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

Annual Progress Report FY 1988

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ABSTRACT

The kokanee Oncorhynchus nerka rehabilitation program for Lake Pend Oreille continued to show progress during 1988. Estimated kokanee abundance in early September was 10.2 million fish. This estimate is 70% higher than 1987 and 140% higher than the population's low point in 1986. Increased population size over the past two years is the result of two consecutive strongyearclasses produced from high recruitment of hatchery and wild fry. High recruitment of wild fry in 1988 resulted from good parental escapement (strong year class) in 1987 and relatively high fry survival.

Hatchery fry made up 51% of total fry recruitment (73% of total fry biomass), which is the largest contribution since hatchery supplementation began in the 1970s. High hatchery fry abundance resulted from a large release (13 million fry) from Cabinet Gorge Hatchery and excellent fry survival (29%) during their first aummer in Lake Pend Oreille. Improved fry release strategies enhanced survival, which doubled from 1987 to 1988 and was ten times higher than survival in 1986. Our research goal is to maintain 30% survival so we are very optimistic, but need to replicate additional years to address annual variability.

Five fry release strategies were evaluated in 1988 to enhance fry survival and adult returns to egg-take stations. Two groups here released in Clark Fork River to help establish a spawning run to Cabinet Gorge Hatchery. High river flows (>850 m^3/s; >30,000 ft^3/s) during the early release (June) helped flush fry quickly to Lake Pend Oreille and increased survival (27%) threefold over previous releases during lower flows (<570 m^3/s; <20,000 ft^3/s). Survival from the midsummer release (29%), which was barged down Clark Fork River to avoid low flow problems, was not significantly higher (P>0.l0) than survival from the early release. The true success of these releases will be evaluated when adults return to cabinet Gorge Hatchery in 1991 and 1992.

Fry released to support the Sullivan Springs spawning run also survived well (29%) in 1988. This represents a 61% increaseoverlastyear, possibly the result of reduced mortality during release into the creek. Two open water releases were made late spring and midsummer. The early release had the lowest survival (22%) of all strategies, whereas the late release had the best survival (36%). Abundant forage and low predation may have contributed to higher survival.

The fishery and egg-take may decline for the next couple years as two weak year classes mature. Effects of the rehabilitation program should be evident by 1991 when the first strong year classes produced from Cabinet Gorge Hatchery enter the fishery and escapement.

INTRODUCTION

Lake Pend Oreille supported the most popular kokanee salmon Oncorhynchus nerka fishery in Idaho from the 1940s until the early 1970s. The sport and commercial fishery yielded 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 fran 1965 to 1985, resulting in an annual harvest of less than 100,000 fish, with a moan catch rate of approximately 1.0 kokanee/h (Bowles et al. 1987). Goals of the kokanee rehabilitation program include an annual harvest of 750,000 kokanee averaging 25 cm long and catch rates averaging 2.0 fish/h. In addition to providing an important fishery, kokanee are the primary forage for trophy Kamloops (Gerrard) reainbow trout Oncorhynchus mykiss and bull trout Salvelinus confluentus in Lake Pend Oreille. Goals of the trophy rainbow rehabilitation program include an average size of 3.2 kg/fish, with trout over 9 kg making up 5% of the harvest.

Several factors contributed to the initial decline of kokanee abundance. Hydropower developnent adversely iqacted spawning success of kokanee salmon. 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 Fend Oreille River approximately 35 km downstream of Lake Fend 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). Cabinet Gorge Dam was constructed on the Clark Fork River (river km 24) for power generation by Washington Water Power Company (WWP). Completion of this dam in 1952 blocked an important kokanee spawning run into Clark Fork River and its tributaries. Declining kokanee abundance may have been accelerated by commercial and sport fishing. The establishment of opossum shrimp Mysis relicta in Lake Pend Oreille during the mid-1970s adversely impacted kokanee recruitment. Idaho Department of Fish and Came (IDFG) introduced Mysis in 1968 to enhance the kokanee forage base. Theexpected response of increased kokanee growth and survival did not occur because mysids competed with postemergent kokanee fry for cladoceran zooplankton. Competition with and predation on zooplankton by mysids delayed production of two cladocerans (Daphnia and Bosmina) that are essential juvenile kokanee forage during the first few weeks of feeding (Rieman and Bowler 1980). Increased growth of older kokanee did not occur because of spatial segregation between Mysis and feeding kokanee. Mysids remain in deepwater during daylight hours and migrate to surface waters at night. Kokanee are visual feeders and are thus able to feed on the shrimp for short periods at dawn and dusk (Rieman 1977).

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. IDF'G restricted kokanee sport harvest and terminated the commercial fishery in 1973. hatchery production of kokanee for Lake Pend Oreille was established by 1974 and helped stabilize population numbers. Delayed planting of hatchery fry until midsumner to avoid early season forage deficiencies increased hatchery fry survival up to 13 times over wild fry (Bowler 1981). Hatchery production kept the fishery from total collapse, 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 Pend Oreille. Researoh indicated that releases of up to 20 million fry annually my be necessary to restore the fishery to historic levels (Rieman 1981).

In an effort to enhance Lake Pend Oreille kokanee production, Cabinet Gorge Hatchery was built on the Clark Fork River 4 km below Cabinet Gorge Dam. Cost of the hatchery was approximately $2.2 million and represented a cooperative effort among BPA, WWP and IDFG. BPA funding was fran on-site resident fish mitigation funds mandated by the Northwest Power Act of 1980. Construction and evaluation of Cabinet Gorge Hatchery is specified by Measure 804(e)(5) of the Colmbia River Basin Fish and Wildlife Program (NWPPC 1984). Cabinet Gorge Hatchery was operational by November 1985 and at full capacity will provide up to 20 million kokanee fry for release into the Pend Oreille system. Rebuilding the kokanee population to attain the goal of over 750,000 kokanee harvested annually and 300,000 hours of effort will depend on production from this hatchery.

This research project was developed by IDFG in cooperation with BPA and WWP to evaluate the contribution of Cabinet Gorge Hatchery to the Lake Pend Oreille kokanee stock and fishery and to provide recommendations for optimizing kokanee production and survival. BPA provided the majority (>90%) of funding for this project. Funds from WWP were used for the fry marking study that examined the feasibility of differentially marking kokanee release groups. WWP also provided funding assistance for evaluating kokanee fry release strategies, which included providing requested discharge rates from Cabinet Gorge Dam.

OBJECTIVES

1. To monitor the kokanee population in Lake Pend Oreille as production increases from Cabinet Gorge Hatchery, including population size, age composition and hatchery-wild composition.

2. To monitor changes in kokanee age composition, growth and survival in relation to population density and carrying capacity of Lake Pend Oreille.

3. To evaluate kokanee release strategies by estimating kokanee fry emigration rate, timing and survival with respect to river discharge, diel timing, moon phase, release site, fish size and number of fry released.

4. To determine feasibility of differentially marking fry release groups by evaluating retention and mortality associated with various marks.

5. lb obtain index information on natural spawning kokmee to monitor contribution of hatchery-m fish.

6. !Ibmm..itorthezooplankton camunity in Lake Pend Oreille and relate to ChangesinkOtiabundance.

RECOMMENDATIONS

1. Although hatchery fry survival in Iake pend Oreille during 1988 nearly met cu research goal of 30%, release strategies should bs replicated in 1989 to evaluate annual variability before major conclusions are drawn.

2. A miinimum of 4 million fry should be released in Clark Fork River each year to provide a potential egg supply of at least 15 million eggs for cabinet Gorge Hatchery. Fry releases into Clark Fork River should coincide with the end of spring runoff during at least 30,000 ft^3/s nighttime flows to insureoptimal fry survival and imprinting.

3. A minimum of 3 million fry should be released into Sullivan Springs each year to maintain a potential egg supply of at least 15 million eggs. Fryreleases into Sullivan Springs Creek should not occur before thermal stratification of Lake Fend Oreille (typically mid-July) to insure adequate forage.

4. All fry released at Cabinet Gorge Hatchery and Sullivan Springs should be imprinted with morpholine which will be used as an adult attractant. A representative portion of fry (>40,000 fish) released in Clark Fork River and Sullivan Springs should be fin clipped to evaluate adult return rates.

5. Average fry length at the time of release should be 50+2 nn for production fish.

6. Thermally marking otoliths of kokanee fry in Cabinet Gorge Hatchery should be discontinued because of low water temperature and inadquate tehrmal gradient. Thermally marking otoliths of kokanee embryos should be evaluated.

7. Additional egg sources will be needed for 1989 and 1990 to supplement low projected egg-take (8 million and 10 million eggs, respectively) at Sullivan Springs. A minimum of 5 million additional eggs/year will be necessary to maintain the kokanee recovery program and avoid large fluctuations in year class strength.

STUDY AREA

Lake Fend Oreille is located in the panhadle of Idaho (Figure 1). It is the largest lake in Idaho, with a surface area of 383 km^2, mean depth of 164 m and maximum depth of 351 m. Mean surface elevation of Lake Pend Oreille is 629 m. The Clark Fork River is the largest tributary to Lake Pend Oreille. Outflow from the lake forms the Pend Oreille River.

Lake Pend Oreille is a tempeate, oligotrophic lake. Sumner temperatures average approximately 9°C in the upper 45 m (Reiman 1977; Bowles et al. 1987, 1988). 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 fran 5 to 11 m.

A wide diversity of fish species are present in Lake Pend Oreille. Kokanee entered the lake in the early 1930s, presumably fran Flathead Lake, and were well established by the 1940s. 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 spiny ray species.

METHODS

Kokanee Population Structure

Kokanee population structure in Lake Pend Oreille was determined fran fish collected with a midwater trawl during the first week of September. Fish from each sample were counted, measured, weighed and checked for maturity. Sagitta otoliths were excised for aging. The midwater trawl was towed by a 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 sonar. Each oblique haul sampled the entire vertical distribution of kokanee, as determined from echograms produced by a Ross 200 angstrom depth sounder with two hull-ted transducers (22° and 8° beam angles). The vertical distribution of kokanee was divided into 3.5 m layers; usually 3 to 5 layers encanpassed the vertical distribution of kokanee. A standard 3.5 min tow was made in each layer, sampling 2,832 m3 of water over a distance of 305 m. Total volume of water sampled for each trawl haul varied from 8,496 to 14,160 m^3, depending on the vertical distribution of kokanee.

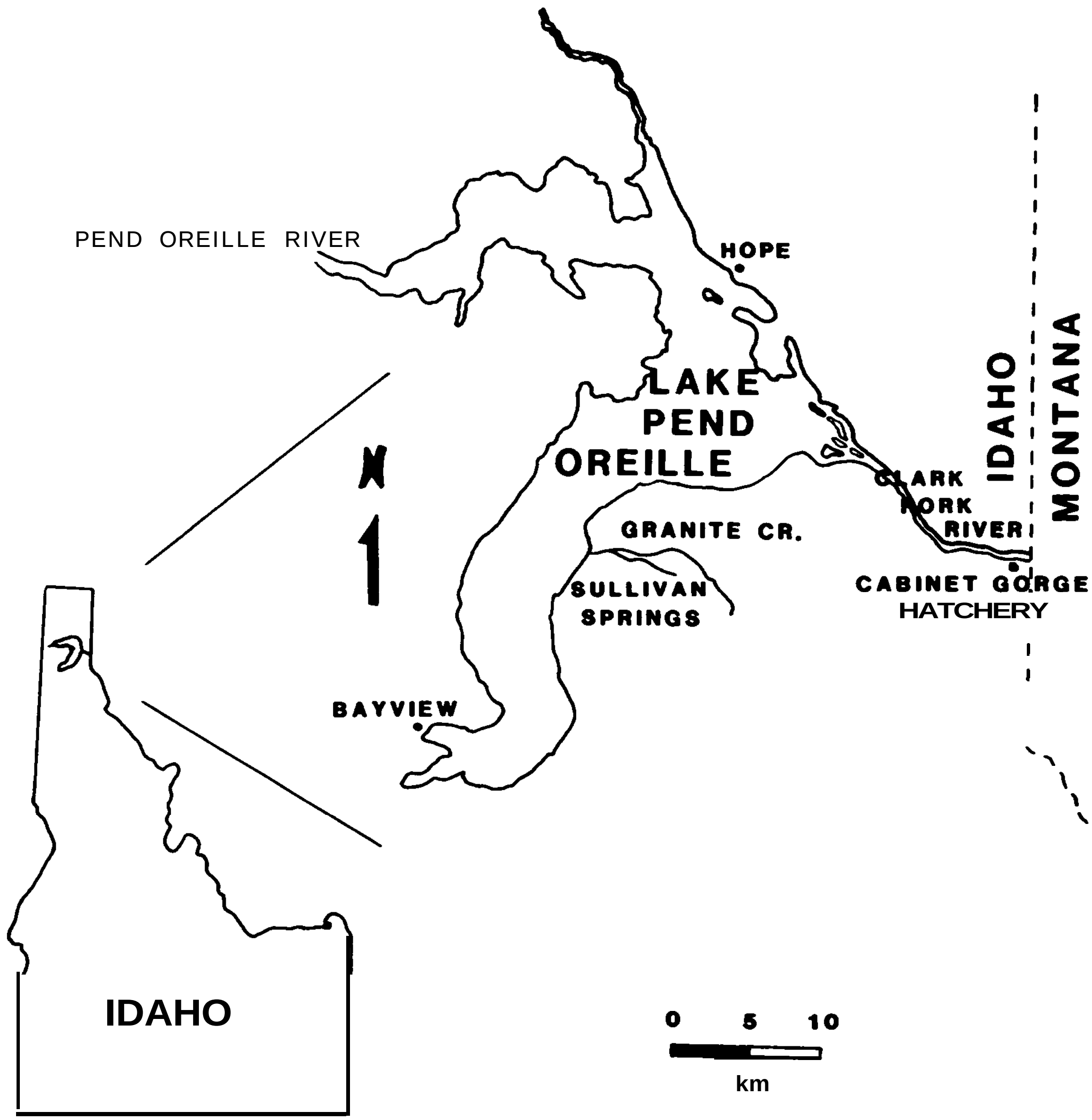

Figure 1. Map of Lake Pend Oreille, Idaho.

A stratified systematic sampling scheme was used to estimate kokanee abundance and density. Lake Pend 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 was calculated from the 36.6 m contour in the northern end 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. Total sample size in 1988 was 36 hauls.

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 estimate (total and by section) were divided by respective lake surface areas to calculate kokanee densities (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 early September of marked or unmarked fry. Fry survival was estimated from potential egg deposition (PED) and release date (hatchery fry only) to September abundance in Lake Pend Oreille. PED was calculated by multiplying average fecundity by estimated mature female kokanee abundance. Hatchery-reared fry were differentiated among release groups by a tetracycline mark and/or analyzing daily growth increments on fry otoliths. Annual survival was estimated for age 1+ and older kokanee by canparing trawl-estimated abundance for each year class between years. Relative distribution of kokanee age classes was determined from abundance estimates for trawl catches within each section.

Fry Marking

Tetracycline

Fry were marked with tetracycline during hatchery residence. Tetracycline (TM-100) was mixed with fish feed at the rate of 5.5% of diet weight and fed to kokanee fry for 10 d prior to their release into Lake Pend Oreille. All fry were marked and held inside the hatchery or under covered raceways because the mark degrades when exposed to ultraviolet (UV) light. Kokanee fry captured in the trawl during early September were examined for tetracycline marks with a longwave (3,600 angstrom) ultraviolet light. When exposed to ultraviolet light, a yellow sheen is observed around the mandibles, opercles and bases of pelvic and pectoral fins. This mark is visible for several months after release (Bowles et al. 1988).

Section	Area (hectares)
1	3.166
2	3.220
3	3,739
4	4,036
5	3,373
6	5,011

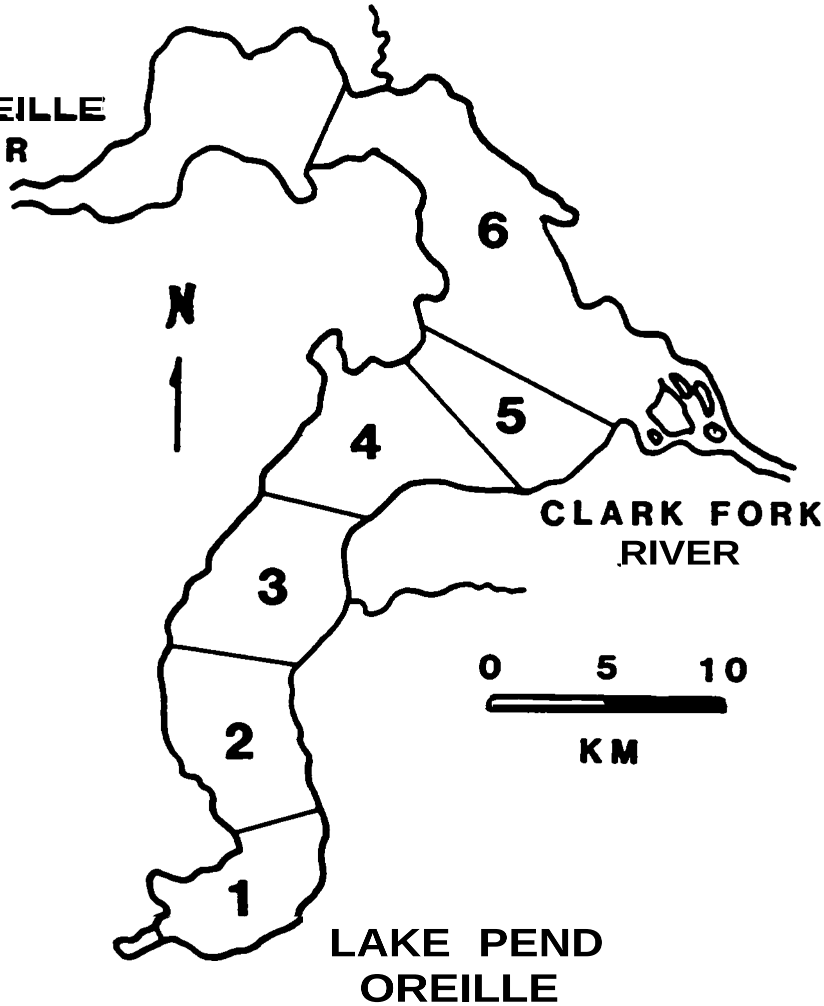

Figure 2. Stratified sampling sections and respective areas (hectares) used during 1988 for trawling and kokanee abundance estimation on Lake Pend Oreille, Idaho.

Otolith Coding

Release date mark. Otoliths from kokanee reared at Cabinet Gorge Hatchery exhibit an obvious change in width of daily growth increments at the time of their release (Bowles et al. 1988). This mark was used to distinguish hatchery residence from lake residence. Kokanee released on different dates were identified by counting daily growth increments 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 (Spurr 1969). The proximal surface was polished (600 grit paper) and otolith microstructure observed (1000 power) with an oil imnersion compound microscope interfaced with a video camera and monitor.

Thermal mark. Water temperature was manipulated at Cabinet Gorge Hatchery to determine the feasibility of thermally marking kokanee fry otoliths. A single mark was administered to 5 million fry (25 mm) in late March. Water temperature was raised from 2.0°C to 8.8% over 8 h. The elevated temperature was maintained for 3 d before reducing to 3.5°C over 8 h. Changes in width and opacity of daily growth increments were examined two weeks after the mark was administered to determine if the mark was distinguishable.

Fin Clip

A fin was clipped from selected groups of kokanee fry to help evaluate fry-to-adult return rates to spawning stations at Cabinet Gorge Hatchery and Sullivan Springs Creek. Possible clips included the adipose fin and left or right pelvic fins. Fry were clipped at least 1 week prior to release and averaged 48 mm total length (1,100 fry/kg). 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.

Fry Release Strategies

Five fry release strategies were evaluated to optimize survival of fry in Lake Rend Oreille and adult returns to egg-take stations at Cabinet Gorge Hatchery and Sullivan Springs Creek. Table 1 summarizes location, date, size and number of fish released and marks used to differentiate release groups.

Clark Fork River

Approximately 4.7 million fry were released in Clark Fork River to establish a spawning run to Cabinet Gorge Hatchery. All fry were imprinted with morpholine ($5x10^{-5}$ mg/L in hatchery water) for 3 d prior to release. Morpholine was also added to hatchery water flowing from the fish ladder at

Table 1. Hatchery-reared kokanee fry released into Lake Pend Oreille Idaho, during 1988.

Release strategy[a]	Release site	Release dates	Time	Number release (millions)	mean size (mm)	Marks[a]
Clark Fork River						
Early summer	Cabinet Gorge Hatchery	6/15	dusk	3.414	51	Otolith code
Mid-summer (barge)	Cabinet Gorge hatchery (barged to Clark Fork River mouth)	7/5-9	day/dusk	I.297	48	Otolith code Tetracycline
			Subtotal	4.711		
Sullivan Springs	Sullivan Springs	7/11-14	day/night	‘1.139	49	Otolith code
			Subtotal	5.139		
Open Water						
Early summer	Northern Lake Pend Oreille	6/27	day	1.607	46	Otolith code Tetracycline
Mid-summer	Southern Lake Pend Oreille	7/26	day	1.570	51	Otolith code Tetracycline
			Subtotal	3.177		
			Total	13.027	49	

[a] Refer to the Methods section for detailed description:; of realease strategies and marks.

Cabinet Gorge Hatchery into Clark Fork River for 3 d following each release. Two strategies were evaluated for fry released into Clark Fork River.

Early season release. Approximately 3.4 million fry were released through the Cabinet Gorge Hatchery fish ladder into Clark Fork River on June 15, 1988. This release was scheduled to coincide with high nighttime river flows resulting from spring snowmelt. This early season release allowed Washington Water Power Company (WWP) to provide an average hourly discharge of 809 m^3/s (28,600 ft^3/s) flows from Cabinet Gorge Dam for 2.5 nights following the fry release (Figure 3). Nighttime electrofishing (DC) near the mouth of Clark Fork River (22 km from hatchery) was used to estimate fry emigration rate and potential fry mortality from predation. Fry emigration rate was estimated by comparing catch-per-unit-effort of fry from three stations in the Clark Fork River delta sampled for two nights following the fry release. Stomachs were examined from potential predators caught during electrofishing to determine relative degree of predation throughout the night. Approximately 50,000 fry were fin clipped (left pelvic fin) to provide an estimate of the fry-to-adult return rate for spawners migrating to the hatchery in 1991 and 1992.

Midsummer release. During July 5-9, 1988, approximately 1.3 million fry were barged down Clark Fork River and released into Lake Pend Oreille near the river mouth. This strategy evaluated the feasibility of transporting fry down Clark Fork River during midsummer when nighttime flows are low (3,000 ft^3/s) but availability of forage (cladoceran zooplankton) in Lake Fend Oreille is high. Transportation was necessary because fry emigration success to Lake Pend Oreille during low (<20,000 ft^3/s) nighttime flows is poor (Bowles et al. 1987, 1988). Fry were barged to allow them to imprint on Clark Fork River water which may enhance adult returns to Cabinet Gorge Hatchery for spawning. The 8.5 m pontoon barge held 8.8 m^3 water in two circular tanks which were aerated and plumbed to provide a constant flow of river water to fry. The barge transported a maximum of 150,000, 48 mm fry (18 kg/m3 loading density) each 4 h trip from Cabinet Gorge Hatchery to Lake Fend Oreille (22 km). Marks used to distinguish this release group during trawling included tetracycline and the otolith date-of-release mark. Approximately 40,000 fry were also fin clipped (right pelvic) to help evaluate adult returns for spawning in 1991 and 1992.

Sullivan Springs

Approximately 5.1 million fry were transported by truck from Cabinet Gorge Hatchery to Sullivan Springs Creek during July 11-14, 1988. The fry were transported at a density of 208 kg/m3 in 10.0°C water and released into 8.1°C creek water. The purpose of this release was to insure continued adult returns to the egg-take station on this spring-fed tributary to Lake Pend Oreille. The otolith date-of-release mark was used to distinguish fry during autumn trawling in Lake Pend Oreille. Approximately 40,000 fry were also fin clipped (adipose) to evaluate adult returns for spawning in 1991 and 1992.

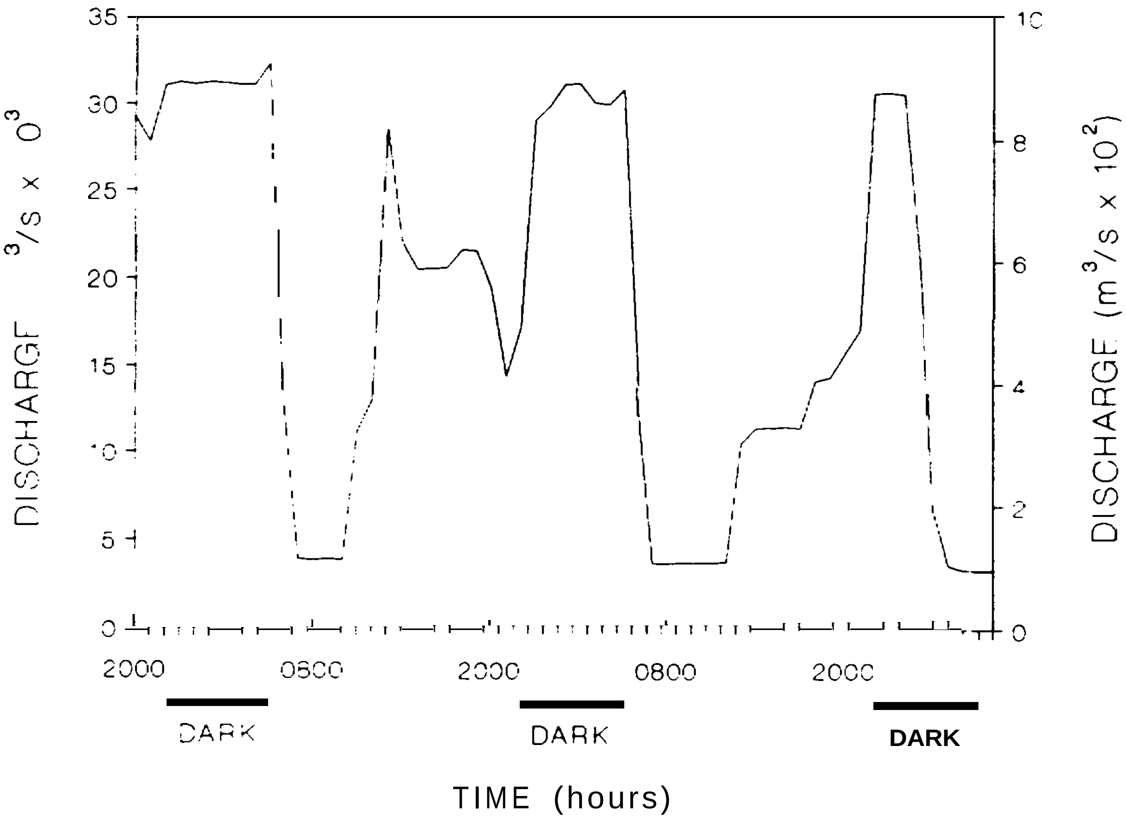

Figure 3. **Discharge from Cabinet Gorge Dam into Clark Fork River during three nights (June 15-17, 1988) following the fry release (at 2100 hours the first night) from Cabinet Gorge Hatchery.**

Open Water

Approximately 3.2 million fry were released into Lake Pend Oreille to evaluate survival of open water releases made before and after thermal stratification of Lake Pend Oreille. All fry were markedwithtetracycline which was used with the otolith date-of-release mark to differentiate release groups.

Late spring release. Approximately 1.6 million fry were released June 27 in northern Lake Pend Oreille, 3 km southwest of Hope, Idaho (Figure 1). Kokanee were trucked at a density of 208 kg/m3 in 9.1°C water from Cabinet Gorge Hatchery to the town of Hope. Each truck was transported to the release site on a 40 ton barge towed by a 300hp tugboat. Approximately 30% of the fry were released 10 m deep into Lake Pend Oreille (11.7°C). Other fry were acclimated to lake surface water (15.5°C) over a 45 min period prior to release at the surface of Lake Pend Oreille.

Midsummer release. Approximately 1.6 million fry were released July 26 in southern Lake Pend Oreille, 2 km east of Bayview, Idaho (Figure 1). Kokanee were trucked at a density of 208 kg/m3 in 10.9°C water from Cabinet Gorge Hatchery to the town of Bayview. Each truck was transported to the release site with an 80 ton mrk barge and tug supplied and operated by the U.S. Department of Navy, Naval Acoustic Research Detachment. Fish were acclimated to lake water (16.5oC) for 45 min prior to surface water release into Lake Fend Oreille.

Egg Take

Since 1974, Idaho Department of Fish and Game has maintained a permanent weir at the mouth of Sullivan Springs Creek (tributary to Granite Creek), a major kokanee spawning tributary to Lake Pend Oreille (Figure 1). This egg take station has provided kokanee eggs for Lake Pend Oreille, as well as enhancanent activities for other lakes. Additional eggs were collected from kokanee spawners collected at Clark Fork Hatchery on Spring Creek and the Cabinet Gorge Hatchery fish ladder on Clark Fork River.

Naturally Spawning Kokanee

Adult kokanee were enumerated along lakeshore and tributary stream spawning areas to provide an index of naturally spawning kokanee abundance. Counts were made by walking each area once during the first week of December, the estimated peak of spawning activity. Only predetermined portions of lakeshore spawning areas were surveyed, whereas entire spawning areas were censused in tributary streams. Trestle Creek was also censused in September to determine use by early run kokanee spawners.

Age and Length at Maturity

Total length was measured and otoliths extracted fran mature kokanee collected during the late fall spawning season for spawner age and length distributions. Spawners were collected at Scenic Bay with a gill net and from the weir on Sullivan Springs Creek. Additional carcasses were collected from other tributary streams. Age of maturity was also estimated for kokanee collected during September trawling.

Zooplankton

The zooplankton community was sampled in the southern, central, northern and Clark Fork River delta portions of Lake Fend Oreille (Figure 4). Five random samples were collected monthly from each section from May through October in teh main body of the lake and from June through September in the delta section. Samples in the main body of the lake were collected with a 0.5 m diameter ring plankton sampler calibrated by a General Oceanics flow meter and equipped with a 130 micron net and bucket. 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. Samples from the shallower delta section were collected with a Miller high-speed plankton sampler quipped with a flow meter and 130 micron net and bucket. In the delta, the entire water column was sampled with oblique tows stepped at 1.5 m intervals. The sampler was 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. Up to 30 organisms/genus/sample were measured by projecting their image on a calibrated screen. Mean lengths were calculated for each month and lake section. Analysis of variance, utilizing a stratified random sampling scheme, was used to compare zooplankton densities and lengths both spatially and temprally.

Mysid Shrimp

Mysis were sampled at nightduringthe dark moon phase the first week of June. Five samples were collected randomly in each of the three main-lake sections designated for zooplankton sampling (Figure 4). Samples were collected with a Miller high-speed sampler equipped with a General Oceanics flow meter and a 130 micron plankton net and bucket. Stepped oblique tows were made fran 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. *Mysis* from each sample were counted and differentiated by age class (juvenile or adult). Density estimates were based on volume of water filtered and comparisons made between age classes and among lake sections and years.

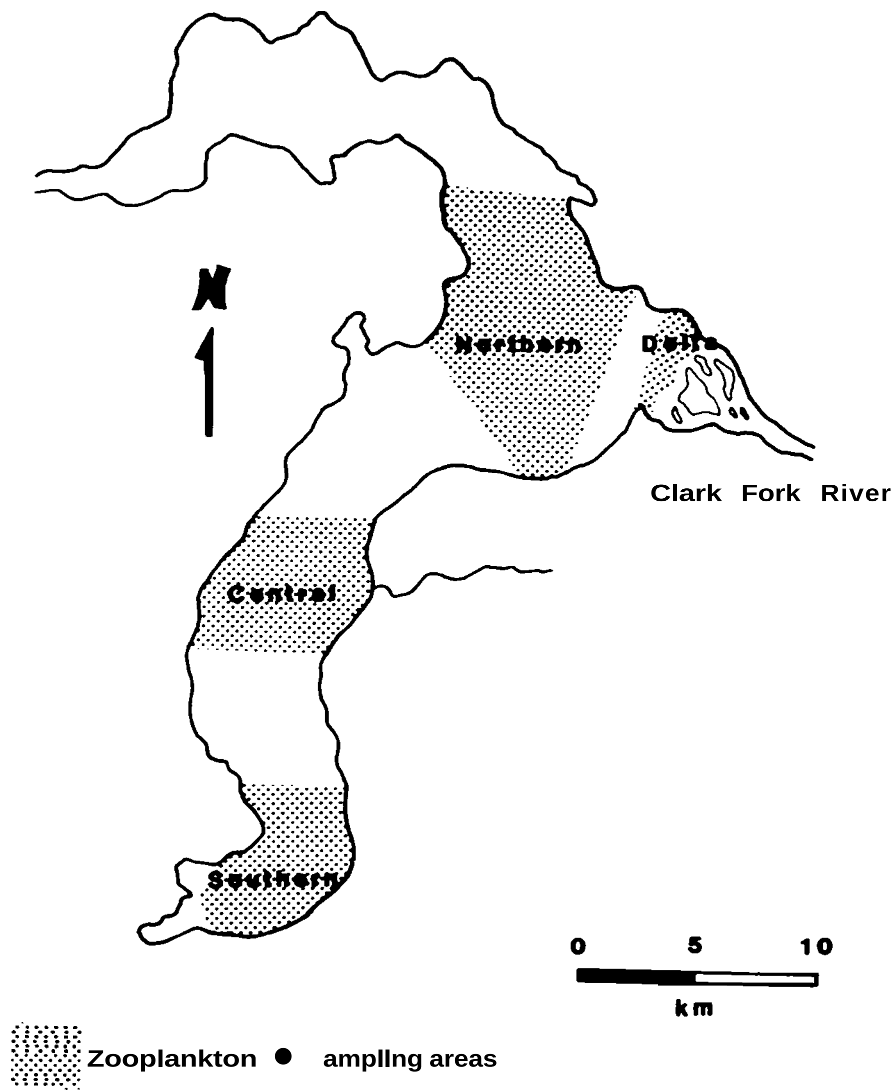

Figure 4. **Zooplankton sampling areas on Lake Pend Oreille, Idaho.**

Water Temperature and Transparency

Thermal stratification of Lake Bend 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 50 m depths at l m intervals for the first 5 m and at 5 m intervals thereafter. Water transparencies were monitored temporally and spatially. A Secchi disk reading was taken in the southern, central and northern sections of Lake Pend Oreille each month from May through October.

RESULTS

Kokanee Abundance, Distribution and Biomass

Estimated total kokanee abundance during earlySeptember 1988, was 10.21 million fish (Figure 5). Contribution of individual year classes was 7.31 million for the 1987 year class (age 0+), 1.66 million for the 1986 year class (age l+), 0.51 million for the 1985 year class (age 2+), 0.38 million for the 1984 year class (aqe 3+) and 0.35 million for the 1983 year class (age 4+).

Estimated average kokanee density for the entire lake (all age classes combined) was 451 fish/hectare (Figure 6; Appendix A). Densities ranged from a high of 534 kokanee/hectare in Section 6 to a low of 334 kokanee/hectare in Section 5. Age 0+ wild kokanee densities were highest in southern and central sections of Lake Bend Oreille, whereas hatchery fry densities were highest in the northern and central sections of the lake. Densities of age l+ kokanee were highest in the northern section of Lake Pend Oreille and lowest in southern sections. In general, age 2+ and older kokanee densities were highest in southern sections and lowest in northern sections of Lake Fend Oreille.

Estimated kokanee bianass in Lake Pend Oreille during early September was 181,650 kg (8.02 kg/hectare) (Table 2). Bianass of hatchery-reared kokanee fry was 7,490 kg (0.33 kg/hectare), 73% of total fry biomass in the lake. Estimated bianass of age l+ and older kokanee was 171,450 (7.57 kg/hectare). Length frequencies and mean lengths and weights of kokanee caught in the trawl are shown in Figure 7 and Table 2.

Spawning Escapement

An estimated 574,500 mature kokanee comprised the Lake Bend Oreille spawning population in 1987 (Bowles et al. 1988). The 1987 spawning run to Sullivan Springs Creek was approximately 83,600 kokanee (15% of the total

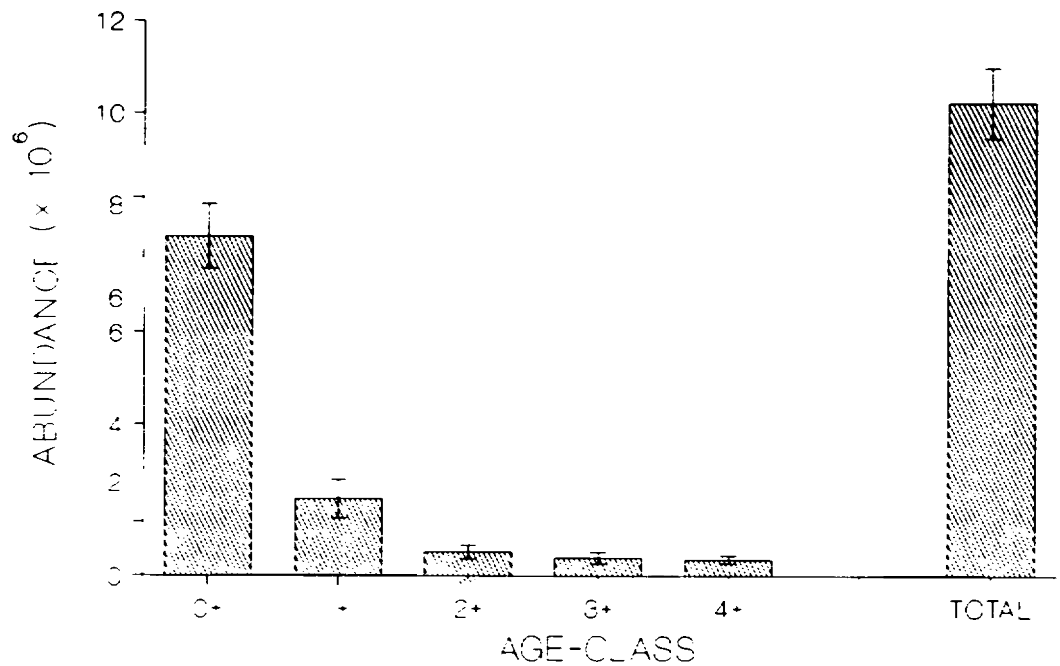

Figure 5. Estimated kokanee abundance, with 90% confidence intervals, during early September, 1988, Lake Pend Oreille, Idaho.

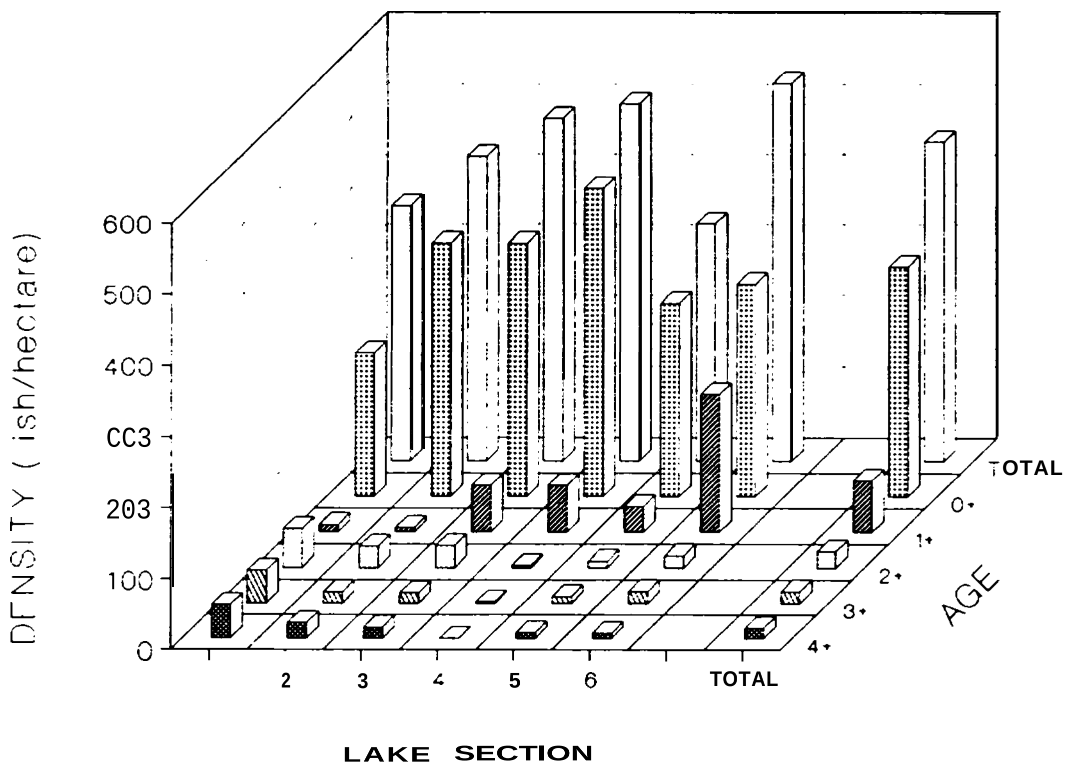

Figure 6. Kokanee density in Lake Pend Oreille, Idaho, by age Class and lake section during early September, 1988.

Table 2. Mean length, weight and biomss of kokanee caught trawling during early September, 1988, Lake Pend Oreille, Idaho.

Age class	Mean length (mn)	Mean weight (g)	Bianass kg	kg/hectare
Age 0+				
Hatchery	62	2.00	7,487	0.33
Wild	45	0.76	2,711	0.12
Combined	54	1.39	10,198	0.45
Age 1+	138	21	33,960	1.50
Age 2+	205	69	35,311	1.56
Age 3+	242	116	44,595	1.97
Age 4+	270	166	57,586	2.54
All Ages			181,650	8.02

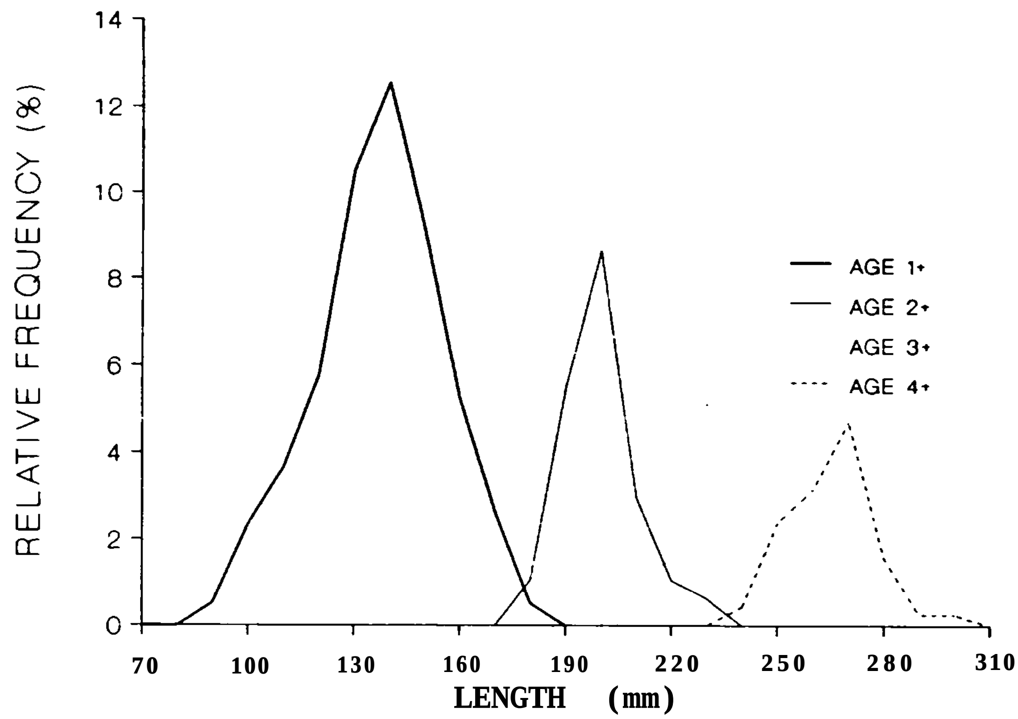

Figure 7. Length frequency of kokanee, by age class, in Lake Pend Oreille, Idaho, during early September, 1988.

escapenent) and extended from the first week in November to early January. The estimated return of hatchery-reared fry as adults in 1987 was 3.5%. One-time late spawning kokanee counts (December) in other tributaries ranged fran 2,760 in South Gold Creek to none in most tributaries in northern Lake Pend Oreille. Lakeshore spawner counts ranged from 1,436 kokanee on southern lakeshore areas to 350 on northern lakeshore beaches (Appendix B). A count of 410 early run kokanee spawners was made in Trestle Creek during September 1987.

The 1988 spawning population estimate of 446,240 kokanee was derived fran September trawling data. The spawning run to Sullivan Springs Creek during 1988 was approximately 68,000 kokanee (15% of total escapament) and extended from the first week in November to the end of December. one-tine late spawning kokanee counts (December) in other tributaries ranged from 9,000 spawners in Spring Creek to 0 spawners observed in Johnson, Twin, Trestle and Garfield creeks (Appendix B). Counts of lakeshore spawning kokanee ranged from 2,100 on southern beaches to only 37 kokanee spawners counted on northern lakeshore areas. A count of 422 early run kokanee spawnerswas made in Trestle Creek during September

Age and Length at Maturity

Age composition of mature kokanee captured during trawling in 1988 was 25% age 3+ and 75% age 4+ (N=61). An estimated 29% of age 3+ kokanee were mature and consisted of 37% males and 63% females Approximately 97% of age 4+ kokanee were mature and consisted of 44% males and 56% females. Age composition of kokanee spawned during 1987 from Sullivan Springs Creek was 93% age 4+ and 7% age 3+ (N=72). Age composition for spawners collected during 1988 will be reported in the Annual Report for fiscal year 1989.

Mean lengths of kokanee spawners did not vary significantly (P>0.05) between years or among spawning sites during 1987 and 1988 (Table 3). Mean lengths of male kokanee ranged from 280 mm to 291 mm total length, whereas man length of female kokanee ranged from 257 mm to 277 mm total length.

Potential Egg Deposition

Estimated total potential egg deposition for 1987 was 126.5 million with 108.3 million eggs attributed to natural spawning and a potential of 18.2 million eggs available fran artificially spawned kokanee at Sullivan Springs. Estimated abundance of mature female kokanee during 1987 was 283,600 (Bowles et al. 1988). Approximately 41,800 female kokanee were spawned at the Sullivan Springs trap, which left an estimated 241,800 female kokanee to spawn naturally throughout Lake Pend Oreille and its tributaries. Fecundity averaged 446+32 (N=43, alpha=0.05) viable eggs/female.

Estimated total potential egg deposition for 1988 was 118.3 million with 102.3 million eggs attributed to natural spawning and a potential of 16.0 million eggs available fran artificially spawned kokanee at Sullivan

Table 3. Mean total length (mm) of kokanee spawners collected from four locations on Lake Pend Oreille, Idaho, during 1987 and 1988. A 95% error bound is specified for each estimate. Sample size is in parentheses.

Location	1987 Male	1987 Female	1988 Male	1988 Female
Sullivan Springs Creek	283±4 (37)	277±4 (38)	283±5 (20)	275±4 (36)
Southern lakeshore	281±4 (17)	262±21 (3)	291±6 (10)	271±6 (11)
Southern tributary (Gold Creek)	280±6 (12)	269±5 (8)	280±7 (14)	257±4 (15)
Northern tributary (Spring and Trestle creeks)	283±5 (26)	272±5 (14)	285±4 (19)	274±10 (6)

Springs. Estimated abundance of mature female kokanee was 241,000 fish determined from September trawling. Approximately 32,700 female kokanee were spawned at the Sullivan Springs trap, which left an estimated 208,300 female kokanee to spawn naturally throughout Lake Pend Oreille and its tributaries. Fecundity averaged 490±22 (N=36, alpha=0.05) viable eggs/female.

Egg Take

Egg take for Lake Pend Oreille during 1987 totaled 17.2 million. Kokanee spawned at Sullivan Springs provided 16.6 million eggs (408±25 eggs/female; N=43, alpha=0.05), which represents a 91% spawning efficiency. An additional 0.6 million eggs were taken at Cabinet Gorge Hatchery from kokanee migrating up Clark Fork River.

Total egg take during 1988 was 14.2 million. Egg take at Sullivan Springs was 14.1 million (430±22 eggs/female; N=22, alpha=0.05), which represents a spawning efficiency of 88%. An additional 0.1 million eggs were taken at Cabinet Gorge Hatchery.

Fry Emigration and Predation

Relative catches of hatchery-reared kokanee fry at the mouth of Clark Fork River indicated that 93% of fry emigrating to Lake Pend Oreille completed the joumey the first night following their release at Cabinet Gorge Hatchery. The remaining 7% of successful emigrants arrived at the lake by 0230 hours the second night following their release.

Predation on kokanee fry during emigration through the lower Clark Fork River and delta was minimal. No kokanee were observed in stomachs of squawfish Ptychocheilus oregonsis (N=13), peamouth Mylocheilus caurinus (N=15) or largescale suckers Catostomus macrocheilus (N=15) collect& electrofishing during two nights following the fry release at Cabinet Gorge Hatchery. All squawfish captured were immature and less than 300 mm total length. No trout or char were captured.

Survival and Recruitment

Estimated kokanee fry survival (hatchery and wild fish combined) from potential egg deposition to early September trawl sampling was 5.8% for the 1987 year class. Survival estimates for hatchery and wild fry were 21% and 3.3%, respectively. A survival rate of 29% was estimated for 1987 year class hatchery-reared fry fran time of release mid-June through July to fall sampling in early September.

Fry survival from release to fall trawling was 27±4% for the early season release in Clark Fork River, 29±5% for the midsummer release (barged) in Clark Fork River, 294% for fry released in Sullivan Springs Creek, 22±6% for the early season open water release (north) and 36±4% for the midsummer open water release (south) (Figure 8). Fry survival associated with the midsummer open water release was significantly higher ($P<0.10$) than for early season open water and early season Clark Fork River releases. Pairwise comparisons between other release strategies did not show significant differences ($P>0.10$).

Hatchery fry provided an estimated 51% of the total kokanee fry recruitment in 1988. Fry released into Sullivan Springs and Clark Fork River made up 20% and 18%, respectively, of total fry recruitment in Lake Pend Oreille, (40% and 35% of hatchery fry recruitment). Open water releases contributed 13% to total fry recruitment (25% of hatchery fry recruitment). Although dispersal of hatchery-reared fry throughout the lake was evident following 1 to 2.5 months of lake residence, abundance remained highest in lake sections near release sites (Figure 9).

Estimated annual survival (late summer 1987 to late Summer 1988 for wild and hatchery fish combined) was 47% for the 1986 year class (age 1+), 66% for the 1985 year class (age 2+), 46% for the 1984 year class (age 3+) and 81% for the 1983 year class (age 4+).

Fry Marking

Analysis of daily growth rings on kokanee fry otoliths indicated an obvious mark at the time of release which separated hatchery residence from lake residence. Mean width of daily growth increments was approximately two times larger during hatchery residence than lake residence. Approximately 47% of counts ($N=100$) from the time-of-release mark to the otolith margin fell within the expected number of days from the releases to fall sampling. Over 96% of counts were within 2 d of the expected dates.

Producing a discernable thermal mark on kokanee fry otoliths was not successful in 1988. Growth increments examined on 25 pairs of otoliths two weeks after water temperature manipulation failed to show a consistent mark associated with the elevated temperature.

Mysid Shrimp

Density of *Mysis* in Lake Pend Oreille during early June, 1988, averaged 0.047 organisms/L (Figure 10). This estimate was significantly higher ($P=0.001$) than the 1987 estimate (0.020 organisms/L) and similar ($P=0.262$) to the 1986 estimate (0.039 organisms/L). Total densities during 1986-1988 were similar ($P=0.389$) between southern and central lake sections and significantly lower ($P=0.005$) in the northern section.

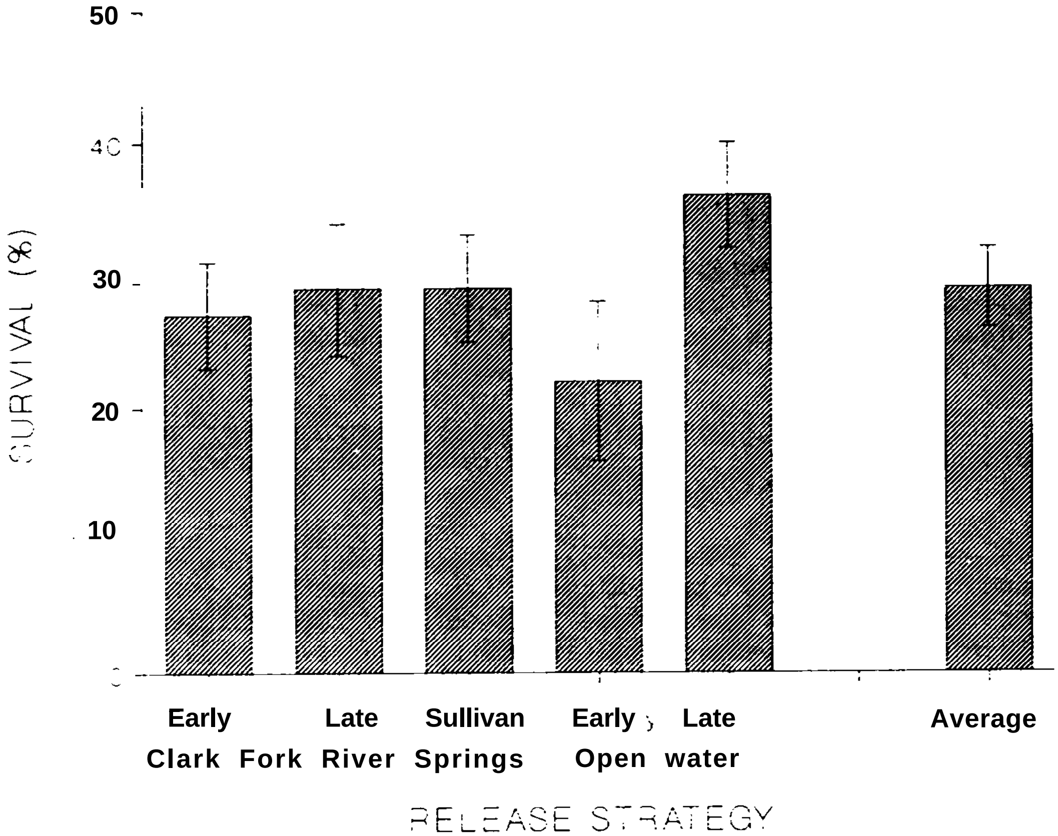

Figure 8. **Estimated survival of hatchery fry during their first summer in Lake Pend Oreille, Idaho, compared among five release strategies evaluated in 1988. A 90% error bound is depicted for each estimate**

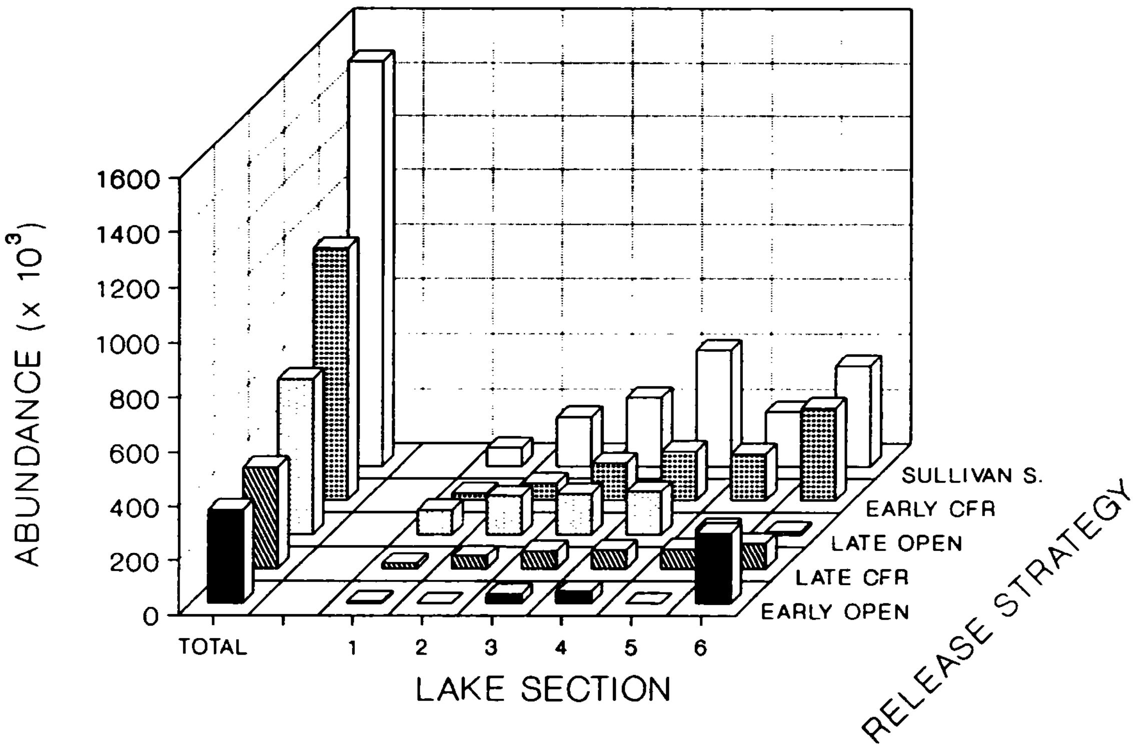

Figure 9. Abundance and distribution of hatchery-reared kokanee fry during early September, 1988, compared among five release strategies into Lake Pend Oreille, Idaho.

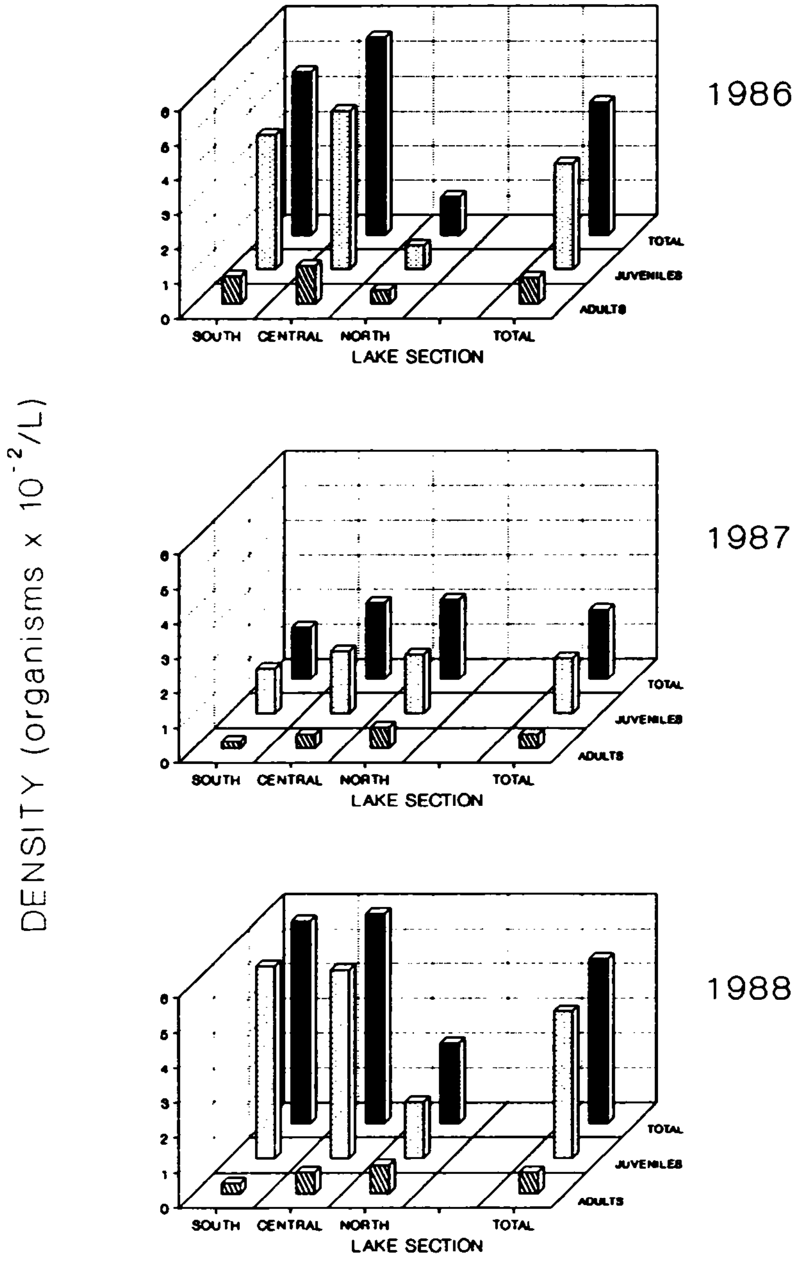

Figure 10. **Mean adult, juvenile and total densities of *Mysis* in Lake Pend Oreille, Idaho, sampled during June, 1986 through 1988.**

Juveniles comprised 89% of total Mysis abundance in Lake Pend Oreille with an average density of 0.042 organisms/L (Figure 10). Estimated juvenile density in 1988 was significantly higher (P=0.001) than 1987 (0.016 organisms/L) but not significantly different (P=0.145) than the 1986 estimate (0.031 organisms/L). Juvenile densities during 1986-1988 were similar (P=0.573) between southern and central lake sections and significantly lower (P=0.002) in the northern section during early June.

Adult mysids comprised 11% of total Mysis abundance during early June, 1988 (Figure 10). Adult density averaged 0.006 organisms/L and was not significantly different (0.106<P<0.271) than estimated density for 1986 (0.008 organisms/L) or 1987 (0.004 organisms/L). Adult densities in 1988 did not vary significantly (P=0.172) among northern, central or southern sections of Lake Pend Oreille.

Zooplankton Community

Generic composition of zooplankton in Lake Pend Oreille from May through October 1988 included Daphnia, Bosmina, Diaphanosoma, Cyclops, Diaptomus and Epischura. Copepod densities were higher than cladoceran densities throughout the sampling period (Figure 11). Cladoceran production peaked in August at approximately 12% of copepod production. Total zooplankton density ranged from approximately 7 organisms/L in May to approximately 36 organisms/L in August (Figure 12). The copepods Cyclops and Diaptomus were the most abundant zooplankters, with combined densities ranging from approximately 7 organisms/L in May to approximately 32 organisms/L in July and August. Average densities of these copepods were significantly higher (P<0.10) in 1988 than the previous three years, and densities during June ware significantly higher (P<0.10) in 1988 and 1987 than 1986 and 1985 (Figures 12 and 13, Appendix C). The cladocerans Daphnia and Bosmina were not common in samples taken during 1988 until July, which is similar to 1985 and 1986 but one month behind cladoceran production in 1987. Bosmina densities in 1988 were significantly lower (P<0.0005) than 1987 as production began later in the year and peaked during July at 0.3 organisms/L compared to a peak of 1.4 organisms/L during August, 1987. Mean density of Daphnia in 1988 did not differ significantly (P=0.167) fran 1987 but production in 1987 began one month earlier and continued one month later. Epischura were rarely found in Lake Pend Oreille until August and densities were lower than 1987 throughout the season. Deaphanosoma were also uncommon in samples until August but densities were higher than 1987 throughout the season. In general, zooplankton densities were similar (P>0.10) among northern, southern and central sections of Lake Pend Oreille (Figure 13, Appendix C). Zooplankton densities in the Clark Fork River delta section were significantly lower (P<0.10) than other lake sections for copepods but significantly higher (P>0.10) for cladocerans (Figure 13, Appendix C).

The largest zooplankter in Lake Pend Oreille during 1988 continued to be Epischura, which averaged 2.0 mm long, followed by Daphnia galeata and D. thorata, which averaged 1.2 and 1.1 mm, respectively. Diaphanosoma and

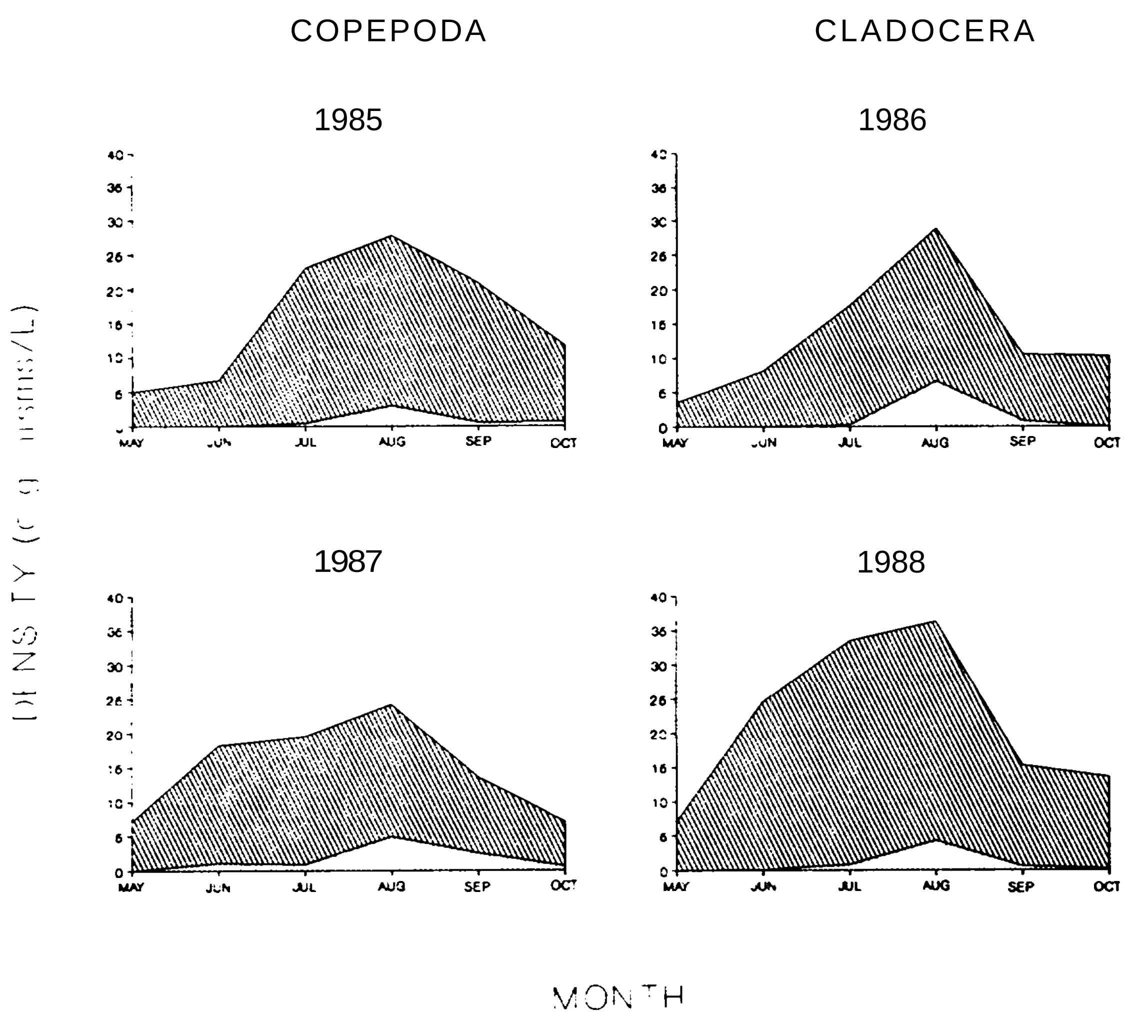

Figure 11. Temporal distribution of Copepoda and Cladocera zooplankton in Lake Pend Oreille, Idaho, May through October, 1985 through 1988.

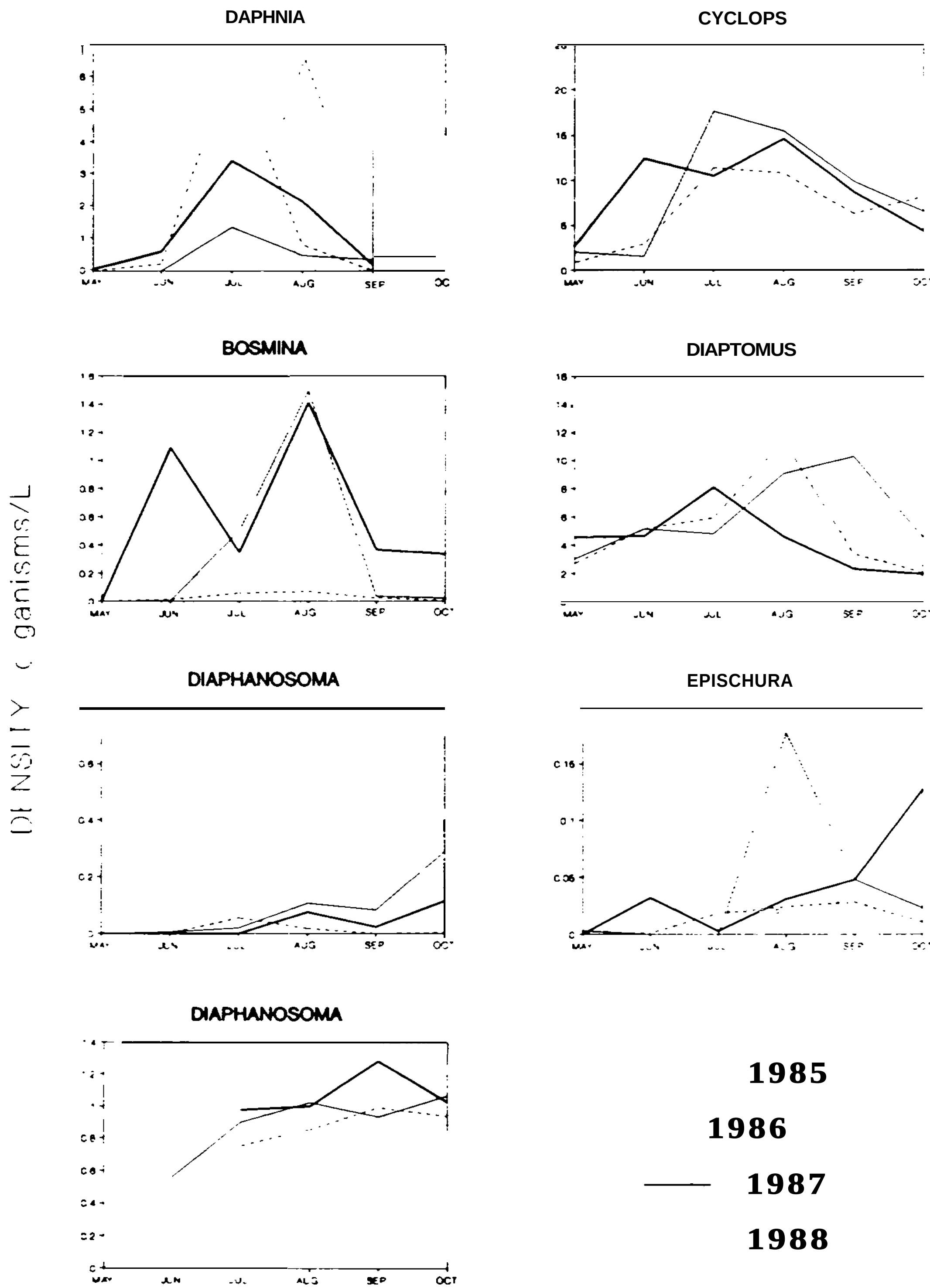

Figure 12. Temporal distribution of mean zooplankton densities in Lake Pend Oreille, Idaho, May through October, 1985 through 1988.

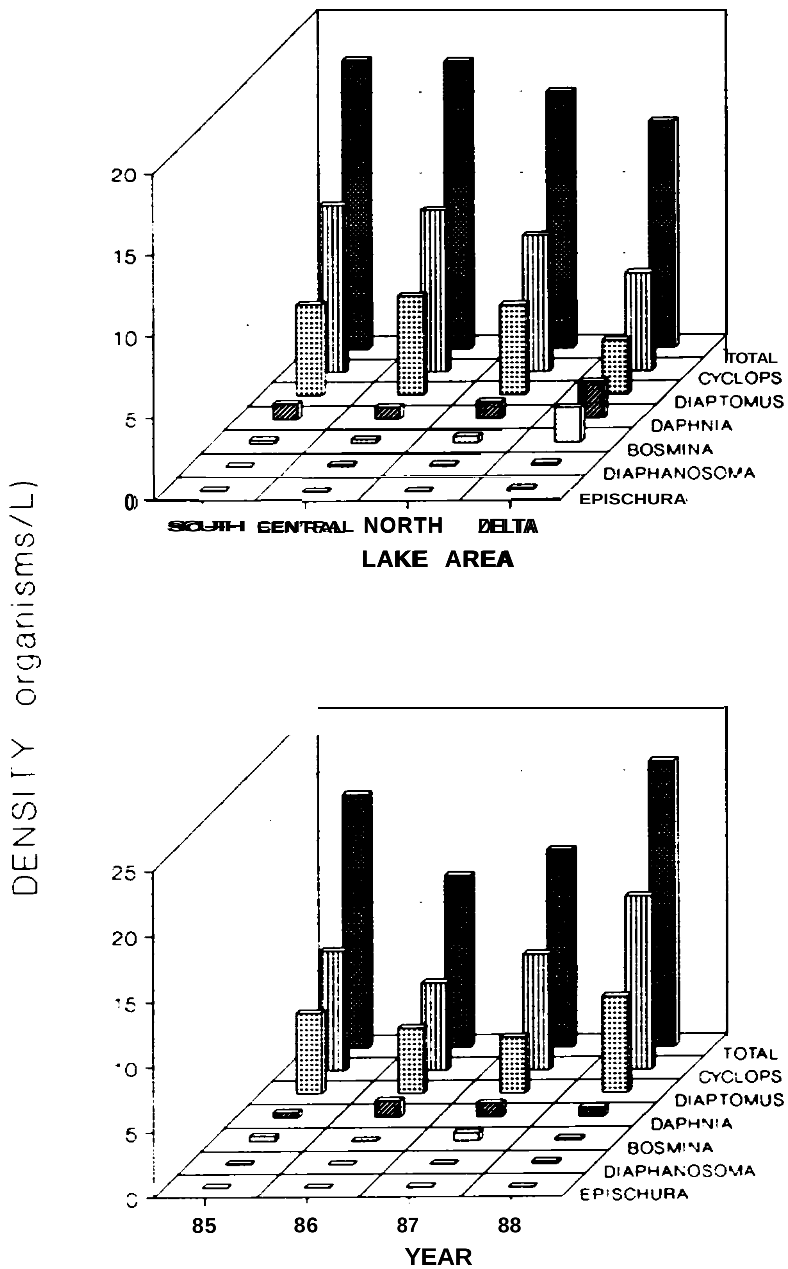

Figure 13. Mean zooplankton densities in Lake Pend Oreille, Idaho, compared among lakes sections and years.

Diaptanus averaged 0.96 and 0.85 mm, respectively. *Cyclops* averaged 0.72 mm long, followed by *Bosmina*, the smallest zooplankter, at 0.36 mm. In general, zooplankton lengths for each genus did not vary significantly (P>0.10) among the last four years or among months and lake sections (Figures 14 and 15, Appendix C).

Water Temperature and Transparency

Surface temperatures of Lake Pend Oreille from May through November 1988 ranged from 7.8° C in November to 21.80 C in August (Figure 16). Thermal stratification began in May and extended through October. At peak stratification (September), the thermocline began at a depth of 15 m and average epilimnetic water temperature was 16.4° C.

Water transparency (Secchi disk) from May through October, 1988, ranged fran 3.4 m in June to 13.6 m in August (Figure 17).

DISCUSSION

Kokanee Population Status

The kokanee population in Lake Pend Oreille during 1988 continued to respond favorably to enhancement efforts. Total abundance was 70% higher in 1988 than 1987 and 140% higher than the populations low point in 1986. This increase can be partially attributed to nigh fry recruitment from Cabinet Gorge Hatchery during the past two years. During eight years of hatchery supplementation prior to completion of Cabinet Gorge Hatchery in 1985, relative contribution of hatchery fish to total kokanee abundance averaged 18% (Figure 18). After only three years of operation, contribution from Cabinet Gorge Hatchery has increased to 43% of total kokanee abundance in Lake Pend Oreille. It is encouraging to note that this increase in relative contribution is not an artifact of declining wild kokanee production, which has also increased during the past two years. The recent increase in kokanee abundance is predominantly a result of enhanced fry recruitment and is thus currently limited to the younger age classes.

Abundance of age 3+ and 4+ kokanee, which comprise nearly 90% of the fishery (Bowles et al. 1986, 1987), was 14% lower than the six year high evident in 1987. Although lower than 1987, abundance of these older fish was similar in 1988 to 1986 and 170% higher than the population's low point in 1984 (Figure 19, Appendix D). Based on an assumed exploitation rate of 25% (Bowles et al. 1987), the fishery may have supported a harvest of approximately 200,000 kokanee (9 fish/hectare) during 1988. This estimate represents approximately 25% of the restoration program goal to produce an annual catch of 750,000 kokanee (33 fish/hectare). Progress toward meeting this goal will not be apparent in the fishery until 1991 and 1992, when strong year classes produced the past two years enter the fishery. Based on

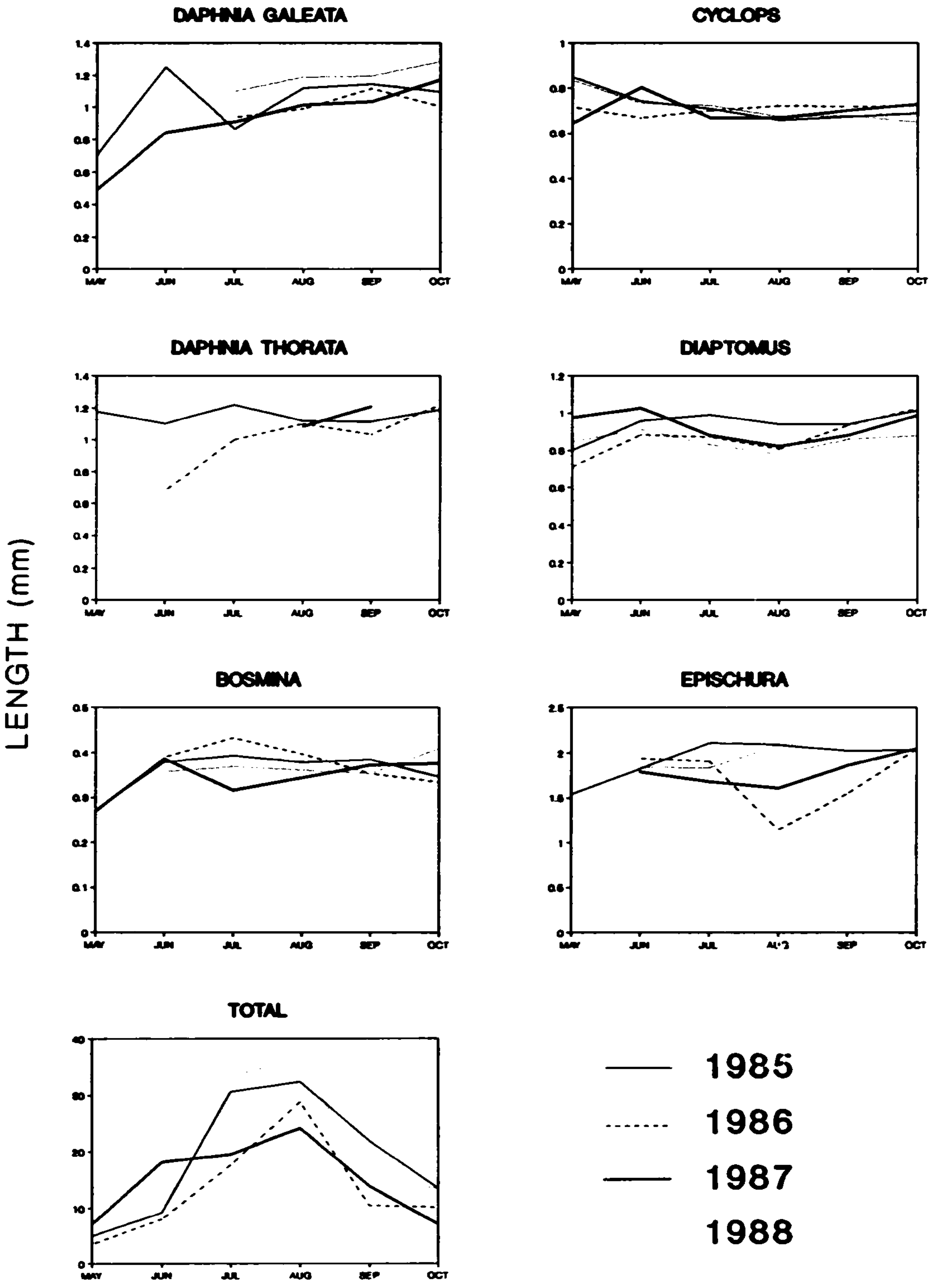

Figure 14. Temporal distribution of mean zooplankton lengths in Lake Pend Oreille, Idaho, May through October, 1985 through 1988.

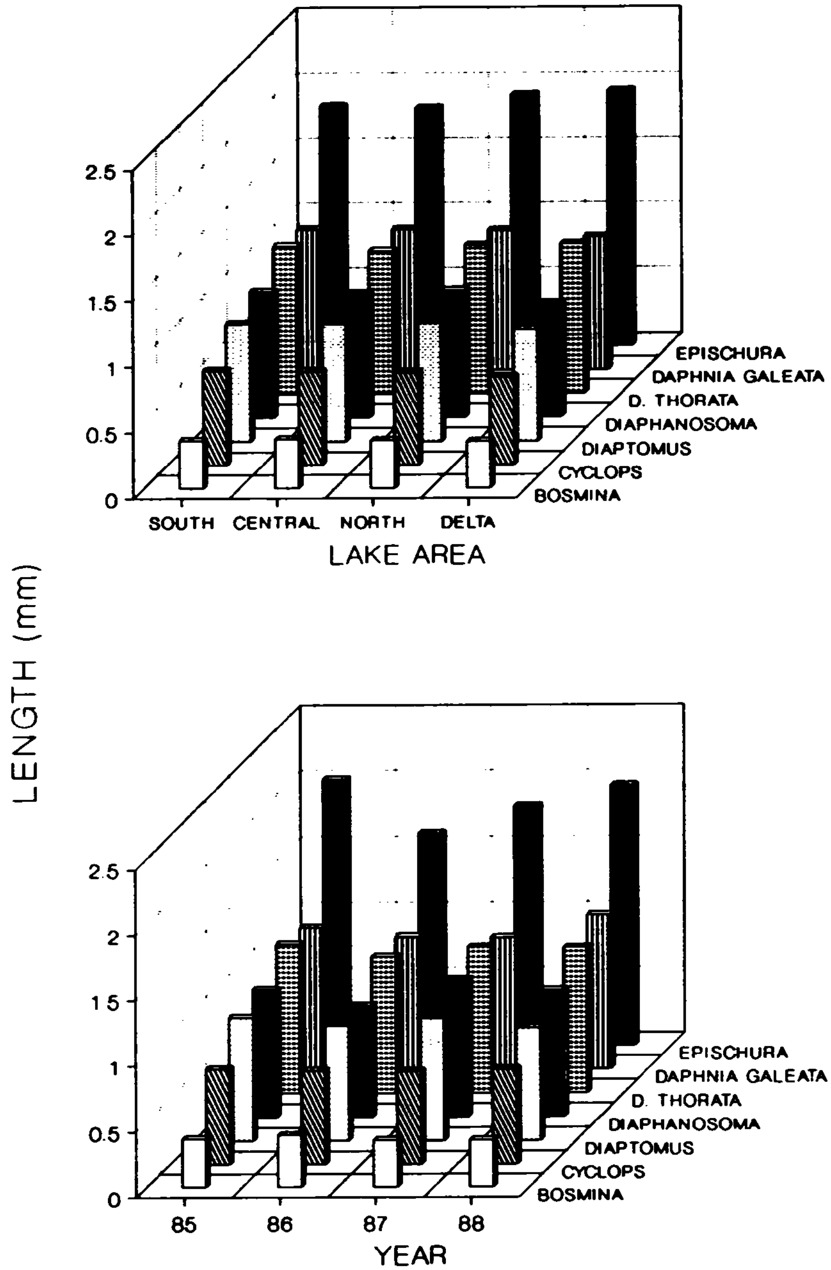

Figure 15. Mean zooplankton lengths in Lake Pend Oreille, Idaho, compared among lake sections and years.

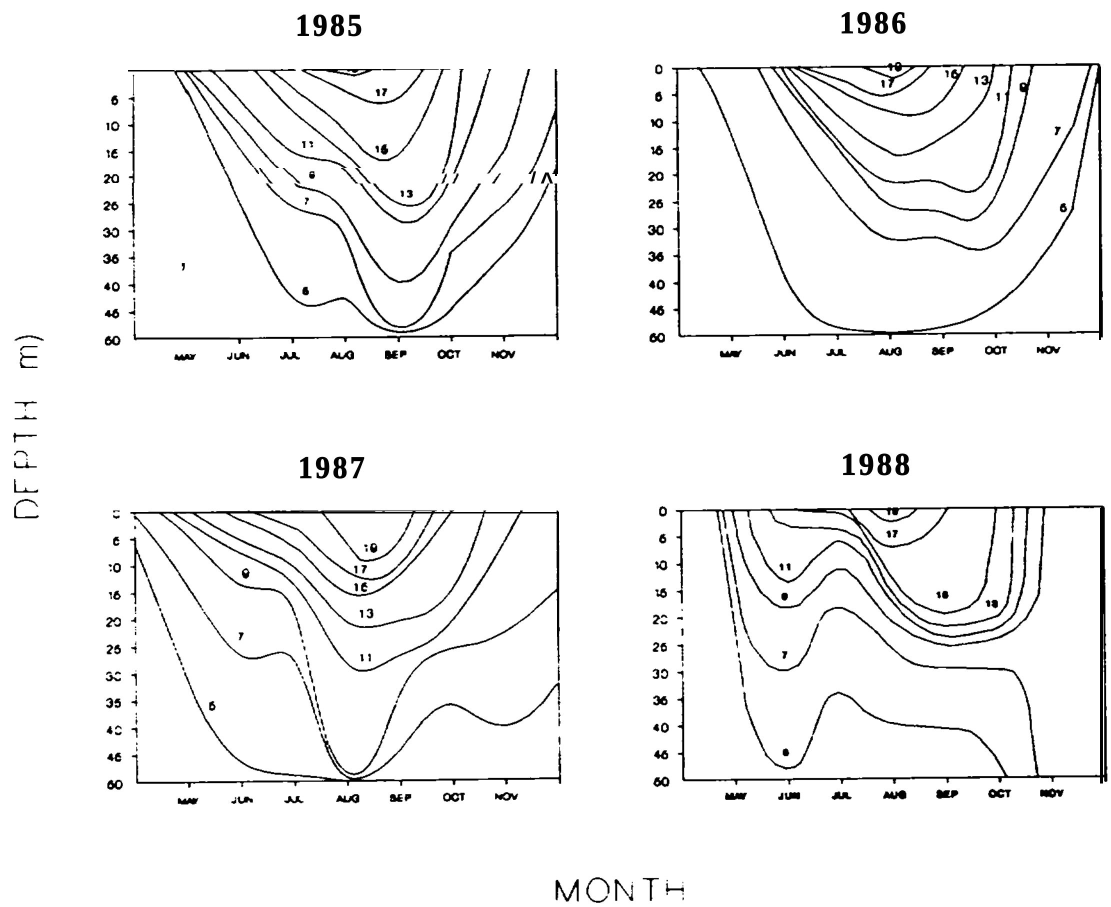

Figure 16. Distribution of thermal isopleths (°C) in the upper 50 m of Lake Pend Oreille, Idaho, May through November, 1985 through 1988.

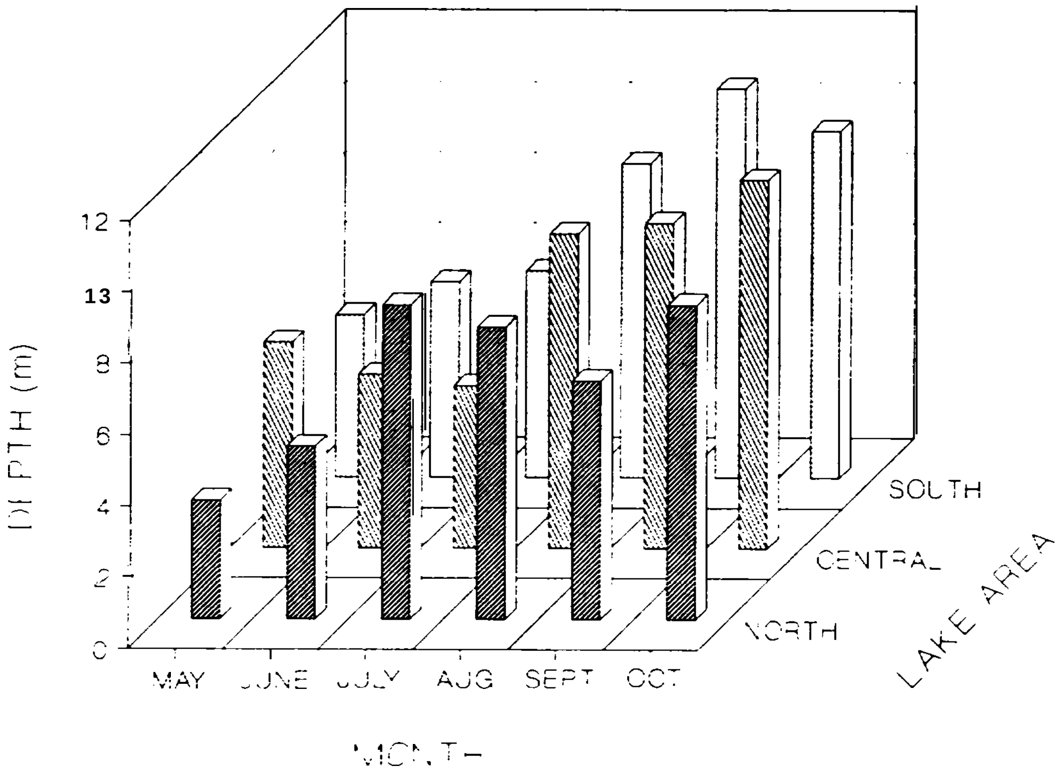

Figure 17. Water transparency (Secchi disk) in three sections of Lake Pend Oreille, Idaho, May through October, 1988.

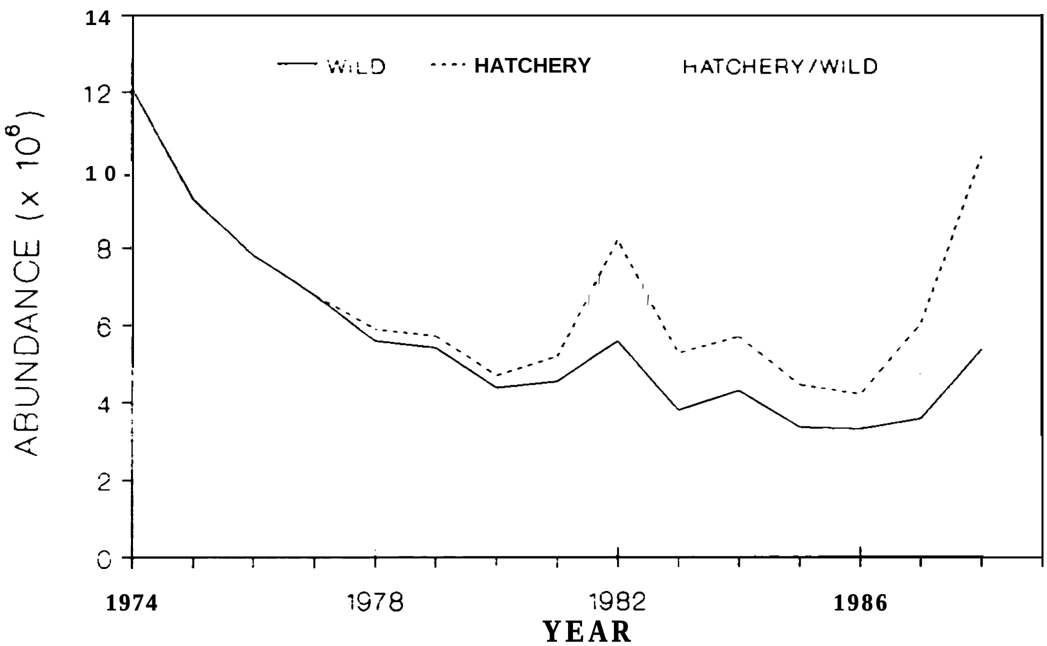

Figure 18. Relative hatchery contribution to total estimated kokanee abundance in Lake Pend Oreille, Idaho, 1974 through 1988. The hatchery-wild component represents contribution from naturally spawning kokanee of hatchery origin.

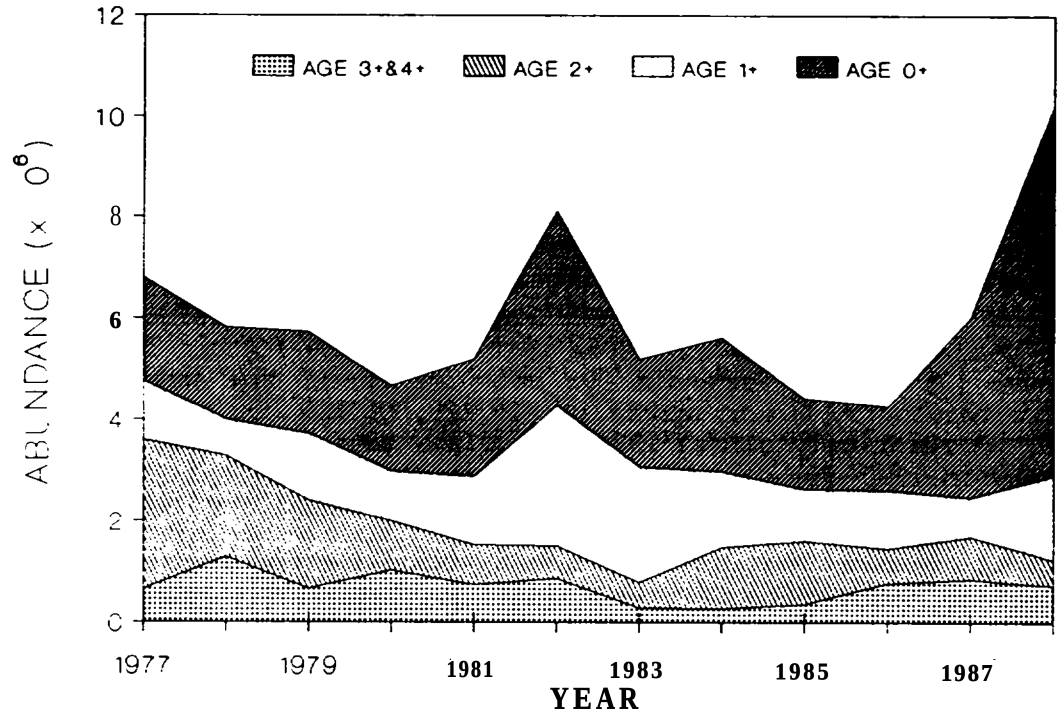

Figure 19. **Total estimated abundance of four kokanee age groups in Lake Pend Oreille, Idaho, 1977 through 1988.**

typical survival and growth of age l+ and older kokanee, annual harvest from Lake Pend Oreille may exceed 400,000 kokanee (18 fish/hectare) by 1991. This projection assumes that carrying capacity of Lake Rend Oreille is adequate to support increased kokanee abundance. If forage becomes limiting, projected benefits my be dampened as a result of reduced survival, growth and age of maturity. Currently, with two strong age classes in Lake Rend Oreille (age 0+ and age l+), there is no evidence of reduced growth, survival or forage. We will continue to monitor these density dependent indicators of carrying capacity as older age classes respond to enhancement efforts.

Although the fishery may respond dramatically to enhancement efforts by 1991 or 1992, the outlook is not as encouraging for 1989 and 1990. A weak 1985 year class (age 2+ in 1988) recruits to the fishery in 1989 as age 3+ kokanee (Figure 20, Appendix D). The impact of this weak year class may reduce harvest by 40% to approximately 120,000 kokanee (5.3 fish/hectare) in 1989. A relatively strong 1986 year class (age l+ in 1988) recruits to the fishery in 1990 and should compensate enough for the weak 1985 year class to provide a similar kokanee harvest as was estimated for 1988 (approximately 200,000 fish).

Fry Recruitment and Survival

Increased kokanee abundance in 1988 waspredominantly the result of enhanced fry recruitment. Fall abundance of age 0+ kokanee in Lake Rend Oreille doubled from 1987 (160 fry/hectare) to 1988 (320 fry/hectare) and is the highest estimate since monitoring began in the mid-1970s (Figure 20; Appendix D). Kokanee densities in other north Idaho lakes (no Mysis present) averaged 300 fry/hectare (N=9 years) in Coeur d'Alene Lake and 550 fry/hectare (N=3 years) in Spirit Lake (Homer et al. 1988).

Enhanced recruitment in Lake Rend Oreille was evident for both wild and hatchery-reared kokanee fry. Recruitment of wild fry was 31% higher in 1988 (158 fry/hectare) than 1987 (121 fry/hectare) and 98% higher than average wild fry recruitment (80 fry/hectare) during the previous ten years (Figure 21). Good recruitment in 1988 was predominantly the result of high parental egg deposition, resulting fran a strong year class of spawners, and a trend toward older and more fecund spawners over the past several years. Wild recruitment was also enhanced by good egg-to-fall fry survival (3.3%), which was lower than 1987 (4.6%) but higher than the previous nine-year average (1.5%). High survival during the past two years is attributed to increased forage (cladoceran and total zooplankton) during late spring and early summer. Although increased wild fry recruitment in Lake Pend Oreille has greatly benefitted kokanee restoration efforts, conditions regulating wild fry survival remain largely uncontrollable. Rehabilitation efforts must continue to focus on hatchery supplementation to provide a stable recovery.

Kokanee fry production at Cabinet Gorge Hatchery over the past two years has dramatically increased hatchery fry survival and recruitment in Lake Rend Oreille. Hatchery fry in 1988 made up over 50% of total fry

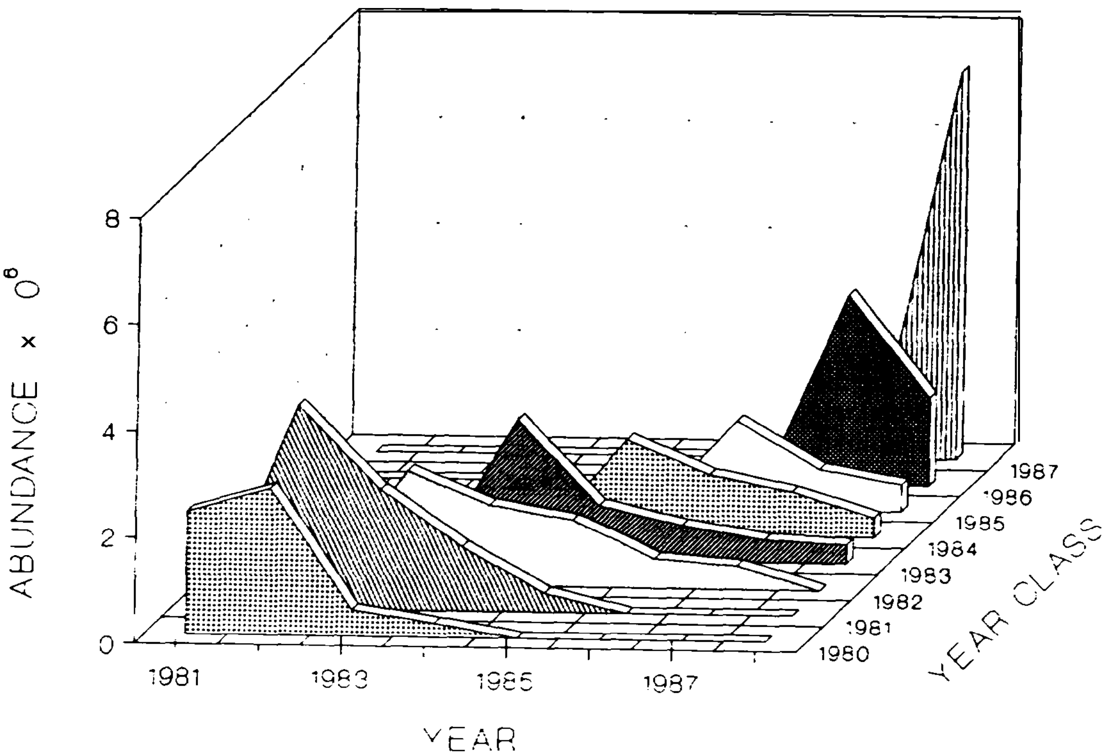

Figure 20. Comparative year class strength of kokanee in Lake Fend Oreille, Idaho, from 1981 through 1988.

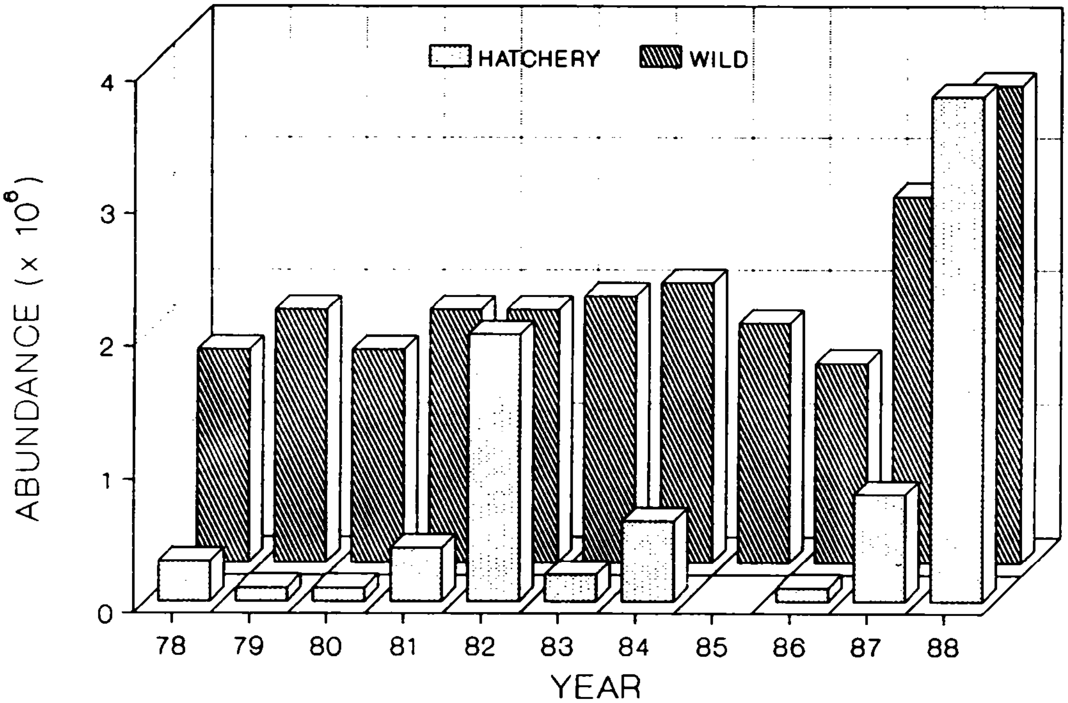

Figure 21. Total abundance of wild and hatchery-reared kokanee fry in Lake Pend Oreille, Idaho, during late summer, 1978 through 1988. Hatchery contribution in 1985 was not estimated.

recruitment, which averaged less than 20% during the previous ten years (Figure 21). Contribution to recruitment biomass was even more significant (73%) because hatchery fry were 2.5 times heavier than wild fry during fall trawling. Recruitment of hatchery fry was nearly five times higher in 1988 (165 fish/hectare) than 1987 (35 fish/hectare) as a result of a larger release (13 million vs. 6 million) and improved postrelease survival.

Hatchery fry survival from release date to fall sampling has increased each year since production at Cabinet Gorge Hatchery began in 1986 (Figure 22). Kokanee population modeling indicated fry survival fran time of release to fall sampling must approach 30% to meet the fishery harvest goal of 0.75 million kokanee annually (Bowles et al. 1988). The success of fry releases in 1988 (29% survival) is very encouraging but requires replication before major conclusions are inferred. Initial improvements in survival resulted from releasing larger fry (50 mm) from Cabinet Gorge Hatchery than was possible fran other hatcheries (30 mm) (Bowles et al. 1988). Survival was bolstered further in 1988 by improving fry release strategies.

Release Strategies

Five fry release strategies were evaluated during 1988 to improve postrelease fry survival and enhance spawning runs to Cabinet Gorge Hatchery and Sullivan Springs Creek. Although all release strategies were designed to maximize fry survival, highest priority was to enhance spawning runs to provide eggs for the recovery program.

Survival of kokanee fry released at Cabinet Gorge Hatchery improved dramatically in 1988. Improving fry survival during emigration from Cabinet Gorge Hatchery to Lake Pend Oreille is critical to the establishment of a run back into the hatchery. Prior to 1988, fry were released midsumner into Clark Fork River to coincide with increased food supply in Lake Pend Oreille. Success of these releases was often very poor as a result of low nighttime flows to aid emigration and abundant predators in the lower Clark Fork River and delta (Bowles et al. 1988). Two release strategies were evaluated during 1988 to circumvent these constraints.

The first release occurred mid June to coincide with spring runoff. High nighttime river flows (850 m^3/s; 30,000 ft^3/s) helped flush fry quickly (93% within one night) to Lake Pend Oreille and increased survival three fold over releases during lower flows (<570 m^3/s; <20,000 ft^3/s) for similar sized fry (50 mm). Enhanced survival during emigration apparently compensated for lower food availability in bake Pend Oreille at this time. Survival was also enhanced by a relative absence of predators in the lower Clark Fork River and delta following the release. Northern squawfish are common residents of the river (Jeppson and Platts 1959) and are effective predators of salmon emigrants (Brett and McConnell 1950; Foerster 1968). These predators were apparently spawning upriver and on lakeshores during mid-June and did not contribute substantially to fry mortality during emigration.

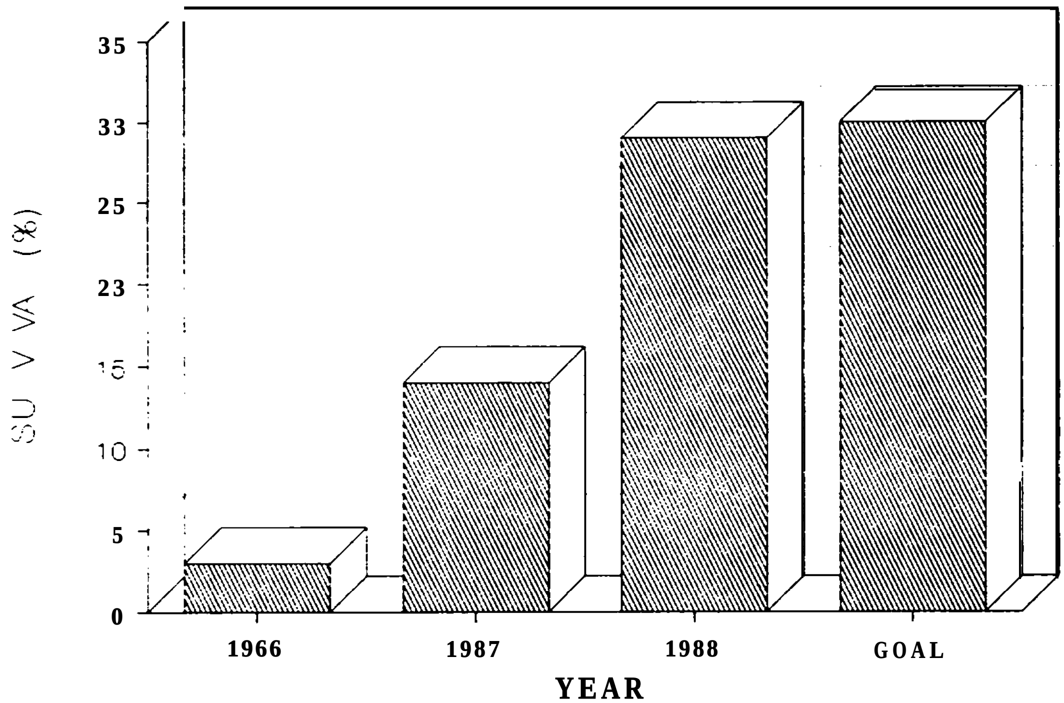

Figure 22. Estimated survival of kokanee fry during their first summer in Lake Pend Oreille, Idaho, following release from Cabinet Gorge Hatchery, and survival goal established for the kokanee restoration program.

The second Clark Fork River release occurred in July to coincide with thermal stratification and increased forage production in Lake Pend Oreille. Although fry were barged down Clark Fork River to avoid low flow problems of disorientation and predation, survival was not significantly higher than the earlier fry release during high river flow. Although barging obviously improved survival of fry released under low flow (<570 m^3/s; <20,000 ft^3/s) conditions (29% vs. 10% survival), it is not known if barging affected the inprinting process. The effort and flow requirements for barging kokanee were also constraining. River flow must exceed 20,000 ft^3/s for safe navigation, and a maximum of 150,000, 50-mm fry can be transported per barge. Full support of the Cabinet Gorge Hatchery run (approximately 8 million fry) by barging would require over 50, 4-h trips each year. In light of these constraints, initial success of the early season (high flow) release is very encouraging. The true success of these releases will be evaluated (from fin-clipped fish) when adults return to spawn at Cabinet Gorge Hatchery in 1991 and 1992.

Survival in 1988 (29%) was the highest ever documented for fry released into Sullivan Springs Creek. Kokanee have been released annually into Sullivan Springs Creek since 1977 to enhance adult returns for egg take. Documented survival from release to fall sampling in bake Pend Oreille ranged fran 7% to 18% and averaged 12%. Survival in 1988 was 61% higher than in 1987, although fry size (50 mm) and date of release (midsummer) were similar between releases. This increase may be the result of reduced injury or mortality of fry during release. In 1987, fry were released under pressure into a shallow (<30 cm) graveled area of the creek. Wring 1988, fry were released into deeper water (>80 cm) to reduce forceful impact with the sediment.

The primary objective of open water releases was to maximize fry survival and subsequent return to the creel. It is doubtful these fish will contribute substantially to Cabinet Gorge Hatchery or Sullivan Springs Creek spawning runs but may augment natural lakeshore spawners.

Fry released offshore during midsumner survived better (36%) than any other releaseduring 1988,whereas fry from the early season release had the lowest survival (22%). Factors contributing to high survival may include abundant forage (cladoceran zooplankton) and low predation due to schooling behavior of fry in Lake Fend Oreille and avoidance of riverine and shoreline predators. Several factors may have contributed to low fry survival from the early open-water release. Fry were slightly smaller (46 mm) than other releases (48-51 mm) and forage less abundant than midsummer. Probably the most important factor was the release method. Approximately 30% of the fry were not acclimated to surface temperature (16°C) and released 10 m deep (12°C) into Lake Pend Oreille, where temperature was similar to hatchery water (9°C). Many of these fry rose immediately to the lake's surface after release and may have suffered thermal and pressure shock. During the midsumner release, all fry were acclimated to surface water temperature prior to release at the surface of Lake Pend Oreille. As a result of transportation constraints, direct comparison of early vs. late open-water fry releases may be confounded because the early release was in the north end and the late release in the south end of bake Fend Oreille. Evaluating differences between these release sites my be necessary before temporal comparisons can be made.

Approximately 12 million fry will be available for release into Lake Pend Oreille in 1989. Highest priority for fry releases should be to support Clark Fork River and Sullivan Springs Creek runs. Based on 1987 and 1988 survival rates, a minimum of 4 million fry are needed for Clark Fork River and 3 million for Sullivan Springs Creek to support escapement of 75,000 kokanee and 15 million eggs for each site. Surplus fry should be used to replicate other release strategies evaluated during 1988.

Fry Marking

Marks used to distinguish release groups among trawl-caught kokanee fry were very successful in 1988. Wild fry and hatchery fry fran five release strategies were differentiated using a combination of tetracycline and otolith marks. The tetracycline mark has proven successful for fry in Lake Pend Oreille since 1978 (Bowles et al. 1988). A date-of-release check on otolith microstructure was used in 1987 and 1988 to successfully differentiate hatchery release groups and wild fry. This is a passive mark induced environmentally during the transition from hatchery to lake residence and was identifiable up to 90 d after fry were released into Lake Pend Oreille.

Although these marks provide successful differentiation of kokanee fry, it is uncertain if they will be discernible on age l+ and older kokanee. Examination of otoliths and vertebrae with UV light microscopy during 1989 will help determine if the tetracycline mark can be distinguished after a year or longer in Lake Pend Oreille. During 1989, we will also examine otoliths from age l+ kokanee for the release-date-mark, although it is unlikely this single mark will be identifiable at that time.

Manipulating water temperature to produce a single check on otoliths of kokanee fry did not provide a reliable mark. Tempering constraints at Cabinet Gorge Hatchery resulted in very low water temperature (2%) and slow growth when the mark was attempted. Daily growth increments were very close together which resulted in a poor mark. In addition, only one mark was possible because the necessary temperature gradient between water sources at Cabinet Gorge Hatchery was available for less than two weeks. Multiple marks are necessary if the thermal mark is to be useful because a single mark is indistinguishable from other extraneous checks common during hatchery residence. By manipulating water temperature periodically, a known pattern can be laid down similar to Morse Code (Brothers 1985). Higher water temperature (8-10°C) during the marking period is also desirable because daily growth increments will be wider and thus easier to distinguish. Although these constraints preclude marking kokanee fry at Cabinet Gorge Hatchery, thermally marking kokanee embryos may be a viable option. Incubation temperatures are commonly 10°C and less water is required. Thermal marks have been made successfully on otoliths of salmon and char embryos (Brothers 1985; Volk et al. 1987).

Kokanee Forage Availability

Increased abundance of kokanee forage (zooplankton) during late spring and early summer my have enhanced survival of kokanee fry in 1987 and 1988. Wild kokanee fry typically merge in June when fry are ineffective predators on fast-moving copepods but can effectively utilize the slower-moving cladocerans (Rieman and Bowler 1980). Establishment of Mysis in Lake Pend Oreille has greatly reduced cladoceran production during early summer through predation prior to thermal stratification of the lake (Reiman and Falter 1981; Bowles et al. 1987). Cladoceran production during the past two years began earlier than typical, particularly in 1987, and total zooplankton densities were higher than normal during May and June. Increased cladcceran abundance during early summer made these important forage items available to wild fry during their critical postemergent stage of developnent.

Changes in early season zooplankton production, particularly cladoceran, is regulated predominantly by water temperature and thermal stratification but may also be affected by changes in Mysis abundance. Mysids prey heavily on cladoceran zooplankton (Bowers and Vanderpoeq 1982) and are most effective predators prior to thermal stratification of the lake (Rieman and Falter 1981; Bowles et al. 1988). After stratification, Mysis are spatially segregated from these zooplankton by warm (>14-18°C) epilinmal waters (Beeton 1960; Nero and Davies 1982; Nero and Sprules 1986). During 1987, early thermal stratification of Lake Pend Oreille coupled with relatively low mysid density (Figure 23) resulted in the highest survival of wild fry ever documented for Lake Pend Oreille (Bowles et al. 1988). Although drought conditions persisted in 1988, the Mysis population rebounded and thermal stratification occurred later than the previous year. This reduced early season cladcceran production and wild fry survival compared to 1987. In spite of this reduction, cladcceran production and wild fry survival were higher in 1988 than typical during nondrought years. A similar affect of early cladoceran production was observed in 1974, which was also considered a drought year (Rim 1977).

Annual fluctuations in Mysis abundance are apparently common in Lake Pend Oreille (Figure 23) and have been documented in other lakes containing mysids (Lasenby et al. 1986). The impact of these fluctuations on kokanee fry survival is of lesser importance than annual changes in timing and extent of thermal stratification of Lake Fend Oreille. We will continue to monitor zooplankton and mysid populations to better define their relationship and impact on kokanee survival.

Spawning

High spawner escapement and egg take during the past two years have greatly benefitted kokanee rehabilitation efforts. The maturing of two

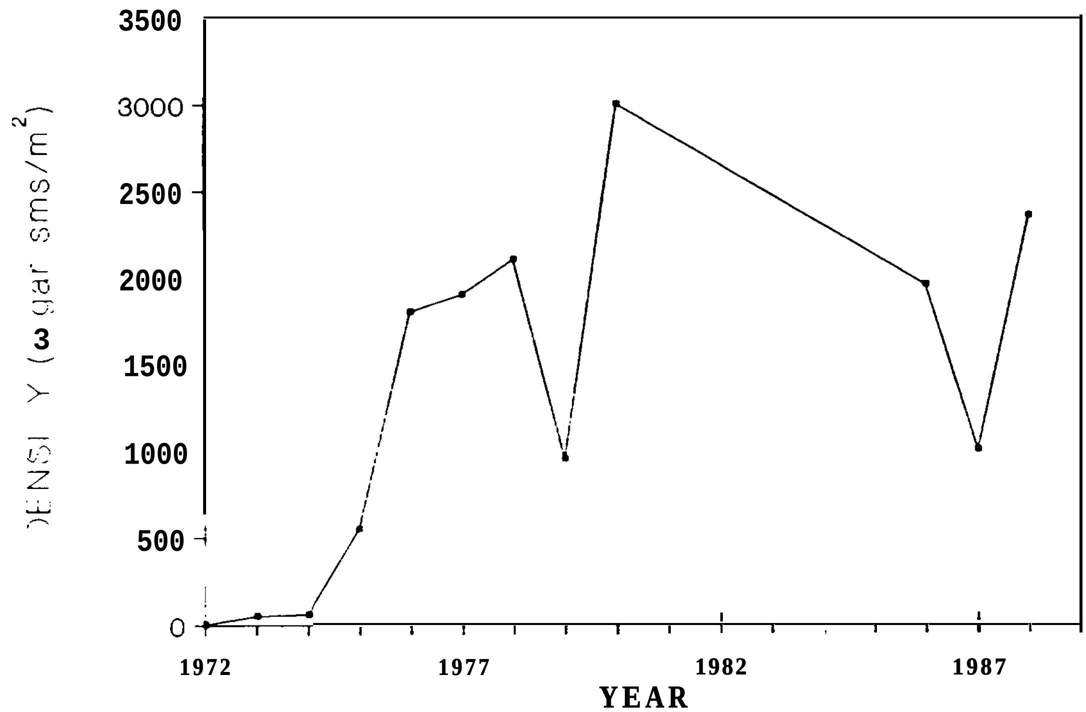

Figure 23. Estimated density of Mysis in Lake Fend Oreille, Idaho.

relatively strong year classes increased escapement by over 40% from 1986 to 1987 and 1988. Potential egg deposition increased even more dramatically (70%) as a result of increased age at maturity and fecundity over the past several years. This trend toward older (age 4+) and more fecund (480 eggs/female) spawners was also evident in mean spawner lengths, which has increased by 13% over the past 12 years (Figure 24). As kokanee become more numerous in Lake Pend Oreille, age at maturity and fecundity are expected to stabilize and possibly decline. These trends will be monitored closely to help establish hatchery production levels that will optimize size and abundance of kokanee in the fishery.

Spawner escapement to Sullivan Springs was 15% of total escapement in 1987 and 1988 and has varied from 1.7% to 28% during the past 12 years. Depending on weather conditions (Bowles et al. 1987), escapement to Sullivan Springs should remain at approximately 15% of total escapement during the next two years. Although Sullivan Springs fry-to-adult "return" rates averaged over 10% during the early 1980s, rates have remained under 5% since the mid 1980s (Appendix E). Based on estimated annual mortality, these latter rates are more indicative of actual fry-to-adult returns. Higher "return" rates in the early 1980s were probably biased by wild kokanee utilizing Sullivan Springs.

Egg take at Sullivan Springs was 12% lower in 1988 than 1987 and will probably decline further in 1989 and 1990 as a result of weaker year classes maturing and relatively low fry releases into Sullivan Springs Creek. Spawning at Sullivan Springs may provide only 8 million eggs during 1989 and 10 million during 1990 but should rebound to nearly 20 million eggs by 1991. Alternative egg sources should be developed to provide an additional 5 million eggs for 1989 and 1990. This is necessary to support the rehabilitation program and avoid large fluctuations in year class strength. Potential local sources include Spring Creek, Clark Fork River and Lake Coeur d'Alene.

Although spawners have been abundant in Clark Fork River during 1987 and 1988, few have volunteered into the Cabinet Gorge Hatchery fish ladder and trap. Spawning at Cabinet Gorge Hatchery has provided less than 2 million eggs since completion of the hatchery in 1985. Contribution from adult returns to Cabinet Gorge Hatchery will continue to be low until 1991. Some adults (age 3+) may return in 1989 from the first fry released at the hatchery in 1986, but the projected run is small (<6,000 spawners, <1 million eggs) because fry were not imprinted on morpholine and fry survival was low (3%)(Bowles et al. 1987). Escapement should improve slightly in 1990 (22,000 spawners, 4 million eggs) from enhanced fry survival and morpholine imprinting. The success of fry releases in 1988 should be evident by 1991 when escapement to Cabinet Gorge Hatchery may approach 90,000 spawners and 18 million eggs.

These projections assume that mortality, fecundity and age at maturity remain relatively static as kokanee abundance increases in bake Pend Oreille and that adults will target on the morpholine attractant to insure migration up the Cabinet Gorge Hatchery fish ladder. These parameters are being monitored carefully, and projections will be modified as necessary.

Figure 24. Mean total length of male and female kokanee spawners from Lake Pend Oreille, Idaho.

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APPENDICES

Appendix A. Kokanee age class density (fish/hectare in Lake Pend Oreille during late summer, 1988. A 90% error bound is listed with each estimate.

Age class	Origin	Lake section 1	2	3	4	5	6	Total
0+	Hatchery (total)	66.5±19.5	130.5±23.4	171.1±45.7	215.7±45.7	134.6±53.8	223.1±64.7	165.3±19.3
	Clark Fork River							
	Early summer[a]	8.4±2.8	19.1±5.4	36.7±8.5	44.8±10.1	50.9±23.2	67.8±22.3	40.6±6.5
	Mid-summer[b]	6.3±2.0	14.3±3.4	18.0±2.5	17.5±4.8	22.2±15.5	19.1±7.5	16.6±3.0
	Sullivan Springs[c]	21.0±7.2	54.2±12.4	67.0±15.9	105.0±22.8	59.2±20.5	73.1±23.5	65.7±8.0
	Open Water							
	Early summer[d]	2.1±0.6	0	9.0±0.7	11.0±3.0	0	51.9±19.8	15.2±4.4
	Mid-summer[e]	28.7±8.7	43.0±10.8	40.4±5.1	37.4±9.8	7.2±6.3	2.3±1.0	25.2±2.9
	Wild	135.6±44.0	225.4±41.8	184.6±36.4	218.3±40.3	131.7±41.6	74.7±19.4	157.5±14.8
	Wild & Hatchery	202.1±57.7	355.9±58.5	355.7±59.4	434.0±83.8	271.3±94.5	297.8±75.6	322.8±30.6
1+	Wild & Hatchery	9.6±5.1	5.9±6.0	65.9±30.7	65.8±30.6	36.2±32.4	194.0±70.3	73.1±17.9
2+	Wild & Hatchery	53.5±25.8	29.9±14.7	30.9±18.5	3.2±3.5	8.8±6.6	17.4±15.9	22.7±6.4
3+	Wild & Hatchery	46.4±15.8	15.9±12.1	15.2±13.3	1.7±2.8	9.9±8.8	17.2±15.9	16.9±5.2
4+	Wild & Hatchery	47.5±16.7	22.4±18.5	16.2±8.6	0	7.9±4.8	7.0±6.0	
Total	Wild & Hatchery	359.1±71.5	429.9±86.6	483.9±82.2	504.7±108.8	334.1±82.4	533.5±56.4	450.9±33.6

[a] Hatchery-reared kokanee fry released into Clark Fork River.
[b] Hatchery-reared kokanee fry barged down Clark Fork River and released into Lake Pend Oreille.
[c] Hatchery-reared kokanee fry released into Sullivan Springs Creek.
[d] Hatchery-reared kokanee fry released offshore northern Lake Pend Oreille.
[e] Hatchery-reared kokanee fry released offshore southern Lake Pend Oreille.

Appendix B. Maximum single late-run (early run included for Trestle Creek) kokanee counts made during the 1972-1978 and 1985-1986 spanning seasons on Lake Pend Oreille and its tributaries, excluding the Granite Creek drainage.

	Maximum single counts										
Area	1972	1973	1974	1975	1976	1977	1978	1985	1986	1987	1988
Lakeshore											
Bayview	2,626	17, 156	3,588	9,231	1.525	3,390	798	2,915	1,720	1,377c	2,100
Farragut	25	0	0	0	0	0	0	--	10	0	4
Idlewild Bay	13	0	25	0	0	0	0	--	--	--	--
Lakeview	4	200	la	0	0	25	0	4	127	59	0
Ellisport Bay and Hope	1	436	975	0	0	0	0	0	0	0	--
Trestle Creek Resorts	0	1,000	2,250	0	115	75	138	2	35	350	2
Sunnyside	0	25	0	0	0	0	0	0	0	0	--
Fisherman Island	0	0	75	0	0	0	0	--	--	--	--
Anderson Point	0	0	50	0	0	0	0	--	--	--	--
Camp aay	0	617	0	0	0	0	0	0	0	0	--
Garfield Bay	0	400	20	0	0	0	0	0	6	0	35
Subtotal	2,669	19,834	7,001	9,231	1,640	3,490	936	2,921	1,898	1,786	2,141
Percent of Total	294	62%	25%	64%	33%	40%	192	322	10%	20%	14%
Tributaries											
South Gold Creek	1,030	1,875	1,050	440	0	30	--	235	1,550	2,761	2,390
North Gold Creek	744	1,383	1.068	663	130	426	--	696	1,200	2,750	880
Cedar Creek	0	267	44	16	11	0	0	--	--	--	--
Johnson Creek	0	0	1	0	0	0	0	—	la2	0	0
Twin Creek	0	0	135	1	0	0	0	5	0	0	0
Mosquito Creek	0	503	0	0	0	0	0	--	—	--	--
Clark Fork River	539	3,520	6,180	0	--	--	--	--	--	--	--
Lightning Creek (Lower)	350	500	2,350	995	2,240	1,300	44	127	165	75	6
Spring Creek	2,610	4,025	9,450	3,055	910	3,390	4,020	5,284	14,000	1,500[d]	9,000
Cascade Creek	--	--	--	--	--	--	--	--		0	119
Trestle Creek	1,293	la	1,210	15	0	40	0	0	0	0	0
Trestle[a]	--	1, loo	217	14.555	1,486	865	1.589	208	1,034	410	422
Garfield Creek	0	0	25	0	0	0	0	--	1	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
Percent of Total[b]	71%	38%	75%	36%	67%	60%	a14	68%	90%	80%	86%
Total[b]	9,235	31,925	28,514	14,416	4,931	8,676	5,000	9,268	18,996	8,872	14,839

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 during early December.

Appendix c. Statistical comparison (ANOVA) of zooplankton densities and lengths among lake sections and years, Lake Pend Oreille, Idaho. Lake section abbreviations are: Southern = S, Central = C, Northern = N, Clark Fork River delta = D. Nonsignificant (P>0.lO) contrasts are delineated by a Common line under each contrast. Estimated density and length increase left to right for lake sections and years.

Zooplankter	P level for main effect: Lake section	P level for main effect: Year	main effect contrasts (P>0.lO): Lake section	main effect contrasts (P>0.lO): Year
		Density		
Cyclops	0.001	0.000	D N C S	86 87 85 88
Diaptomus	0.001	0.000	D N S C	87 86 85 88
Epischura	0.001	0.003	N C S D	86 88 87 85
Bosmina	0.000	0.000	S C N D	86 88 85 87
Diaphanosoma	0.175	0.000	S N C D	86 87 85 86
Daphnia	0.001	0.023	C S N D	85 88 87 86
Total	0.148	0.000	D N C S	86 87 85 88
		Length		
Cyclops	0.001	0.451	D N C S	87 86 88 85
Diaptomus	0.043	0.000	D S C N	88 86 87 85
Epischura	0.221	0.000	C S N D	86 87 88 85
[redacted]	0.293	0.002	D S N C	87 88 85 86
Diaphanosoma	0.388	0.002	D C S N	86 88 85 87
Daphnia galeata	0.339	0.000	D N S C	87 86 85 88
D. thorata	0.808	0.521	C S N D	86 88 87 85

Appendix D. Estimated year class abundance (millions) of kokanee made by midwater trawl in Lake Pend Oreille, Idaho, 1978 through 1988. The two oldest age classes were combined for estimates from 1978 through 1985.

Year	Year estimated										
class	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978
1987	7.31										
1986	1.66	3.55									
1985	0.51	0.78	1.66								
1984	0.38	0.84	1.15	1.79							
1983	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					0.27	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	1.82
1976									1.03	1.70	0.71
1975										0.67	2.00
1974											1.29
Total	10.21	6.01	4.27	4.47	5.62	5.21	8.12	5.20	4.68	5.69	5.82
Density (No./ hectare	450	266	189	198	249	230	358	230	207	251	257

Appendix E. **Kokanee spawned from Sullivan Springs Creek from 1976 through 1988, number of eggs collected, subsequent fry released into Sullivan Springs and adult return rate**

Year	Kokanee spawned	Eggs collected	Fry released following year[a]	Estimated returning adults from hatchery releases and year returned		Adult returns as a percent of fry released
1976	10,200	913,000	757,700	55,500 42,200	(1980) (1981)	12.96
1977	17,560	2,040,000	1,598,800	135,300 29,000	(1981) (1982)	10.28
1978	16,875	1,400,000	1,745,700	118,000 58,000	(19 2) (1983)	10.08
1979	12,005	1,451,400	1,081,400	42,000 75,660	(1983) (1984)	10.88
1980	48,760	4,186,700	2,219,800	54,340 46,810	(1984) (1985)	4.56
1981	112,820	11,653,000	2,487,800	27,935 20,060	(1985) (1986)	1.93
1982	115,850	11,432,900	2,875,589	22,170 77,773	(1986) (1987)	3.48
1983	79,850	6,320,000	3,214,512	5,854	(1987)	
1984	122,000	15,000,000	3,428,279			
1985	75,500	10,600,000	1,594,731			
1986	42,230	7,337,000[b]	2,847,345			
1987	83,627	16,600,000[c]	5,138,800			
1988	60,555	14,058,000[d]				

[a] Additional fry were released in other areas.
[b] An additional 1.76 million eggs were collected from Spring Creek and the Clark Fork River, 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 egg take to 17.22 million.
[d] An additional 0.10 million eggs were collected from Clark Fork River, bringing the to 14.16 million.