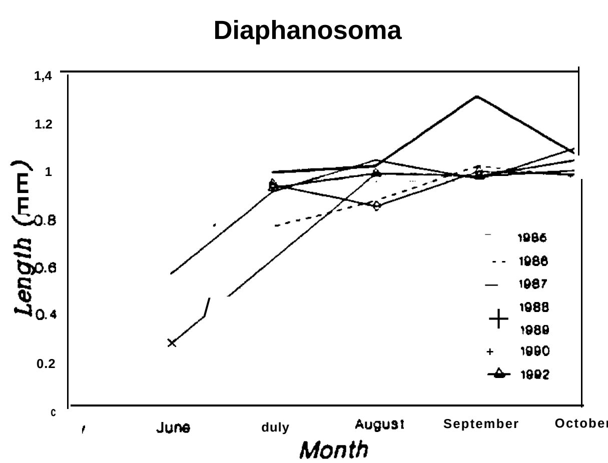


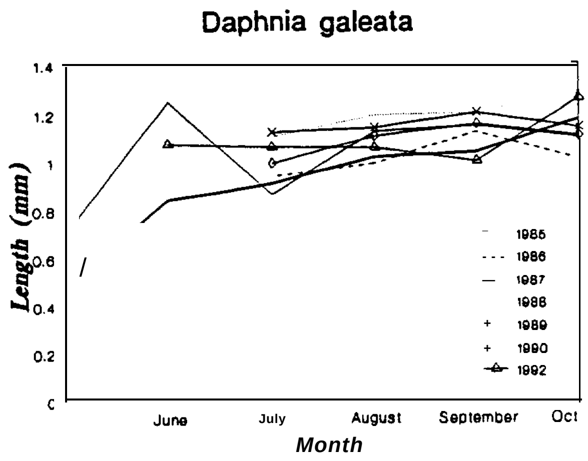
Appendix Q. Mean lengths of seven species or genera of zooplankton by month and year at Lake Penal Oreille, 1985 through 1990 and 1992.

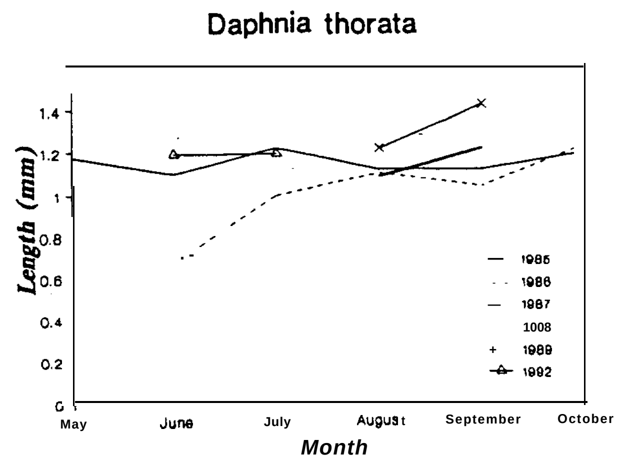


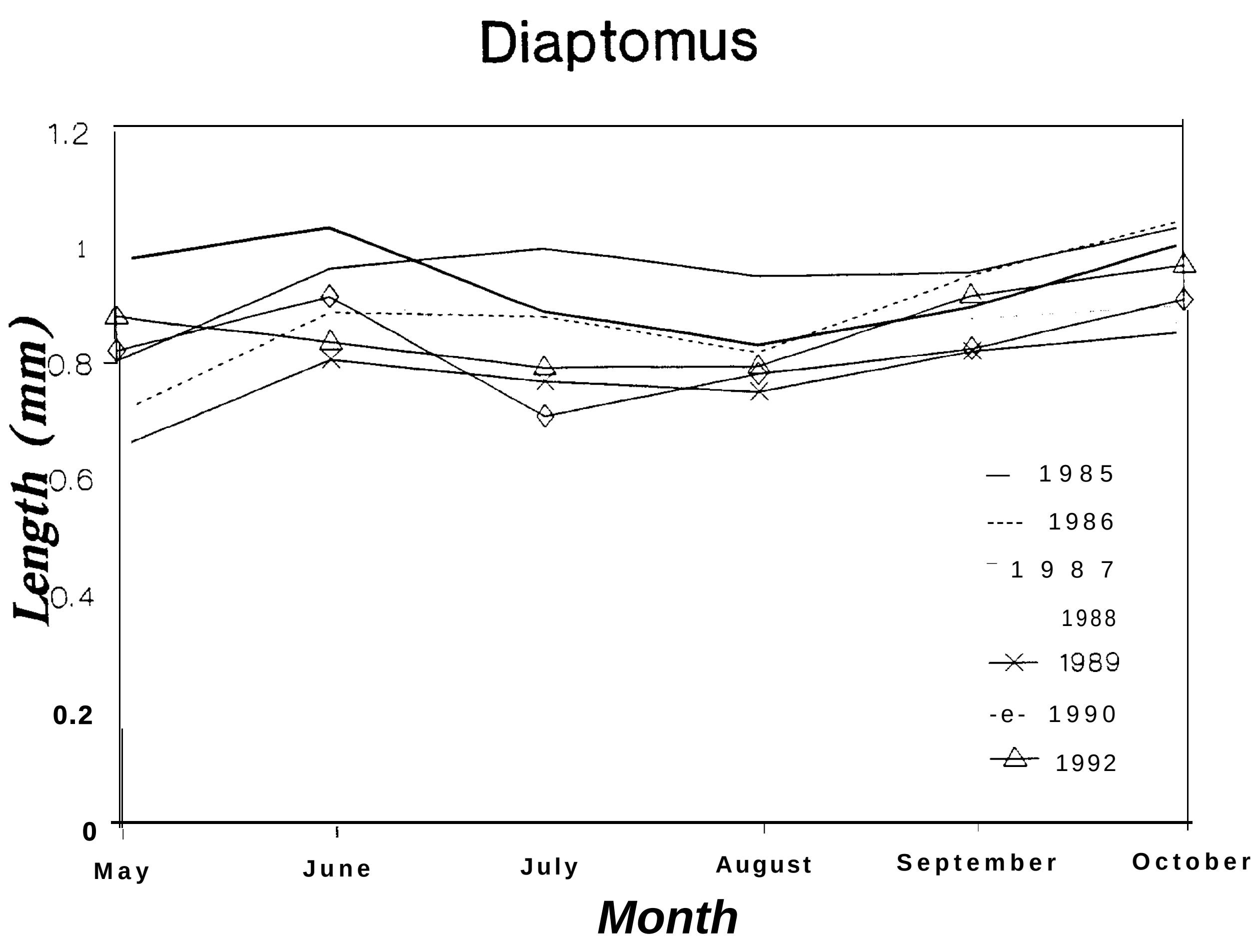




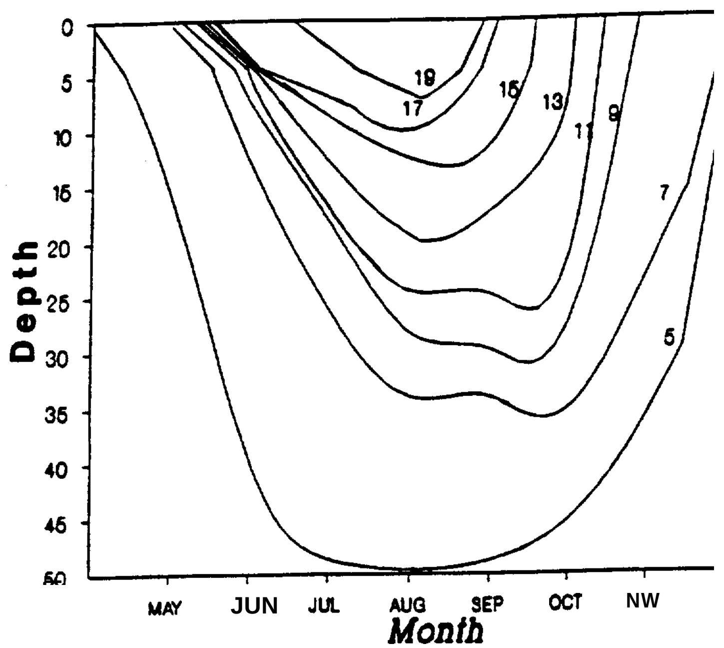


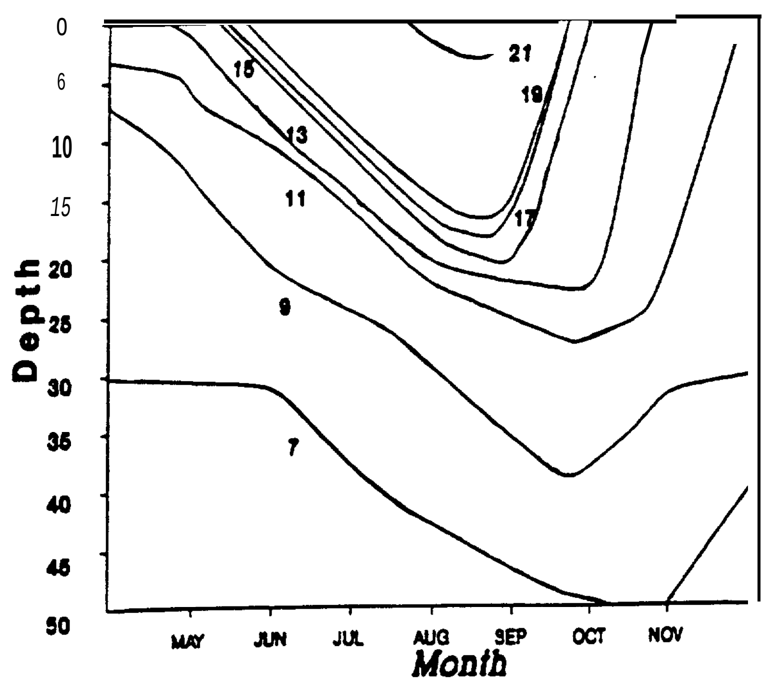

Daphnia galeata
Length (mm)
1.4
1.2
1
0.8
0.6
0.4
0.2
C
June
July
August
September
Oct
Month
1985
1986
1987
1988
1989
1990
1992


Daphnia thorata
Length (mm)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
May
June
July
August
September
October
Month
1985
1986
1987
1008
1989
1992


Diaptomus
Length (mm)
1.2
1
0.8
0.6
0.4
0.2
0
May
June
July
August
September
October
Month
1985
1986
1987
1988
1989
-e- 1990
1992

Appendix R. Distribution of thermal isopleths (^{o}C) in the upper 50 m of Lake Penal Oreille, Idaho, May through November, 1986 - upper figure (an example of slow thermal development) and 1992 - lower figure (an **example of rapid thermal development).**





Appendix S. Secchi depth visibility for the south (S), central (C), and north (N) Sections of Lake Penal Oreille from May through October, 1985 - 1992.

	May			June			July			August			September			October		
Year	S	C	N	S	C	N	S	C	N	S	C	N	S	C	N	S	C	N
1985	--	--	--	5.1	--	3.3	6.8	--	5.8	13.3	10.6	9.8	11.2	--	9.1	10.0	10.3	8.6
1986	3.9	--	3.9	4.6	3.4	2.7	--	--	--	10.4	8.2	--	--	--	--	9.4	7.3	7.0
1987	4.6	5.8	3.4	5.5	4.9	4.9	5.8	4.6	8.8	8.8	8.8	8.2	10.9	9.1	6.7	9.8	10.4	8.8
1988	5.5	6.1	3.9	6.1	5.8	3.4	7.9	8.8	7.0	11.6	13.7	9.8	10.0	9.8	7.9	8.8	8.5	8.5
1989	4.6	4.3	2.1	4.3	6.4	--	7.6	7.3	7.0	12.8	7.6	9.1	11.3	10.4	8.8	10.4	10.1	9.4
1990	7.6	5.8	2.7	6.1	8.8	3.7	8.2	7.0	6.4	6.1	8.2	7.6	9.8	9.1	7.3	7.6	6.1	5.1
1991	5.5	5.1	4.9	3.7	3.9	7.6	6.4	5.5	8.2	8.8	7.6	7.3	6.7	8.2	5.5	7.9	4.6	--
1992	5.8	5.1	3.9	6.7	6.1	5.1	8.8	--	--	10.4	--	9.1	9.8	7.9	6.7	8.8	8.5	8.8
Mean	5.36	5.37	3.01	5.41	5.59	3.86	7.53	6.82	6.75	10.10	9.41	8.74	10.04	8.84	7.81	8.79	8.24	7.6
Range	3.9	4.3	1.2	4.3	3.4	2.7	5.8	4.6	5.5	6.1	7.6	7.6	7.3	6.7	6.7	5.5	6.1	4.6
	7.6	5.8	3.9	6.7	8.8	5.1	8.8	8.8	8.8	12.8	13.7	9.8	11.3	10.4	9.1	10.4	10.4	9.4
SD	1.19	0.66	1.06	0.83	1.83	0.87	0.97	1.52	1.18	2.51	2.11	0.95	1.37	1.34	0.96	1.59	1.55	1.83