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

Annual Progress Report FY 1990

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ABSTRACT

Rehabilitation of kokanee Oncorhvnchus nerka in Lake Pend Oreille met with some success in 1990, but unexpected results have raised new questions. Estimated kokanee abundance during late August of 1990 was about 6.9 million fish. This is a decline of 19% from 1989, a continued decrease since 1988. The decreased population was attributed to low stocking of hatchery fry (7.3 million), lower wild fry survival in 1990 (1-5%), and exceptionally poor survival of fish ages 3+ and 4+. Average survival of the older fish was only 11% in 1990 compared to 72% in prior years. Compensatory survival was noted for kokanee ages 1+ and 2+, with an average of 81% in 1990 compared to 44% in 1989.

Hatchery fry comprised 47% of the total kokanee fry recruitment in 1990 (80% of fry biomass). This contribution ranked third behind 1988 and 1989 since hatchery supplementation began in the 1970s. Survival of hatchery fry was 20%, the second highest since this investigation began. Three release strategies were tested in 1990, of which the best survival was recorded for the south shoreline at 28%, followed by the Sullivan Springs release at 23%, and 15% for the early Clark Fork River release. Survival of hatchery-reared kokanee fry is still below the goal of 30%. Good survival of fry from the south shoreline and Sullivan Springs releases was attributed to large size of kokanee fry (52 mm), warm water temperatures of July, and higher Cladoceran densities compared to June. Lower survival of the early Clark Fork release is attributed to the exceptionally high river flows (850 cm^3/s) and low density of zooplankton.

Findings of 1990 indicate a more comprehensive approach to managing kokanee must take into account predator stockings and predator/prey interaction. An unexpected low adult escapement was responsible for an egg-take of only 5.6 million eggs in 1990, 58% of the previous year, which will limit experimental stocking in 1991. Modification of the fish ladder at the Cabinet Gorge Fish Hatchery to improve adult escapement is strongly recommended to increase egg-take.

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INTRODUCTION

Lake Pend 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 1 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 Kamloops (Gerrard) rainbow trout Oncorhvnchus mvkiss and bull trout Salvelinus confluentus in Lake Pend Oreille.

Several factors contributed to the initial decline of kokanee abundance. Hydropower development adversely impacted 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 Pend Oreille River, approximately 35 km downstream of Lake Pend 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 also adversely affected kokanee. Mysis were introduced in 1968 by the Idaho Department of Fish and Game (IDFG) to enhance the kokanee forage base. The expected response of increased kokanee growth and survival did not occur because mysids competed with post-emergent 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. Mysis remain in deep water during daylight hours and migrate to surface waters at night. Kokanee are visual feeders and are only 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. IDFG 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 midsummer to avoid early season food 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. 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 Pend Oreille kokanee fishery. It is the largest kokanee hatchery in the world and is 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 from 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 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 Pend Oreille. 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. 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, die1 timing, moon phase, release site, fish size, and number of fry released.

4 To determine the statistical reliability of the date-of-release mark and daily growth increments of kokanee otoliths used to differentiate wild from hatchery fry and identify release groups.

5 To obtain index information on natural-spawning kokanee to monitor contribution of hatchery-reared fish.

6 To monitor the zooplankton community in Lake Pend Oreille and relate to changes in kokanee abundance.

STUDY AREA

Lake Pend 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, 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 temperate, oligotrophic lake. Summer temperatures (May to 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 (>ll) 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.

A wide diversity of fish species are present in Lake Pend Oreille. Kokanee entered the lake in the early 1930s, presumably from Flathead Lake, and were well established by the 1940s. Other game fish include: Kamloops (Gerrard) rainbow trout, bull trout, rainbow trout Oncorhvnchus mykiss westslope cutthroat trout Oncorhvnchus clarki lewisi, lake whitefish Coresonus culpeaformis, mountain whitefish Prosopium williamsoni, and several spiny ray species.

METHODS

Kokanee Population Structure

Kokanee population structure in Lake Pend Oreille was determined by collecting kokanee with a midwater trawl during the last week of August. Fish from each sample were counted, measured, weighed, and checked for maturity. Sagitta otoliths were excised for aging. The midwater trawl 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 m 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-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-min 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 Pend Oreille was divided into six sections or strata

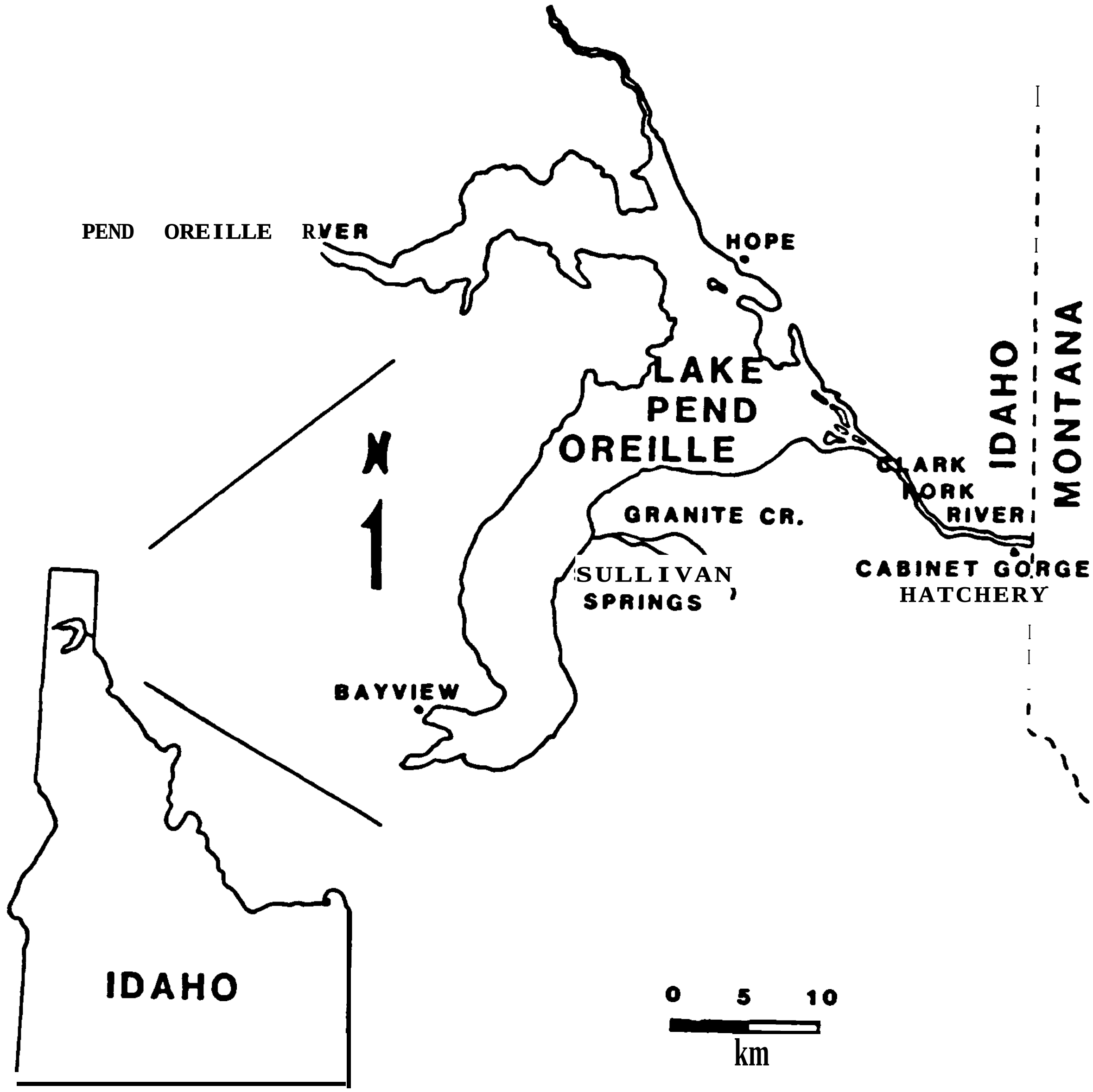


Figure 1. Map of Lake Pend Oreille, Idaho.

(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. Total sample size in 1989 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 was 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 (number/hectare) for each age class. Confidence intervals (90%) were calculated to compare estimates among age classes, lake sections, and years.

Survival

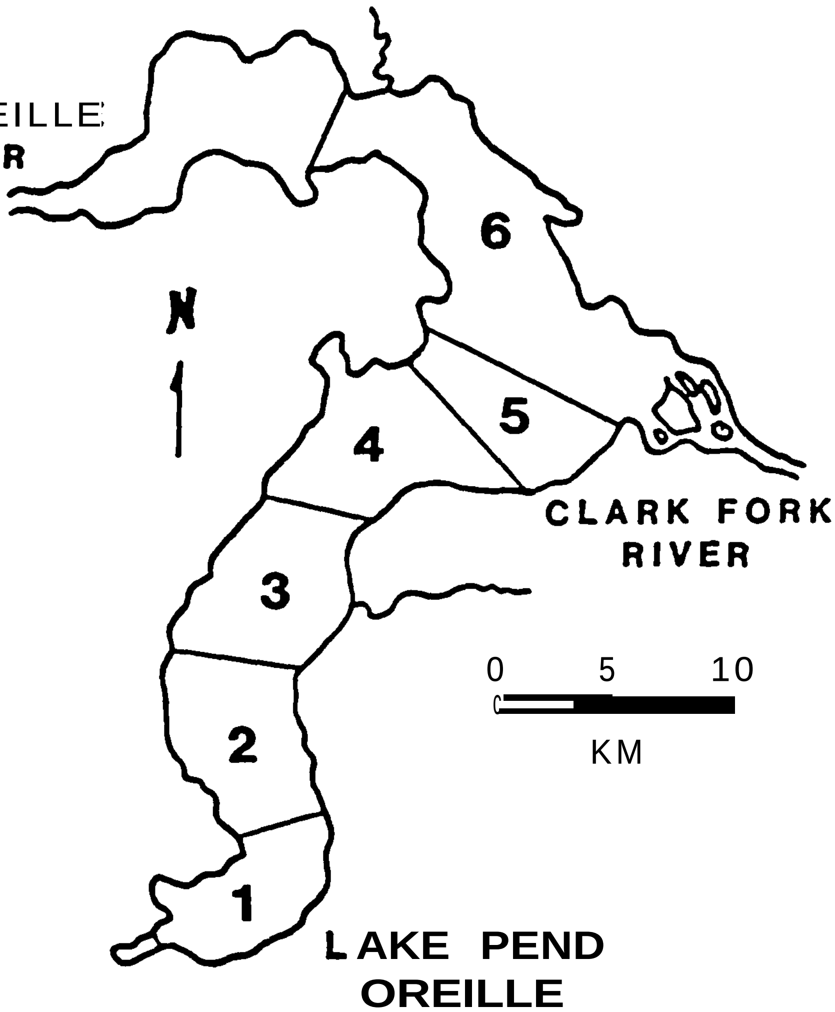
Recruitment and survival of hatchery-reared and wild fry were determined from trawl catches during late August of marked or unmarked fry. Fry survival was estimated from potential egg deposition (PED) and release date (hatchery fry only) to late August abundance in Lake Pend Oreille. PED was calculated 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 comparing 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

Otolith Coding

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, 1989). 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 immersion compound microscope interfaced with a video camera and monitor.

Otoliths from age 1+ kokanee collected during autumn trawling were examined for a date-of -release mark similar to that described for kokanee fry. This mark was used to distinguish fish of hatchery vs wild origin.



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 1990 for trawling and kokanee abundance estimation on Lake Pend Oreille, Idaho.

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 one week prior to release and averaged 50 mm total length (1,054 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

Three fry release strategies were evaluated to optimize survival of fry in Lake Pend 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 3.5 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 three days prior to release. Morpholine was also added to hatchery water flowing from the fish ladder at Cabinet Gorge Hatchery into Clark Fork River for three days 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 26, 1990. This release was scheduled to coincide with high nighttime river flows resulting from spring snowmelt. This early season release allowed WWP to provide an average hourly discharge of 1,800 m^3/s (65,000 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. The otolith date-of-release mark was used to distinguish fry during autumn trawling in Lake Pend Oreille. Approximately 60,000 fry were fin-clipped (left pelvic) to provide an estimate of the fry-to-adult return rate for spawners migrating to the hatchery in 1993 and 1994.

Table 1. Hatchery-reared kokanee fry released into Lake Pend Orville. Idaho, during 1990.

Release Strategy	Release Dates	Time	Released Number (millions)	Mean size (mn)	Mark
Clark Fork River Early	26 June	Dusk	3.4	50±2	Otolith Code 60K LV clip Size (vs wild)
Sullivan Springs	10-12 July	Day	3.2	50±2	Otolith Code 60K AD clip
Shore1 i ne	24-25 July	Night	1.1	50±2	Otolith Code
	TOTAL		7.7		

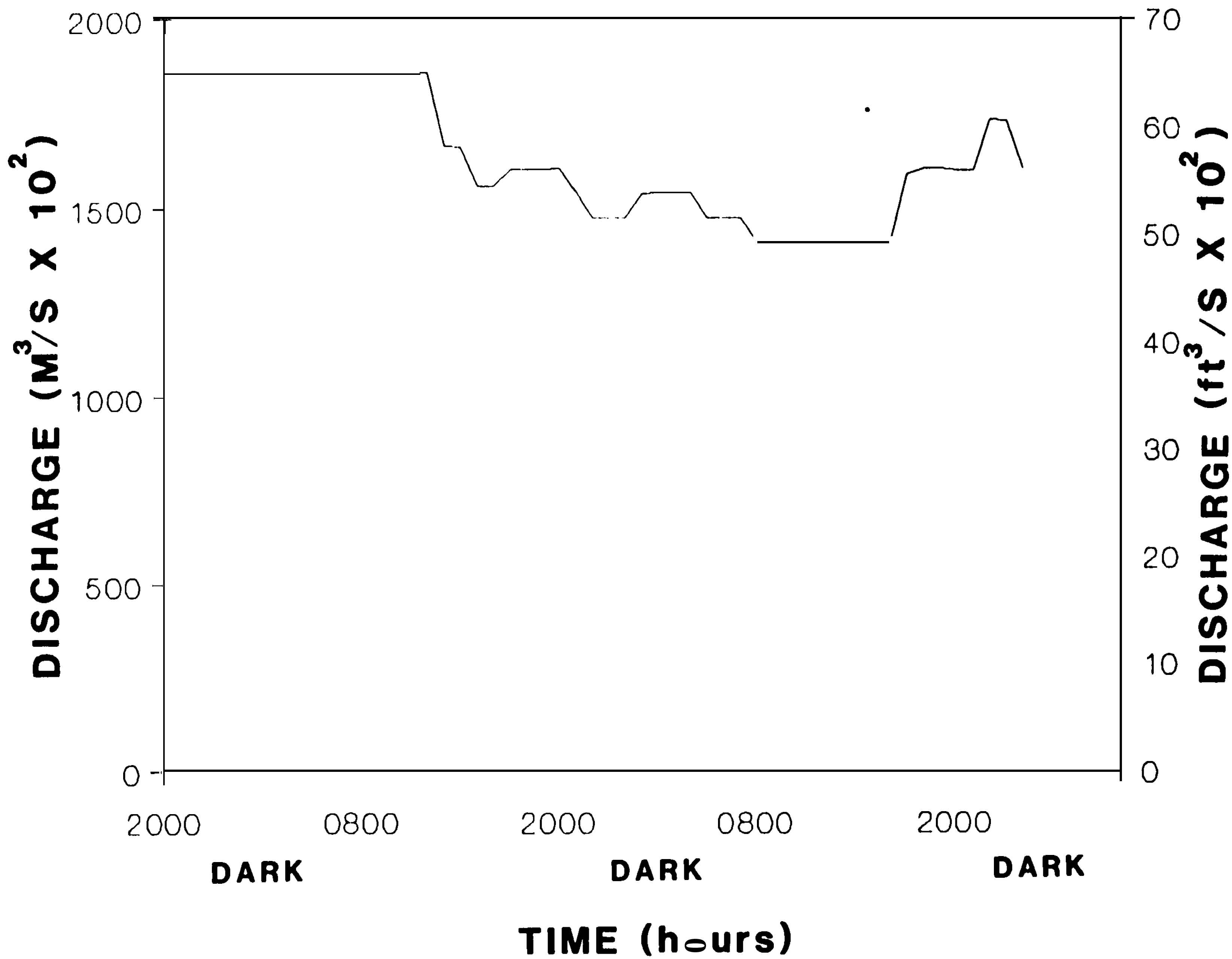


Figure 3. Discharge from Cabinet Gorge Dam into Clark Fork River during three nights (June 26-28 1990) following the fry release (at 2100 hours the first night) from Cabinet Gorge Hatchery.

Sullivan Springs

Approximately 3.2 million fry were transported by truck from Cabinet Gorge Hatchery to Sullivan Springs Creek during July 10-11, 1990. The fry were transported at a density of 55 to 59 kg/m^3 in 10.0°C water and released into 7.2°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 60,000 fry were also fin-clipped (adipose) to evaluate adult returns for spawning in 1993 and 1994.

Open Water

Approximately 2.7 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.

South Shoreline

Approximately 1 million fry were released July 24-25, 1990 in southern Lake Pend Oreille at Farragut State Park public boat launch, 2 km southeast of Bayview, Idaho (Figure 1). Kokanee were trucked at a density of 50 to 74 kg/m^3 in 11.6°C water from Cabinet Gorge Hatchery to Farragut State Park. They were acclimated for 120 min to lake surface water of 22.0°C and released. However, because of a pump failure, about 30% of the release group was released without acclimatization. This release strategy evaluated the survival of kokanee from a less expensive release along shoreline. The otolith date-of-release mark was used to distinguish this release group from trawl samples.

Egg-Take

Since 1974, IDFG 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 enhancement activities for other lakes. Additional eggs were collected from kokanee spawners at 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 from mature kokanee collected during the late fall spawning season for spawner age and length distributions. Spawners were collected from Spring Creek and the weir at Sullivan Springs Creek. Age of maturity was also estimated for kokanee collected during August trawling.

Mysid Shrimp

Mysis were sampled at night during the dark moon phase the first week of June. Five samples were collected randomly in the southern, central, and northern portions of Lake Pend Oreille (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 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. 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.

Size and sex data were recorded for Mysis from two samples/lake section. Mysids 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

The zooplankton community was sampled in the southern, central, and northern portions of Lake Pend Oreille (Figure 4). Five random samples were collected monthly from each section from May through October in the main body of the lake and from June through September in the delta section. However, samples from the Delta were discontinued after 1989 but data are included in this

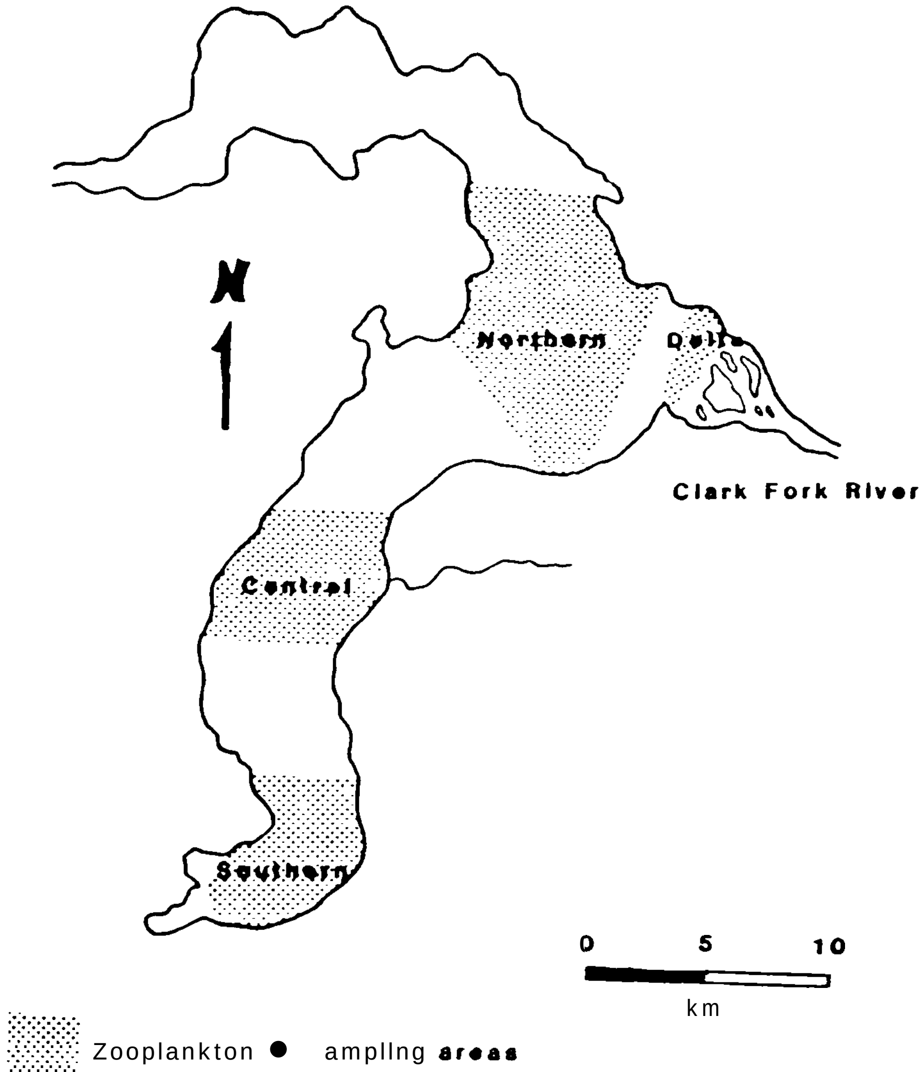


Figure 4. ZOOPLANKTON SAMPLING AREAS on LAKE PEND OREILLE, IDAHO

report. 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. 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 temporally.

Water Temperature and Transparency

Thermal stratification of Lake Pend 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 1 -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 thermocline. 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.

Angler Effort and Harvest

A creel survey was conducted during the 1990 fishing season to provide minimum estimates of angling effort, catch, and harvest of sport fishes. The 1990 survey incorporated a sampling design similar to that used in 1980 and 1985 (Ellis and Bowler 1981; Bowles et al. 1987).

The creel season was temporally stratified to reduce variability and provide seasonal catch comparisons. Creel data was collected from April 15 through November 30, 1990. The survey was stratified into five 6-week periods to correspond with periods used in surveys prior to 1990. Each period was further stratified into three 2-week intervals.

Creel data were collected from 12 major access areas throughout the survey from the north end of the lake and south end (north: Garfield Bay, Trestle Creek, Johnson Creek, Island View, River Delta, and Ellisport Bay; south: Farragut, MacDonalds, Boileaus, JD' s, Vista Bay, and Scenic Bay). Several access areas (Trestle Creek, Johnson Creek, Island View, JD's, Vista Bay, and Scenic Bay) were not sampled during low use periods.

Survey data were expanded by day type (weekends and weekdays) to estimate harvest, catch, and effort (hours and angler-days) for each interval, period, and entire season. An angler-day was defined as one angler's fishing trip, regardless of actual fishing time. The number of anglers interviewed on a given day was multiplied by the number of similar day types within a two-week interval to estimate the minimum number of angler-days for each interval. Similar expansions were used to estimate harvest, catch, and hours of effort. Interval estimates were summed for each period, and period estimates were summed to represent the entire season. Expanded estimates were classified as "estimated minimum" because some anglers exited the lake through unsurveyed landings.

An instantaneous fishing boat count was made periodically to determine the proportion of anglers interviewed during a creel day and to gain a more precise estimate of total pressure. Counts were made by a Cessna 180 at randomly-selected times of a creel day. The lake was divided into five segments and fishing boats counted in each.

RESULTS

Kokanee Abundance, Distribution and Biomass

Trawling for kokanee occurred on August 20-24, 1990, and it usually took six to seven steps at each site. Estimated total kokanee abundance during late August 1990 was 6.93 million fish (Figure 5). Contribution of individual year classes was 3.35 million for the 1989 year class (age 0+), 1.59 million for the 1988 year class (age 1+), 1.45 million for the 1987 year class (age 2+), 0.33 million for the 1986 year class (age 3+), and 0.20 million for the 1985 year class (age 4+). Age 5+ kokanee were not caught by trawling in 1990 (1983 year class).

Estimated average kokanee density for the entire lake (all age classes combined) was 306 kokanee/hectare (Figure 6; Appendix A). Densities ranged from a high of 441 kokanee/hectare in Section 1 to a low of 218 kokanee/hectare in Section 3. Age 0+ wild kokanee densities were highest in southern and central sections of Lake Pend Oreille, whereas hatchery fry densities were uniform in distribution throughout much of the lake but were exceptionally low in Section 5. Densities of age 1+ kokanee were highest in the northern section of Lake Pend Oreille and lowest in Section 5. Densities of age 2+ and age 3+ kokanee were highest in the southern section of Lake Pend Oreille and lowest in central sections. Densities of age 4+ kokanee were equally abundant in all sections of the lake.

Estimated kokanee biomass in Lake Pend Oreille during late August was 171,343 kg (7.57 kg/hectare) (Table 2). Biomass of hatchery-reared kokanee fry was 3,203 kg (0.14 kg/hectare), 82% of total fry biomass in the lake. Estimated biomass of age 1+ and older kokanee was 168,140 (7.43 kg/hectare). Length

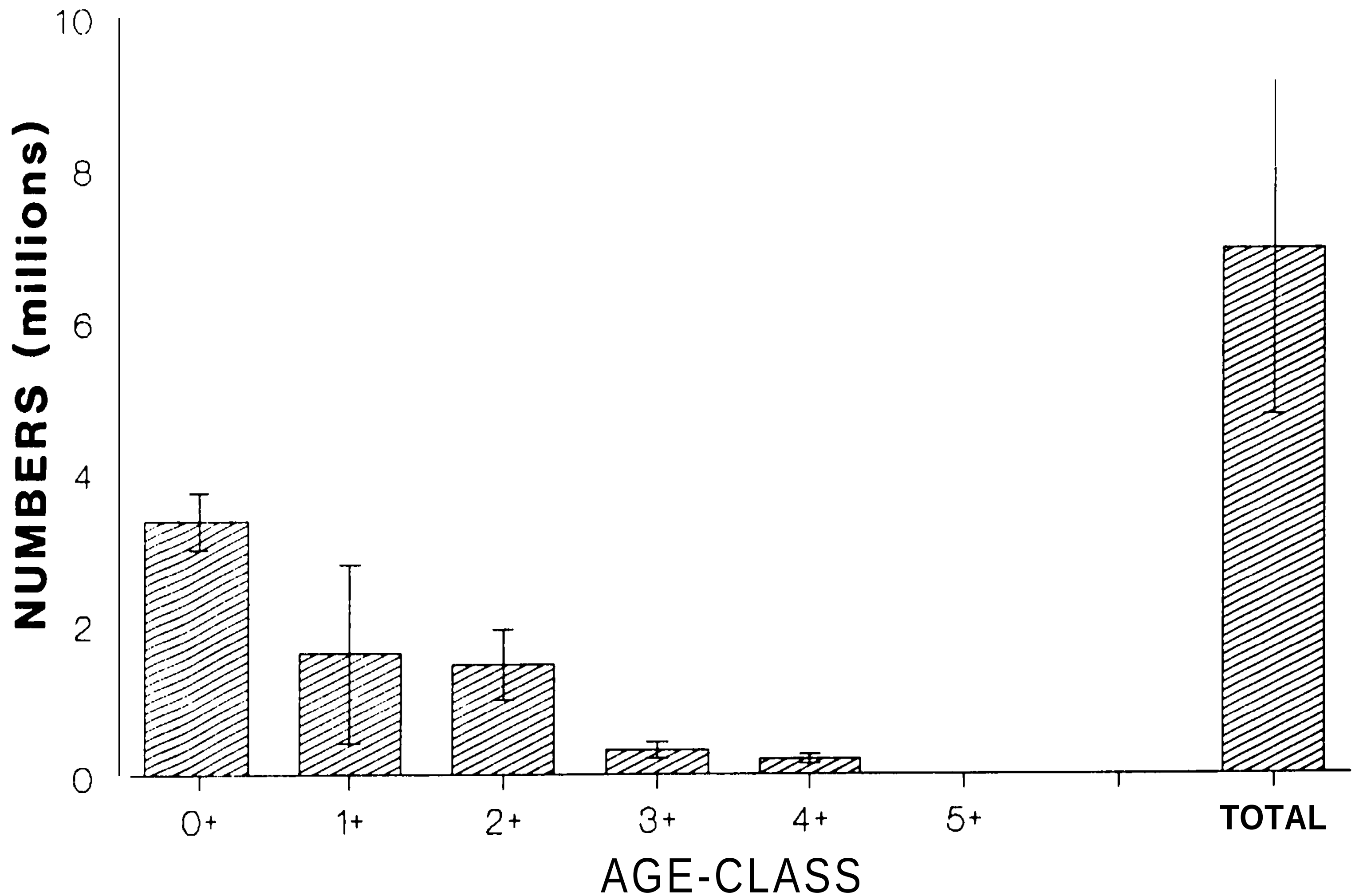


Figure 5. Estimated kokanee abundnnce with 90% confidence intervals, during late August, 1990, l.ake Pend Oreille, Idaho

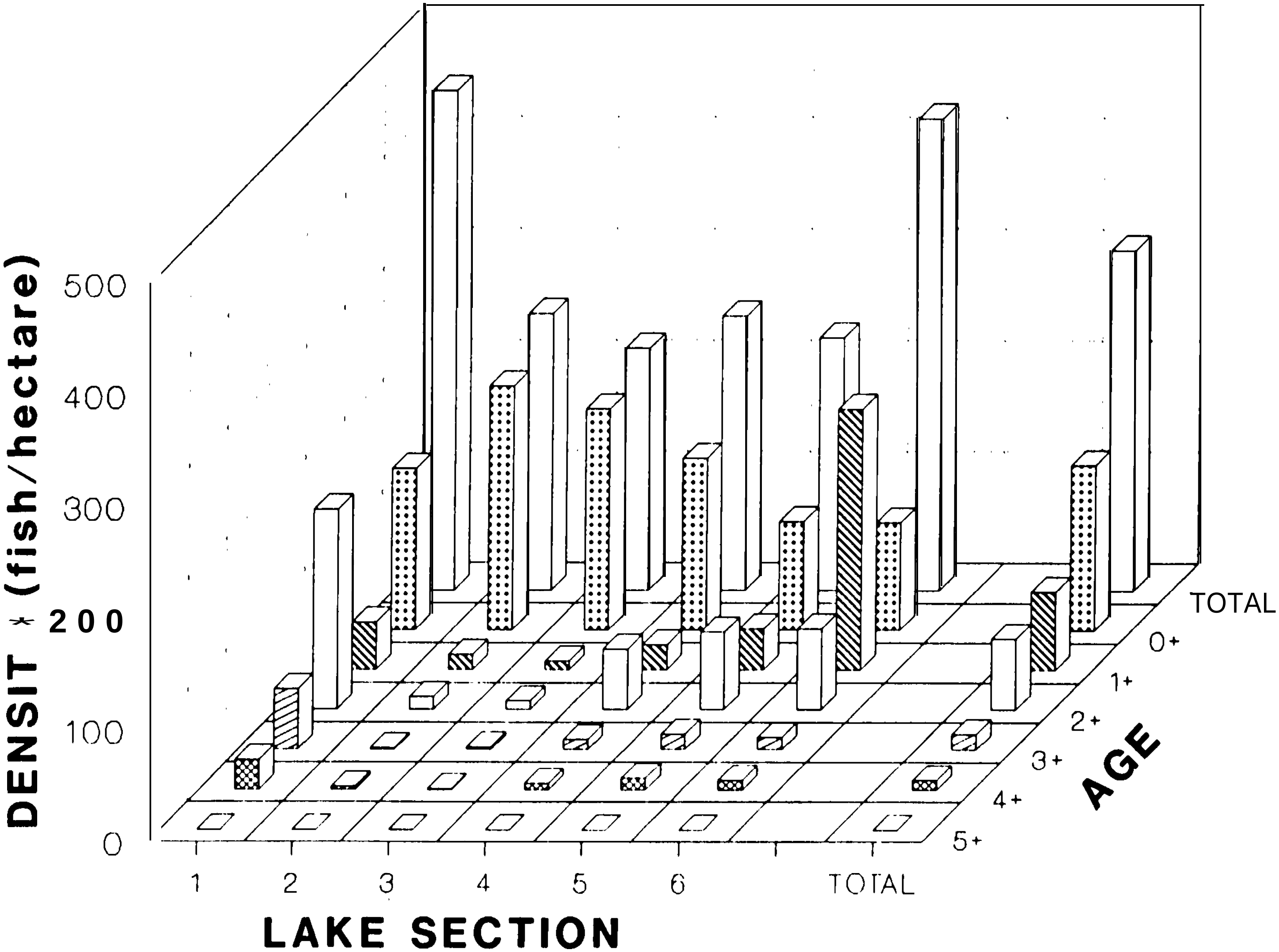


Figure 6. Kokanee density in Lake Pend Oreille, Idaho, by age class and lake section during late August, 1090.

Table 2. Mean length, weight and biomass of kokanee caught trawling during late August, 1990, Lake Pend Oreille, Idaho.

Age class	Mean length (mm)	Mean weight (g)	Biomass kg	Biomass kg/hectare
Age 0+				
Hatchery	63	2.05	3,203	0.14
Wild	35	0.35	628	0.03
Combined	48	1.00	3,831	0.17
Age 1+	145	20.2	32,355	1.43
Age 2+	196	58.6	85,253	3.76
Age 3+	229	98.0	31,910	1.41
Age 4+	249	111.2	21,825	0.96

TABLE2

frequencies and mean lengths and weights of kokanee caught in the trawl are shown in Figure 7 and Table 2.

Spawning Escapement

An estimated 371,600 mature kokanee comprised the Lake Pend Oreille spawning population in 1990. The 1990 spawning run to Sullivan Springs Creek was approximately 57,454 kokanee (15% of the total escapement) and extended from early November 1990 to early January 1991. The estimated return of hatchery-reared fry as adults in 1990 was 0.5%. One-time late-spawning kokanee counts (December) in other tributaries ranged from 4,400 spawners in Spring Creek to 0 spawners observed in Johnson, Cedar, Trestle, and Garfield creeks (Appendix B). Counts of lakeshore-spawning kokanee ranged from 2,036 on southern beaches to only 75 kokanee spawners counted on northern lakeshore areas. A count of 525 early run kokanee spawners was made in Trestle Creek during September.

Age and Length at Maturity

Age composition of mature kokanee captured during trawling in 1990 was 42% age 3+ and 58% age 4+ (N=31). An estimated 52% of age 3+ kokanee were mature and consisted of 48% males and 52% females. All of the age 4+ kokanee were mature and consisted of 61% males and 39% females, while age 5+ kokanee were not caught. Age composition of kokanee spawned during 1989 from Sullivan Springs Creek was 3% age 5+, 79% age 4+, and 18% age 3+ (N=97). Age composition for spawners collected during 1990 was 68% age 4+ and 32% age 3+ (N=65) at Sullivan Springs. A subsample of kokanee spawners from Spring Creek was 91% age 4+ and 9% age 3+ (35).

Mean lengths of kokanee spawners did not vary significantly ($P>0.05$) among spawning sites during 1990. Mean lengths of male kokanee from Sullivan Springs and Spring creeks were 260 ± 2 mm (N=60) and 265 ± 3 mm (N=22), respectively. Mean lengths of female kokanee were 247 ± 3 mm (N=90) from Sullivan Springs Creek and 255 ± 3 mm (N=13) from Spring Creek.

Potential Egg Deposition

Estimated total potential egg deposition for 1990 was 63.9 million, with 58.6 million eggs attributed to natural spawning and a potential of 5.3 million eggs available from artificially-spawned kokanee at Sullivan Springs, and about 0.35 million from the ladder at Cabinet Gorge Hatchery. Estimated abundance of mature female kokanee was 167,232 fish determined from August trawling. Approximately 23,150 female kokanee were spawned at the Sullivan Springs trap, which left an estimated 144,082 female kokanee to spawn naturally throughout Lake Pend Oreille and its tributaries. Fecundity averaged 382 ± 18 (N=45, alpha=0.05) viable eggs/female.

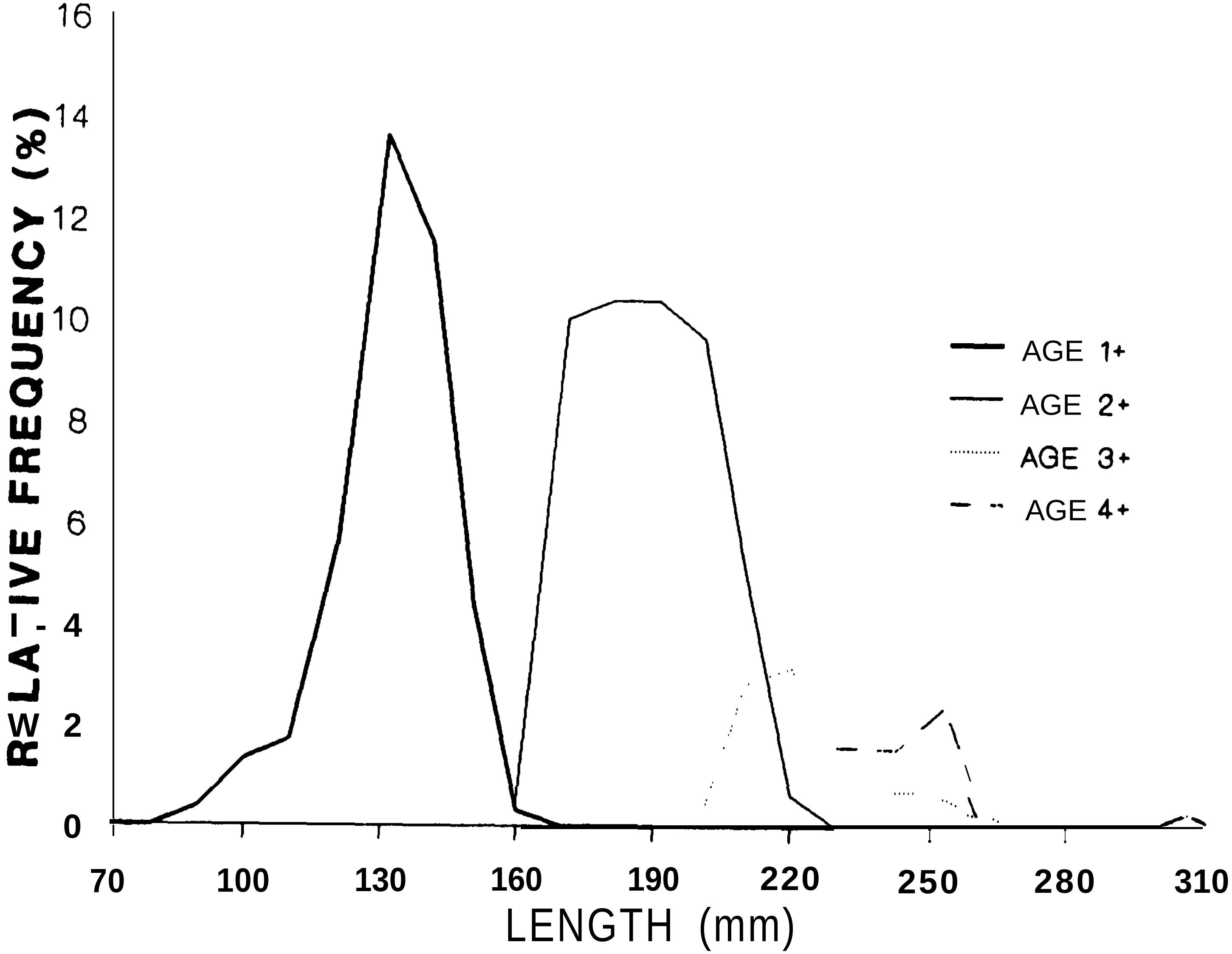


Figure 7. Length frequency of kokanee, by age class, in Lake Pend Oreille, Idaho, during late August, 1990.

Egg-take

Egg-take from the 1990 year class for Lake Pend Oreille totaled 5.65 million. Kokanee spawned at Sullivan Springs provided 5.30 million eggs, 353 eggs/female (N=45), which represents a 922 spawning efficiency. An additional 0.35 million eggs were taken at Cabinet Gorge Hatchery from kokanee migrating up Clark Fork River.

Fry Emigration and Predation

Relative catches of hatchery-reared kokanee fry at the mouth of Clark Fork River indicated that 99% of fry successfully emigrating to Lake Pend Oreille completed the journey the first night following their release at Cabinet Gorge Hatchery. Kokanee fry were first observed at the mouth less than 3 h following their release.

Predation on kokanee fry during emigration through the lower Clark Fork River and delta must have been minimal. High flows of the Clark Fork River made it difficult to sample predators, but of those captured, none had eaten a kokanee. No kokanee fry were observed in the stomachs of squawfish Ptvchocheilus orwonsis (N=2), largescale suckers Catostomus macrocheilus (N=6), mountain whitefish (N=9), brown trout Salmo trutta, and peamouth Hvlocheilus caurinus (N=1) collected electrofishing during two nights following the fry release at Cabinet Gorge Hatchery. All squawfish captured were immature and less than 270 mm total length.

Survival and Recruitment

Estimated kokanee fry survival (hatchery and wild fish combined) from potential egg deposition to late August trawl sampling was 2.72 for the 1989 year class. Survival estimates for hatchery and wild fry were 16.32 and 1.5%, respectively. A survival rate of 20±5% was estimated for the 1989 year class hatchery-reared fry from time of release in late June through July to fall sampling in late August.

Fry survival from release to fall trawling was 15±3% for the early season release in Clark Fork River, 23±3% for fry released in Sullivan Springs Creek, and 28±4% for the mid-summer shoreline release (south) (Figure 8). Fry survival associated with the early season Clark Fork River release was significantly lower ($P<0.10$) than the other two releases. Pair-wise comparisons between the other two release strategies did not show significant differences ($P>0.10$).

Hatchery fry provided an estimated 47% of the total kokanee fry recruitment in 1990. Fry released into Sullivan Springs and south shoreline made up 222 and 102, respectively, of total fry recruitment in Lake Pend Oreille, (46% and 202 of hatchery fry recruitment).

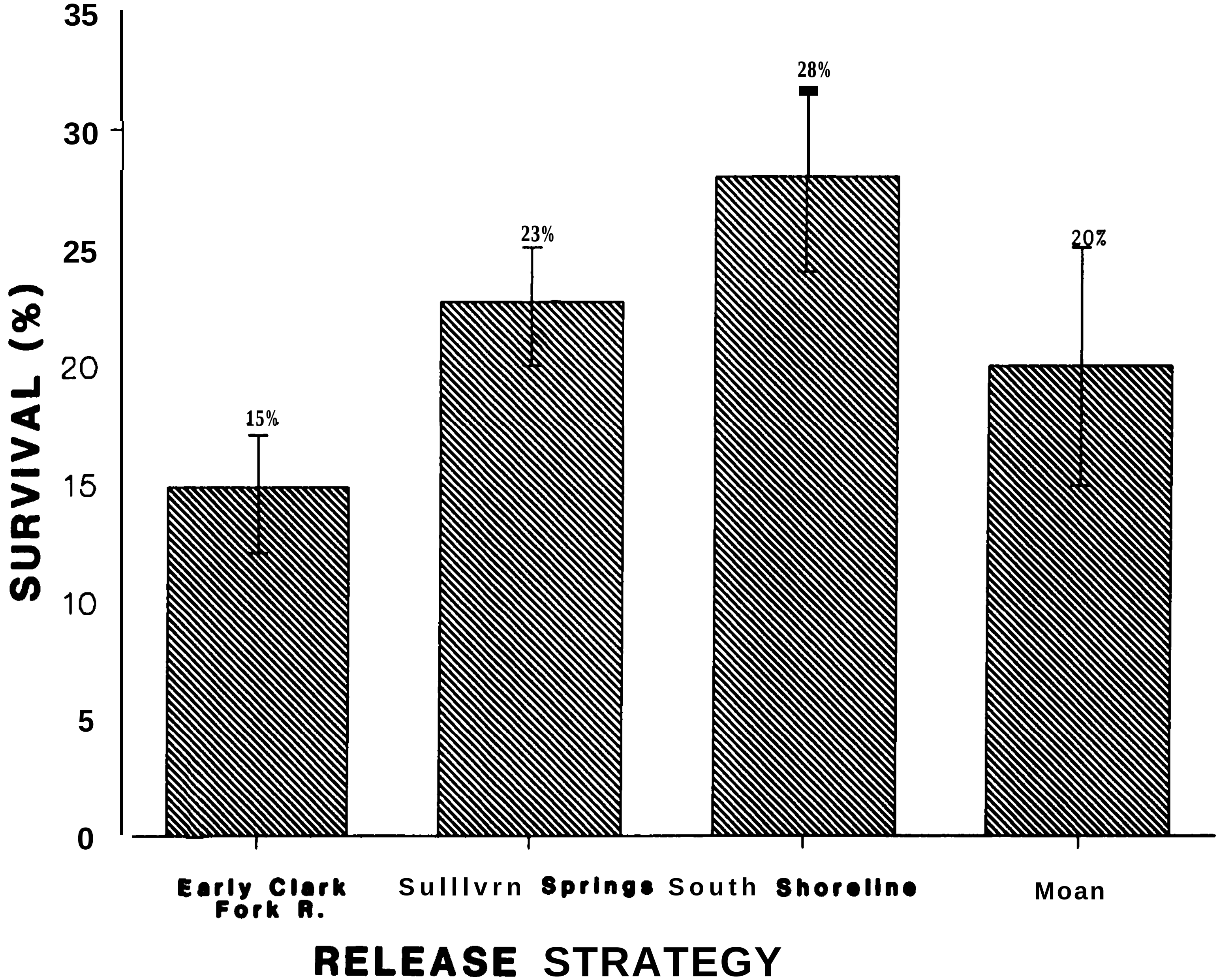


Figure 8. Estimated survival of hatchery fry during their first summer in Lake Pend Oreille, Idaho, compared among three release strategies evaluated in 1990. A 90% error bound is depicted for each estimate.

Although dispersal of hatchery-reared fry throughout the lake was evident following 1 to 2.25 months of lake residence, abundance remained highest in lake sections near release sites (Figure 9).

Estimated annual survival (late summer 1989 to late summer 1990 for wild and hatchery fish combined) was 36% for the 1988 year class (age 1+), 1242 for the 1987 year class (age 2+), 8.9% for the 1986 year class (age 3+), and only 13% for the 1985 year class (age 4+). Survival for age 5+ kokanee could not be calculated because none were caught.

Fry Marking

An obvious mark at the time of release was again evident on kokanee otoliths. This mark separated hatchery residence from lake residence and enabled us to separate wild from hatchery fry. Mean width of daily growth increments was approximately two times larger during hatchery residence than lake residence. About 71% of the daily ring counts (N=108) corresponded precisely with the expected number of days from the releases to fall sampling. All of the counts were within two days of the expected dates.

Mysid Shrimp

Density of Mysis in Lake Pend Oreille during early June 1990 averaged 0.021 organisms/L (Figure 10). This estimate was significantly lower (P=0.016, 0.000, and 0.009) than estimated density for 1986 (0.039 organisms/L) or 1988 (0.047 organisms/L) and 1989 (0.041 organisms/L), but was not significantly different than the 1987 estimate (0.020 organisms/L). Total densities during 1986 to 1990 were similar (P=0.121) between southern and central lake sections and significantly lower (P=0.000) in the northern section compared to the central and southern sections.

Juveniles comprised 76% of total Mysis abundance in Lake Pend Oreille during early June 1990, with an average density of 0.016 organisms/L (Figure 10). Estimated juvenile density in 1990 was not significantly different (0.175<P<0.983) than estimated density for 1987 (0.016 organisms/L) or 1989 (0.025 organisms/L), but was significantly lower (P=0.000) than the 1988 estimate (0.042 organisms/L), the 1986 estimate (P=0.021) (0.031 organisms/L), and 1989 (P=0.016) (0.025 organisms/L). Juvenile densities during 1986 to 1990 were similar (P=0.174) between southern and central lake sections and significantly lower (P=0.000) in the northern section.

Adult mysids comprised 24% of total Mvsis abundance during early June 1990 (Figure 10). Adult density averaged 0.005 organisms/L and was significantly lower (P=0.000) than the estimated density for 1989 (0.016 organisms/L), but was similar to 1986 through 1988. Adult densities in 1990 did not vary significantly (P=0.117) among northern, central, or southern sections of Lake Pend Oreille.

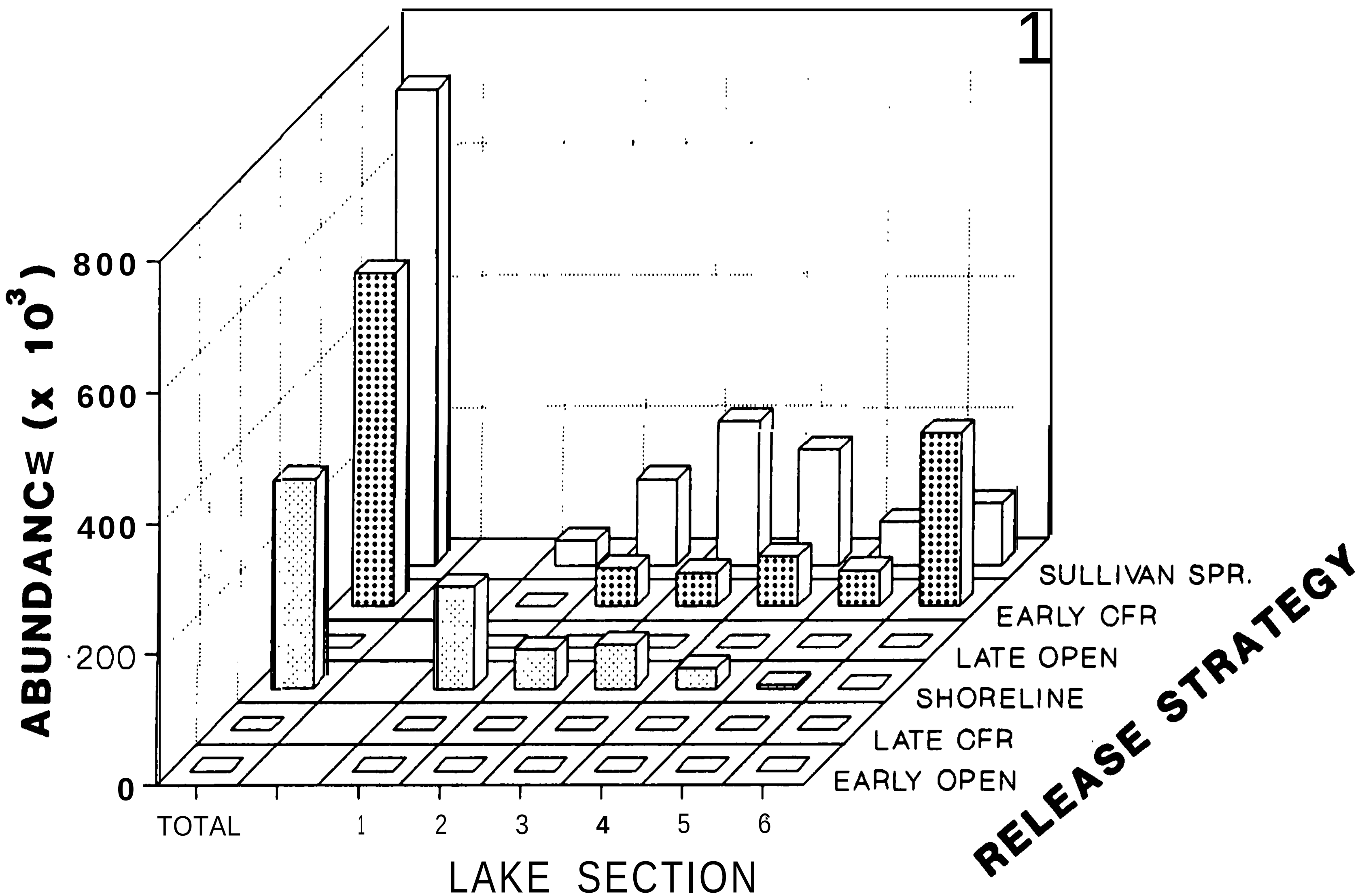


Figure 9. **Abundance and distribution of hatchery-reared kokanee fry during late August, 1990, compared among six release strategies into Lake Pend Oreille, Idaho.**

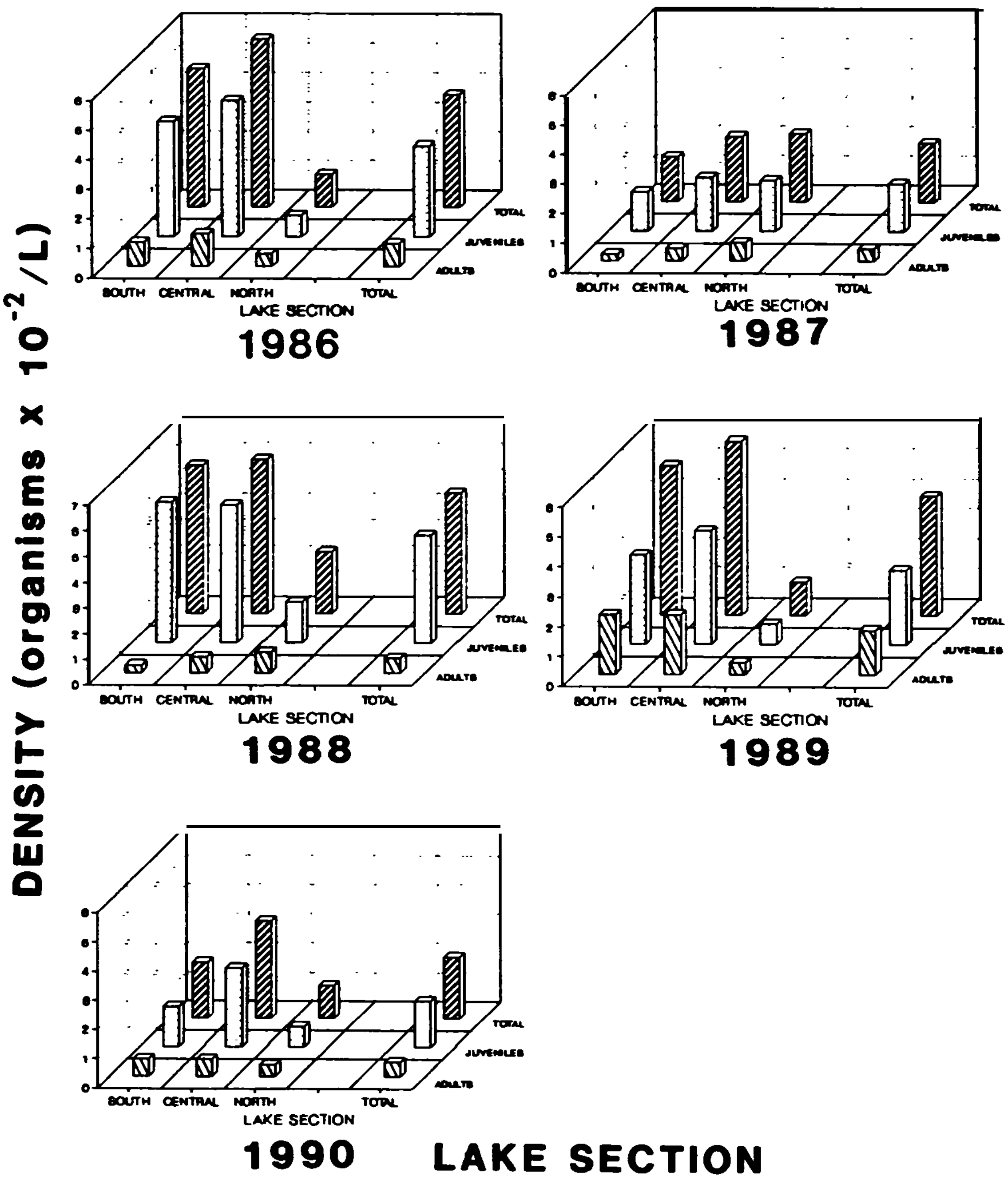


Figure 10. Mean adult, juvenile, and total densities of Mysis in Lake Pend Oreille, Idaho, sampled during June, 1986 through 1990.

A length frequency distribution of Mvsis in Lake Pend Oreille during early June 1990 was constructed and was comprised of contribution of three brood years. The distribution ranged in length from 3 mm to 20 mm (Figure 11). Juvenile mysids made up the 1990 brood year and ranged in length between 3 mm and 9 mm. The 1989 brood year, represented by immature mysids, consisted of 54% males and 46% females, whereas only mature females were observed from the 1988 brood year.

Zooplankton community

The zooplankton community in Lake Pend Oreille from May through October 1990 included Cyclops, Diaotomus, Epischura, Bosmina, Daphnia, and Diaphanosoma. In general, the mean zooplankton density of 17.885 organisms/L in 1990 was the fourth lowest since this study began. Copepod densities were higher than cladoceran densities throughout the sampling periods (Figure 12). Cladoceran density was highest during August and September at approximately 6% and 8% of copepod density, respectively. Total zooplankton density ranged from approximately 7 organisms/L in May to approximately 35 organisms/L in August (Figure 13). The copepods Cyclops and Diantomus were the most abundant zooplankters, with combined densities ranging from approximately 7 organisms/L in May to approximately 33 organisms/L in August. The average density of Cyclops (9.082 organisms/L) was significantly lower (P<0.l0) in 1990 than 1988 (13.226 organisms/L) and higher than 1986 (6.727 organisms/L), whereas the average density of Diantomus (8.037 organisms/L) was significantly different; higher than 1985, 1986, and 1987, a mean of 5.255 organisms/L (Figures 13 and 14, Appendix C). Epischura was the least abundant zooplankter during 1990, with an estimated density of 0.025 organisms/L. In general, cladocerans were extremely uncommon in samples taken during 1990 until August, which was similar to all other years, with the exception of 1989 when densities in July and August were very similar. Bosmina density in 1990 (0.263 organisms/L) was significantly lower (P<0.l0) than 1989 (0.995 organisms/L) and 1987 (0.592 organisms/L). Mean density of Daphnia during 1990 (0.312 organisms/L) was significantly lower than the two highest years; 1986 (1.265 organisms/L) and 1987 (1.077 organisms/L). Diaphanosoma density in 1990 (0.120 organisms/L) was significantly higher (P<0.l0) than 1986. Zooplankton densities were statistically similar (P>0.l0) among northern, southern, and central sections of Lake Pend Oreille (Figure 14, Appendix C). Sampling of zooplankton in the Clark Fork River delta section was discontinued in 1990.

The largest zooplankter in Lake Pend Oreille during 1990 continued to be Epischura, which averaged 2.0 mm long, followed by D. saleata, which averaged 1.1 mm. Dianhanosoma and Diaotomus averaged 0.89 and 0.82 mm, respectively. Cyclops averaged 0.76 mm long, followed by Bosmina, the smallest zooplankter, at 0.39 mm. In general, zooplankton lengths for each genus did not vary significantly (P>0.l0) among the last four years or among months and lake sections (Figures 15 and 16, Appendix C).

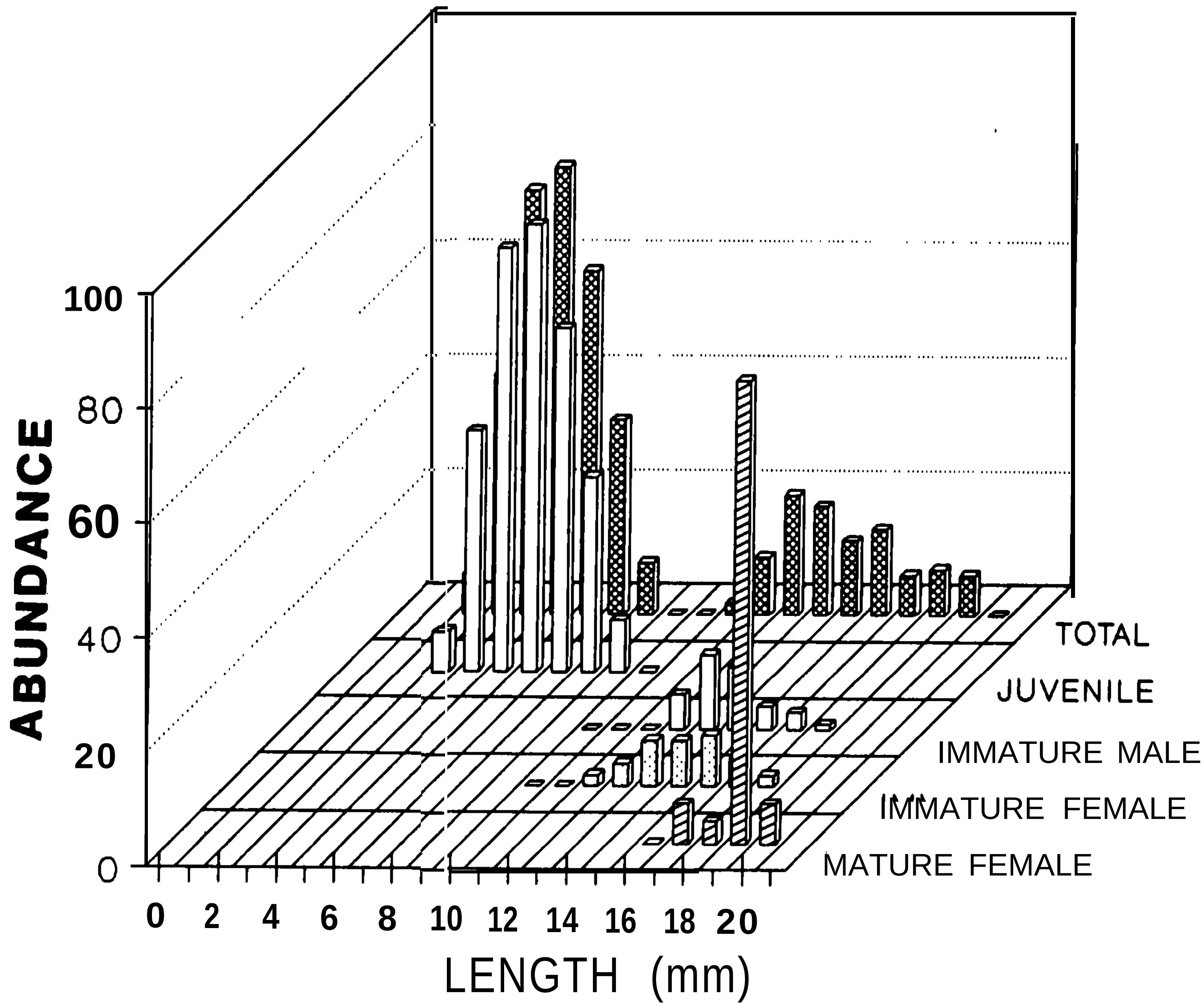


Figure 11. **Length frequency of *Mysis*, by size and sex, in Lake Pend Oreille, Idaho, during early June, 1990.**

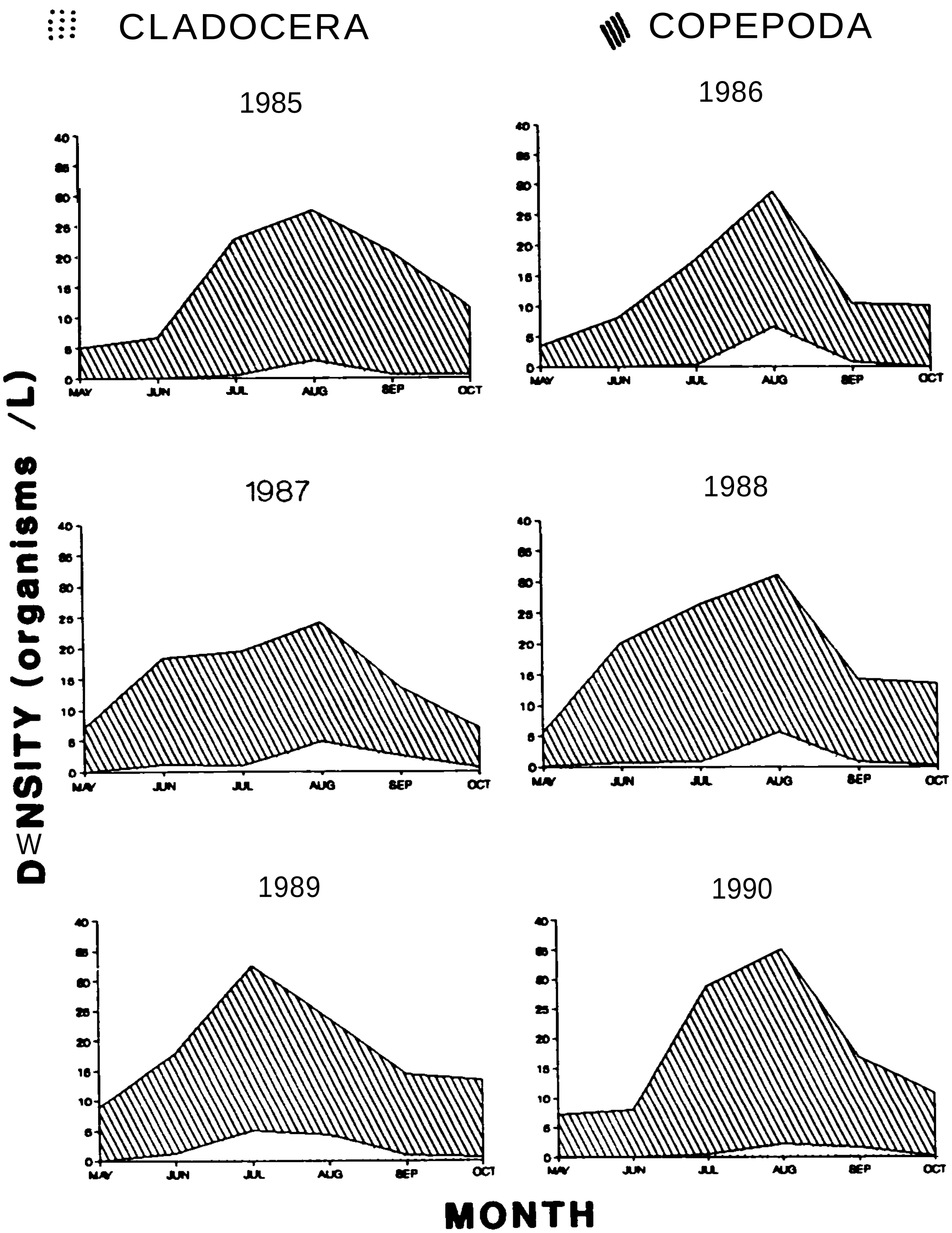


Figure 12. Temporal distribution of Copepoda and Cladocera zooplankton in Lake Pend Oreille, Idaho, May through October, 1985 through 1990.

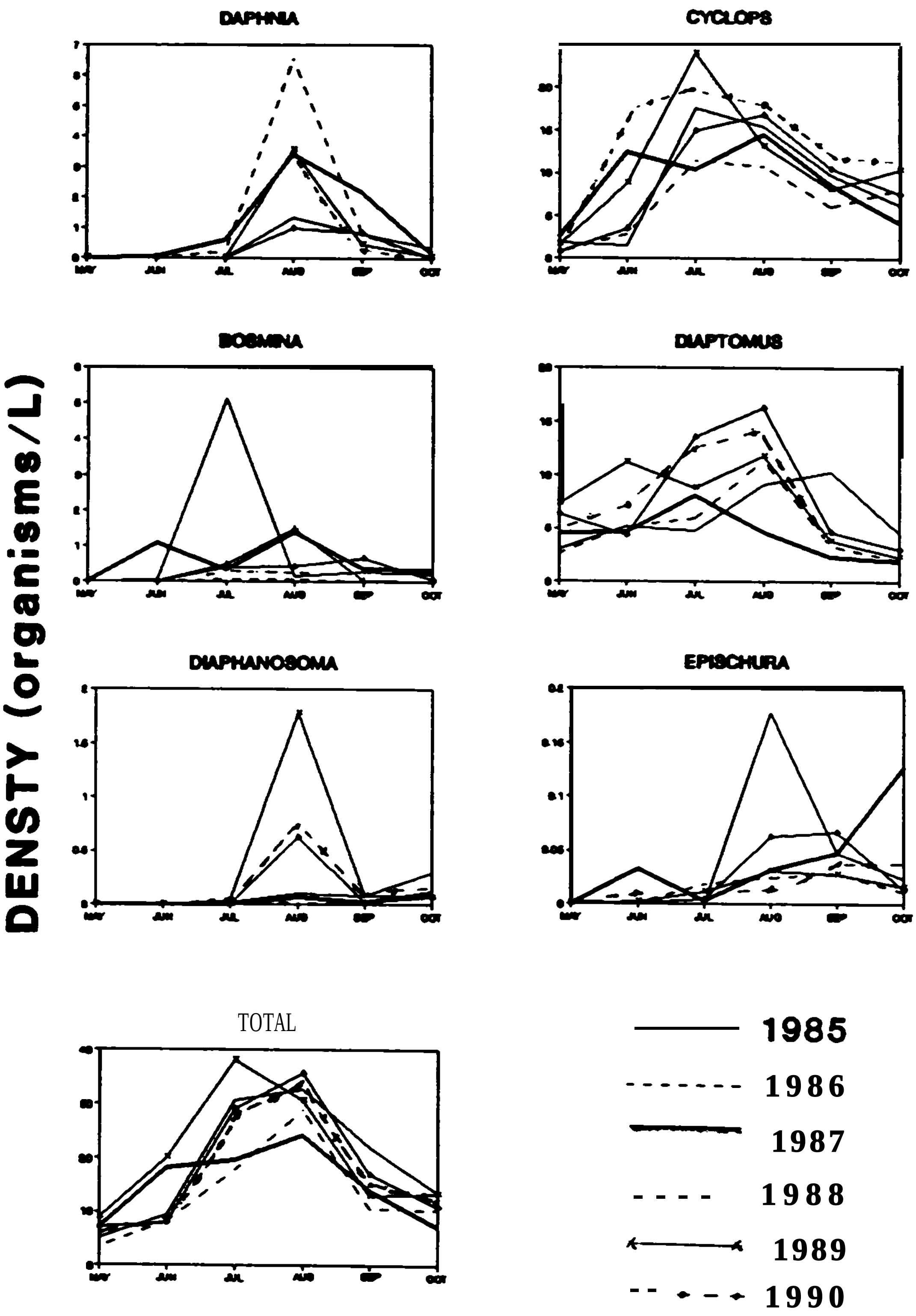


Figure 13. Temporal distribution of mean zooplankton densities in Lake Pend Oreille, Idaho, May through October, 1985 through 1990.

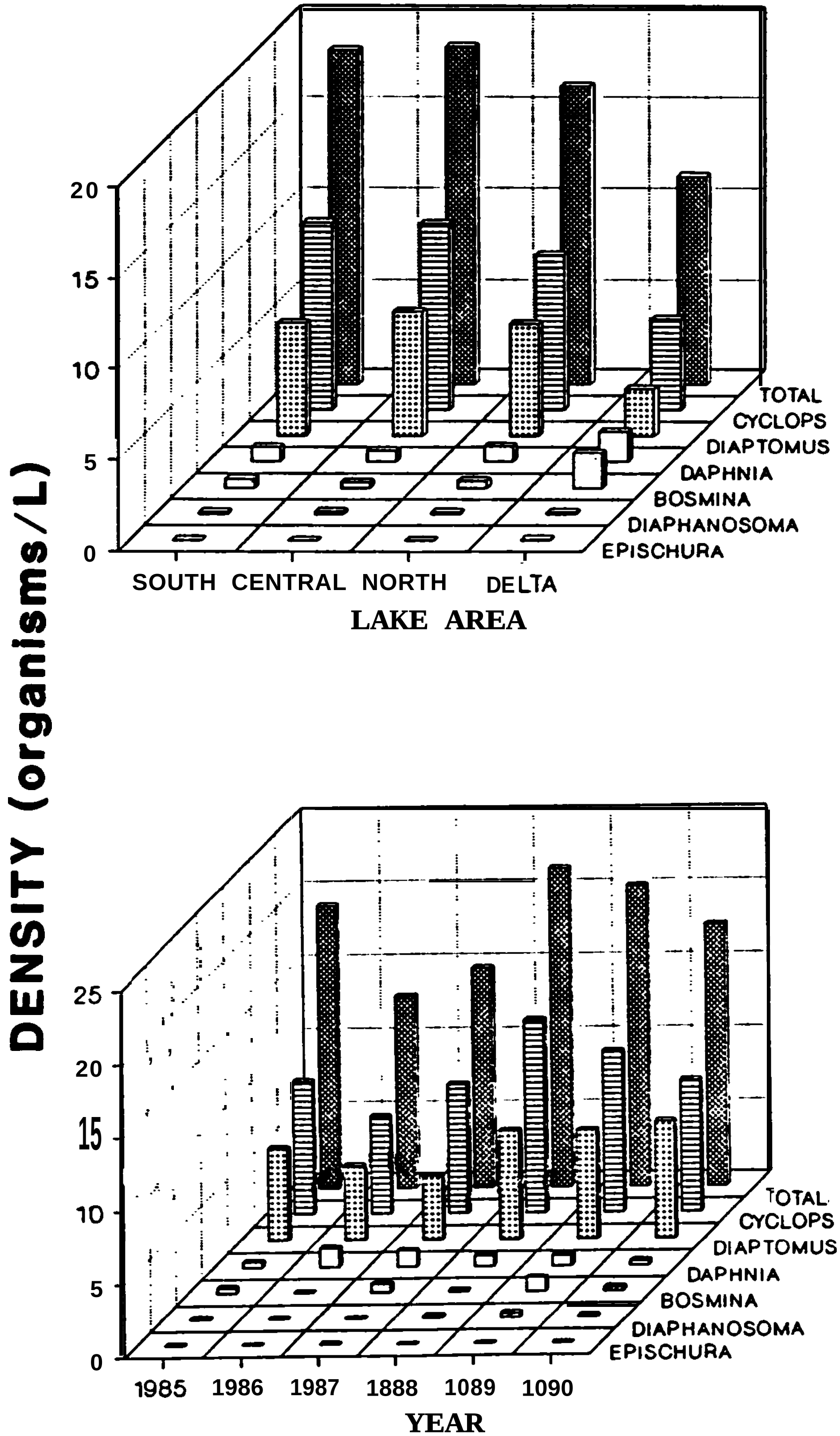


Figure 14. Mean zooplankton densities in Lake Pend Oreille, Idaho, compared among lake sections and years.

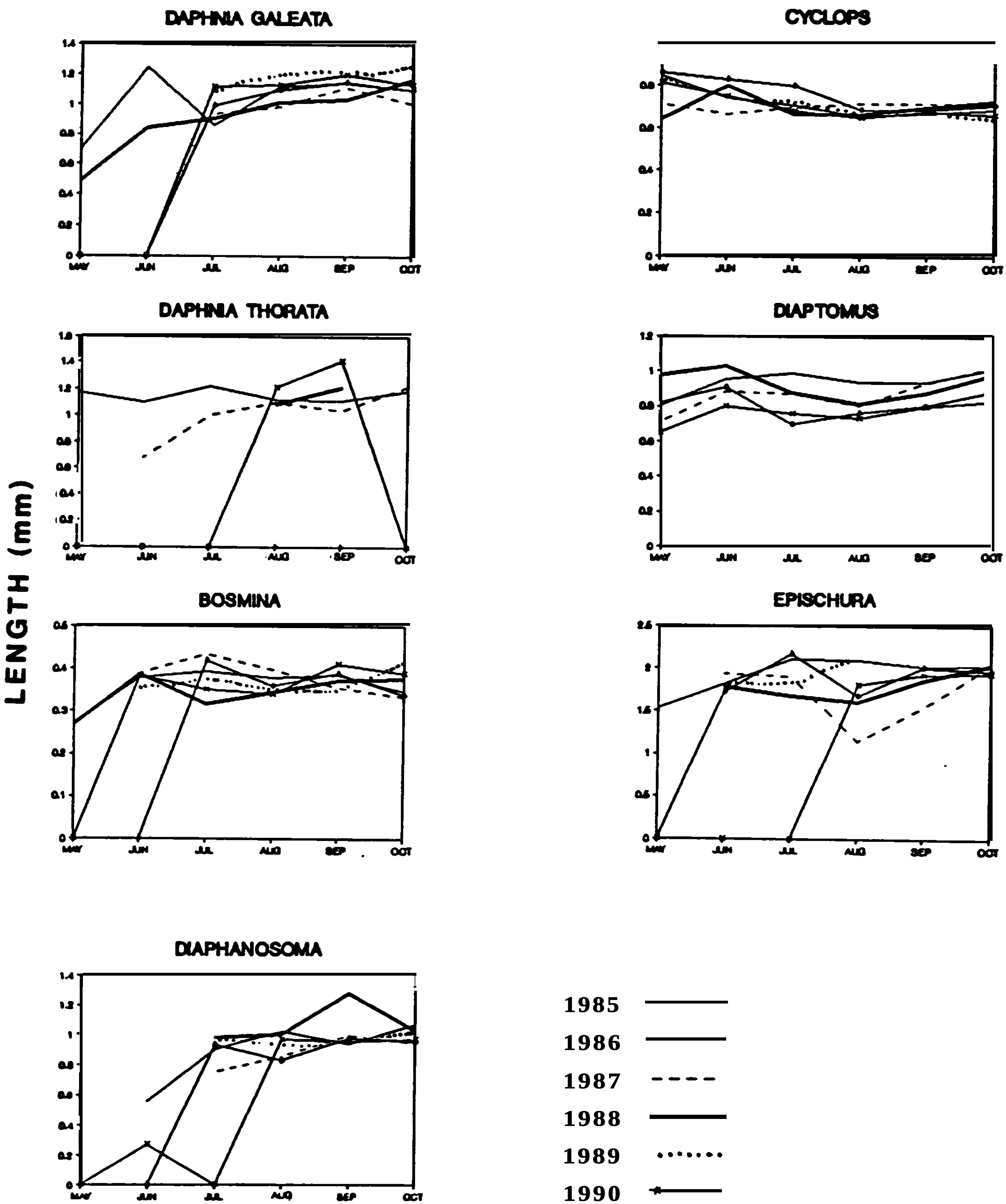


Figure 15. Temporal distribution of mean zooplankton lengths in Lake Pend Oreille, Idaho, May through October, 1985 through 1990.

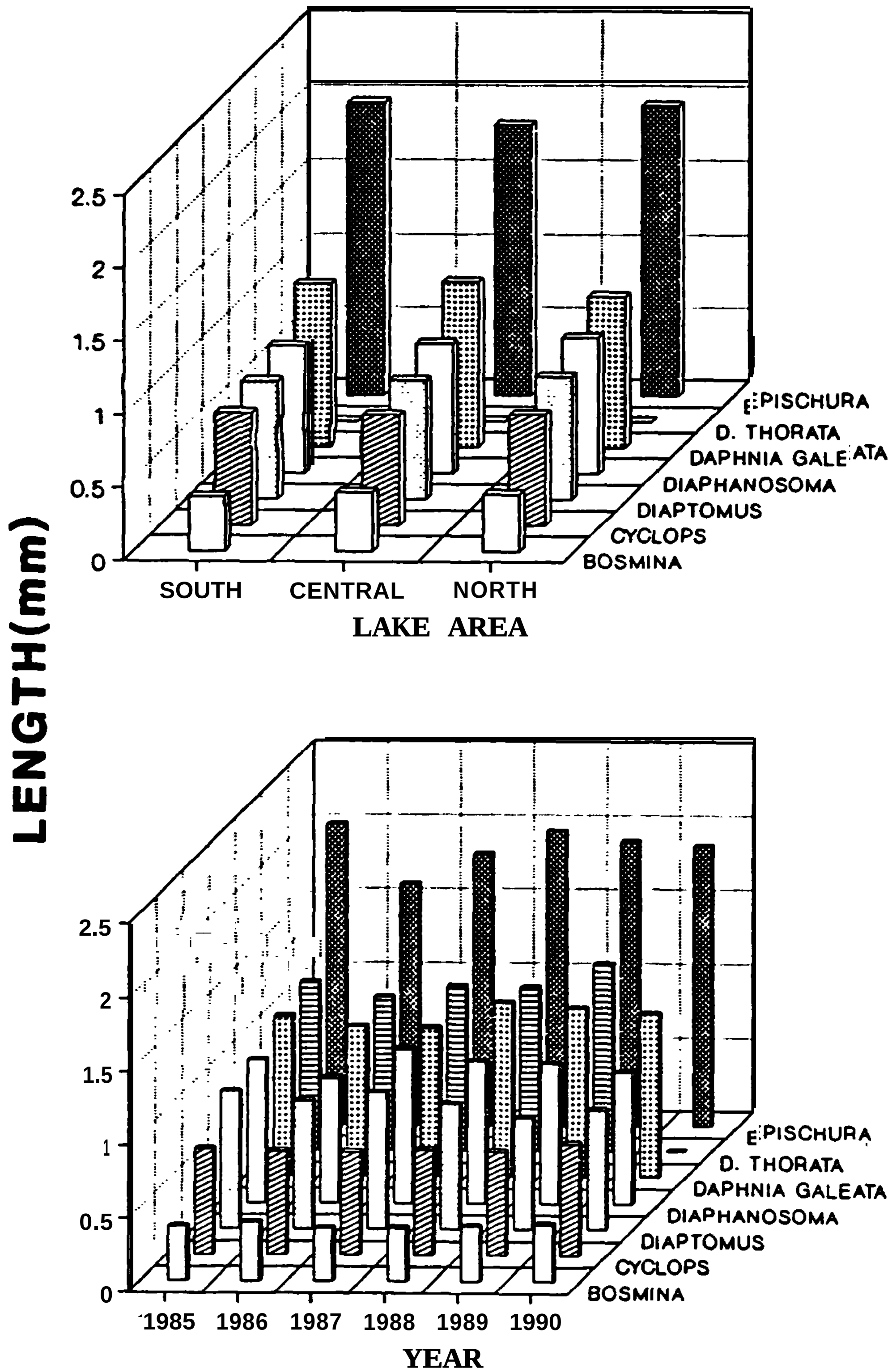


Figure 16. Mean zooplankton lengths in Lake Pend Oreille, Idaho, compared among lake sections for 1990.

Water Temperature and Transparency

Surface temperatures of Lake Pend Oreille from Way through November 1990 ranged from 7.5°C in November to 24°C in August (Figure 17). Thermal stratification began in late June and extended through October. At peak stratification (August), the thermocline began at a depth of 11 m, and average epilimnetic water temperature was 16°C.

Water transparency (Secchi disk) from Way through October 1990 ranged from 2.7 m in May to 8.9 m in August (Figure 18).

The Fishery

Total Catch and Effort

Lake Pend Oreille sport anglers fished an estimated 50,272 hours during 9,953 angler-days and caught 15,141 fish from April 15 to November 30, 1990 (Table 3). Fifty-four percent of the anglers were residents, and they provided 562 of the hourly effort. Came fish harvest included: kokanee, Kamloops rainbow trout (Gerrard), cutthroat trout, bull trout, lake whitefish, mountain whitefish, and various spiny rayed species. Approximately 38% of the anglers fished for kokanee, which comprised 962 of the estimated catch, and 602 of the anglers fished for trout (including bull trout), which comprised 42 of the estimated catch.

A total of 13 instantaneous boat counts by fixed-wing aircraft were made during the 1990 fishing season. Boat count totals ranged from 16 on Way 27 to 428 on April 29, the second day after the opening of the open-water fishing season. Instantaneous boat counts on weekdays averaged 55, while weekends were 148. About 34% of the boats counted by air on weekdays were eventually contacted on shore by a creel clerk, while 222 were contacted on weekends.

Kokanee catch, Harvest, and Exploitation

Anglers seeking kokanee caught an estimated 17,015 kokanee from April 15 to November 30, of which 14,497 (85% of total catch) were harvested (Table 4). Average catch rate for anglers seeking kokanee was approximately 1.09 fish/h for 15,568 hours of effort. An additional 1,150 kokanee were harvested by anglers seeking other species. Mean total length of kokanee sampled from the creel during August was 239 mm. Age structure of the kokanee catch throughout Lake Pend Oreille was estimated at 262 age 2+, 292 age 3+, and 45% age 4+ (Figure 19). Ages of angler-caught kokanee were estimated by comparisons to previously-aged kokanee of similar length caught by trawling. Exploitation of age 2+ (1987 year class) and age 3+ (1986 year classes) kokanee were <1% each. Exploitation

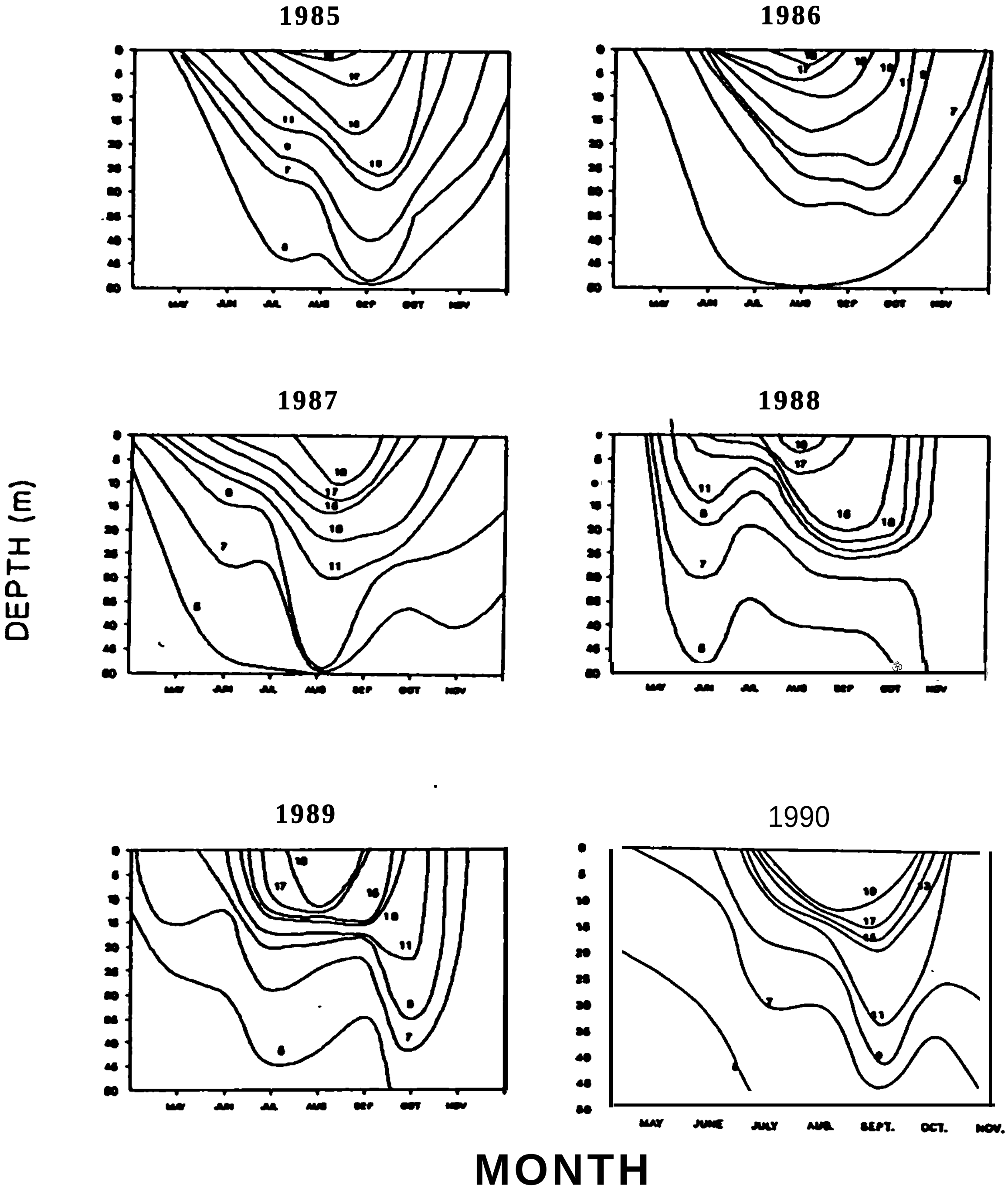


Figure 17. Distribution of thermal isopleths (°C) in the upper 50 m of Lake Pend Oreille, Idaho, May through November, 1985 through 1990.

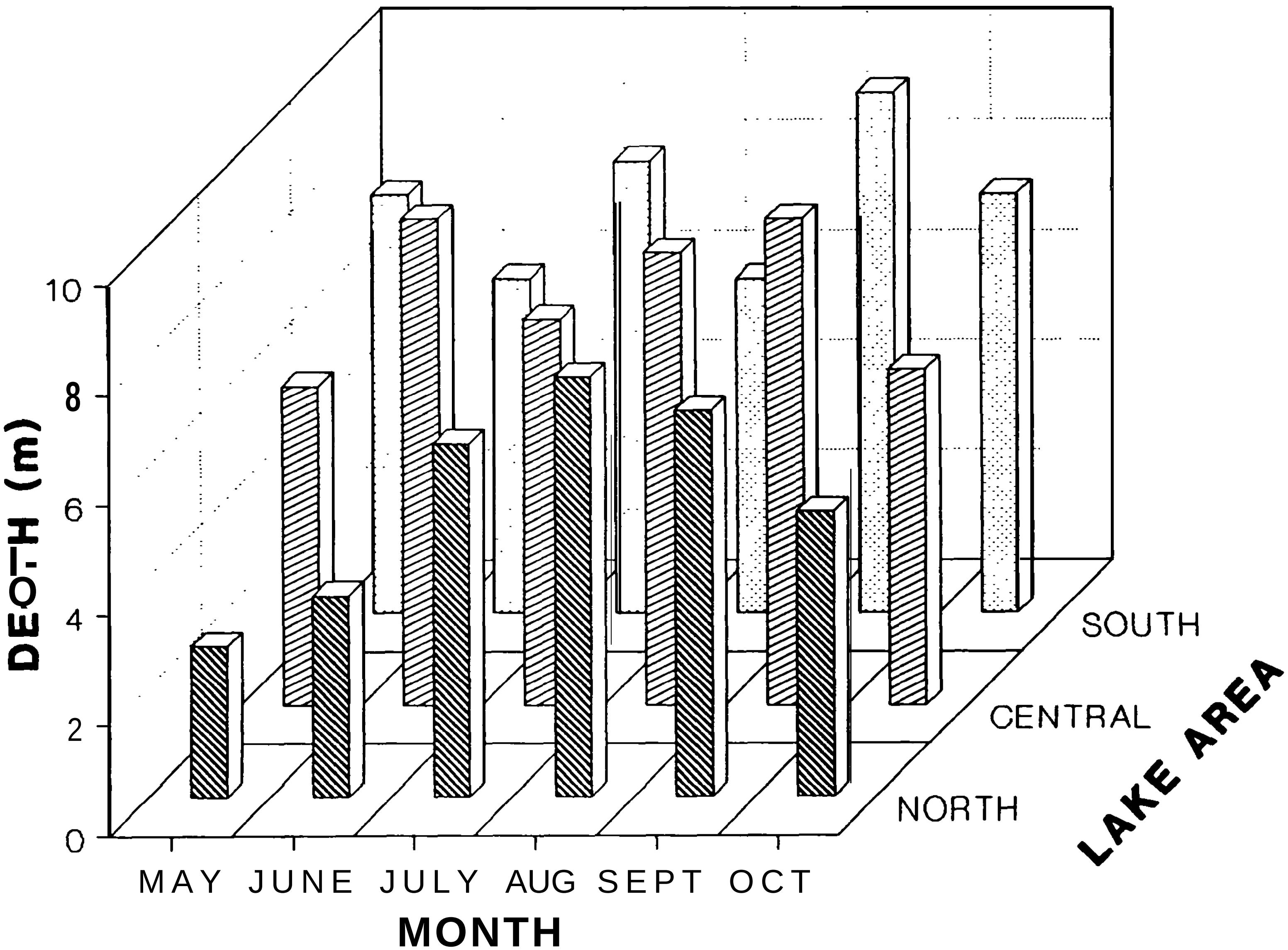


Figure 18. Water transparency (Secchi disk) in three sections of Lake Pend Oreille, Idaho, May through October, 1990.

Table 3. **Estimated** number of **anglers,** effort and **harvest** by survey **period,** Lake **Pend Oreille,** Idaho, 1990.

Period	Anglers	Effort	Harvest									
			Kokanee	Small[a] rainbow	Large[b] rainbow	cut-throat	&11 trout	Lake white-fish	Spiny rays	other trout	Non-game	Totals
Apr 15-May 30	2,704	16,501	30	2	74	31	106	2	0	7	50	302
May 31-Jul 15	2,294	9,695	3,062	18	46	11	50	4	0	10	0	3,201
Jul 16-Aug 30	1,584	6,525	7.398	0	2	0	2	0	0	0	14	7,406
Aug 31-Oct 15	1,485	6,524	3.816	2	20	8	16	0	0	0	0	3,862
Oct 16-Nov 30	1,886	10.619	203	0	138	14	4	0	0	11	0	370
Totals	9,953	50.272	14.499	22[c]	280	64	178	6	0	28	64	15.141

[a]610 mn
[b]610 mm
[c]Illegal take of rainbow <610 mm.

TABLES

Table 4. Estimated catch and harvest for anglers seeking kokanee from April 15 to November 30, Lake Pend Oreille, Idaho, 1990.

Period	Anglers	Effort	Kokanee caught	Kokanee harvested	Other game fish caught	Catch rate (fish/h)		
						Kokanee caught	Kokanee harvested	All game fish
Apr 15-May 30	96	383.5	28	28	4	.07	.07	.08
May 31-Jul 15	1,302	4,878.5	3,536	3,062	185	.73	.63	.76
Jul 16-Aug 30	1,309	5,440.5	9.131	7,388	109	1.68	1.36	1.70
Aug 31-Oct 15	997	4,555.5	4,106	3.816	71	.90	.84	.92
Oct 16-Nov 30	79	309.5	214	203	0	.69	.66	.69
Totals	3.703	15.568.3	17.015	14.497	369	1.09	.93	1.12

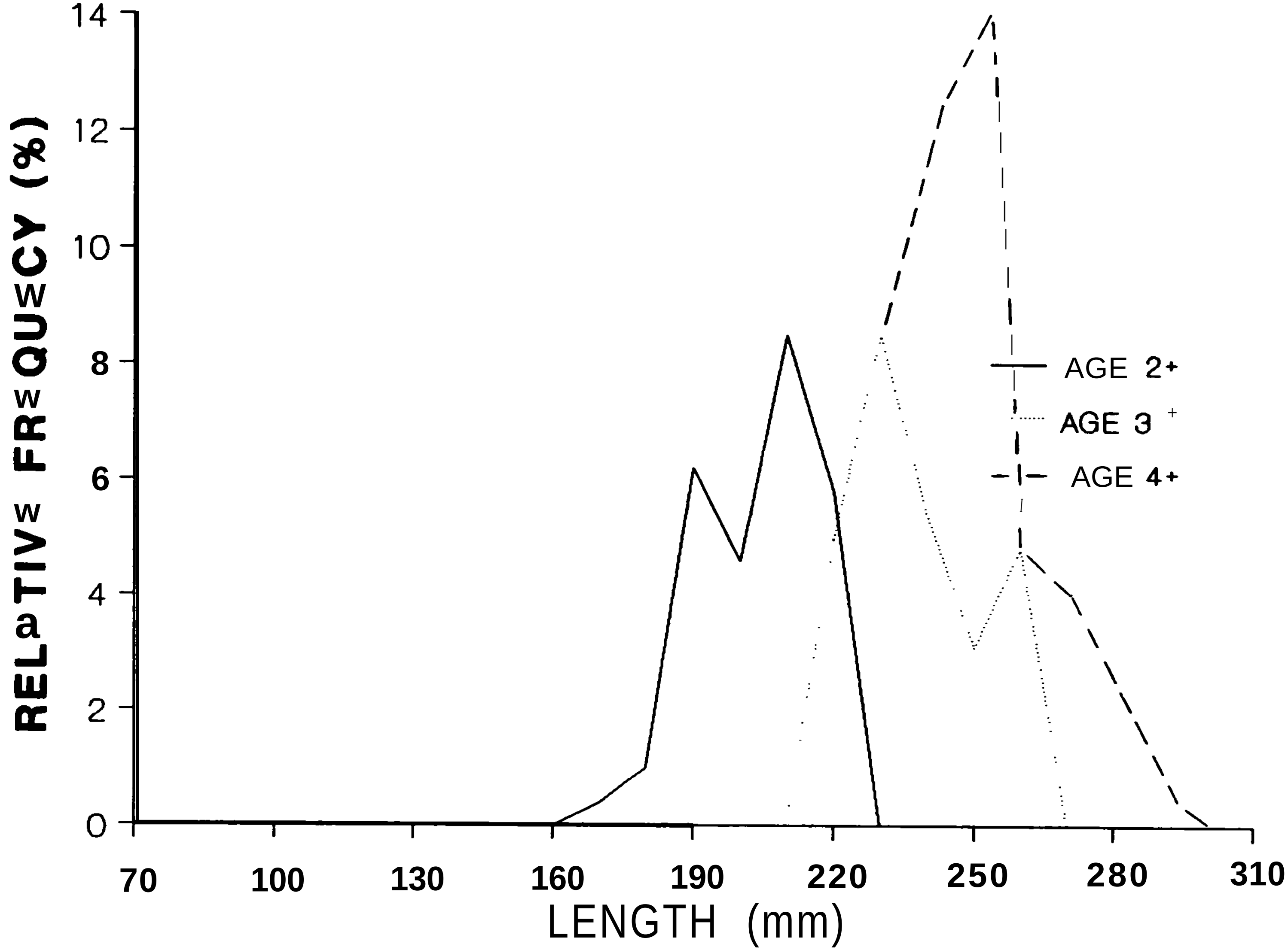


Figure 19. Length frequency distribution of angler-caught kokanee by age class, Lake Pend Oreille, Idaho, 1990.

of age 4+ (1985 year class) was at least 3%. All estimates of exploitation were minimum estimates because the creel effort was only 40% of previous surveys.

Kamloops Rainbow Trout catch and Harvest

Based on angler interviews, the average catch rate for anglers seeking trophy (≥610 mm total length) Kamloops (Gerrard rainbow) from April 15 to November 30 was approximately 83 h/fish (0.12 fish/h) (Table 5). An estimated 411 trophy Kamloops were caught and 254 (62%) were harvested in 34,235 hours of effort (Table 5). An additional 26 trophy Kamloops were harvested by anglers seeking other salmonids (Table 3). Mean total length and weight of trophy Kamloops sampled from the creel were 735 mm and 5.38 kg, respectively. The estimated catch of kamloops <610 mm was 2,191, of which 22 were creeled for a catch rate of 3.7 h/fish (0.27 fish/h).

Bul1 Trout catch and Harvest

Estimated catch rate for anglers seeking bull trout was 7.6 h/fish (0.08 fish/h) (Table 6). The estimated total catch of bull trout was 128, of which 97 (76%) were harvested in 950 hours of effort (Table 6). An additional 50 bull trout were harvested by anglers seeking other species. Mean total length of bull trout sampled from the creel was 529 mm, with a mean weight of 1.52 kg.

Additional Species

Anglers caught 25 ❑ ackinaw and harvested 17 of those (68%). Average length of these fish was 654 mm and the average weight was 3.21 kg. Anglers also caught an additional 173 cutthroat trout, of which 51 were harvested. Average catch rate for anglers seeking cutthroat was 3.7 h/fish (0.27 fish/h). An estimated 30 adipose fin-clipped cutthroat trout (net pen program fish released in May) were caught.

Food Habits

Stomach contents were examined from 12 angler-caught Kamloops rainbow, of which 7 (58%) contained kokanee. For those stomachs containing kokanee, the average was 2.4 fish/stomach. Average length of kokanee was 161 mm. Kokanee were found in 6 of 16 bull trout stomachs for 37% occurrence. For bull trout stomachs containing kokanee, the average was 1.8/stomach. Average length of kokanee was 119 mm.

Table 5. Estimated catch and harvest for anglers seeking large rainbow trout[a] from April 15 to November 30, Lake Pend Oreillo, Idaho, 1990.

Period	Anglers	Effort	Large rainbow caught	Large rainbow harvested	Other trout species caught	Other game fish caught	Large rainbow caught (fish/h)	Large rainbow harvestad (fish/h)	All trout caught (fish/h)	All game fish caught (fish/h)
Apr 15-May 30	2,370	15,406	101	71	540	4	.007	.005	.042	.042
May 31-Jul 15	853	4,528	42	25	306	3	.009	,006	.077	.078
Jul 16-Aug 30	261	1,091	0	0	68	0	0	0	.062	.062
Aug 31-Oct 15	400	2,524	23	20	179	0	.009	,008	.080	.080
Oct 16-Nov 30	1,795	10,666	240	138	1,033	0	.022	.013	.119	.119
Totals	5,687	34,235	411	254	2,126	7	.012	,007	,074	,074

[a]610 mm total length.

Table 6. Estimated catch and harvest of anglers seeklq bull trout from April 15 to November 30, Lake Pend Oreille, Idaho, 1990.

Period	Anglers	Harvest hours	Bull trout cauaht	Bull trout harvested	Other trout species cauaht	Other game fish caught	Catch rate (fish/h) Bull trout cauaht	Bull trout harvested	All trout cauaht	All game fish
Apr I5-May 30	196	691	85	5B	57	2	0.12	0.08	0.20	0.21
May 31-Jul 15	86	227	33	31	10	-	0.14	0.14	0.14	0.14
Jul 16-Aug 30										
Aug 31-Oct 15	8	32	10	8			0.31	0.25	0.31	0.31
Oct 16-Nov 30										
Totals	292	950	126	97	67	2	0.13	0.10	0.20	0.21

DISCUSSION

Kokanee Population Status

Efforts to restore the kokanee population in Lake Pend Oreille demonstrated very good progress from 1986 through 1988 (Bowles et al. 1988). The kokanee population in hake Pend Oreille increased from about 4.3 million in 1985 to 10.2 million fish by 1988 (Figure 20 and Appendix D). However, the population declined 24% in 1989 (Hoelscher et al. 1989) and dropped an additional 19% in 1990 to 6.9 million fish. Initially, the increases in the population were due to increased stocking numbers and improved survival of age 0+ kokanee. The decline in 1989 was attributed to low fry survival that year and poor survival of the age 1+ kokanee. Factors responsible for the decline in 1990 were due to low stockings of kokanee fry; 7.3 million fry in 1990 vs 13.2 million in 1988. Put the most dramatic factor was the change in annual survival of older kokanee (ages 3+ and 4+) from 1989 through 1990. Prior to 1990, mean survival was about 52% for age 3+ fish and 92% for age 4+ kokanee, but in 1990, it was 9% and 13%, respectively (Figure 21).

Several factors may have been responsible for the change in survival, including sampling error and/or predation. Predation appears to be the most logical cause, of which the Kamloops rainbow would be the most important predator. Abundance of Kamloops rainbow has increased as evidenced by improved angling success. For example, catch success for all Kamloops rainbow was 2.5-fold better in 1990, 17 h/fish, than in 1985 when it was 40 h/fish (Bowles et al. 1986).

Predator densities have not been monitored within the last decade, but stockings of hatchery-reared cutthroat, bull, and Kamloops rainbow trout have occurred on an annual basis; about 149,000 Kamloops rainbow 66 mm long were released in 1986. Four hundred and twenty-nine Kamloops rainbow over 610 mm were caught in 1990 and 2,200 smaller fish that year. Food habit analysis of 12 angler-caught Kamloops rainbow and 16 bull trout indicated the main forage of these predators were kokanee. In addition to implementation of a trophy length limit for Kamloops of 610 mm, to be discussed latter in this report. It may be difficult to increase kokanee biomass in Lake Pend Oreille with a larger predator biomass. An indepth predator/prey interaction and bioenergetics evaluation is needed to demonstrate the Kamloops impacts.

Despite the unfavorable changes in the kokanee population status, two positive points are worth noting. First, the decline in the 1987 kokanee year class at age 1+, reported in 1989 (Hoelscher et al. 1990), was an artifact of sampling error. Trawling results of 1990 indicated this year class was well represented at 1.45 million fish compared to an estimate of 1.20 million in 1989 (Appendix D). Thus, the decline noted in 1989 was not as great as first noted. Also, abundance of age 1+ fish in 1990 was the second highest since this study began, 1.59 million kokanee (Figure 20). These improved densities were the result of stocking hatchery kokanee.

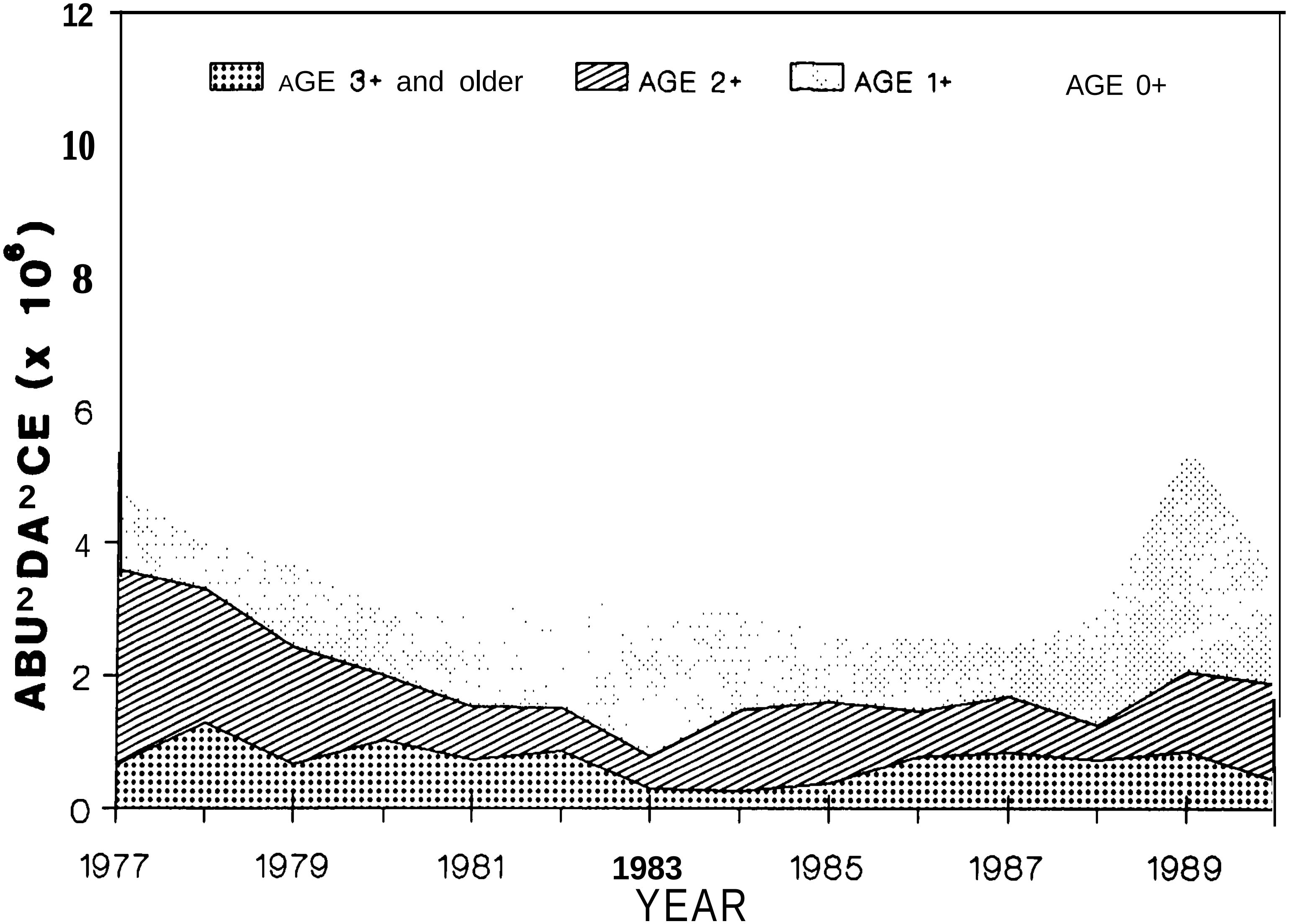


Figure 20. Total estimated abundance of four kokanee age groups in Lake Pend Oreille, Idaho, 1977 through 1990.

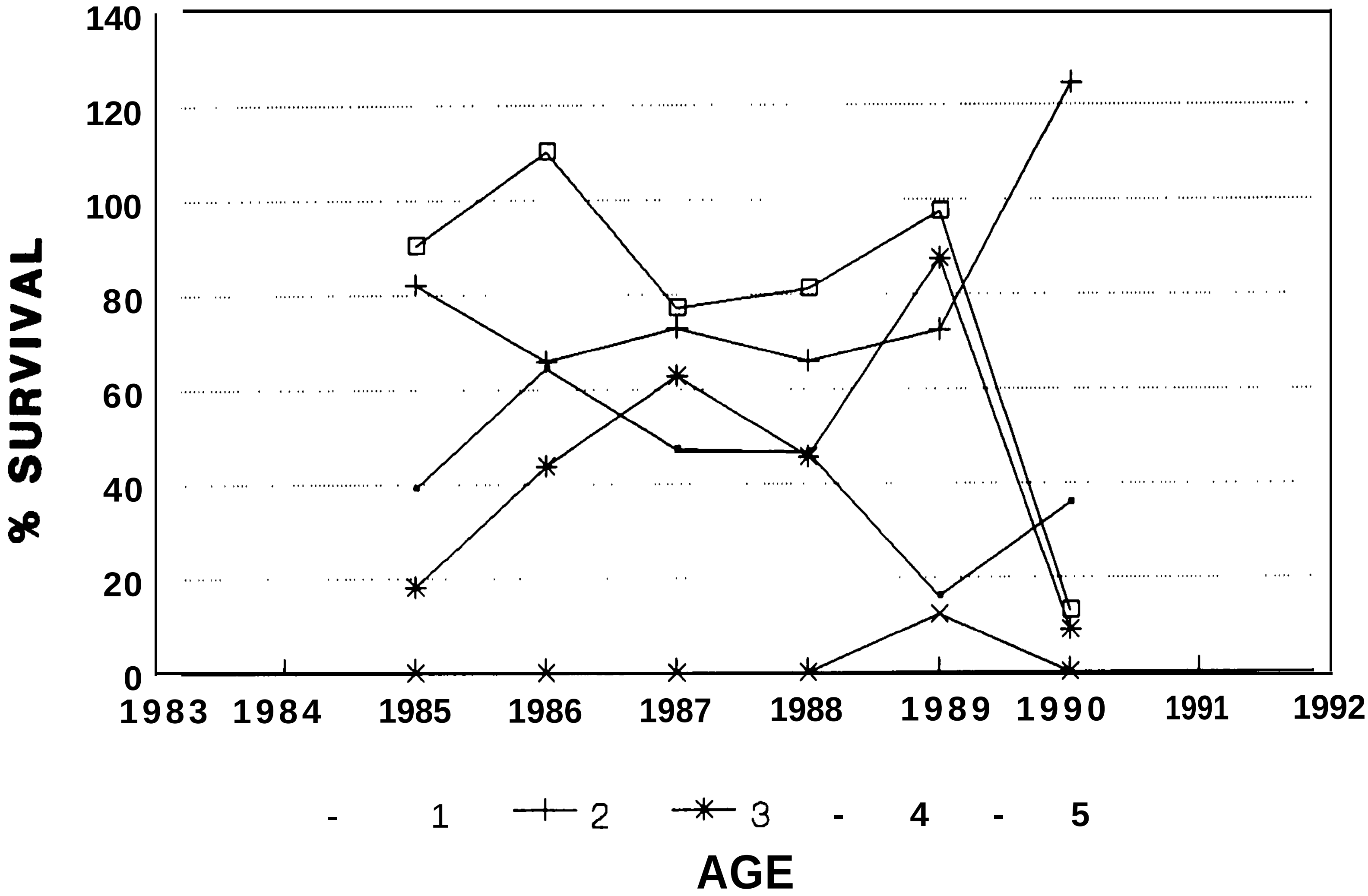


Figure 21. Survival rates of five age groups of kokanee from 1985 through 1990, catches by trawling, Lake Pend Oreille, Idaho.

An apparent compensatory response in survival of age 2+ kokanee was documented in 1990. While survival of age 3+ and 4+ kokanee demonstrated a precipitous drop to a mean of 1 1%, survival of the younger kokanee increased from an average of 44% in 1989 to 81% in 1990 (Figure 20). A portion of this improved survival is due to the underestimate of the age 1+ age group, previously noted. Improved survival of young kokanee could have been due to reduced competition with the older age groups for forage, fewer older fish because of lower survival. Whether or not this is a perceived or a real phenomenon may be determined within the next year of this study. However, a similar observation in compensatory mortality has been made with age groups of kokanee at Lake Coeur d'Alene (Haiolie and Davis 1991). The primary predator in Lake Coeur d'Alene is the chinook. A second possible cause could be a shift in size of prey preference of the 1986 cohort of Kamloops rainbow. Kamloops rainbow become more piscivorous after attaining a length of 450 mm, and large fish may utilize an older kokanee. More information is needed to support this hypothesis.

Hatchery fish still comprise an important segment of the kokanee fishery of Lake Pend Oreille. Prior to construction of the Cabinet Gorge Fish Hatchery, hatchery fish averaged 17% of total abundance (Figure 22). Five years of stocking Lake Pend Oreille with kokanee from the Cabinet Gorge Hatchery has increased the hatchery contribution to 46% of the population.

Fry Recruitment and Survival

Fry recruitment in 1990 was lower than that of 1989 and 1988. Autumn density of age 0+ kokanee was 148 fry/hectare in 1990, a 25% decrease from 1989 (198 fry/hectare) and a 54% decrease from 1988 (320 fry/hectare) (Figure 23; Appendix D). Age 0+ kokanee densities in two other north Idaho lakes during autumn 1990 were substantially higher; 311 fry/hectare for Lake Coeur d'Alene and 260 fry/hectare for Spirit Lake (Maiolie and Davis 1990).

Recruitment of wild fry was the lowest in the last four years of study, but exceeded the hatchery contribution (Figure 24). Wild fry contributed 79 fish/hectare in 1990 compared to 69 fish/hectare of hatchery origin. The contribution of wild fry in 1990 was 20% lower than 1989 (99 fry/hectare) and was 50% lower than 1988 (158 fry/hectare). The decrease in hatchery fry in 1990 from previous years (Figure 24) was due to fewer kokanee fry for stocking. Survival of wild fry in 1990 was only 1.5% compared to 2.2% in 1989 and 3.3% in 1988. It is apparent that environmental factors that influence survival of hatchery fry also affect wild fry (Figure 24). Lower recruitment of wild fry was probably due to slower development of thermal stratification in 1990 (Figure 17) and the fourth lowest zooplankton density since this study began (17.9 organisms/L). It probably was not due to adult escapement in 1989, which was 14%; higher than the previous year (Hoelscher et al. 1990). Nor was it due to a change in the Mysis density, which was the second lowest in the last five years of study (0.021 organisms/L).

Survival of kokanee fry is still 33% below the goal of 30% set for restoration of kokanee in Lake Pend Oreille (Bowles et al. 1988). Survival of

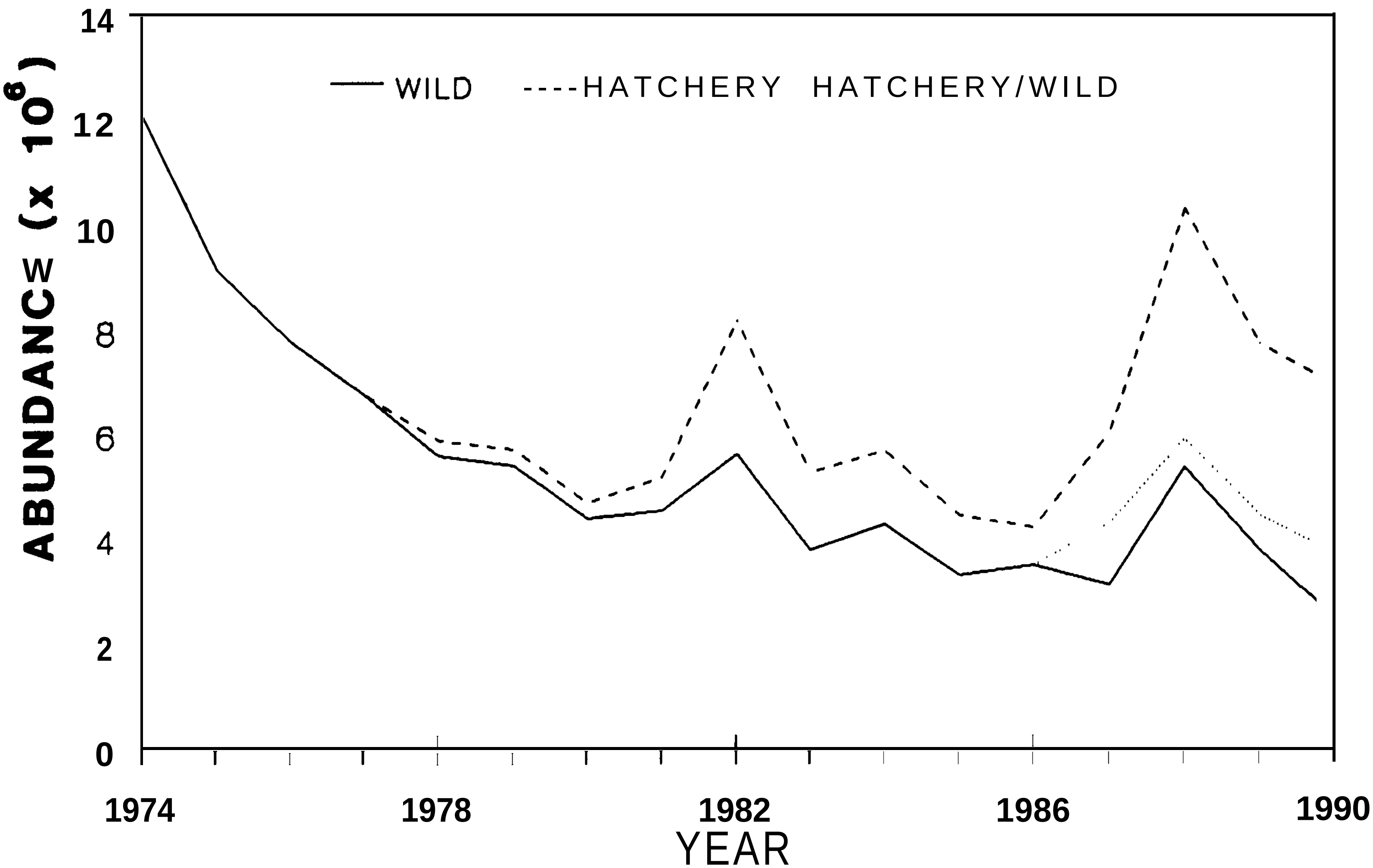


Figure 22. Relative hatchery contribution to total estimated kokanee abundance in Lake Pend Oreille, Idaho, 1974 through 1990. The hatchery-wild component represents contribution from naturally-spawning kokanee of hatchery origin.

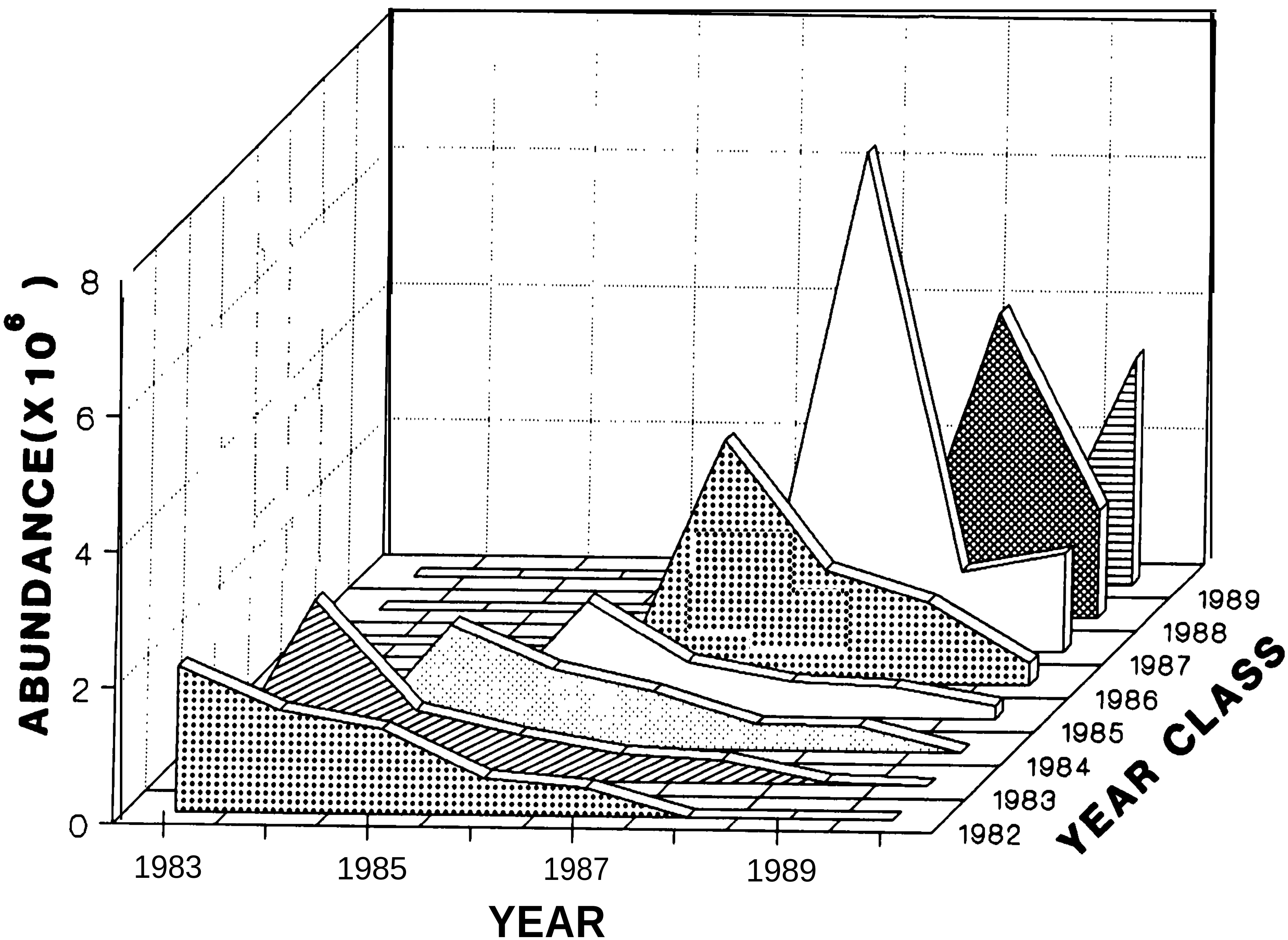


Figure 23. Comparative year class strength of kokanee in Lake Pend Oreille Idaho from 1982 through 1990.

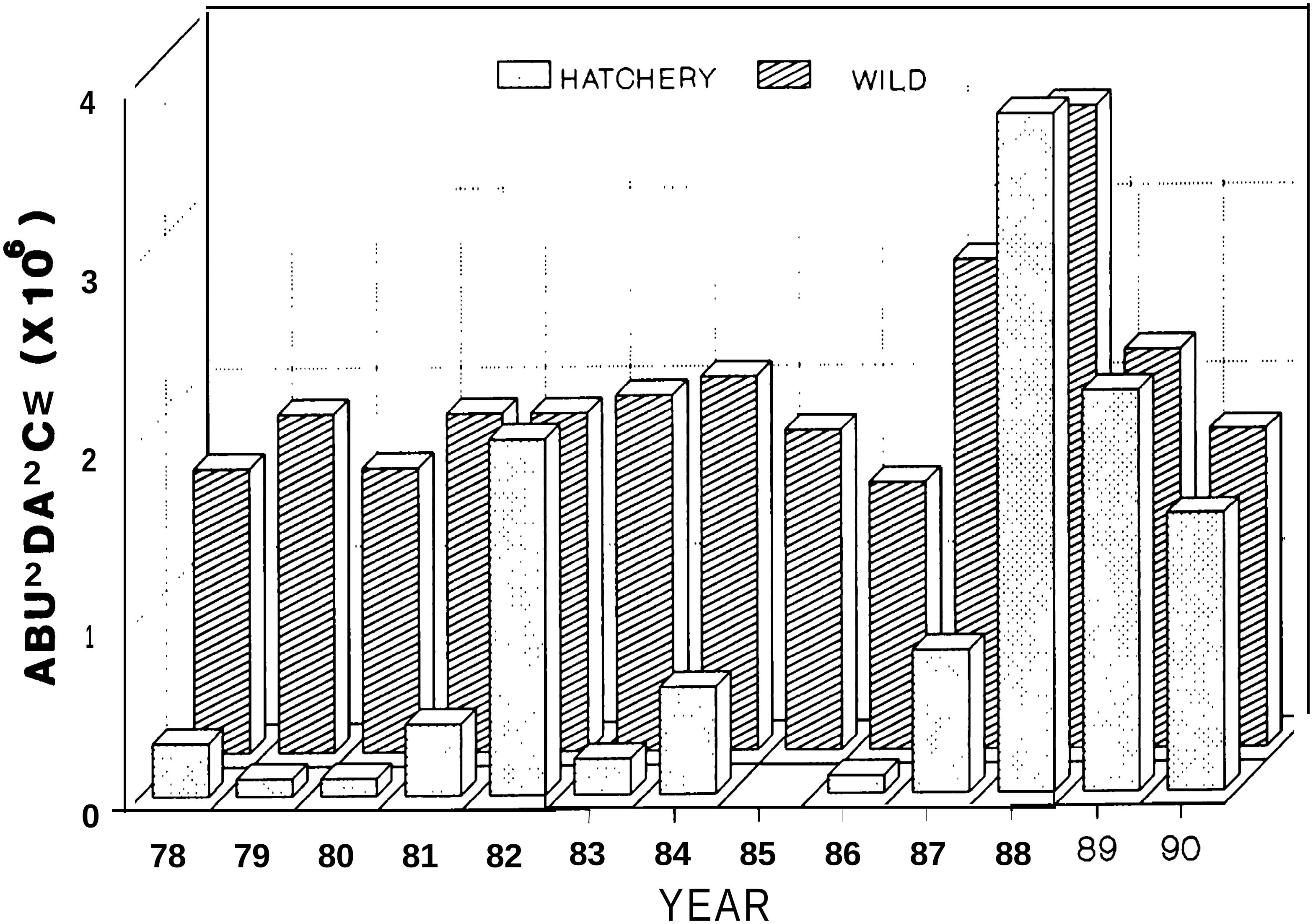


Figure 24. Total abundance of wild and hatchery-reared kokanee fry in Lake Pend Oreille, Idaho, during late summer, 1978 through 1990. Hatchery contribution in 1985 was not estimated.

kokanee fry in 1988 was 292, nearly achieving the management goal of 30% (Figure 25). Survival in subsequent years was much lower at 19%, and 20% for 1989 and 1990, respectively.

Release Strategies

Three release strategies were tested in 1990 all of which were replicates of 1989; Early Clark Fork River release, Sullivan Springs release, and a south shoreline release (Figure 26). The estimate of 20% survival for all release groups in 1990 was the second highest since this investigation began. The best achieved was in 1988 at 299, while 1989 was 192, 1987 was 14%, and 1986 was about 3% (Bowles et al. 1988). Survival within the release strategies of 1990 were very similar to the results of 1989. The south shoreline release was the most successful, with a survival of 28% in 1990 and 27% in 1989. This particular release was especially important because it was the second test of the strategy, and 30% of the release group had to be released before tempering. Normally, fry are tempered mechanically by exchanging lake with stocking tank water. Failure of the pumps and seriously stressed fish forced a release without tempering; lake water was 9°C warmer than tank water. A search of the shoreline several hours after the release revealed few dead fish. Success of this release is partially attributed to the greater zooplankton density at the south end of Lake Pend Oreille, zooplankton densities were reaching their peak in mid-July, and fry were of a large size (about 52 mm), and no doubt development of thermal stratification soon after the release was important.

The release at Sullivan Springs achieved a survival of 23% with no significance (P>O.05) from the shoreline release. The same environmental factors that helped produce high survival of the shoreline release were probably important to the Sullivan Springs fry release. However, total survival for these two groups was similar to the previous year, perhaps because zooplankton densities were similar (P>O.05).

Survival of fry released early into the Clark Fork River was lower than anticipated, 15% compared to 18% in 1989 and 27% in 1988. The success of the early Clark Fork River release is dependent to a large degree on river flows, at least 1,000 m^3\s (36,000 cfs) (Bowles et al. 1989), and food availability in Lake Pend Oreille. The improved survival in 1988 was thought to be due to enhancement by rapid transportation downstream of fry to the lake past riverine predators, primarily the northern sguawfish, an effective salmon smolt predator (Brett and McConnell 1950), Foerster 1968). Electrofishing of the river delta during the 1990 release indicated few adult sguawfish were present. This predator was probably upstream spawning as in 1988 (Bowles et al. 1989). However, flow of the Clark Fork River was about 1,840 m^3\s (65,000 cfs), more than twice the volume needed for good survival. Yet survival was poor, thus, there may be a parabolic relationship between flow and kokanee fry survival with an optimum between 850 and 1,840 m^3\S (30,000--65,000 cfs). Continued experimental release at intermediate flows will help determine if this is a true relationship. Of additional importance was low zooplankton densities during

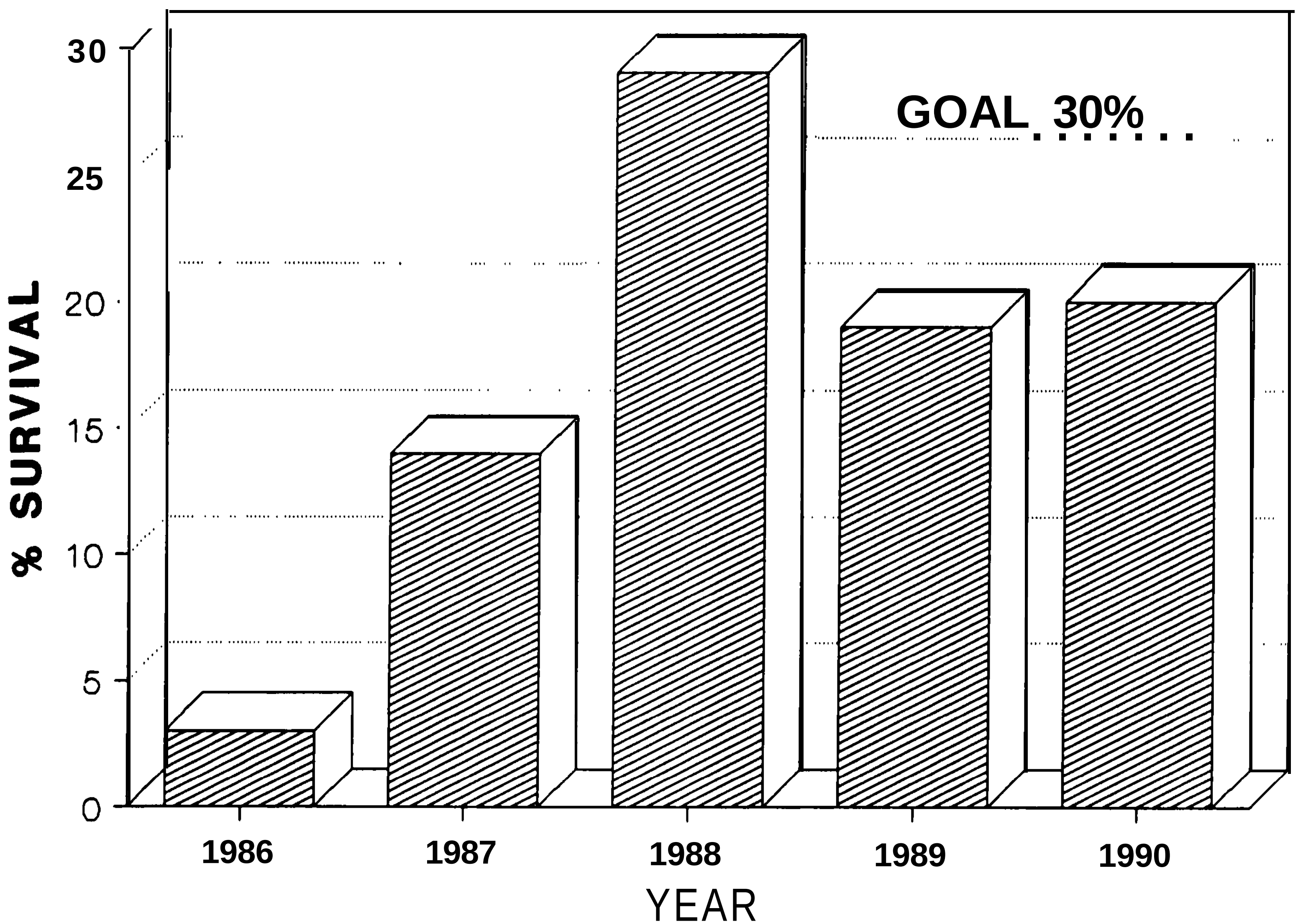


Figure 25. **Estimated survival of kokanee fry during their first summer in Lake Pend Oreille, Idaho, following release from Cabinet Gorge Hatchery, and survival goal established for the kokanee restoration program** 1986 **through** 1990.

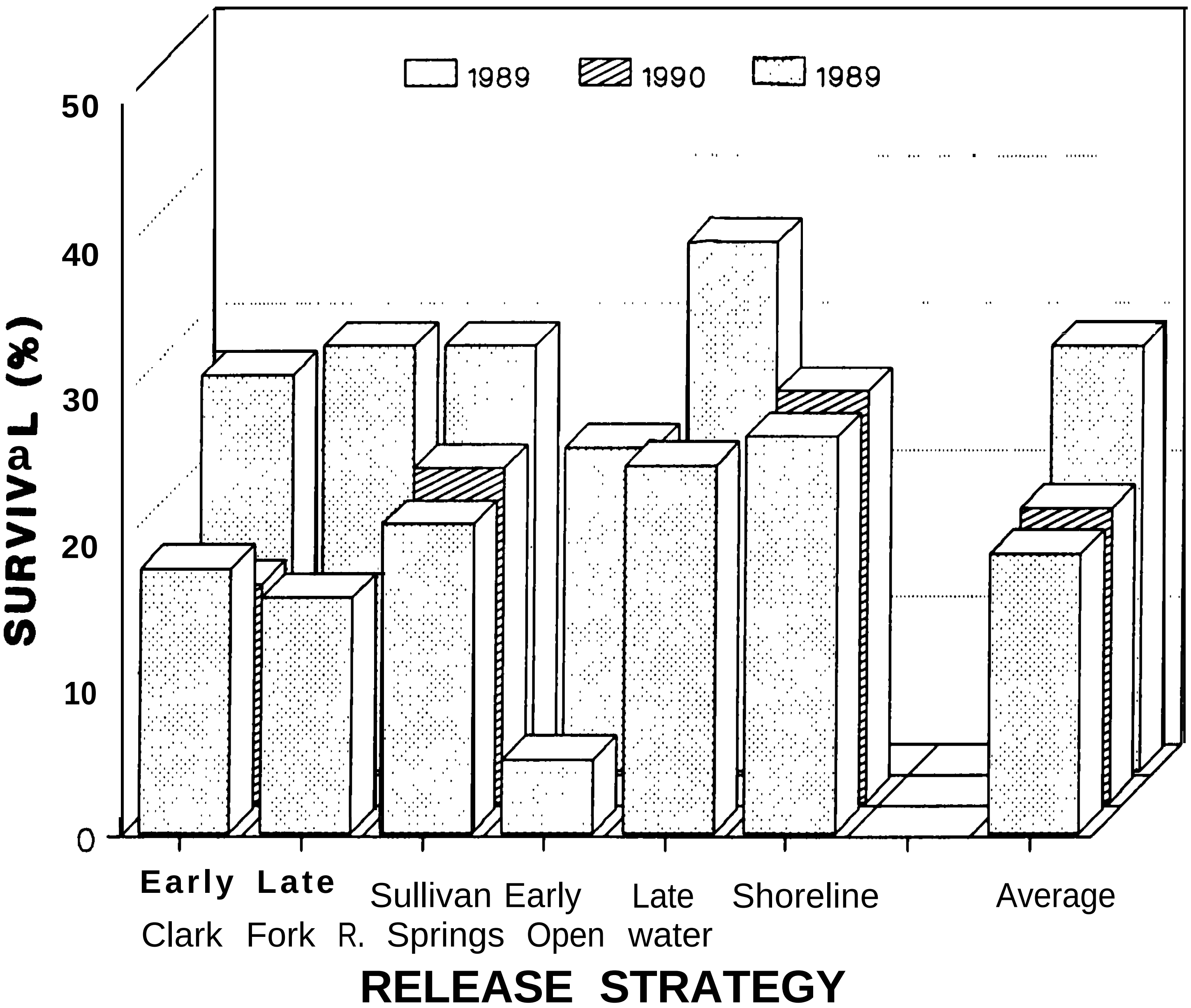


Figure 26. **Estimated survival of hatchery fry during their first summer in Lake Pend Oreille, Idaho, compared among six release strategies and years,** 1988 **through** 1990.

June of 1990. Zooplankton were the lowest of the last four years of study (7.9 organisms/L), and there was a near complete absence of cladocerans.

Stocking strategies were restricted in 1990 because of the low number of eggs taken in 1989. Experimental stockings in 1991 will be even more restricted because of a total take of only 5.6 million eggs. If hatchery survival is similar to previous years, we will have about 5.0 million kokanee for stocking in 1991. Sullivan Springs should receive 2.5 million fry, the Clark Fork release should receive the additional 2.5 million fry. These two release groups have priority because the egg-take is dependent on the return of adults to respective release locations.

Improvement in the configuration of the ladder at the Cabinet Gorge Fish Hatchery is imperative to achieving a satisfactory escapement of kokanee to the Cabinet Gorge Hatchery. At the present time, the escapement to the hatchery is far below the 30% egg contribution needed for success. A prespawn ascent of adult kokanee in the Clark Fork River was witnessed by state personnel, perhaps numbering in the thousands and passing the ladder. Although 750 ascended the ladder, many more were not attracted and bypassed it.

A seventh release strategy utilizing embayments of Lake Pend Oreille may have strong merit for testing in future years. Jaemicke et al. (1987) provided data that suggested growth and survival of sockeye salmon fry in Alaskan Lakes could be improved if they were released in protected bays. They found food production was higher in such locations, in addition to near shore cover. Food included chironomids, which are visually abundant in some bays of Lake Pend Oreille, which include Idlewild, Bottle, Scenic, Garfield, and Ellisport Bays. Such a stocking strategy would be prohibitive in 1991 because of the low egg-take, but this release could prove productive when sufficient fry are available.

Fry Marking

Three marks have been used in the progress of this study to differentiate hatchery from wild kokanee and to segregate release groups. Tetracycline marking was used in 1989 (Hoelscher et al. 1990), fins have been clipped on a subsample of two groups since 1988, while the otolith date-of-release mark was used each year of study. Kokanee with clipped fins have not been identified in sampling.

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. in progress). The analysis was carried out as time permitted and included data from 1988, 1989, and 1990.

Analysis of covariance was used to test the reliability of counting daily growth increments in kokanee otoliths that, in turn, were used to identify individual release strategies. Significant correlation coefficients were found between daily otolith growth increments and number of days out for all three years of study. This indicated the daily otolith increment counting method was a reliable technique to determine release dates and identify release strategies.

Multiple R values were always over 0.99, while P levels were 0.000. Comparison of the slopes for the three years of study indicated they were similar, but the constants for 1988 and 1989 were different. This difference could have been due to differences in aging between years or sample size. Some error, no doubt, was due to the fact the precise release date was unknown for some fish because stockings sometimes occurred on several dates.

Up to six different release strategies were tested in this study. Between 47% and 71% of the daily growth increment counts were exactly the same as the number of days from release to capture. About 96% of the daily ring counts were within two days of the total number of days from release. We recommend continued use of the daily ring count method and a difference in at least five days be used between release strategies.

Future effort must include analysis of otoliths of older kokanee to determine if this technique can be used to distinguish wild from hatchery contributions. Fin clipping of a subsample of 60,000 hatchery fry will also continue in 1991. The first cohort of fin-clipped hatchery fry is expected to return as 3+ adult kokanee to egg-take stations in 1991.

Kokanee Forage Availability

Total zooplankton densities in 1990 were the fourth lowest in six years of study (17.9 organisms/L). Cladoceran densities were extremely low and did not improve until August, but were still low (about 2.0 organisms/L). Kokanee fry can catch cladocerans much more easily than the faster copepods (Rieman and Bowler 1980). Most wild kokanee emerge in June in Lake Pend Oreille, and the slower-moving cladocerans were unavailable to them at a critical stage in their life. The unavailability of cladocerans until August was probably the main reason for the poor wild fry survival, and in part, the poor survival of fish from the early Clark Fork release, as explained earlier.

The predator/prey interaction of Mvsis and cladocerans in Lake Pend Oreille is well understood (Rieman and Falter 1981, Bowles et al. 1987). Mysis are important predators of cladocerans and have reduced the densities in Lake Pend Oreille (Bowers and Vanderpoeg 1982). Mysis are most effective predators prior to thermal stratification (Rieman and Falter 1981, Bowles et al. 19881, after which the warmer water (>14°-18°C) segregates them from the zooplankton (Beeton 1960, Nero and Davies 1982). The density of Mvsis in 1990 was the fourth lowest since this study began (Figure 27) and may also have been related to lower food availability. Thermal stratification during 1990 was slower to develop in Lake Pend Oreille compared to other years and resulted in an even lower wild fry survival than previous years. It will be important to try to develop information that can provide clues to the changes in kokanee carrying capacity as a result of the interaction with Mvsis and the food source.

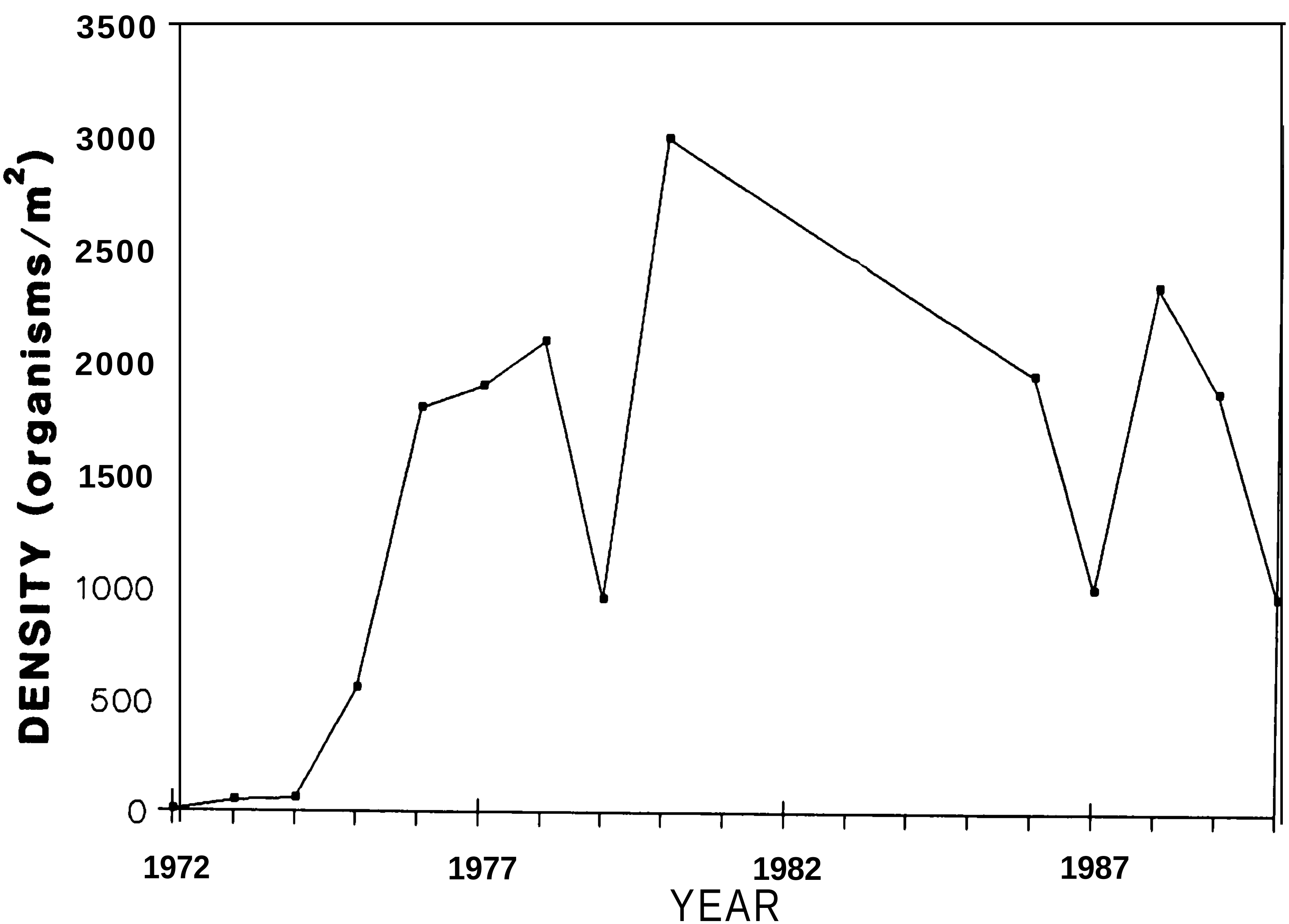


Figure 27. Estimated density of Mysis in Lake Prnd Oreille, Idaho.

Spawning

Escapement of the kokanee spawning stock decreased from 469,766 fish in 1989 to 371,600 fish in 1990; a decline of 21%. The most important reason for this decline was the exceptionally low survival of age 3+ and 4+ kokanee, as explained earlier in this report. Total escapement at Sullivan Springs in 1990 was 28% less than that of 1989, 57,424 kokanee vs 79,450. Lower escapement resulted in a substantially lower egg-take; 5.3 million eggs in 1990 as compared to 9.6 million eggs in 1989. Predictions of 1989 were for a slightly improved escapement and egg-take. But low escapement was a result of low survival of age 3+ and 4+ kokanee, which also seriously affected the potential egg deposition, as would be expected. Potential egg deposition in 1990 was only 63.9 million eggs, 54% of the estimated value in 1989. In addition, early maturation of a greater proportion of age 3+ kokanee also affected the potential egg deposition by reducing the mean number of eggs/female. Fecundity averaged 446 viable eggs/female in 1988, it was 426 eggs/female in 1989, and 382 eggs/female in 1990. The change from 1988 to 1989 was not significant ($P>0.OS$), but it was between 1988 and 1990 ($P<0.05$).

Contrary to the total escapement count at Sullivan Springs, the total one-time counts at other tributary streams and the shorelines were 2-fold higher in 1990 compared to 1989. The total count in 1990 was 8,373 spawners (Appendix B) compared to 4,603 in 1989. Bayview accounted for 2,036 spawners in 1990 compared to 875 in 1989, while the one-time counts at Spring Creek were 4,400 and 2,400 for the same years. Counts at other sites were slightly higher in 1990, but in general were similar. Flow conditions of tributary streams were better in 1990, making it easier to count adults, but this does not explain the increased number of fish sighted in Bayview.

Earlier maturity for kokanee sampled in 1990 is also an important factor of concern. An estimated 29% of the kokanee age 3+ caught by trawling in 1988 were mature (63% female), only 14% of the age 3+ kokanee were mature in 1989 (71% female), but in 1990, about 52% of the age 3+ fish were mature (52% female). Age analysis of kokanee collected from Sullivan Springs was 20% age 3+ in 1988, in 1989 it was 18% age 3+, but in 1990 it was 32% age 3+ (N=65). However, age analysis of 35 kokanee spawners at Spring Creek indicated only 9% were age 3+. Early maturation of kokanee is often a product of high population density (Rieman et al. 1990) or reduced carrying capacity. For example, kokanee density in Lake Coeur d'Alene is 766 fish/hectare and 100% of the age 3+ kokanee are mature. Kokanee density in Lake Pend Oreille is 306 fish/hectare, but the presence of _Mysis_ shrimp has probably reduced carrying capacity, the extent of which is unknown. Kokanee density reached a post _Mysis_ introduction peak of 450 fish/hectare in 1988, although density was estimated at 341 fish/hectare (Figure 22 Appendix D). In 1989, it was probably over 400 fish/hectare when the age 1+ sampling error is considered (Hoelscher et al. 1990). The question thus arises, have we met carrying capacity of kokanee in Lake Pend Oreille? This will be an important matter of concern. A question of secondary consideration in dealing with young age at maturity involves rapid growth of hatchery fish and the early maturation factor. This point may be of concern at this time because kokanee stocked in 1987 at Sullivan Springs, now age 3+, were released at 44 mm, while fish released in 1986 and earlier were 32 mm. This will be an important factor to follow.

Mean length of kokanee in the spawning escapement has decreased since 1988 (Figure 28), when the population was at a peak density since the 1960s. Male kokanee from Sullivan Springs were 283 mm, 277 mm, and 260 mm for 1988, 1989, and 1990, respectively. Female kokanee averaged 275 mm, 266 mm, and 247 mm for the same years. The smaller mean length of kokanee is probably the most important reason fecundity has decreased. In turn, younger age at maturity is responsible for smaller mean length. In addition, the percent adult return at Sullivan Springs has decreased in proportion to fry stocked (Appendix E).

The Fishery

Kokanee fishing in Lake Pend Oreille is still far below the quality of fishing experienced in the mid-1960s. As mentioned previously, the harvest statistics generated in 1990 are substantially below the actual harvest. An estimated kokanee harvest of 14,500 fish is far below the project goal of 750,000. Although, catch effort of kokanee improved slightly in 1990, 1.09 fish/h compared to 1.0 fish/h of 1985 and the 1970s. However, Rieman (et al. 1990) indicated catch effort could remain good even if kokanee populations are at low densities.

Total catch of kokanee in 1990 could have been higher, but an unusually cool spring water temperature and extensive rain events slowed fishing success. For example, fishing success averaged 0.4 fish/h for the first two 6-week fishing periods in 1990, catch rate for the same periods in 1985 averaged 0.7 fish/h (Bowles et al. 1986).

Angler-caught kokanee had a mean length of 238 mm (9.4 in) (N=259) during 1990, which was slightly less than that of previous surveys and the project objective of 250 mm (9.8 in) (Figure 28). The mean length of kokanee harvested in 1985 was 250 mm (9.8 in) (Bowles et al. 1986) and was 256 mm (10.1 in) in 1980. The unusually high natural mortality incurred by the age 4+ cohort and the absence of age 5+ fish can be attributed to the decline in mean size. Most of the 1990 harvest was age 2+ and 3+ fish (54%), while the remainder was age 4+. Age 4+ kokanee caught in the trawl ranged from about 225 mm (8.9 in) to 275 mm (10.8 in) (Figure 7).

Exploitation of kokanee in Lake Pend Oreille was low compared to previous years. Exploitation of kokanee was about 15% in 1985 (Bowles et al. 1986) and only about 4% in 1990.

Catch success of large (≥610 mm) Kamloops rainbow improved from a catch rate of 232 h/fish in 1985 to 84 h/fish in 1990. A minimum length limit of 610 mm was adopted for the Lake Pend Oreille fishery in 1988. Imposition of this new regulation and the 37% release rate for rainbow over the minimum length may be responsible for the improved fishery. About 78% of the Kamloops over 430 mm

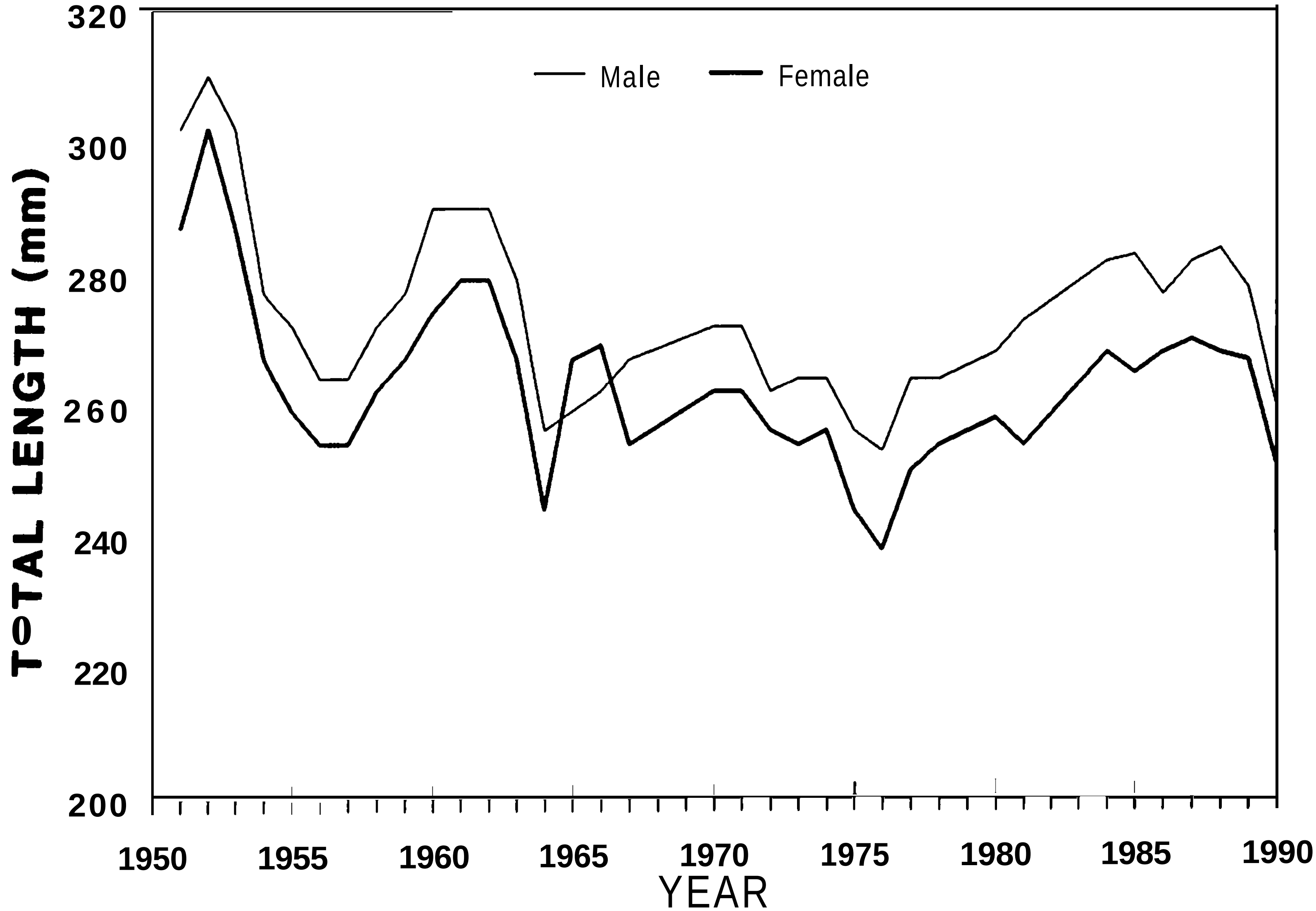


Figure 28. Mean total length of male and female kokanee spawners from Lake Pend Oreille, Idaho.

were harvested in 1985, but only 62% over 610 mm were taken in 1990. Since 1983, about 10,000 pure strain Kamloops are stocked each year, and the contribution of wild fish is unknown. The ultimate impact of the improved stock of these large predators on the kokanee population is unknown. Catch success of all sizes of rainbows also improved from 1985 (catch rate of 44 fish/h) to 1990 (catch rate of 18 fish/h).

RECOMMENDATIONS

1. A minimum of 2.0 million fry should be released in Clark Fork River each year to provide a potential egg supply for Cabinet Gorge Hatchery. Fry releases into Clark Fork River should coincide with the end of spring runoff during at least 850 m^3/s (30,000 ft^3/s) nighttime flows to insure optimal fry survival and imprinting.

2. Approximately 3.0 million fry should be released into Sullivan Springs Creek each year to maintain an egg supply of at least 12.5 million eggs. Fry releases into Sullivan Springs Creek should not occur before thermal stratification of Lake Pend Oreille (typically mid-July) to insure adequate forage.

3. Release approximately 0.75 to 1.0 million fry along the south shoreline in 1991 to replicate results and determine annual variability in survival.

4. All fry released at Cabinet Gorge Hatchery and Sullivan Springs Creek should be imprinted with morpholine, which will be used as an adult attractant. A representative portion of fry ($\geq$60,000 fish) released in Clark Fork River and Sullivan Springs Creek should be fin-clipped to evaluate adult return rates.

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

6. Evaluate the reliability of otoliths for discerning the date-of-release in age 1+ and older kokanee.

7. A sample of 1,000 kokanee from the Clark Fork spawning run should be fin-clipped. This will enable us to calculate the proportion of adult kokanee ascending the river and successfully making it up the ladder at the Cabinet Gorge Hatchery.

8. Evaluation of the predator/prey interaction and bioenergetics of Kamloops rainbow. This could provide direction for the predator stocking program and should be done.

ACKNOWLEDGEMENTS

Sue Morrison and Brian Hoelscher assisted with various sampling and analysis activities. Many individuals provided assistance during trawling on Lake Pend Oreille. Personnel from Cabinet Gorge and Clark Fork hatcheries were responsible for spawning activities and provided valuable assistance and advice during development and implementation of fry release strategies. Joe Chapman and his staff at Cabinet Gorge Hatchery were great help throughout the season and were responsible for all fry marking activities.

Washington Water Power provided the maximum possible flows during fry releases into the Clark Fork River. Fred Holm from Bonneville Power Administration provided technical and administrative advice throughout the year. Virgil Moore reviewed the draft report.

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A P P E N D I C E S

Appendix **A.** Kokanee age class density (fish/hectare) in Lake Pend Oreille during late summer, **1990.** A 902 error bound is listed with each estimate.

Age class	Origin	Lake section 1	2	3	4	5	6	Total
0+	Hatchery (total)	61.1(16.8)	75.5(17.0)	89.9(22.5)	70.4(19.9)	37.7(11.2)	74.0(23.0)	69.0(8.2)
	Clark Fork River							
	Early summer[a]	0.0(0.0)	17.9(4.0)	13.9(3.5)	19.0(5.4)	16.4(4.9)	53.0(16.5)	22.5(3.9)
	Sullivan Springs[b]	11.8(3.3)	39.7(8.9)	58.0(14.6)	43.8(12.4)	19.7(5.8)	18.9(6.5)	32.0(3.9)
	Shoreline[c]	49.3(13.6)	17.9(4.0)	18.0(4.5)	7.6(0.5)	1.7(0.5)	0.0(0.0)	14.1(2.2)
	Wild	83.0(22.8)	142.8(32.2)	108.1(27.1)	84.0(23.7)	59.2(17.6)	22.8(7.1)	79.2(8.9)
	Wild & Hatchery	144.1(39.7)	218.3(49.2)	198.0(49.7)	154.4(43.6)	97.0(28.7)	96.7(30.1)	148.2(16.5)
1+	Wild & Hatchery	42.8(37.3)	13.9(12.4)	8.0(6.4)	22.4(30.9)	37.1(42.2)	233.9(232.2)	70.6(52.3)
2+	Wild & Hatchery	179.2(103.8)	11.8(9.8)	8.4(13.5)	54.2(55.4)	69.4(18.0)	72.4(47.5)	64.2(20.8)
3+	Wild & Hatchery	54.0(30.0)	1.2(1.2)	2.4(2.5)	9.5(8.0)	13.7(6.9)	11.4(5.4)	14.4(4.7)
4+	Wild & Hatchery	26.8(13.6)	2.8(2.9)	1.0(1.6)	5.3(3.0)	10.2(9.5)	8.5(3.0)	8.7(2.6)
5+	wild & Hatchery	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
Total	Wild & Hatchery	144.1(39.7)	218.3(49.2)	198.0(49.7)	154.4(43.6)	97.0(28.7)	96.7(30.1)	306.1(70.1)

[a] Hatchery-reared kokanee fry released into Clark Fork River.
[b] Hatchery-reared kokanee fry released into Sullivan Springs Creek.
[c] Hatchery-reared kokanee fry released from shore southern Lake Pend Oreille.

Appendix B. Maximum single late run (early run included for Trestle Creek) kokanee counts made during the 1973-1978 and 1985-1990 spawning seasons on Lake Pend Oreille and its tributaries, excluding the Granite Creek drainage.

Area	Maximum single counts											
	1973	1974	1975	1976	1977	1978	1985	1986	1987	1988	1989	1990
Lakeshore												
Bayview	17,156	3,588	9,231	1,525	3,390	798	2,915	1,720	1,377[c]	2,100	875	2,036
Farragut	0	0	0	0	0	0	--	10	0	4	--	--
Idlewild Bay	0	25	0	0	0	0	--	--	--	--	--	--
Lakevlew	200	18	0	0	25	0	4	127	59	0	0	75
Elllsport Bay and Hope	436	975	0	0	0	0	0	0	0	--	--	--
Trestle Creek Resorts	1,000	2,250	0	115	75	138	2	35	350	2	2	--
Sunnyslde	25	0	0	0	0	0	0	0	0	--	--	--
Fisherman Island	0	75	0	0	0	0	--	--	--	--	--	--
Anderson Point	0	50	0	0	0	0	--	--	--	--	--	--
Camp Bay	617	0	0	0	0	0	0	0	0	--	--	--
Garfield Bay	400	20	0	0	0	0	0	6	0	35	--	0
Subtotal	19,834	7,001	9,231	1,640	3,490	936	2,921	1,898	1,786	2,141	877	2,111
Percent of Total	62%	25%	64%	33%	40%	19%	32%	10%	20%	14%	19%	25%
Tributarles												
South Gold Creek	1,875	1,050	440	0	30	--	235	1,550	2,761	2,390	830	834
North Gold Creek	1,383	1,068	663	130	426	--	696	1,200	2,750	880	448	458
Cedar Creek	267	44	16	11	0	0	--	--	--	--	--	--
Johnson Crwk	0	1	0	0	0	0	--	182	0	0	0	0
Twin Creek	0	135	1	0		0	5	0	0	0	0	0
Mosquito Creek	503	0	0	0	8	0	--	--	--	--	--	--
Clark Fork River	3,520	6,180	0	--	--	--	--	--	--	--	--	--
Llghtnlng Creek (Lower)	500	2,350	995	2,240	1,300	44	127	165	75	6	--	--
Spring Creek	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	119	48	45
Trestle Creek	18	1,210	15	0	40	0	0	0	0	0	0	0
Trestle[a]	1,100	217	14,555	1,486	865	1,589	208	1,034	410	422	466	525
Garfleld Creek	0	25	0	0	0	0	--	1	0	0	0	0
Subtotal	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]	38%	75%	36%	67%	60%	81%	68%	90%	80%	86%	81%	75%
Total[b]	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 partlal count only because heavy wave actlon kept spawners offshore and uncountable.
[d] Count made thlrd week of December because low flows In Llghtnlng Creek resulted In a complete passage barrler during early December.

Appendix C. Statistical comparisons (ANOVA) **of** zooplankton densities and lengths from **1985** to **1990** 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>O.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.

Zooplankton	P level for main effect: Lake section	P level for main effect: Year	Main effect contrasts (P>O.lO): Lake section	Main effect contrasts (P>O.lO): Year
		Density		
Cyclops	0.926	0.000	NCS	86 97 90 85 89 88
Diaptomus	0.784	0.000	NSC	87 86 8 5 89 88 90
Epischura	0.678	0.001	NCS	90 86 88 89 87 85
Bosmina	0.097	0.000	CNS	86 88 90 85 87 89
Diaphonosoma	0.980	0.000	SNC	86 87 85 90 88 89
Daphnia	0.446	0.027	CSN	85 90 88 89 87 86
Total	0.898	0.00	NCS	86 87 90 85 89 88

APPACD

Appendix C. Continued.

Zooplankton	P level for main effect: Lake section	P level for main effect: Year	Main effect contrasts (P>O.lO): Lake section	Main effect contrasts (P>O.lO): Year
		Length		
Cyclops	0.838	0.586	NSC	87 86 89 88 85 90
Diaptomus	0.448	0.000	SCN	89 88 86 87 85 90
Epischura	0.718	0.000	C S N	86 87 89 88 85 90
Bosmina	0.145	0.002	SNC	87 88 90 85 89 86
Diaphanosoma	0.409	0.002	SCN	8 6 89 88 85 90 8 7
Daphnia galeata	0.659	0.000	NSC	87 86 85 90 89 88
D. thorata	0.779	0.024	NCS	86 88 87 85 90 89

APPACD

Appendix D. Estimated year class abundance (millions) of kokanee made by midwater trawl in Lake Pend Oreille, Idaho, 1979 through 1990. The two oldest age classes were combined for estimates from 1979 through 1985.

Year class	Year estimated											
	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979
1989	3.35											
1988	1.59	4.48										
1987	1.45	1.17	7.31									
1986	0.33	1.20	1.66	3.55								
1985	0.20	0.45	0.51	0.78	1.66							
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							0.27	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
1976											1.03	1.70
1975												0.67
Total	6.93	7.71	10.21'	6.01	4.27	4.47	5.62	5.21	8.12	5.20	4.68	5.69
Density (No./hectare)	306	341	450	266	189	198	249	230	358	230	207	251

Appendix E. Kokanee spawned from Sullivan Springs Creek from 1976 through 1990. number of eggs collected. subsequent fry released into Sullivan springs and adult return rate.

Year Class	Kokanee spawned	Eggs collected	Fry released following year[a]	Estimated returning adults from hatchery releases and year returned	Adult return as a percent of fry released
1976	10.200	913.000	757.700	55.500 (1980) 42.200 (1981)	12.96
1977	17.560	2,040,000	1,598,800	135.300 (1981) 29,000 (1982)	10.28
1978	16.875	1,400,000	1,745,700	118.000 (1982) 58,000 (1983)	10.08
1979	12.005	1.451.400	1,081,400	42,000 (1983) 75.660 (1984)	10.68
1980	48.760	4,186,700	2.219.800	54,340 (1984) 46.810 (1985)	4.56
1981	112.820	11.653.000	2,487,800	27,935 (1985) 20,060 (1986)	1.93
1982	115,850	11,432,900	2.875.589	22.170 (19%) 77,773 (1987)	3.40
1983	79.850	6,320,000	3.214.512	5,854 (1987) 48,444 (1988)	1.69
1984	122.000	15.000.000	3.420.279	12.111 (1988) 34,983 (1989)	1.40
1985	75,500	10.600.000	1.594.731	16.462 (1989)	
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]	3,538,000		
1989	70.600	9,372,000[e]	3,200,000		
1990	51.445	5,300,000[f]	3,200,000		

[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 total to 14.16 million.
[e] An additional 0.21 million eggs were collected from Clark Fork River, bringing the total to 9.59 million.
[f] An additional 0.30 million eggs were collected from Clark Fork River, bringing the total to 5.6 million.