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

Annual Progress Report 1991

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

Annual Progress Report
for FY 1991

by

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ABSTRACT

Initially, rehabilitation of kokanee Oncorhynchus nerka met with apparent success reaching a peak abundance of 10.2 million fish in 1988. However, a decline of 47% followed from 1988 through 1991 to 5.4 million fish. The decreased population was attributed to poor recruitment of wild fish, poor egg take, thus, low stocking of hatchery fry (7.3 million in 1990 and 5.0 million in 1991 compared to about 13.0 million in 1988), and poor survival of fish ages 3 and 4 (average survival of the older fish was only 35% in 1990 compared to 72% in prior years but it was 68% in 1991). In addition, standing stocks of kokanee have remained relatively stable (x = 8.6 kg/hectare) since 1986 despite the dramatic changes in density. Prior to this study (1985) standing stocks were substantially higher (x = 13.6 kg/hectare). The kokanee population is probably operating below carrying capacity.

Hatchery fry comprised 59% of the total kokanee recruitment in 1991 (93% of fry biomass). This contribution of 1.06 million fry ranked fifth behind 1988 (3.74 million), 1989 (2.25 million), 1982 (1.89 million), and 1990 (1.56 million) since hatchery supplementation began in the 1970s. Survival of hatchery fry was 21% in 1991, the second highest since this investigation began. Two release strategies were tested in 1991 of which the best survival was recorded for the Sullivan Springs release at 23% while the early Clark Fork River release continued to have lowest survival at 18%. Survival of hatchery reared kokanee fry is still below the goal of 30% and it appears that this goal may not be attainable most years. Statistical analysis between number of days from fry release to recapture day and fry survival did not reveal a relationship ($P = 0.43$). Survival of fry from late releases is higher ($P = 0.05$) than early releases but no difference ($P \geq 0.71$) was detected between stocking locations.

Good survival of fry from the Sullivan Springs releases was attributed to large size of kokanee fry (55 mm), warm water temperatures of July, and higher cladoceran densities compared to June. Lower survival of the early Clark Fork River release is attributed to the exceptionally high river flows (1,984 cm^3/s or 70,000 ft^3/s) and low density of zooplankton.

Age of adult kokanee sampled at Sullivan Springs was 1% age 2, 46% age 3, and 53% age 4. The high proportion of age 3 kokanee resulted in lower average fecundity. Recovery of about 160 fin clipped kokanee at Sullivan Springs provided evidence of imprinting. About 0.4% of the marked kokanee released in 1988 returned to spawn at age 3. This failure of a spawning run to Clark Fork River and low (<0.0001%) returns to the Cabinet Gorge Hatchery is a major concern.

Total fishing effort was 460,679 h (±20%) or about 12 h/hectare. A sport fishery survey indicated anglers harvested 276,457 fish of which 227,140 were kokanee and 2,157 Gerrard rainbow trout Oncorhynchus mykiss (>610 mm) while an additional 14,800 rainbow trout Oncorhynchus mykiss were released. The harvest of kokanee is at 33% of the management goals, but the harvest of large Gerrard rainbow trout was the best in 15 years.

INTRODUCTION

Lake Pend Oreille supported the most popular kokanee fishery in Idaho from the 1940s until the early 1970s. The sport and commercial harvest provided an average annual harvest of one million kokanee and 360,000 h 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). An enhancement program for the kokanee was implemented to achieve the goals of an annual harvest of 750,000 kokanee averaging 250 mm in length with catch rates averaging 2.0 fish/h. In addition to providing an important fishery, kokanee are the primary forage for trophy Gerrard rainbow trout and bull trout Salvelinus confluentus in Lake Pend Oreille.

Several factors have contributed to the decline of kokanee abundance in Lake Pend Oreille. Hydropower development and consequential water level management adversely impacted spawning success and survival of eggs as well as fry 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 and M. Maiolie, personal communication Idaho Department of Fish and Game). In addition, wave action during and after drawdown washes fines down to potential kokanee spawning habitat. Thus, leaving less than suitable spawning sites for kokanee. 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 may also have adversely affected kokanee. Shrimp were introduced in 1968 and were well established by 1975 (Rieman and Falter 1981). The Idaho Department of Fish and Game (IDFG) introduced them to enhance the kokanee forage base. The expected response of increased kokanee growth did not occur because mysids migrate to depths in excess of 60 m during daylight hours making them unavailable to feeding kokanee. Predation on zooplankton by shrimp delayed production of two cladocerans (Daphnia and Bosmina) that are preferred juvenile kokanee forage during the first few weeks of feeding (Rieman and Bowler 1980).

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 h of effort will depend on production from this hatchery.

A Project Review meeting during spring of 1991 scrutinized the previous six years research findings and identified future direction and points of concern. Six major concerns were identified during the meeting; 1) a decline in the kokanee fishery since the 1968 peak, 2) the predator density has apparently increased in Lake Pend Oreille (as evidenced by improved catch success for rainbow trout), 3) it is unknown whether or not hatchery fish are being imprinted and are returning to Sullivan Springs and the Cabinet Gorge Fish Hatchery, 4 and 5) age and size at maturity of kokanee may have changed at Lake Pend Oreille, and we do not know the causative factors, 6) young kokanee may be entrained in the Pend Oreille River the extent of which is unknown. Some of these concerns were addressed during the 1991 field season and were blended into the main objectives of the study.

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 50% 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 and equipment.

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 survival by release site, fish size and number of fry released.
4. 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 or about 38,300 hectares, mean depth of 164 m and maximum depth of 351 m. Mean surface elevation of Lake Pend Oreille is 629 m. Deep water habitat used by kokanee is considered to be 22,647 hectares. The Clark Fork River is the largest tributary to Lake 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

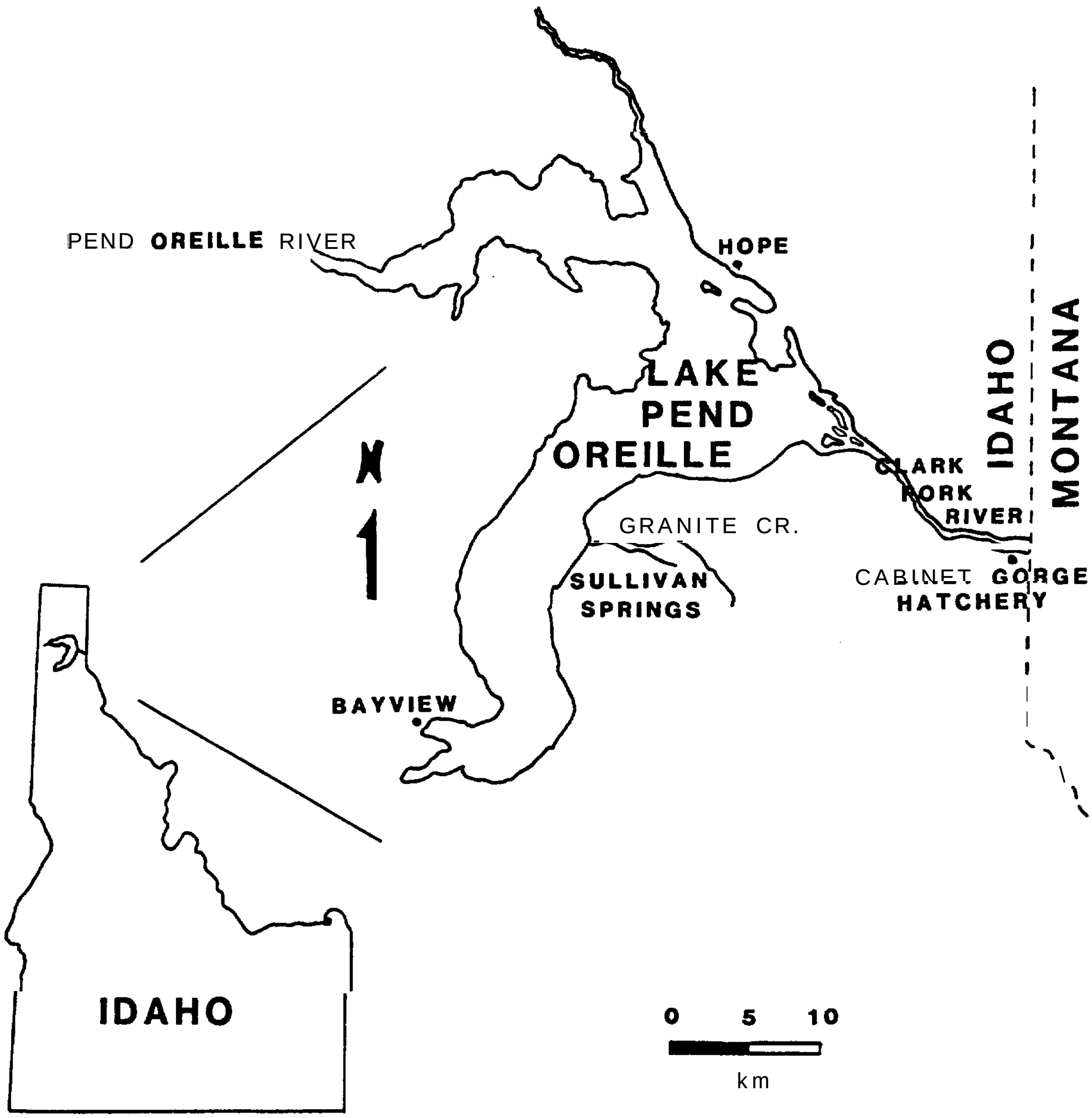


Figure 1. Map of Lake Pend Oreille, Idaho.

et al. 1987, 1988, 1989). Thermal stratification typically occurs from late June to September. The N:P ratio is typically high (>11) and indicates primary production may be P limited (Rieman and Bowler 1980). Mean chlorophyll "a" concentration during summer is approximately 2 micrograms/L. Summer mean water transparency (Secchi disk) ranges from 5-11 m. Operation of Albeni Falls Dam on the Pend Oreille River keeps the lake elevation stable at 628.4 m during summer (July-September) then reduces lake level to about 625.3 during winter.

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, westslope cutthroat trout Oncorhynchus clarki lewisi, lake whitefish Coregonus culpeaformis, mountain whitefish Prosopium williamsoni, and several cool and warm water species.

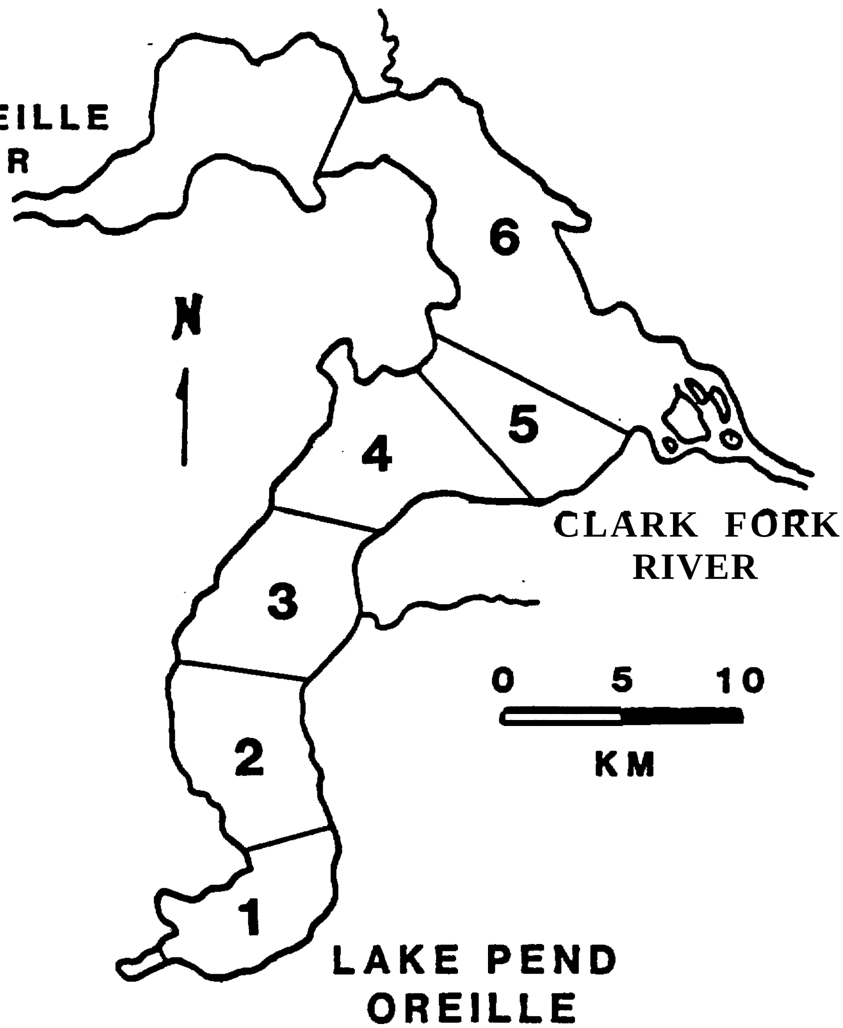
METHODS

Kokanee Population Structure

Kokanee population structure in Lake Pend Oreille was determined by collecting kokanee 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 a depth sounder. 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 three to five 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 Fend Oreille was divided into six sections or strata (Figure 2). The area of each section was calculated for the 91.5 m contour; however, Section 6 (the northern end) was calculated from the 36.6 m contour because of shallower water. The 91.5 m contour was used because it represents the pelagic area of the lake where kokanee are found during late summer (Bowler 1978). Six transects were systematically selected within each section and one haul (sample) was made along each transect. Total sample size in 1991 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 estimates (total and by section) were divided by respective lake surface areas to calculate kokanee densities in number/hectare (N/hectare) for each age class. Confidence intervals (90%) were calculated to compare estimates among age classes, lake sections and years.



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 1991 for trawling and'kokanee abundance estimation on Lake Pend Oreille, Idaho.

Survival

Recruitment and survival of hatchery-reared and wild fry were determined from trawl catches of marked or unmarked fry during late August. Fry survival was estimated from potential egg deposition (PED) and release date (hatchery fry only) to the 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 and from wild fry by analyzing a date of release mark and 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 (1,000 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, if distinguishable, would **be** used to identify fish of hatchery vs. wild origin.

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. Differential fin clips were also used to segregate two length groups of kokanee fry released at Sullivan Springs. The long-range objective was to determine the affect of hatchery growth/size on age-at-maturity. Possible clips included the adipose fin and left or right pelvic fins. Fry were clipped at least one week prior to release and averaged 56.5 mm total length (1,054 fry/kg). However, one group released at Sullivan Springs averaged 43 mm. 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

Two fry release strategies were evaluated in 1991 to estimate survival of fry in Lake Pend Oreille and provide 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.

Table 1. Hatchery-reared kokanee fry released into Lake Pend Oreille, Idaho, during 1991.

Release Strategy	Release Dates	Time	Released number (millions)	Mean size (mm)	Mark
Clark Fork River Early	26 June	Dusk	2.61	49.4±2	Otolith Code 60K Lv clip Size (vs wild)
Sullivan Springs	9-10	Day July	2.57	56.5±2 (2.27 million)	otolith Code 30K AD clip (Large Fry)
				43.0±2 (30K)	30K RV clip (Small Fry)

KOKCAB.TAB

Clark Fork River

Approximately 2.61 million fry were released in Clark Fork River to establish a spawning run to Cabinet Gorge Hatchery. All fry were imprinted with morpholine (5×10^{-5} mg/L in hatchery water) for 30 d prior to release. Morpholine was also added to hatchery water flowing from the fish ladder at Cabinet Gorge Hatchery into Clark Fork River for 3 d following the single release.

Early **season** release-Approximately 2.61 million fry were released through the Cabinet Gorge Hatchery fish ladder into Clark Fork River on 26 June 1991. The mean length for these fry was 49.4 mm (±2 mm) This release was scheduled to coincide with high nighttime river flows resulting from spring snowmelt, however, spring time flows far exceeded the anticipated 990 m^3/s (35,000 ft^3/s). The WWP provided an average discharge of 1,984 m^3/s (70,000 ft^3/s).

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 1994 and 1995.

Sullivan Springs

Approximately 2.57 million fry were transported by truck from Cabinet Gorge Hatchery to Sullivan Springs Creek during July 9-10, 1991. The fry were transported at a density of 55 to 59 kg/m^3 with a tank temperature of 9° and a stream of 8°. The purpose of this release was to insure continued adult returns to the egg-take station on this spring-fed tributary to Lake Pend Oreilie. The otolith date-of-release mark was used to distinguish fry during autumn trawling in Lake Pend Oreille. Approximately 30,000 fry (56.5 mm TL) were adipose fin clipped while a second group of 30,000 smaller fry (43 mm TL) were marked with a right ventral clip to evaluate adult returns for spawning in 1994 and 1995 and differences in age at maturity.

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.

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 eariy run Trestle Creek, East Hope shoreline, Spring Creek, Clark Fork River, and the weir at Sullivan Springs Creek. Age of maturity was also estimated for kokanee collected during September trawling.

Mysis Shrimp

We sampled shrimp at night during the dark moon phase the first week of November. Five samples were collected randomly in each of the southern, central, and northern portions of Lake Pend Oreille (Figure 3). Samples were collected with a Miller high-speed sampler equipped with a General Oceanics flow meter and a 100 micron plankton net and bucket. Stepped oblique tows were made from 46 m to the surface, sampling for 10 s at each 3 m interval. The sampler was towed approximately 1.5 m/s and raised 0.5 m/s with an electric winch. Shrimp from each sample were counted and differentiated by age class (juvenile or adult). Density estimates were based on volume of water filtered and comparisons were not made between age classes and among lake sections and years as in previous years because past sampling was done in June as opposed to November in 1 991.

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

Zooplankton

The zooplankton community was sampled in the southern, central, and northern portions of Lake Pend Oreille (Figure 3). Five random samples were collected monthly from each section from May through October in the main body of the lake, Samples in the main body of the lake were collected with a 0.5 m diameter ring plankton sampler calibrated by a Kahl Scientific 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. Analysis of variance, utilizinq a stratified random sampling scheme, was used to compare zooplankton densities 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 60 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 1 m intervals to better define the metalimnion. Water transparencies were monitored temporally and spatially. A Secchi disk reading was taken in the southern, central, and northern sections of Lake Pend Oreille each month from May through October.

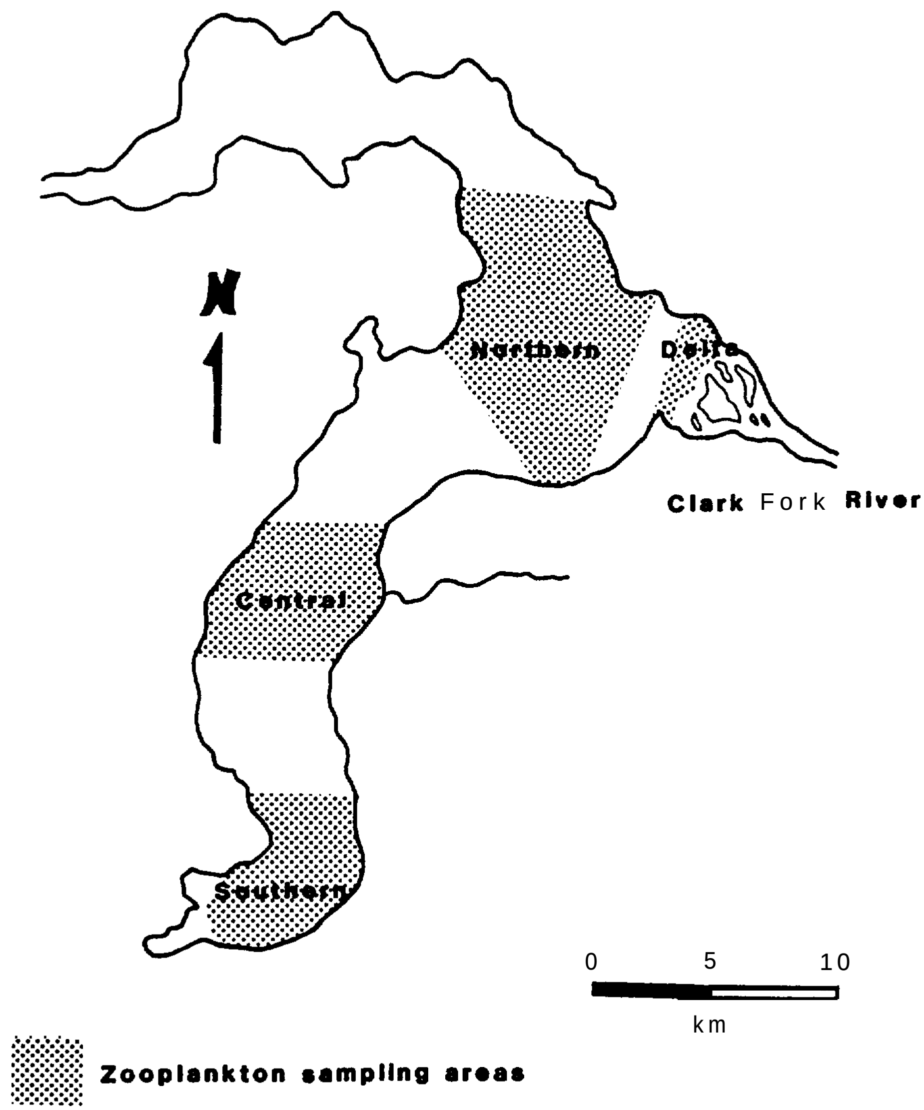


Figure 3. Shrimp and zooplankton sampling areas on Lake Pend Oreille, Idaho.

Angler Effort and Harvest

A creel survey was conducted during the 1991 fishing season to provide estimates of angling effort, catch, and harvest of sport fishes. The 1991 survey followed the Idaho Creel Census program (McArthur et al., 1991).

The creel season was temporally stratified to reduce variability and provide seasonal catch comparisons. Creel data was collected from April 15 through November 30, 1991. The survey was stratified into five six-week periods to correspond with periods used in surveys prior to 1991.

Creel data were collected by up to five creel clerks 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, Kamloops Resort, Rend Oreille Shores, and Ellisport Bay; south: Farragut, MacDonalds, Boileaus, JD' s, Vista Bay, and Scenic Bay). Several access areas (Trestle Creek, Johnson Creek, Kamloops Resort, JD's, Vista Bay, and Scenic Bay) were not sampled during low use periods. Information was taken from complete and incomplete trips.

Instantaneous fishing boat counts were made periodically to determine the fishing pressure for week-days and weekends. Counts were made by a Cessna 180 or 125 at randomly selected times of a creel day.

Survey data were expanded by day type (weekends and week-days) to estimate harvest, catch and effort (hours and angles--days) for each interval, period, and entire season. An angler-day was defined as one angler's fishing trrp, regardless of actual fishing time. Interval estimates were summed for each period, and period estimates were summed to represent the entire season (McArthur 1991).

RESULTS

Kokanee Abundance, Distribution, and Biomass

Trawling for kokanee occurred September 5 through 17, 1991, and it usually took six to seven steps at each site. A total of 533 kokanee were caught of which 236 were age 0. Estimatedtotalkokaneeabundanceduring September 1991 was 5.6 million fish (±18%)(Figure 4). Contribution of individual year classes was 1.99 million (±17%) for the 1990 year class (year eggs were laid)(age 0), 0.83 million (±37%) for the 1989 year class (age 1), 1.77 million (±25%) for the 1988 year class !age 2), 0.77 million (±32%) for the 1987 year class (age 3), 0.23 million (±12%) for the 4986 year class (age 4) while age 5 kokanee were not caught with the trawl in 1991 (1985 year class).

Estimated average kokanee density for the deep water portion of the lake (see Study Area) was 248 kokanee/hectare (all age classes combined) (Figure 5, Appendix A). Densities of age 1 and older kokanee, calculated independently, ranged from a high of 282 kokanee/hectare in Section 6 to a low of 62 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 generally uniform in distribution throughout much of the lake but were highest in section 4. Densities of age 1 kokanee were highest in the northern section of Lake Fend 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 highest in Section 1, lowest in Section 6 and equally abundant in remaining sections of the lake.

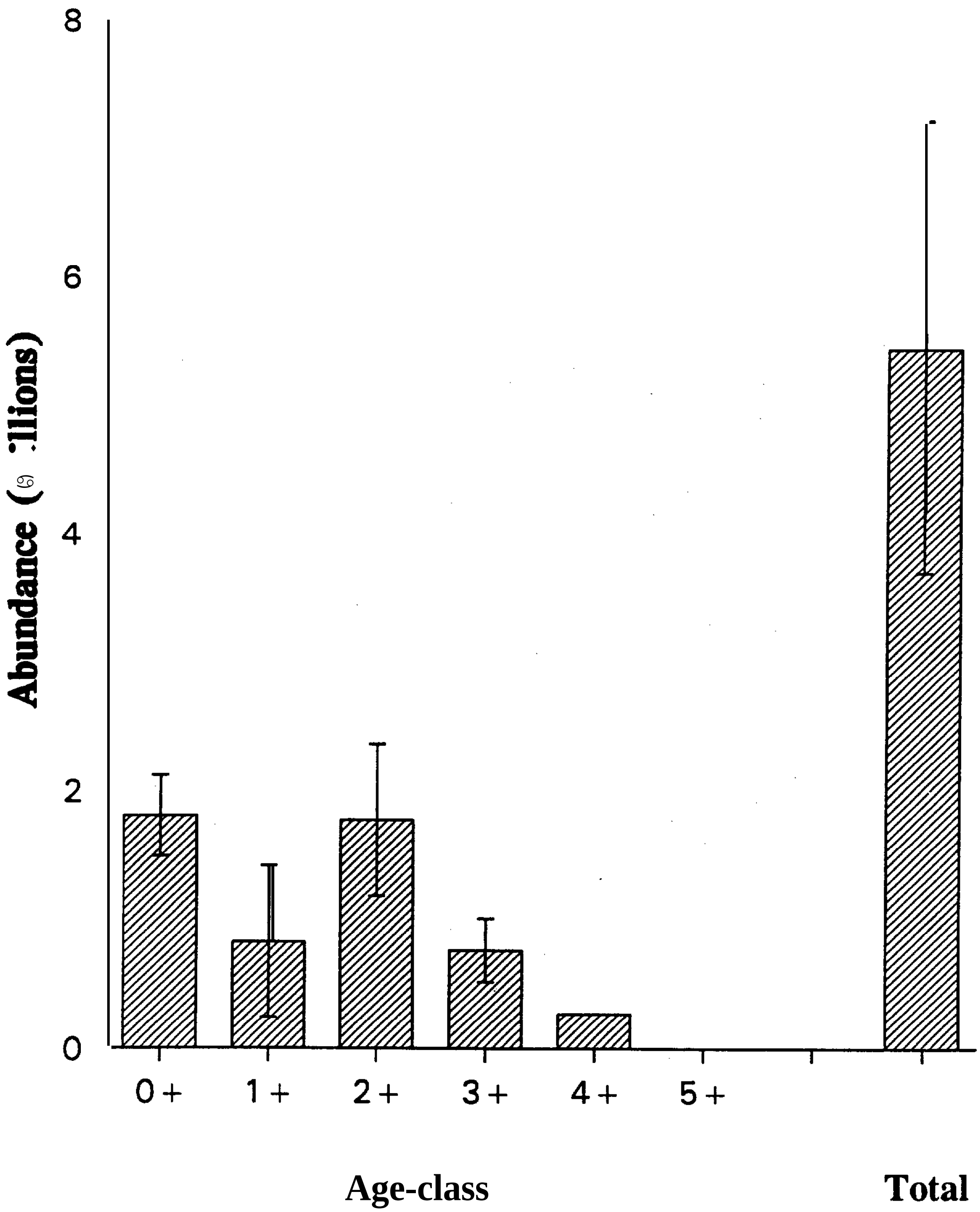


Figure 4. Estimated kokanee abundance, with 90% confidence intervals during September 1991, Lake Pend Oreille, Idaho.

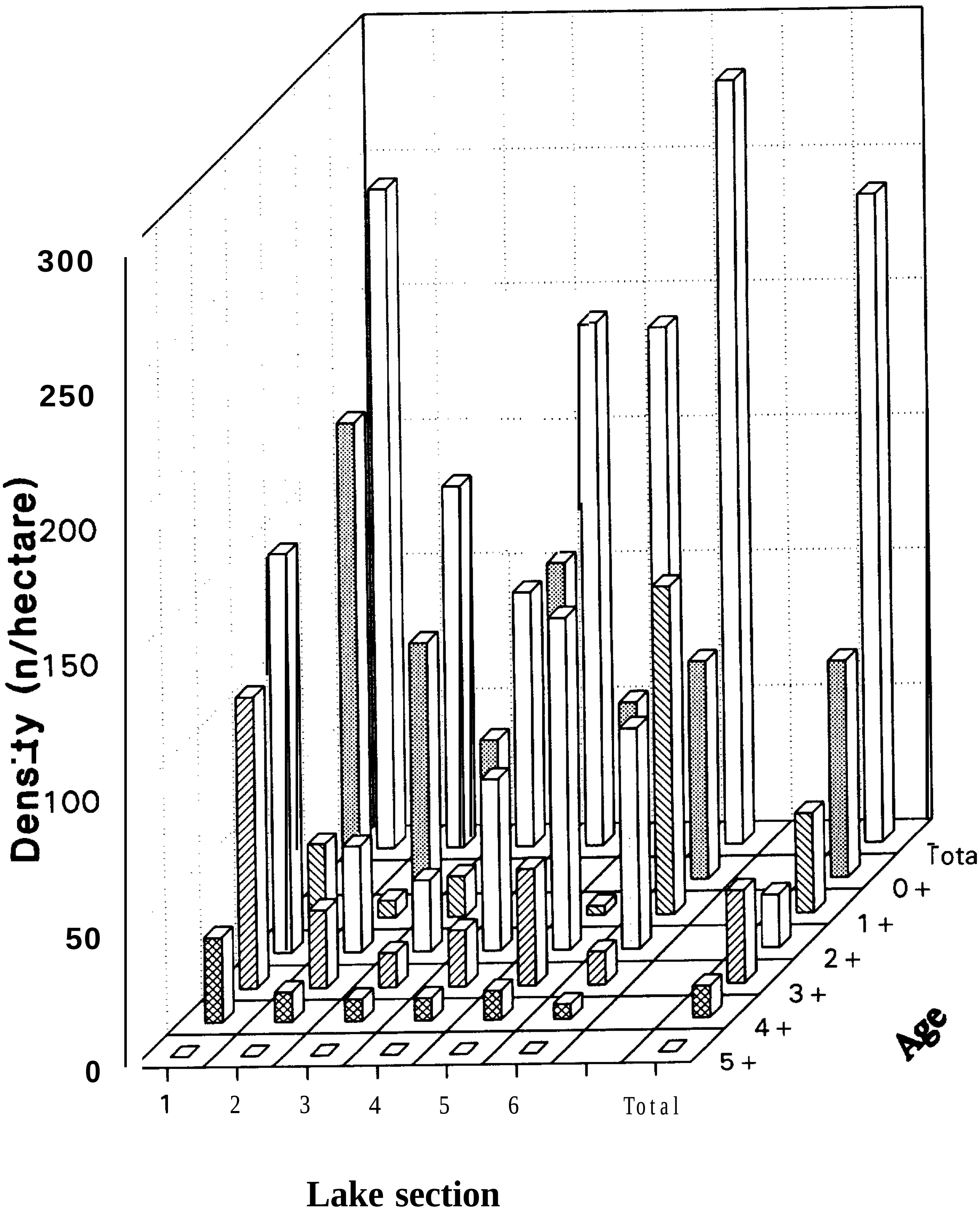


Figure 5. Kokanee density in Lake Pend Oreille, Idaho, by age class and lake section during September 1991.

Estimated kokanee biomass in Lake Pend Oreille during August was 202,262 kg (8.93 kg/hectare)(Table 2). Biomass of hatchery-reared kokanee fry was 2,678 kg (0.12 kg/hectare), 92% of total fry biomass in the lake. Estimated biomass of age 1 and older kokanee was 199,378 kg (8.8 kg/hectare). Length frequencies and mean lengths and weights of kokanee caught in the trawl are shown in Figure 6 and Table 2.

Spawning Escapement

An estimated 540,000 mature kokanee comprised the Lake Pend Oreille spawning population in 1991. The 1991 spawning run to Sullivan Springs Creek was approximately 85,713 kokanee and extended from early November 1991 to early January 1992. One-time **late** spawning kokanee counts (December) in **other** tributaries ranged from 2,710 spawners in Spring Creek to 0 spawners observed in Johnson, Cedar, Twin, and Garfield creeks (Appendix B). Counts of lakeshore spawning kokanee ranged from 1,530 on southern beaches to only 192 kokanee spawners counted on northern lakeshore areas. A count of 995 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 1991 was 38% age 3 and 62% age 4 (N = 29). An estimated 35% of age 3 kokanee were mature and consisted of 27% males and 73% females (N = 31). All of the age 4 kokanee were mature and consisted of 50% males and 50% females, while age 5 kokanee were not caught. Age composition of kokanee spawned during 1991 from Suliivan Springs Creek was 1% age 2, 46% age 3, and 53% age 4 while age 5 kokanee were present but were not part of the random sample (N = 123). Age composition for spawners collected during 1990 was 32% age 3 and 68% age 4 (N = 65) at Sullivan Springs. A sample of kokanee spawners collected from several other traditional spawning areas in 1991 was: 41% age 3 and 59% age 4 (N = 34) for Spring Creek; at the East Hope shoreline it was 34.5% age 3 and 65.5% age 4 (N = 29); North Gold Creek it was 3.6% age 2, 42.9% age 3, and 53.6% age 4 (N = 28); and for early Trestle Creek spawners it was 58% age 3 and 42% age 4 (N = 26).

Mean lengths of kokanee spawners were significantly (P > 0.05) different among some spawning sites during 1991. Mean lengths of male kokanee were; Sullivan Springs 250 ± 2 mm (N = 132), Trestle Creek 242 ± 6 mm (N = 12), East Hope 251 ± 5 mm (N = 29, North Gold Creek 245 ± 6 mm (N = 16), and Spring Creeks 241 ± 6 mm (N = 18), respectively. Mean lengths of female kokanee were; Sullivan Springs 253 ± 3 mm (N = 110, Trestle Creek 242 ± 6 (N = 12), East Hope 237 ± 7 mm (N = 14), North Gold 233 ± 7 mm (N = 12), and from Spring Creek 234 ± 5 mm (N = 16).

Potential Egg Deposition

Estimated total potential egg deposition for 1991 was 92.89 million with 86.31 million eggs attributed to natural spawning and **a** potential of 6.36 million eggs available from artificially spawned kokanee at Sullivan Springs and about 0.22 million from the ladder at Cabinet Gorge Hatchery. Estimated abundance of mature female kokanee was 270,040 fish determined from September trawling. Approximately 20,140 female kokanee were spawned at the Sullivan Springs trap, which left an estimated 249,900 female kokanee to spawn naturally throughout Lake Pend Oreille and its tributaries. Fecundity averaged 344 (±18%)(N = 53, alpha = 0.05) eggs/female.

Table 2. Mean length, weight, and biomass of kokanee caught trawling during late September 1991, Lake Pend Oreille, Idaho.

Age class	Mean length (mm)	Mean weight (g)	Biomass Density kg	kg/hectare	N/ha
Age 0+					
Hatchery	67	2.50	2,678	0.12	47
Wild	32	0.28	205	0.01	40
Combined	49	0.96	2,883	0.13	87
Age 1+	150	25.6	21,084	0.93	37
Age 2+	193	47.3	83,610	3.69	78
Age 3+	218	83.2	63,904	2.82	34
Age 4+	241	114.8	30,781	1.36	12
TOTAL			202,262	8.93	248

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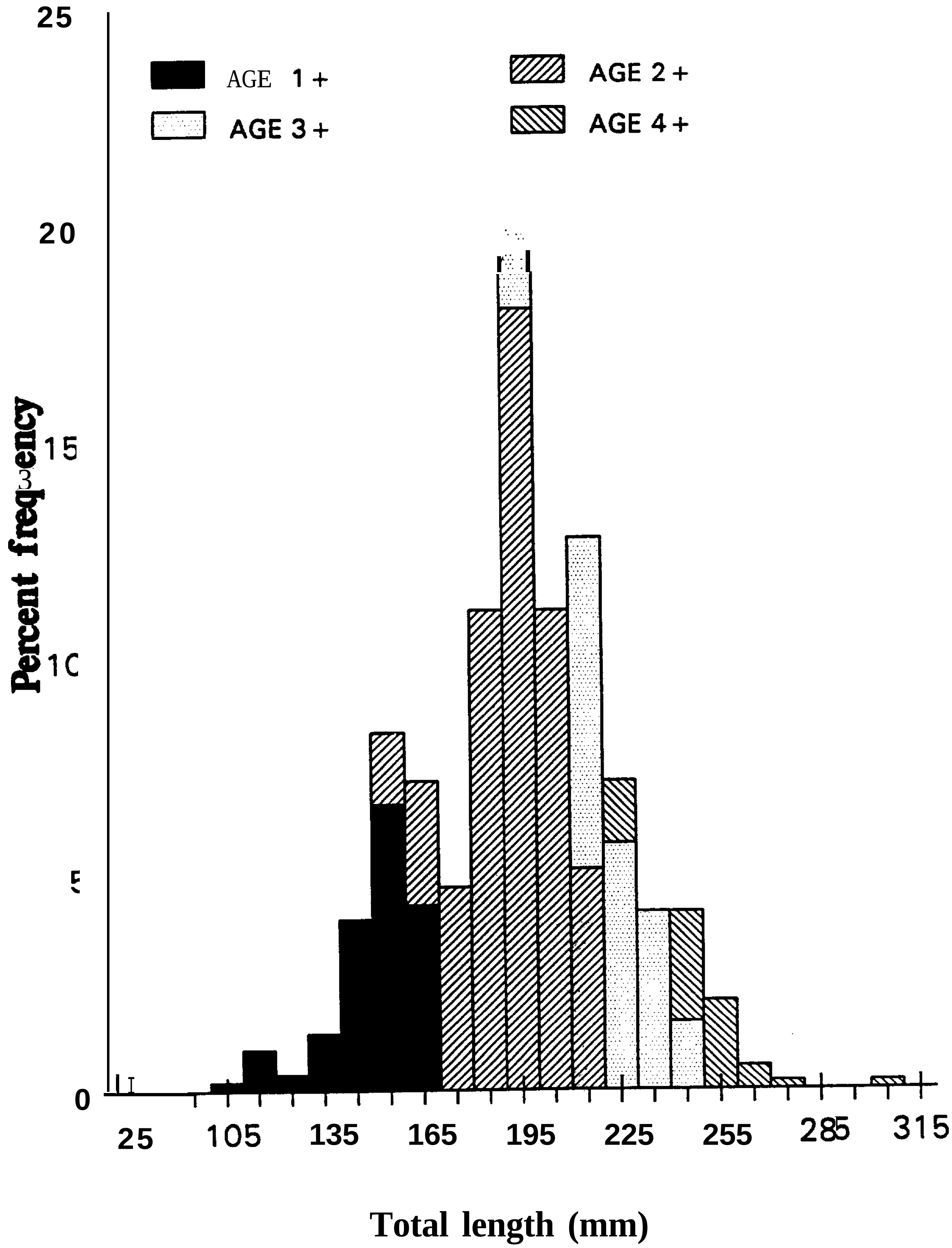


Figure 6. Length frequency of kokanee, by age class, in Lake Pend Oreille, Idaho, during September 1991.

Egg Take

Hatchery personnel collected 6.58 million eggs during 1991. Kokanee spawned at Sullivan Springs provided 6.36 million eggs (316 eggs/female, N = 53), which rewresented a 92% spawning efficiency. An additional 0.22 million eggs were taken at Cabinet Gorge Hatchery from kokanee migrating up Clark Fork River.

Survival and Recruitment

Wild kokanee fry survival from potential egg deposition to early September trawl sampling was only 1.3% in 1991. Hatchery fry survival from egg collection to early September trawl was 19%. Estimated kokanee fry survival (hatchery and wild fish combined) from potential egg deposition to early September trawl was 2.8% for the 1990 year class. A survival rate of 20.7% (±5%) was estimated for the 1990 year class hatchery-reared fry from time of release, late June through July, to sampling in early September.

There was no significant difference in fry survival (18.3% ± 4%) for the early season release in Clark Fork River, and (23.1% ± 5%) for fry released in Sullivan Springs Creek (Figure 7). Hatchery fry were 59% of the total kokanee fry netted in 1991.

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 8).

Estimated annual survival (late summer 1990 to late summer 1991 for wild and hatchery fish combined) was 25% for the 1989 year class (age 1), 111% for the 1988 year class (age 2)(over 100% because of changes in vulnerability to trawl gear) , 53% for the 1987 year class (age 3), and 82% for the 1986 year class (age 4). Survival for age 5 kokanee could not be calculated because none were caught with the trawl.

Analysis of Release Sites and Time

Regression analysis was used to compare the relationship between survival of age 0 kokanee for each release group in 1988 (N = 5) and 1989 (N = 6) and number of days from release to capture date. We did not find a statistical relationship (P = 0.12 and P = 0.15, respectively) between survival of kokanee and total number of days from release to capture.

ANOVA testing and Tukey's statistic were used to compare stocking time (early release vs late), survival between years, and survival between release sites. Late (summer) releases had significantly higher survival ($P < 0.02$) than early releases. We calculated a significant difference in survival between years ($P < 0.05$)(survival of age 0 kokanee in 1988 was higher than 1989, 1990, and 1991). Additional testing, accounting for a repeated measures design (between years), indicated there was no difference in survival between stocking sites ($P > 0.71$).

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

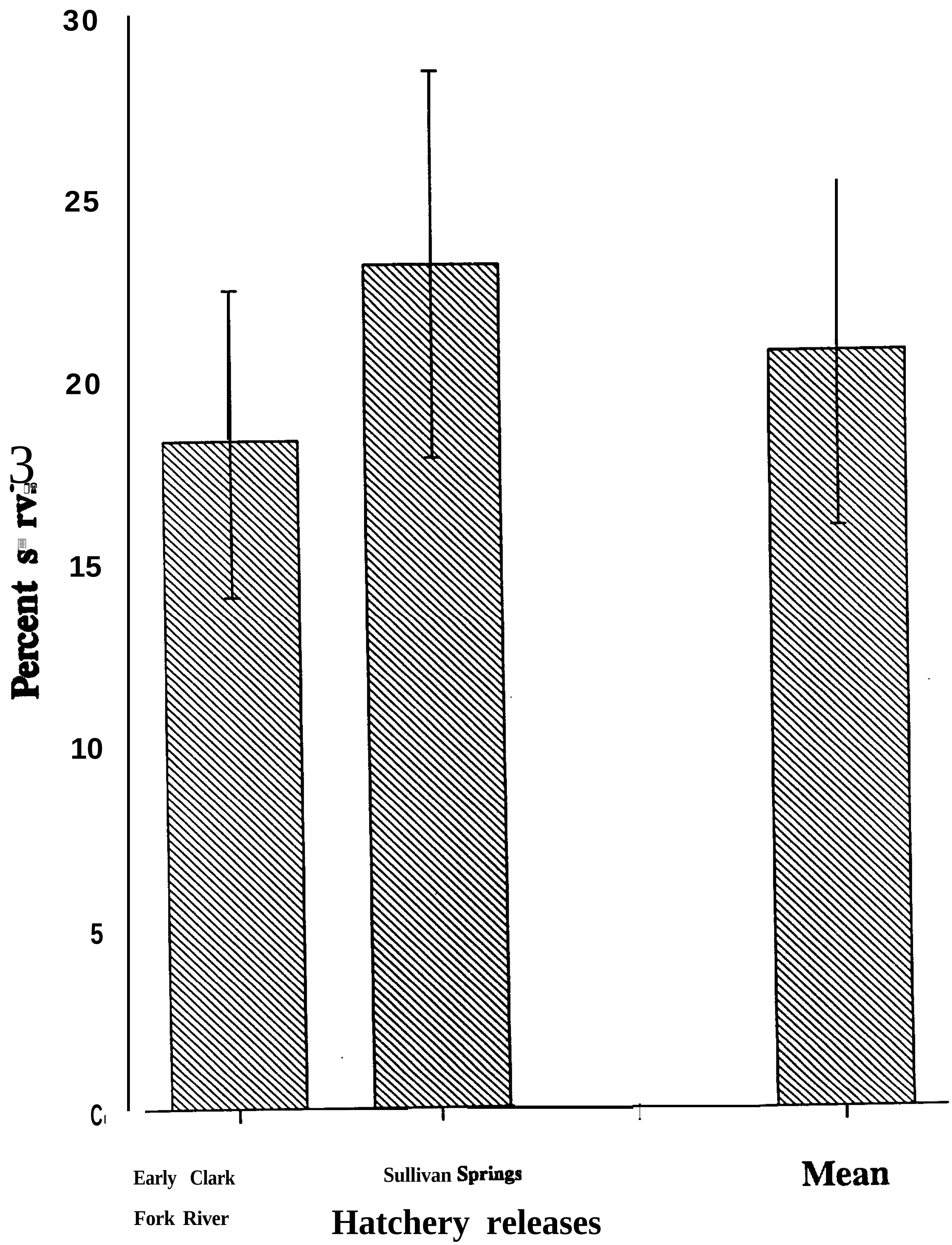


Figure 7. Estimated survival of hatchery fry during their first summer in Lake Pend Oreille, Idaho, compared among three release strategies evaluated in 1991. A 90% error bound is depicted for each estimate.

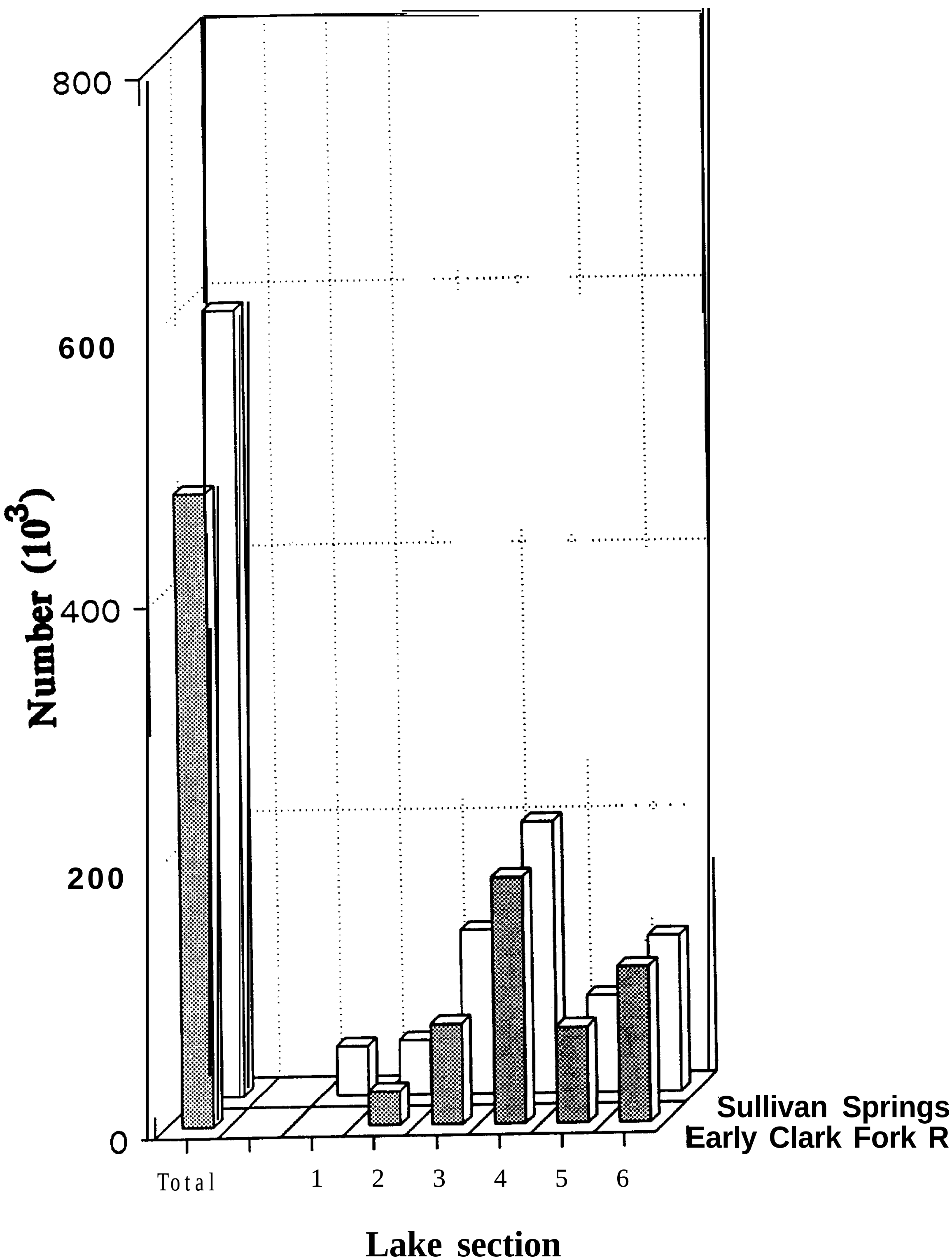


Figure 8. Abundance and distribution of hatchery-reared kokanee fry during early September 1991 compared among two release strategies in Lake Pend Oreille, Idaho.

approximately two times larger during hatchery residence than lake residence. About 35% of the daily ring counts (N = 55) of the Sullivan Springs group were within one day of the expected number of days from the releases to fall sampling, 60% were within two days. Only 14% of the Clark Fork River group were within one day of the expected and only 25% were within two days. About 85% were within five days of the expected.

The 1991 spawning operation recaptured a total of 162 fin clipped kokanee. Sullivan Springs accounted for a total of 151 adipose fin clips (released in Sullivan Springs in 1988), five left ventral fin clips (early Clark Fork River release in 1988), and one right ventral (late Clark Fork River release by barge in 1988). Total spawning escapement to Sullivan Springs was about 85,713 kokanee and of these 75,624 were spawned and checked for fin clips (88%) (Appendix D). Thus, the estimated total escapement of fin clipped kokanee at age 3 to Sullivan Springs was 172 adipose, six left ventral, and one right ventral. The estimate of fin clipped kokanee returning to Sullivan Springs as age 3 is 0.43% of the 40,000 fish clipped at age 0 in 1988. Furthermore, since 0.43% of the marked fish returned, the estimate of the original 5.139 million fish (released as fry at Sullivan Springs in 1988) returning would be 22,098 fish or 56% of the age 3 spawners, the remaining 44% would have been from wild stock. The remaining six left ventral and one right ventral fin-clipped kokanee were strays from the Clark Fork River release in 1988.

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

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

Mysis Shrimp

Sampling for shrimp during June was delayed until mid Autumn. Density of shrimp in Lake Pend Oreille during early November, 1991, averaged 5 organisms/m^3 (±2)(Figure 9). This estimate was significantly lower than density estimates for all other years because of the late sampling date. Thus, further comparisons with other samples collected during June were not done. Analysis of previous years data (1986-1990) indicated total densities during 1986-1990 were similar ($P = 0.121$) between southern and central lake sections and significantly lower ($P = 0.000$) in the northern section (Paragamian et al. 1991).

Juveniles comprised about 76% of total Mysis abundance in Lake Pend Oreilie during early November 1991 with an average density of 5 organisms/m^3 (±2) (Figure 9). The November 1991 density of juveniles, adults, and subadults was not contrasted to other years of this study because they were collected late in the season. However, the estimated juvenile density in 1990 was not significantly different ($0.175 < P < 0.983$) than estimated density for 1987 (16 organisms/m^3) or 1989 (25 organisms/m^3) but was significantly lower ($P = 0.000$) than the 1988 estimate (42 organisms/m^3), the 1986 estimate ($P = 0.021$)(31 organisms/m^3), and 1989 estimate ($P = 0.016$)(25 organisms/m^3).

Juvenile densities during 1986-1990 were similar ($P = 0.174$) between southern and central lake sections and significantly lower ($P = 0.000$) in the northern section.

Adult shrimp comprised 24% of total abundance during early November 1991 and averaged 1 organism/m^3 (±1)(Figure 9). Adult density averaged 5 organisms/m^3

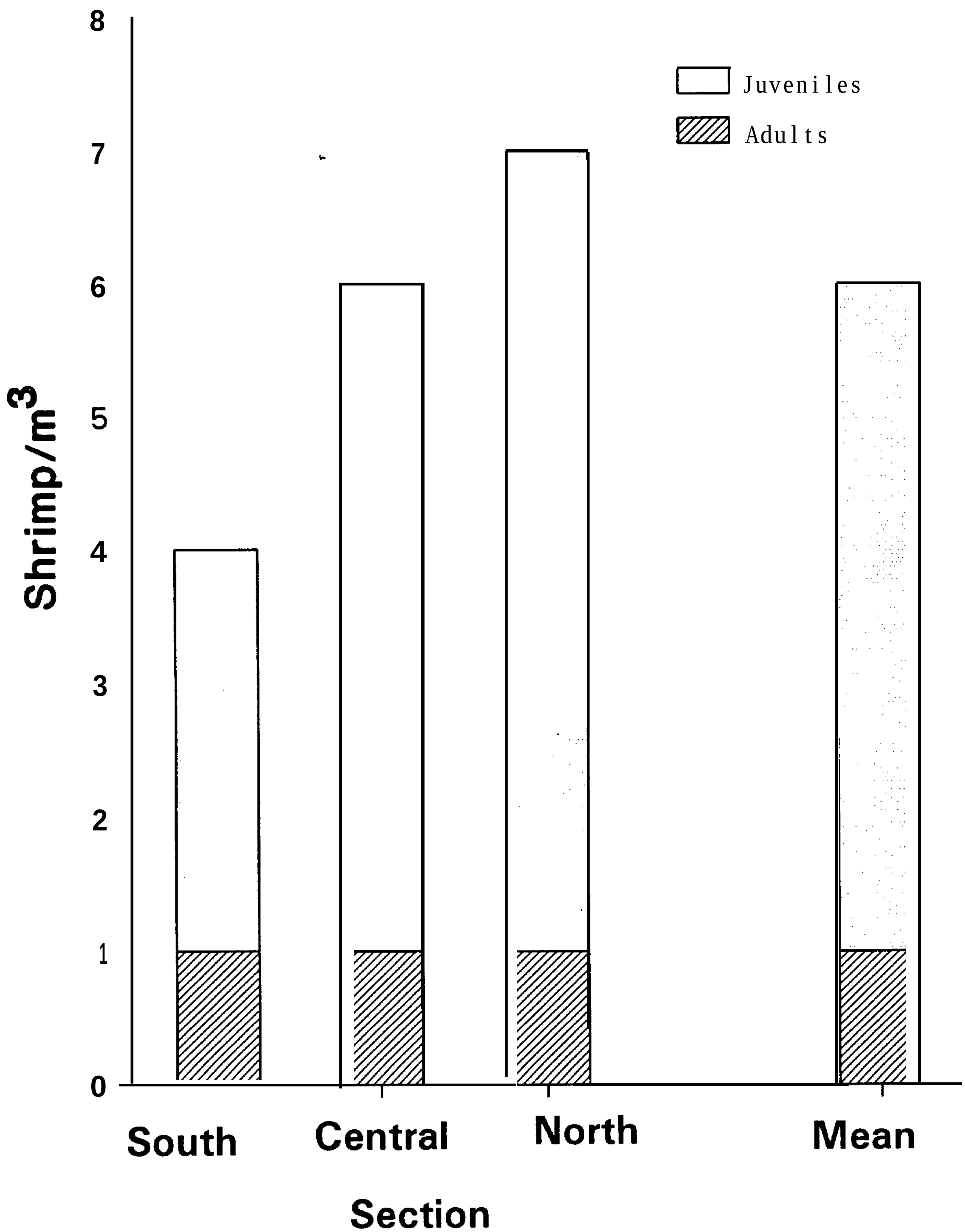


Figure 9. Mean adult, juvenile, and total densities of shrimp in Lake Pend Oreille, Idaho, sampled during November 1991.

in 1990 and was significantly lower (P = 0.000) than the estimated density for 1989 (16 organisms/m^3) 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.

A length frequency distribution of shrimp in Lake Pend Oreille during early November 1991 **was** constructed and comprised of contribution of at least two brood years. The distribution ranged in length from 3 mm to 20 mm (Figure 10). Juvenile shrimp made up the 1991 brood year and ranged in length between 3 mm and 10 mm. The 1990 brood year represented by immature shrimp consisted of 52% males and 48% females. Unusually large females from the 1989 brood year were not evident in our sampling.

Zooplankton Community

The zooplankton community in Lake Pend Oreille from May through October 1991 included Cyclops, Diaptomus, Epischura, Bosmina, Daphnia, and Diaphanosoma. In general, the mean zooplankton density of 12.105 organisms/L (±2.5) in 1991 was the lowest since this study began (Figure 11). Total zooplankton was significantly lower than 1985 (P = 0.00), 1988 (P = 0.00), 1989 (P = 0.00), and 1990 (P = 0.00). Total zooplankton density ranged from approximately 6 organisms/L (±0.5) in October to approximately 25 organisms/L (±1.387) in July. Copepod densities were higher than cladoceran densities throughout the 1991 sampling periods (Figure 12, Appendices F through K). Cladoceran density was highest during August and September at approximately 10% and 15% of copepod density, respectively (Figure 13). The copepods Cyclops and Diaptomus were the most abundant zooplankters, with combined densities ranging from approximately 6 organisms/L in October to approximately 30 organisms/L in July.

The average density of Cyclops in 1991 (6.714 organisms/L ±2.16) was significantly lower (P < 0.03) than 1990 (9.168 organisms/L) lower than 1988 (P = 0.000) (13.226 organisms/L), and lower than 1987 (P = 0.000) (8.87 organisms/L) whereas the average density of Diaptomus in 1991 (5.634 organisms/L ± 1.164) was significantly different than 1987, 1988, 1989, and 1990 (P < 0.05) a grand mean of 6.829 organisms/L (Figure 13, Appendix C). Epischura was the least abundant zooplankter during 1991 with an estimated density of 0.016 organisms/L (±0.003), but this density was significantly lower (P < 0.05) than 1985 and 1987; 0.044 organisms/L and 0.04 organisms/L, respectively. In general, cladocerans were extremely uncommon in samples taken during 1991 until August, which was similar to most other years. Bosmina density in 1991 (0.186 organisms/L ± 0.122) was significantly lower (P < 0.05) than 1987 (0.592 organisms/L) and 1989 (P < 0.000) (0.995 organisms/L). Mean density of Daphnia during 1991 (0.354 organisms/L ± 0.153) was significantly lower (P < 0.001) than the two highest years, 1986 (1.265 organisms/L) and 1987 (1.077 organisms/L). Diaphanosoma density in 1990 (0.073 organisms/L ± 0.015) was significantly lower (P < 0.000) than 1989 (0.337 organisms/L). Zooplankton densities were statistically similar (P > 0.10) among northern, southern, and central sections of Lake Pend Oreille (Figure 13, Appendix C). Sampling of zooplankton in the Clark Fork River delta section was discontinued in 1990.

Water Temperature and Transparency

Surface temperatures of Lake Pend Oreille from May through November 1991 ranged from 9.0°C in May to 21°C in August (Figure 14). Thermal stratification began in late June and extended through September. At peak stratification (August), the thermocline began at a depth of 11 m and average epilimnetic water temperature was about 17°C.

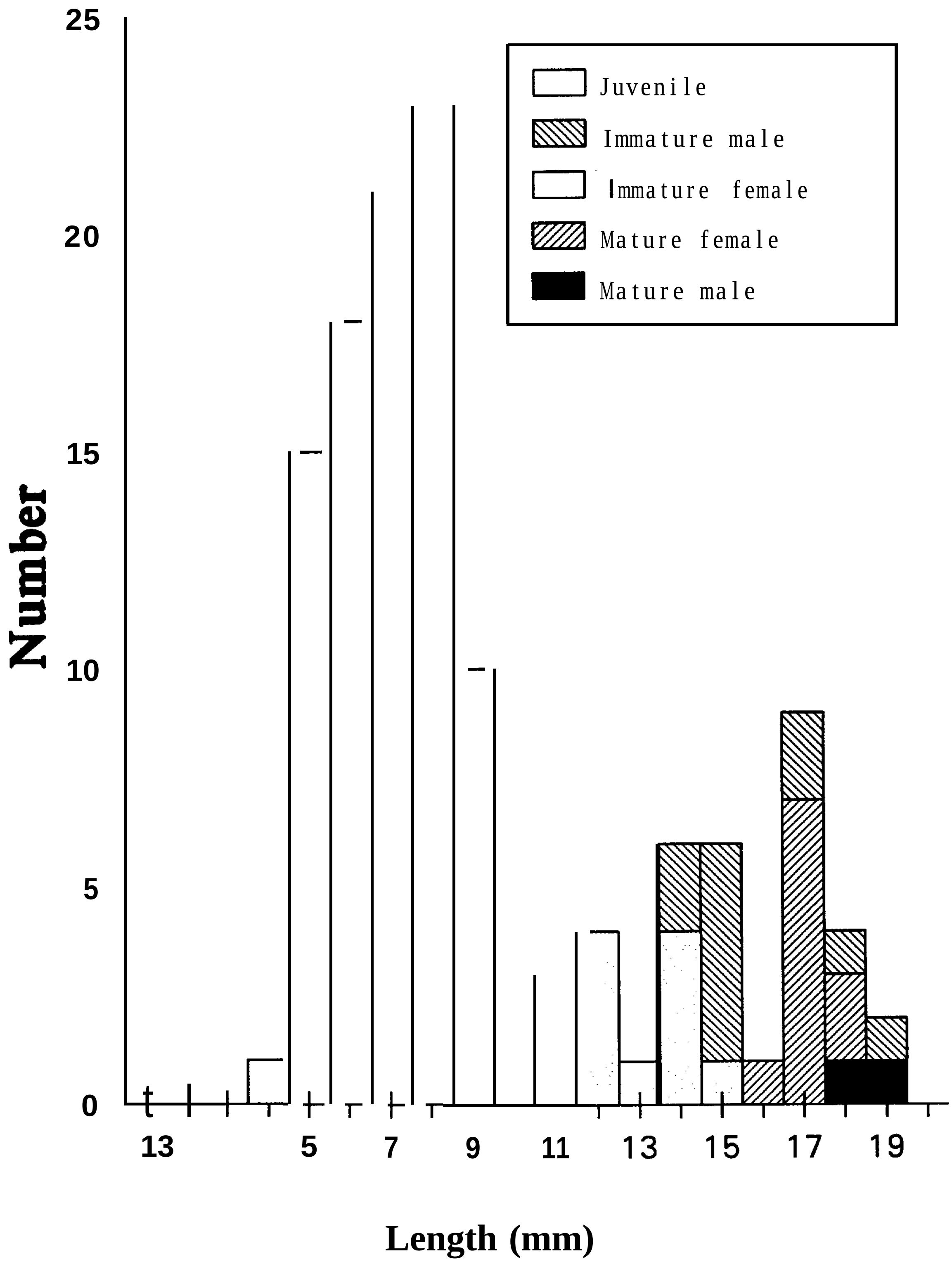
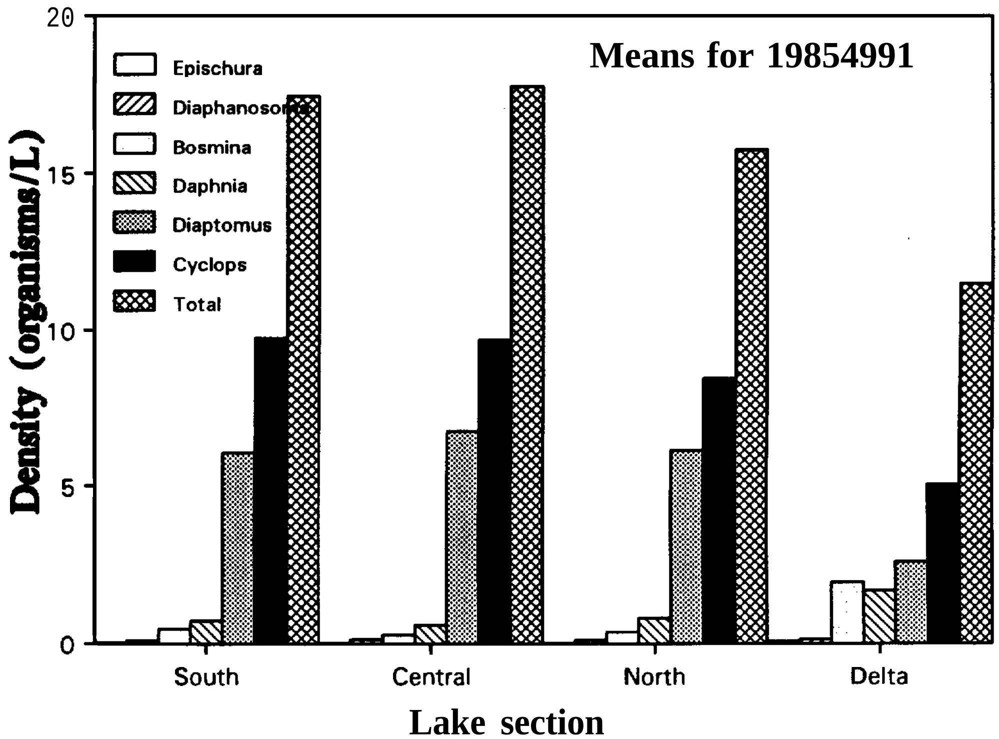


Figure 10. Length frequency of shrimp, by size and sex in Lake Pend Oreille, Idaho, during early November 1991.



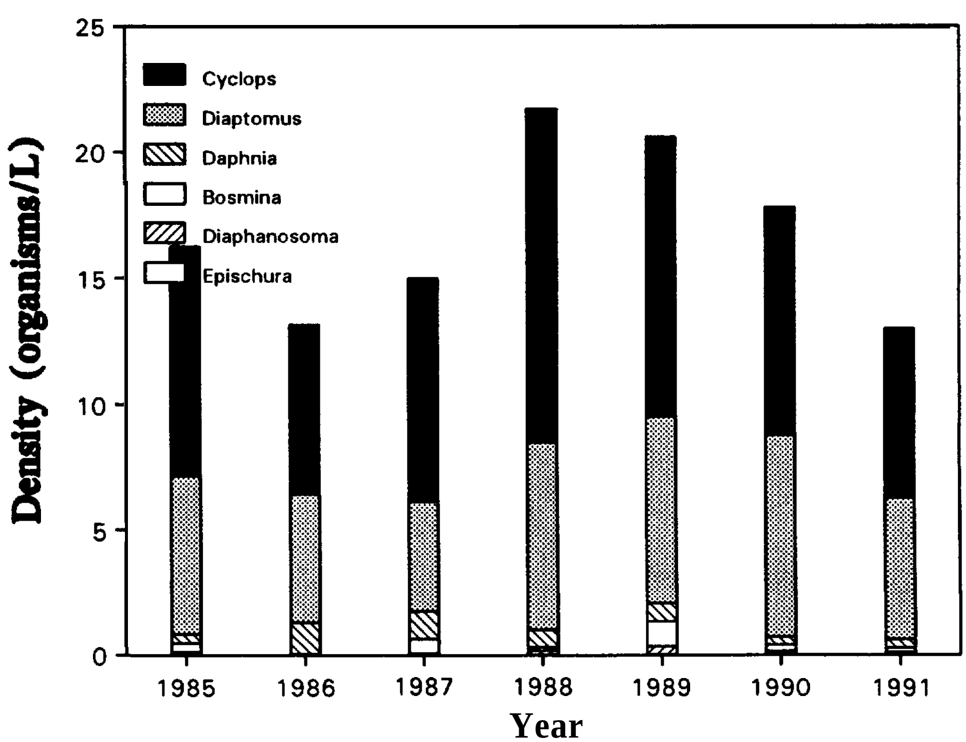


Figure 11. Mean zooplankton densities in Lake Pend Oreille, Idaho, from 1985 through 1991 compared among lake sections (top figure) and eyars (bottom figure).

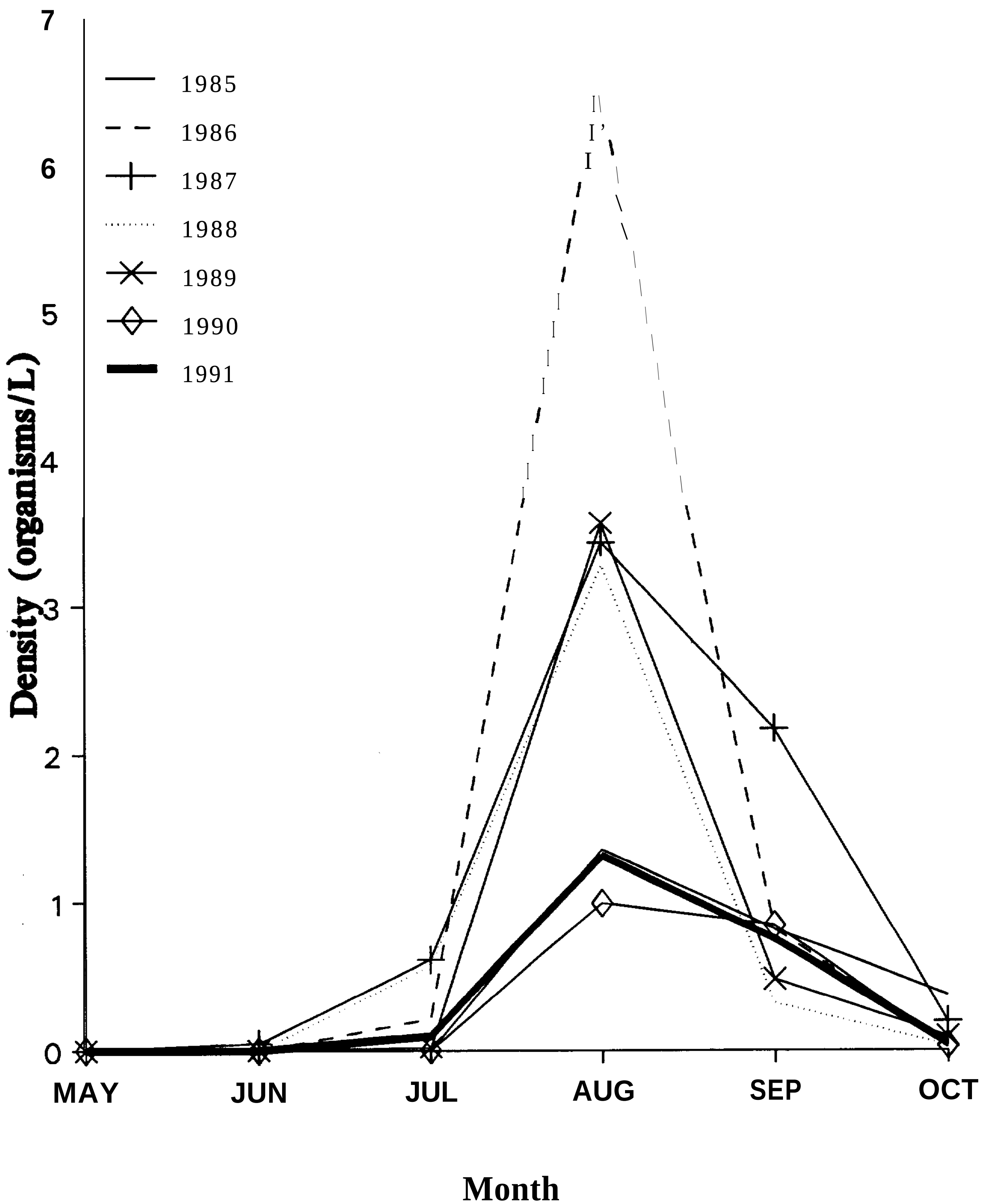


Figure 12. Temporal distribution of mean Daphnia densities in Lake Pend Oreille, Idaho, May through October, 1985 through 1991.

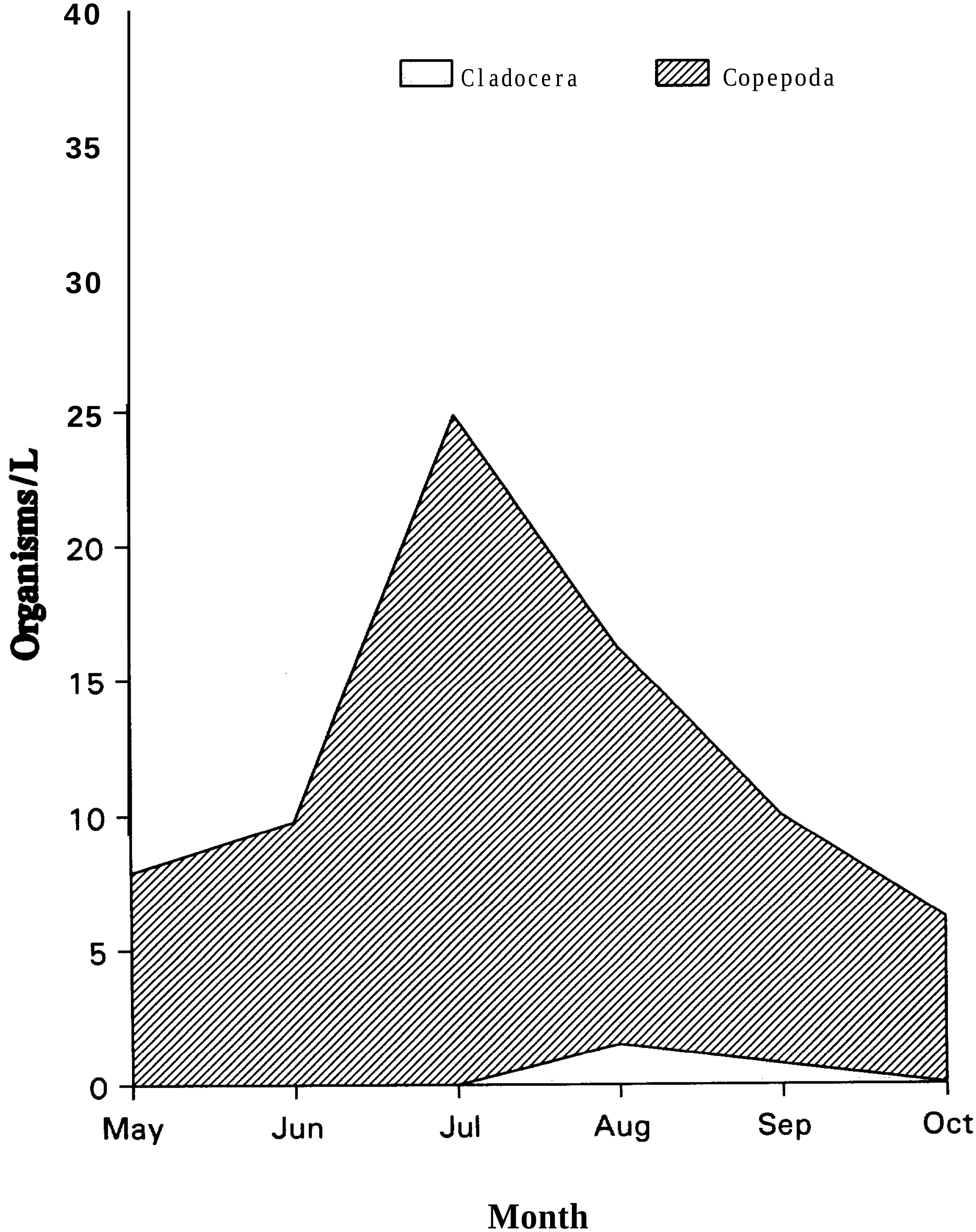


Figure 13. Temporal distribution of Copepoda and Cladocera zooplankton in Lake Pend Oreille, Idaho,Maythrough October 1991.

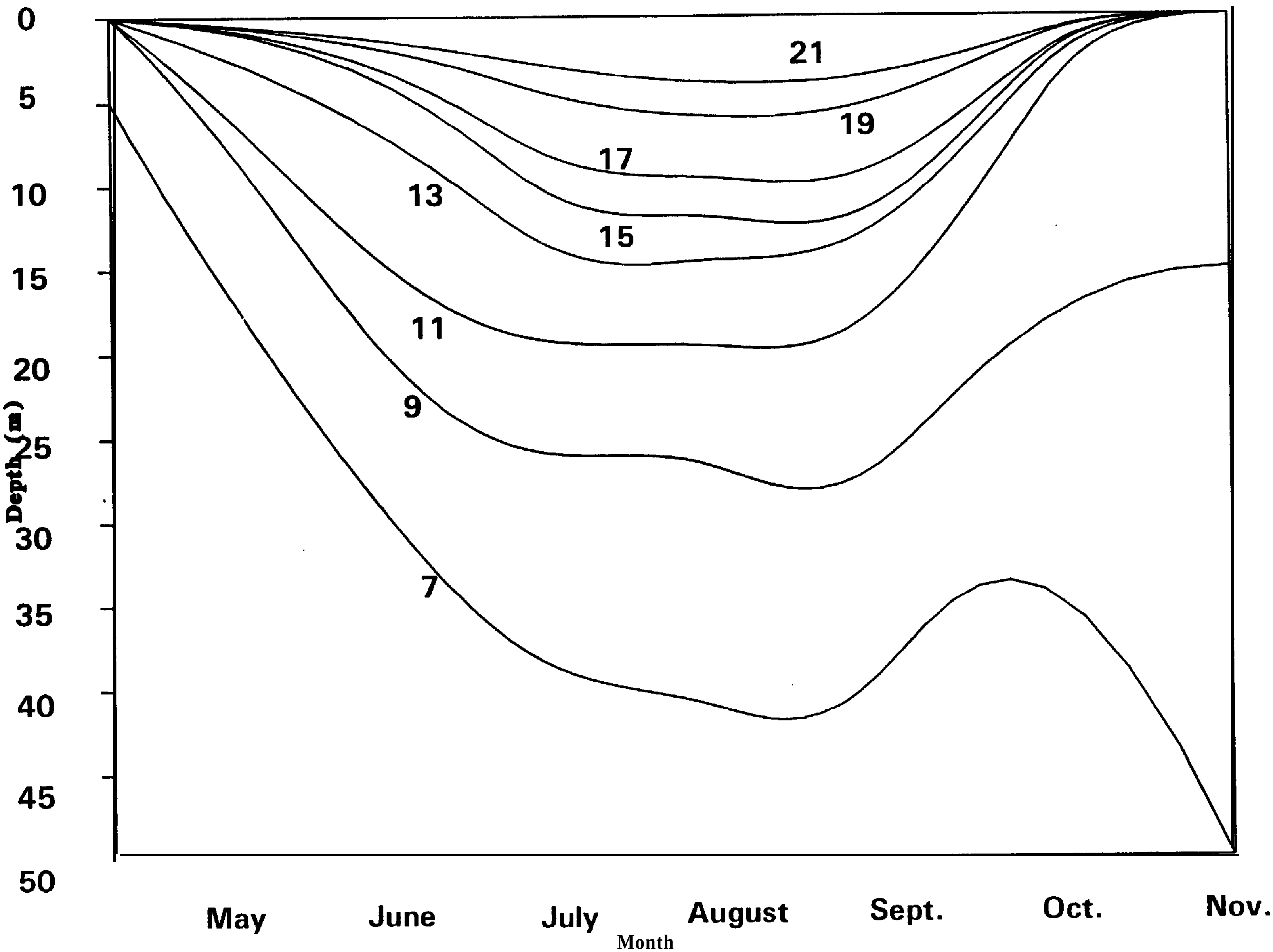


Figure 14. Distribution of thermal isopleths (^{o}C) in the upper 50 m of Lake Pend Oreille, Idaho, May through November 1991

Water transparency (Secchi disk) from May through October 1991 ranged from 2.7 m in May to 8.9 m in September (Figure 15).

The Fishery

Total Catch and Effort

The 1991 creel survey for Lake Pend Oreille is based on interviews with 7,382 anglers, 61 instantaneous boat counts, and an average of 2.25 anglers/boat.

The creel survey was broken into six intervals. The first interval had a significant ($P > 0.05$) disparity in fishery effort between the first nine days and the remainder of that time frame (a fishing derby was conducted during the first nine days). Thus, the first interval was separated into two intervals. Game fish harvest included: kokanee, Gerrard rainbow trout, bull trout, cutthroat trout, lake trout, lake whitefish, mountain whitefish and various spiny rayed species of which yellow perch Perca flavescens was the most common. The estimated total angler catch was 276,547 fish (±20%) of which 237,570 (±20%) were kept. An estimated grand total of 384,461 anglers fished a grand total of 460,679 hours (±20%).

Kokanee Catch, Harvest, and Exploitation

Angler harvest of kokanee from Lake Pend Oreille was estimated at 227,140 fish (Table 3) or about 96% of the total fish harvest. Yield was 22,714 kg or 1.0 kg/hectare based on 22,647 hectare of coldwater habitat.

Mean catch rate for anglers fishing for kokanee was 1.45 fish/h, interval six was the best interval for angling at 2.48 fish/h while interval one was the poorest at 0.001 fish/h (Table 4). The mean length for kokanee in the harvest during September was 242 mm with an average weight of 100 g (Figure 16). Age structure of kokanee in the catch was estimated at 11% age 2, 44% age 3, and 45% age 4 (Figure 16). Ages of kokanee were estimated by comparisons to previously aged kokanee of similar length caught by trawling. Exploitation of age 2 kokanee was 1.4%, age 3 was 6.9%, and age 4 kokanee was 31% (based on Autumn, 1990 population estimates and the 1991 harvest). The combined estimate for age 3 and 4 kokanee was 11%.

Gerrard Rainbow Trout Catch and Harvest

Anglers caught an estimated grand total of 17,165 (25,519) Gerrard rainbow trout during the 1991 fishing season (Table 3). Of this total 2,939 were ≥610 mm. Anglers released 782 or 27% of these large rainbow trout (Table 3). The total catch also included 14,122 Gerrard rainbow trout <610 mm of which 104 of the smaller fish were kept, comprising the illegal harvest.

Gerrard rainbow trout measured during the survey ($N = 274$) ranged from 250 mm to 985 mm with a mean of 735 mm, $SD = 117$ mm (Figure 17). Mean weight of rainbow was 5.72 kg, $SD = 2.49$ kg. The total harvest of Gerrard rainbow trout by weight was estimated at 12,934 kg or 0.57 kg/hectare.

The mean catch rate for all length categories of rainbow trout, by anglers seeking them, was 0.068 fish/h (14.7 h/fish) (Table 4). The mean catch success for the rainbow trout ≥610 mm was 0.013 fish/h (78 h/fish) while that for the smaller rainbow trout was 0.055 fish/h (1.8 h/fish)(Table 4). Interval six was

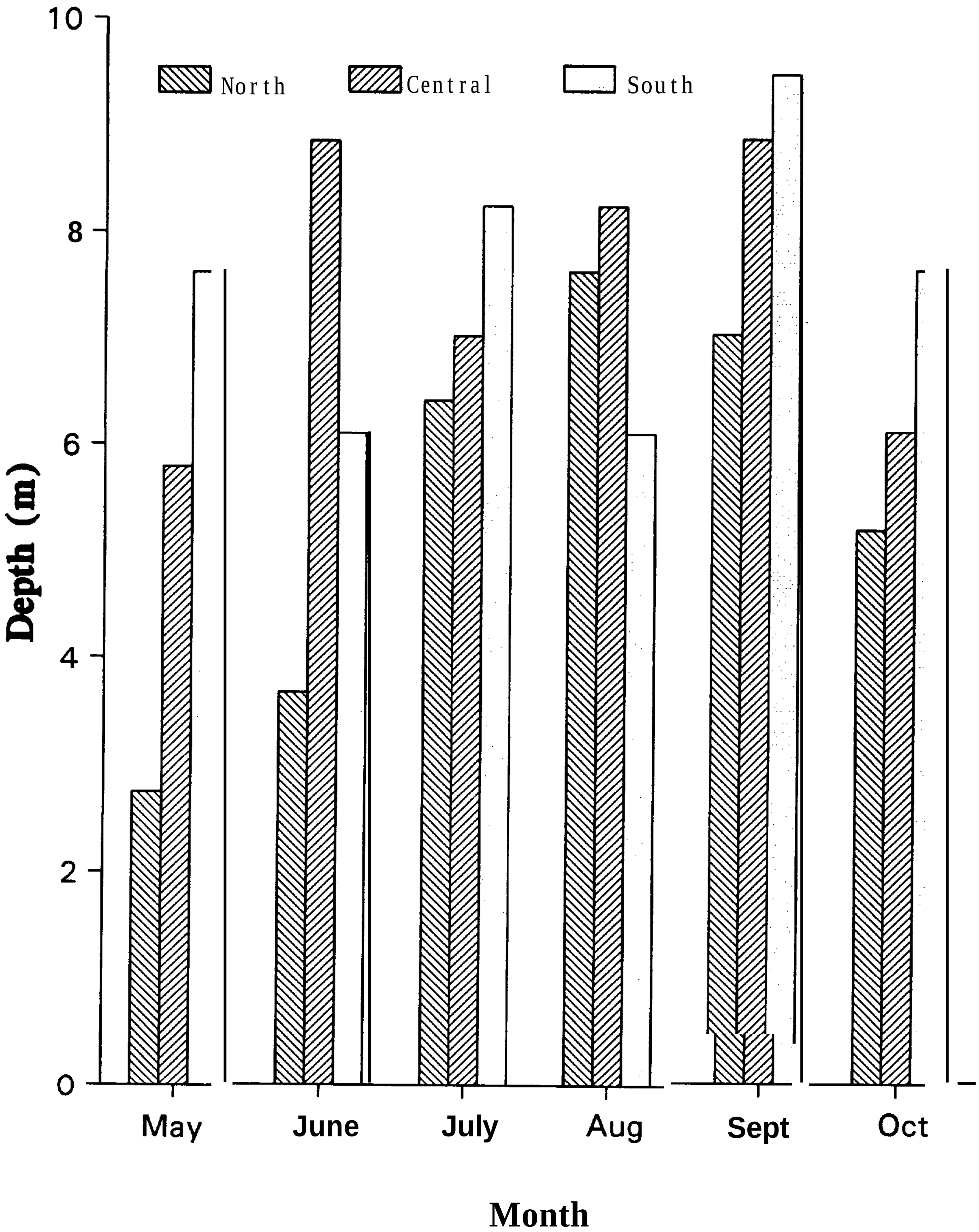


Figure 15. Water transparency (Secchi disk) in three sections of Lake Pend Oreille, Idaho, May through October 1991.

Table 3. Estimated effort, harvest of sport fish and rainbow trout released by survey period, Lake Pend Oreille, Idaho, 1991.

			Harvest					Rainbow trout released	
Period	Effort (h)	Total Catch	Kokanee	Small[a] rainbow	Large[b] rainbow	Cutthroat	Bull trout	Small rainbow	Large rainbow
Apr 27 - May 5	75,877	4,440	52	0	596	23	262	2,976	152
May 6 - May 30	79,834	8,101	3,674	0	25	0	56	559	0
May 31 - Jul 15	83,023	52,424	44,424	0	237	112	801	2,233	166
Jul 16 - Aug 30	88,235	130,183	111,689	50	38	176	241	1,638	0
Aug 31 - Oct 15	68,810	73,705	67,096	54	352	390	298	1,379	0
Oct 16 - Nov 30	64,900	7,694	205	0	909	65	65	5,337	464
Totals	460,679	276,547	227,140	104	2,157	766	1,723	14,122	782

[a]Illegal take of rainbow trout <610 mm.
[b]Harvest of rainbow trout >610 mm.

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Table 4. Estimated catch rate for anglers specifically seeking kokanee, rainbow trout, cutthroat trout, or bull trout during six creel periods from April 27 through November 30, Lake Pend Oreille, Idaho, 1991.

Period	Kokanee caught (fish/h)	All rainbow caught (fish/h)	Large[a] rainbow (fish/h)	Small rainbow (fish/h)	Cutthroat (fish/h)	Bull trout (fish/h)
Apr 27 - May 5	0.001	0.045	0.007	0.038	0.000	0.166
May 6 - May 30	0.034	0.050	0.007	0.043	0.273	0.126
May 31 - Jul 15	0.820	0.073	0.012	0.061	0.172	0.155
Jul 16 - Aug 30	1.870	0.031	0.004	0.027	0.700	0.050
Aug 31 - Oct 15	1.540	0.067	0.009	0.058	0.221	0.278
Oct 16 - Nov 30	2.483	0.102	0.024	0.078	7.500	---
Mean	1.453	0.068	0.013	0.055	0.300	0.148

[a]610 mm total length.

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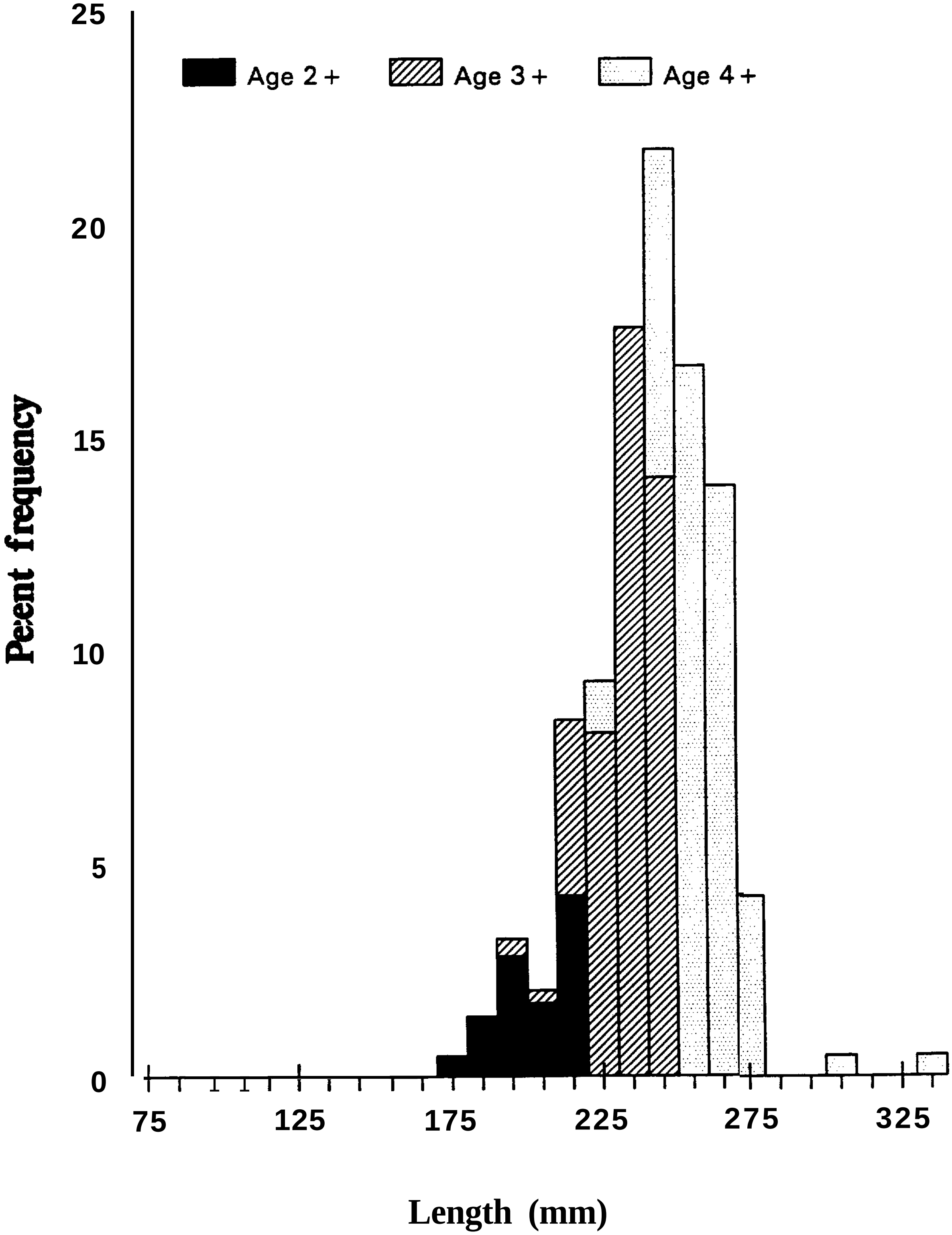

Figure 16. Length frequency distribution of angler caught kokanee by age class, Lake Pend Oreille, Idaho 1991.

the best portion of the fishing season for Gerrard rainbow trout at 0.102 fish/h (9.8 h/fish)(Table 4).

Bull Trout Catch and Harvest

An estimated 1,723 (±896) bull trout were creeled at Lake Pend Oreille during the 1991 fishing season (Table 3). Bull trout measured by creel clerks (N = 161) ranged from 300 mm to 745 mm with a mean length of 492 mm, SD = 83 mm (Figure 17). The mean weight of bull trout in the creel was 1.45 kg while the harvest in weight was estimated at 2,495 kg or 0.11 kg/hectare.

Catch success for anglers fishing for bull trout averaged 0.147 fish/h (6.8 h/fish) during the 1991 fishing season (Table 4). Interval five was the best for bull trout fishing with a catch success of 0.278 fish/h (3.6 h/fish)(Table 4).

Cutthroat Trout Catch and Harvest

Anglers caught a total of 766 cutthroat trout during the 1991 fishing season (Table 3). Cutthroat trout in the harvest (N = 41) ranged from 200-565 mm with a mean length of 373 mm, SD = 84 mm (Figure 17). The mean weight of cutthroat trout was 0.72 kg, SD = 0.52 kg. The total harvest in weight was estimated at 591 kg or 0.003 kg/hectare.

Mean catch success for cutthroat trout anglers was 0.300 fish/h (3.3 h/fish) while interval six was the best interval for fishing at 7.5 fish/h (0.1 h/fish) (Table 4). Three fin clipped (adipose) cutthroat trout that were reared in net pens were identified of the 41 fish actually seen during the fishing season. An additional four fish were identified during a non-creel day at Lake Pend Oreille. This expands to an estimated harvest of 56 cutthroat trout of 138,204 released in 1990 and 1991.

Lake Trout Catch

Forty-three lake trout Salvelinus namaycush were identified in the catch during the 1991 fishinq season. An estimate of total harvest could not be provided. Lake trout measured by creel clerks ranged from 220 mm to 905 mm with a mean length of 594 mm, SD = 173 mm (Figure 17). The mean weight of lake trout was 3.18 kg. Catch success of anglers seeking lake trout was 0.082 fish/h (12.2 h/fish).

Food Habits of Rainbow Trout

Stomach contents were examined from 108 angler caught Gerrard rainbow over 610 mm, of which 56 (52%) were empty, smaller rainbow were not sacrificed. Of the 52 stomachs with food items 49 (94%) contained kokanee. The rainbow trout ranged from 660-938 mm. For those stomachs containing kokanee the average was 3.6 fish per stomach. Average length of kokanee was 146 mm (5.8 in). Three stomachs contained Mysis shrimp and one ants.

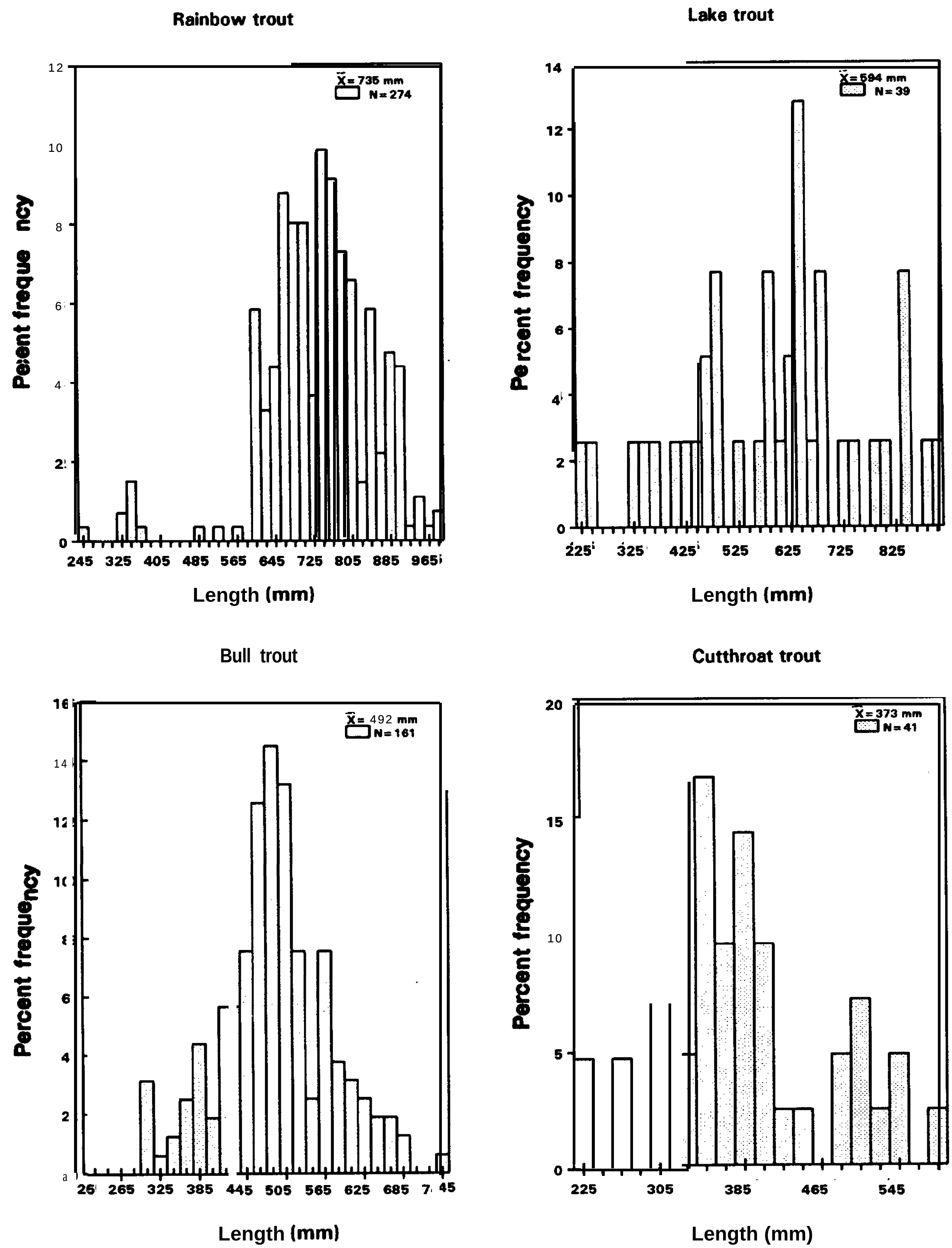

Figure 17. Length frequency distribution of four species of fish caught by anglers, Lake Pend Oreille, Idaho, 1991.

DISCUSSION

Kokanee Population Status

The kokanee population in Lake Pend Oreille declined in 1991 for the third consecutive year (Figure 18 and Appendix D). Initially, the kokanee restoration program, through stockings from the Cabinet Gorge Fish Hatchery, increased the total number of fish from 4.3 million in 1985 to 10.2 million in 1988 (Bowies et al. 1988). But from 1989 through 1991, the population declined to 5.4 million fish. The improved population in 1988 was due to a substantial increase in the number of stocked fry and increased survival of age 0 kokanee. However, low fry survival in 1989 and poor egg takes and subsequent low fry stockings in 1990 and 1991 lead to **a** substantial reduction in the total number of kokanee; 7.3 million fry in 1990 and 5.0 million in 1991. In addition, despite the vastly improved stocking densities of fry and increased densities of age 1 fish there has not been a corresponding improvement in the total numbers of age 3 and 4 kokanee (Figure 18). The most improvement in adult kokanee was recorded in 1991 despite the poor survival of age 3 and 4 in 1990, estimated at 27% and 44%, respectively (Figure 19). Survival of these two age groups averaged 52% and 92%, respectively, and were 53% and 82% in 1991.

Standing stocks of kokanee in Lake Pend Oreille declined from i977 through 1986 (Figure 20). Since 1986, when hatchery supplementation from the Cabinet Gorge Fish Hatchery began, it has ranged from about 8-10 kg/hectare and appears to have stabilized. However, the fishery may be operating below carrying capacity since standing stock ranged from IO-17 kg/hectare from 1977-1984. It is very obvious the hatchery program at Lake Pend Oreille has played an important role in maintaining the kokanee population and has prevented the population from an even greater decline. However, the contribution of wild fish has continued to decline, and if this trend is not changed by greatly improving wild kokanee survival (from egg deposition to fall fry), it is unlikely the hatchery program can maintain the population at its present level (Figure 21). In addition, as the kokanee population declines, predation can become a more important factor. The proportion of kokanee eaten by rainbow trout and other predators increases as the availability of kokanee declines and thus a 'predator trap' is created.

Hatchery fish 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, assuming equal survival (Figure 21). Six years of stocking Lake Pend Oreille with kokanee from the Cabinet Gorge Hatchery has increased the hatchery contribution to 51.4% of the population.

Fry Recruitment and Survival

Fry recruitment in 1991 was the lowest since this study began in 1985 and, as indicated earlier, is a major limiting factor for improved population status (Figure 22). Autumn density of age 0 kokanee was 87 fry/hectare in 1991 compared to 148 fry/hectare in 1990, a 41% decrease and a 25% decrease from 1989 to 1990 (198 fry/hectare) and a 54% decrease from 1988 to 1989 (320 fry/hectare) (Figure 22; Appendix D). Age 0 kokanee densities in two other north Idaho lakes during autumn 1991 were substantially higher 415 fry/hectare for Lake Coeur d'Alene and 1,154 fry/hectare for Spirit Lake (Davis 1992 in progress). Recruitment of wild fry was the lowest in the last 14 years. Wild fry contributed 41 fish/hectare in 1991 compared to 79 fish/hectare in 1990. The contribution of wild fry in 1991 was 32% lower than 1990 which was 20% lower than 1989 (99 fish/hectare) and was 50% lower than 1988 (158 fish/hectare). Although adult escapements have been low, reducing PED, wild fry survival has also been low. Wild fry survival was 1.3% in 1991, 1.5% in 1990, 2.2% in 1989, and 3.3%

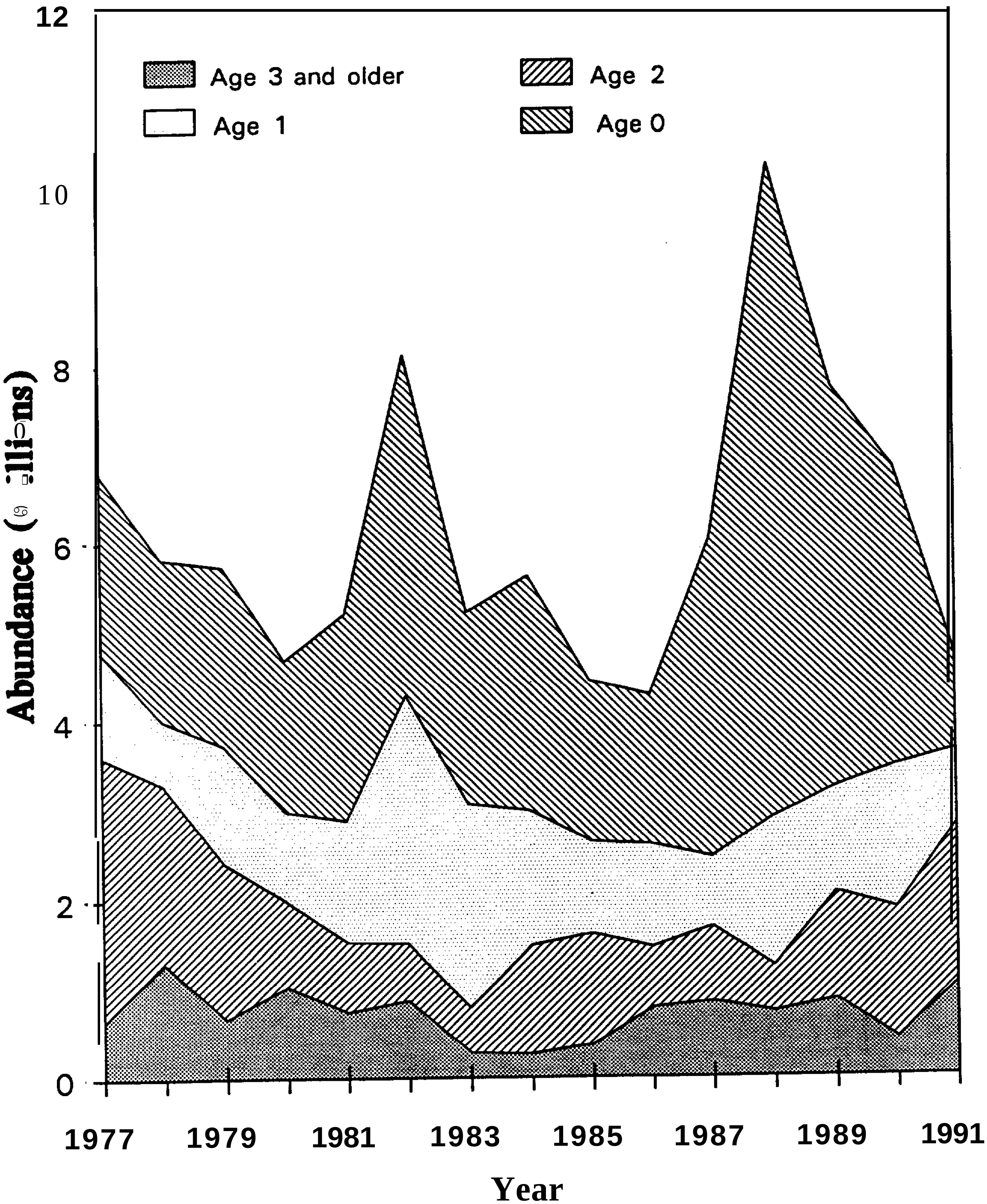

Figure 18. Total estimated abundance of four kokanee age groups in Lake Pend Oreille, Idaho, 1977 through 1991.

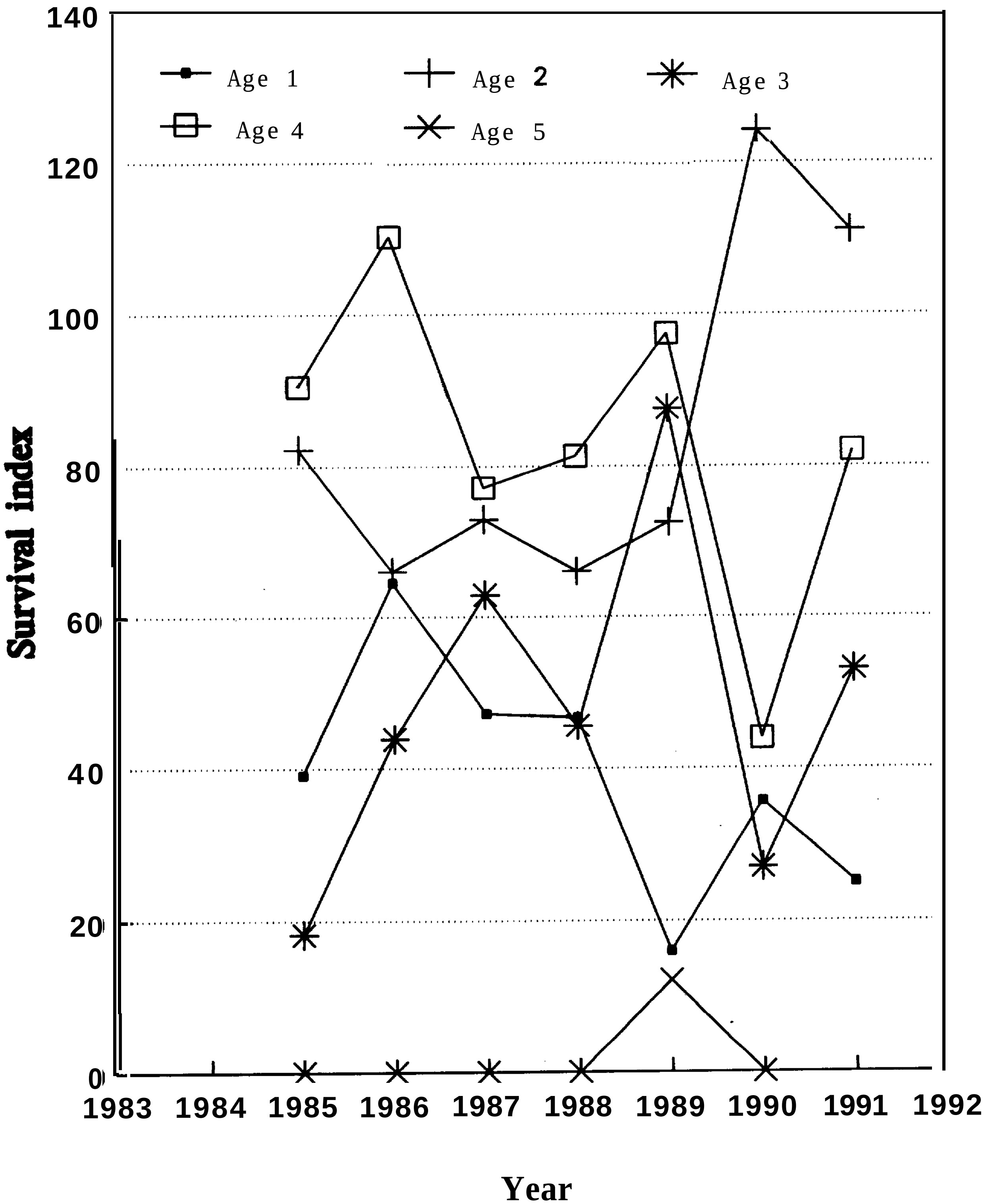

Figure 19. Survival index of five age groups of kokanee from 1985 through 1991, catches by trawling, Lake Pend Oreille, Idaho.

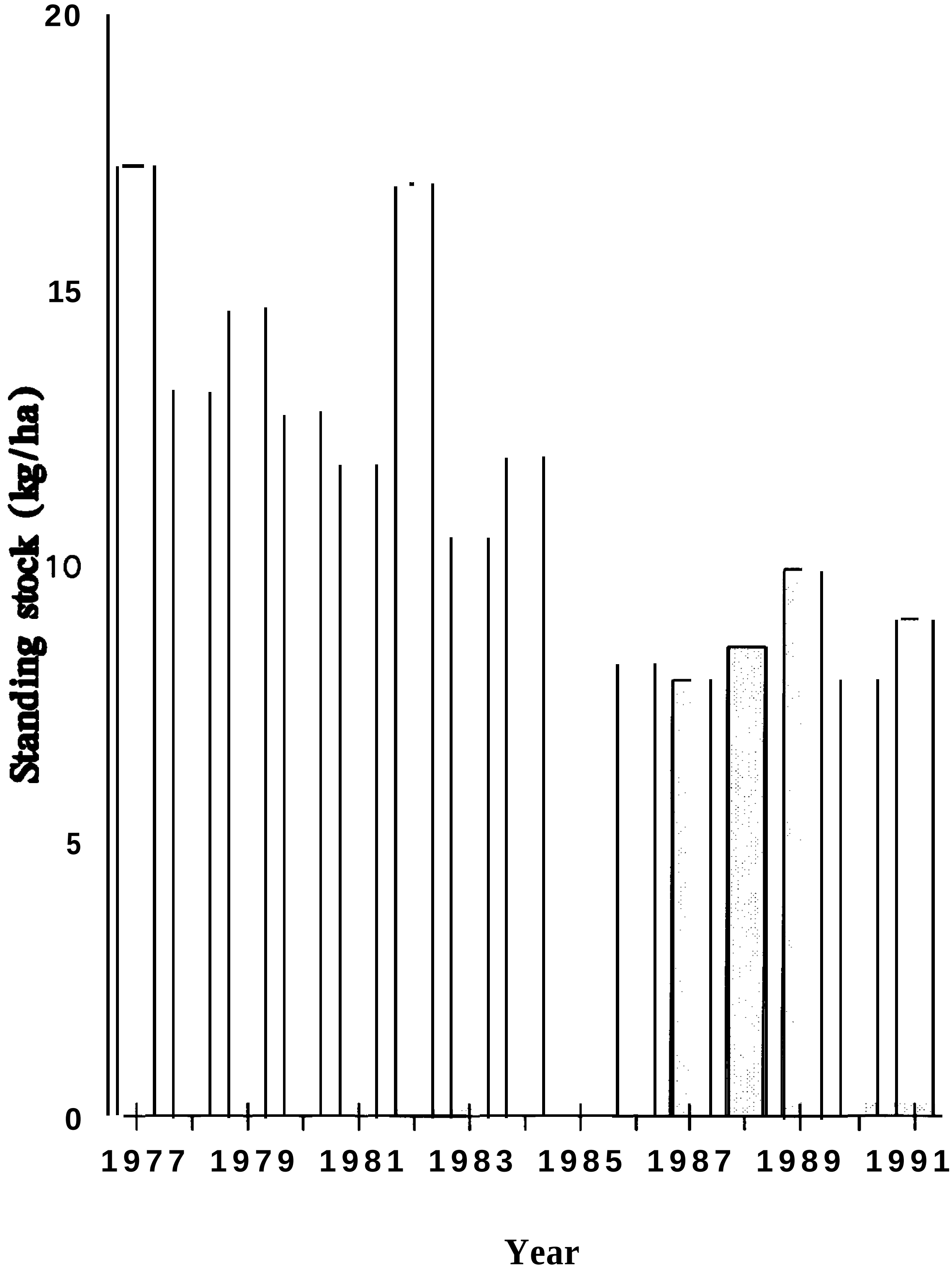

Figure 20. Standing stocks of kokanee in Lake Pend Oreille, Idaho, estimates from mid-water trawl 1977-1991.

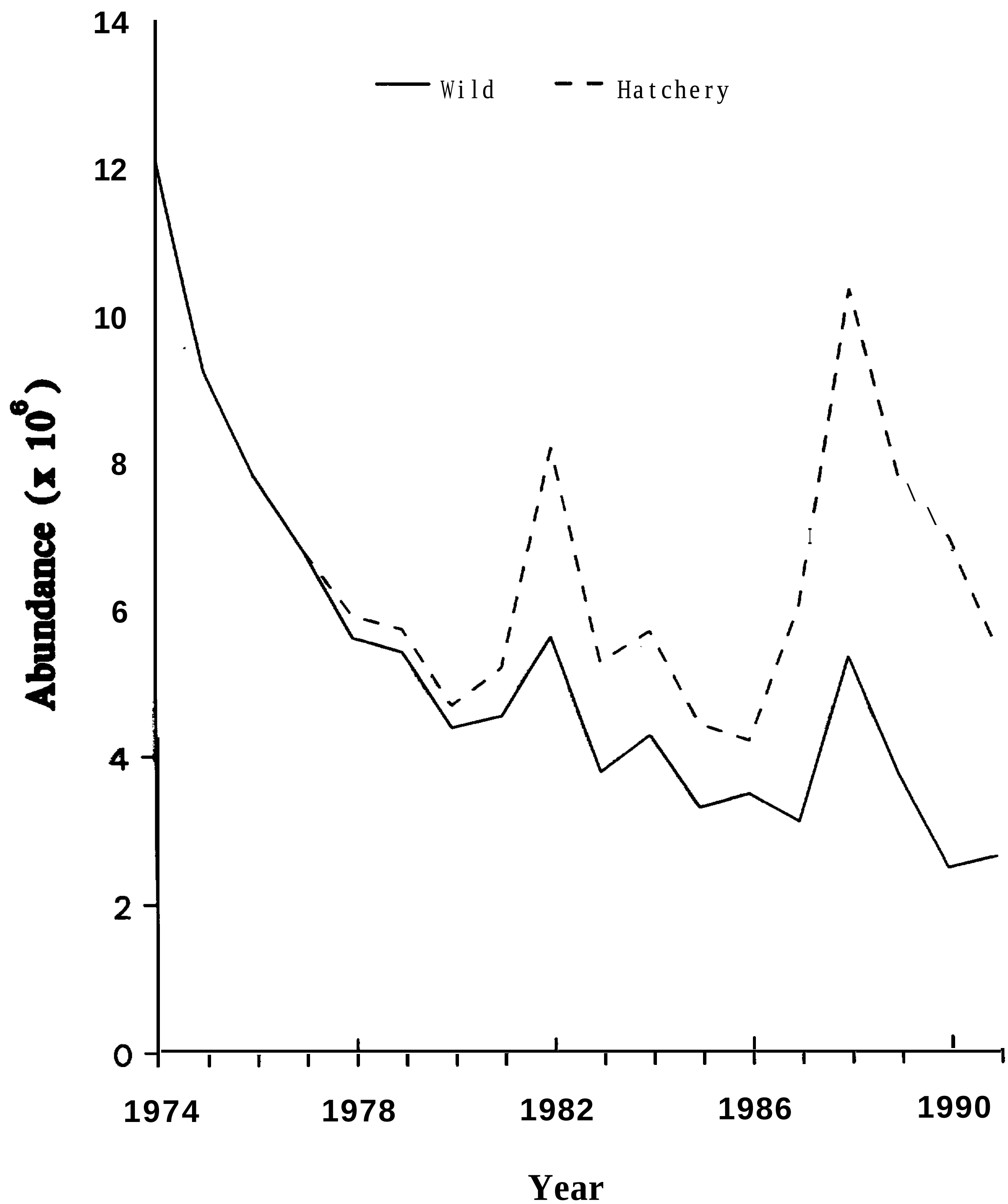

Figure 21. Relative hatchery contribution to total estimated kokanee abundance in Lake Pend Oreille, Idaho, 1974 through 1991.

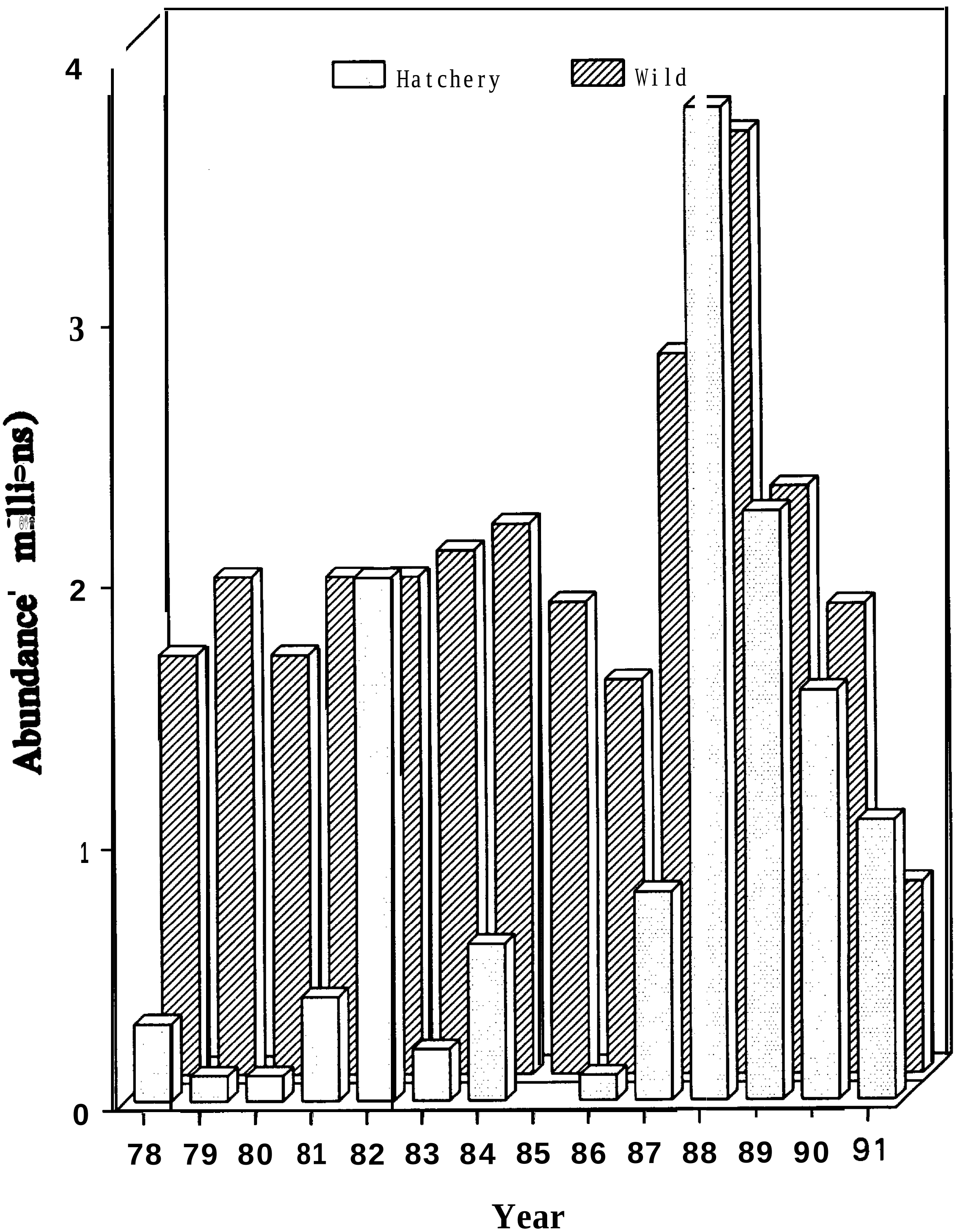

Figure 22. Total abundance of wild and hatchery-reared kokanee fry in Lake Pend Oreille, Idaho, during late summer 1978 through 1991. Hatchery contribution in 1985 was not estimated.

in 1988. Wild fry survival, as well as survival of hatchery fry, is closely linked to thermal development. June of 1991 was the coldest of recent record and zooplankton densities were the lowest of this study (12.1 organisms\L) while the opposite **was** true of 1988 with the earliest thermal development (June) and the highest zooplankton densities (21.7 organisms\L). Within the last five years only 1988 provided **a** hospitable rearing environment for wild as well as hatchery fry. But this natural phenomena is working in concert with man induced factors while fry **are** in the redd e.g. water level fluctuations, shoreline sedimentation, and stream habitat deterioration.

The fishery cannot be maintained by hatchery fry alone. Adult escapement in 1990 **was** 371,600 fish which was also the lowest since this study began while it was 469,000 fish in 1989 (Hoelscher et al. 1990), 574,000 in 1988 (Bowles et **al.** 1987) and 540,000 in 1991. The substantial return in 1991 was thought to be due to the strong 1987 year class released as fry in 1988. The continued decline in the wild stock reduces future egg take potential, reduces the wild component in the fishery, and puts a greater dependence by predators on hatchery fish as **prey**.

Survival of hatchery kokanee fry in 1995 was 20.7%, below the goal of 30% set for restoration of kokanee in Lake Pend Oreille (Eowies et al. 1988). Survival of kokanee fry in 1988 *was* 28.4% (weighted mean), nearly the management goal of 30% (Figure 23). Survival in other years was similar to 1991 at 19.8% and 20% for 1989 and 1990, respectively. At this point survival of about 20% may be the normal for most years.

Variation in survival from year to year would be expected, but 1988 was an unusual year in comparison to other recent years of study. For example it had the second driest July of this study (NOAA 1990, unpublished data) and thermal stratification of Lake Pend Oreille wad the most rapid. In addition these environmental factors led to the most rapid development of zooplankton densities within this study (Paragamian et al. 1991).

Release Strategies

Two release strategies were tested in 1991 to replicate previous years work: an early Clark Fork River release and a Sullivan Springs release (Figure 24).

The kokanee fry release at Sullivan Springs achieved a survival of 23% which was not significantly different ($P > 0.05$) from the early Clark Fork River release. Total survival for these two groups was also similar to the previous year, perhaps because zooplankton densities ($P > 0.05$) and environmental variables **were** similar.

The success of the early Clark Fork River release is largely dependent on river flows of at least 1,000 m^3/s (Bowles et al. 1989) and food availability in Lake Pend Oreille. The better survival in 1988 (Figure 24) was thought to be due to enhancement by rapid transportation of fry downstream to the lake past riverine predators, primarily the northern squawfish <u>Ptychocheilus oregonensis</u> an effective salmon smolt predator (Brett and McConnell 1950, Foerster 1968). Electrofishing of the river delta during the 1990 release indicated few adult northern squawfish were present. This predator was probably upstream spawning as in 1988 (Bowles et al. 1989). Flow of the Clark Fork River in 1991 was about 1,840 m^3/s nearly twice the volume thought to be needed for good survival, but greater flows did not produce higher survival. The additional three years of stocking analysis indicated flows greater than 1,000 m^3/s resulted in reduced survival (Figure 25). One possible reason for this observation may be due to the shape of Lake Pend Oreille and the flows of the Clark Fork River. fiigh flows of cold water may entrain many young kokanee and carry them through to the Pend Oreille River as well as older fish. Sampling of fish populations in the Pend

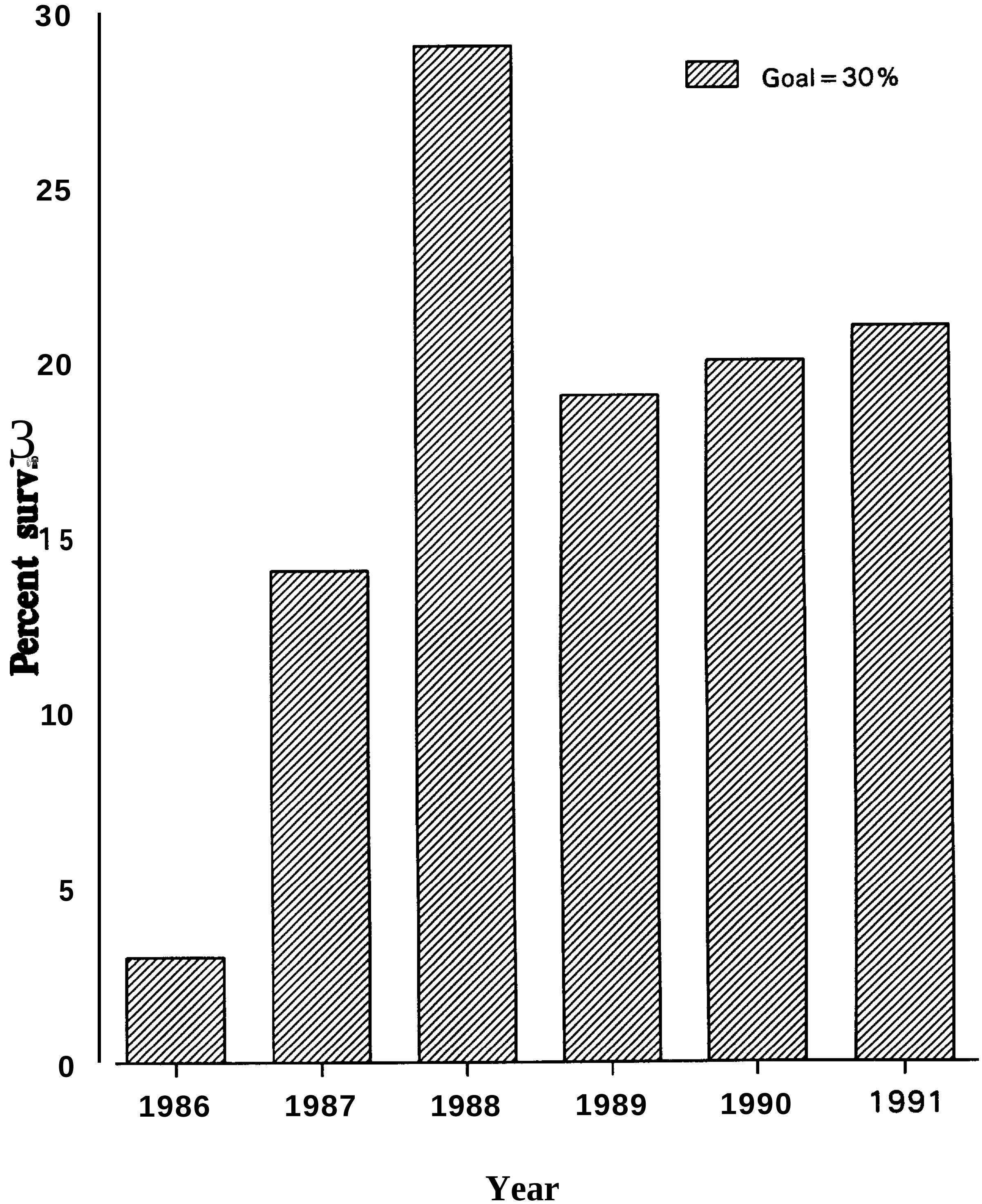

Figure 23. Estimated survival of kokanee fry during their first summer in Lake Pend Oreille, Idaho, following release from Cabinet Gorge Hatchery, and survival goal established for the kokanee restoration program 1986 through 1991.

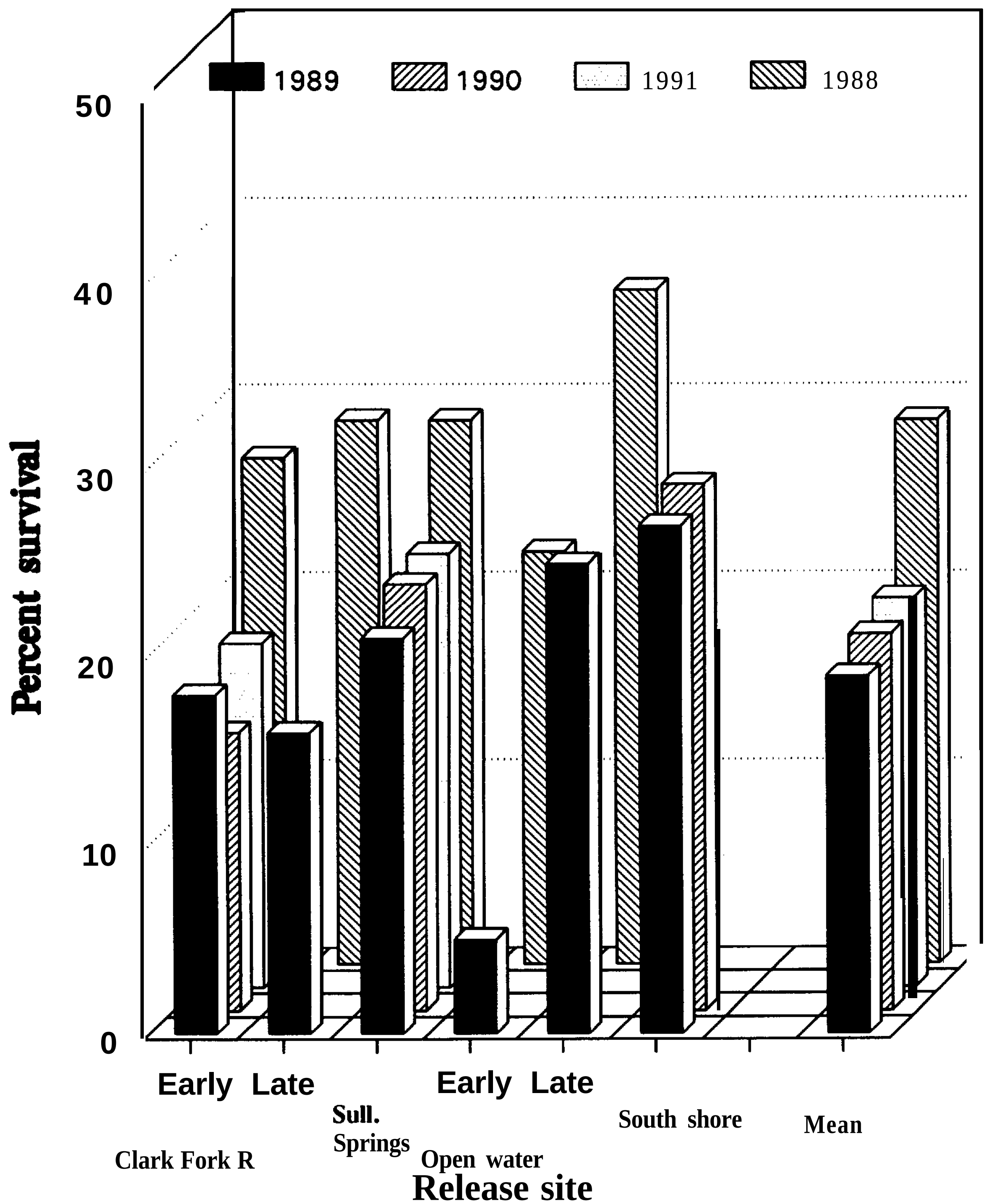

Figure 24. Estimated survival of hatchery fry during their first summer in Lake Pend Oreille, Idaho, compared among six release strategies and years 1988 through 1991.

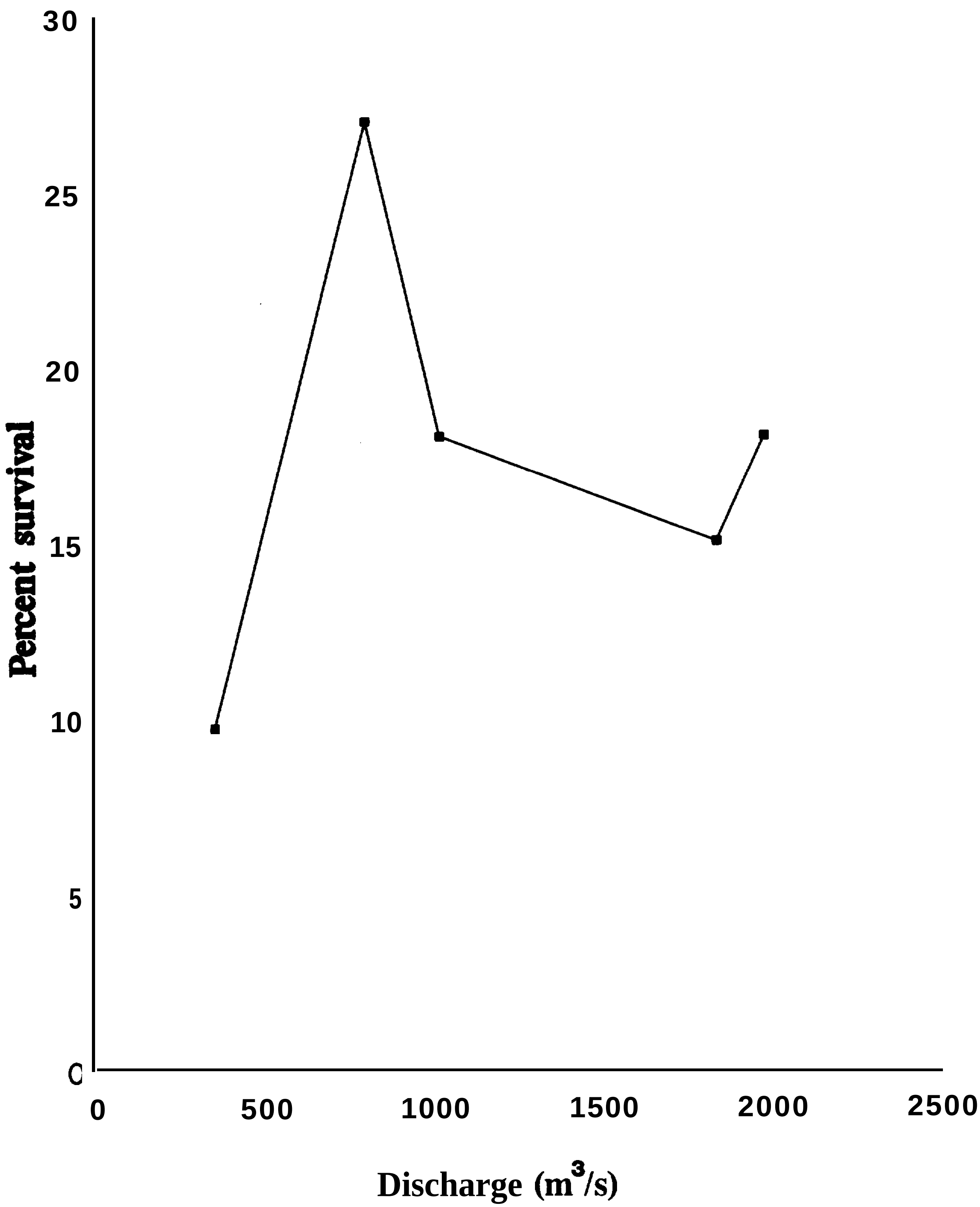

Figure 25. Survival (%) of kokanee fry released early (June) in the Clark Fork River and river low (m^3/s) 1988-91.

Oreille River with electrofishing, beach seine, and experimental gill nets, June-October, documented frequent catches of kokanee 75-266 mm (J. Dupont, personal communication). Most fish ranged from 115-135 mm were captured in June, and the net gear was biased toward capture of fish larger than 75 mm. The total loss through the Albeni Falls project is unknown, but kokanee found in fish samples below the dam made up a small portion of the total catch (Bennett and Liter 1991).

Stocking strategies were restricted in 1990 and 1991 because of the low number of eggs taken in 1989 and 1990. Experimental stockings in 1992 could possibly be increased to three. If hatchery survival is similar to previous years, there will be about 5.5 million kokanee for stocking in 1992. Sullivan Springs could receive 3.5 million fry, the Clark Fork release, an additional 1.0 million fry and the remaining 1.0 million should go into either a south shoreline release or an embayment.

A seventh release strategy utilizing an embayment of Lake Fend Oreille was recommended in 1991. 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 productive bays. They found food production and near shore cover was higher in such locations. Lake Pend Oreille does have several bays that are nutrient rich and would be very suitable for release of kokanee (Camp, Idlewild, and Garfield Bays). The South Shore release is quite similar to embayment habitat and the good survival of kokanee fry may be due to the same conditions as Jaemicke's (1987) findings.

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.

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 (Faragamian et al. in progress). Analysis of covariance was used to test the reliability of counting daily growth rings in kokanee otoliths that in turn were used to identify individual release strategies. Significant correlation coefficients were found between daily otolith rings and number of days out for all three years of study. This indicated the daily otolith ring counting method was a reliable technique to determine release dates and identify release strategies. Up to six different release strategies were tested in this study. Between 47 and 71% of the daily ring counts were exactly the same as the number of days from release to capture. We recommend continued use of the daily ring count method and a difference in at least 5 d be used between release strategies.

Analysis of otoliths of age 1 kokanee was tried for the second time within this study, A sample of 22 otoliths of age 1 kokanee was processed following the same procedure as younger fish. The date-of-release mark could not be distinguished. The method used may be valid, but further refinement is necessary. Temperature treatment of hatchery reared kokanee at the eyed stage or older may be a productive method (Volk et al. 1990). The technique involves a passive mark with radical temperature changes in the fry environment and creates a dark band on the otolith. The banding can be coded and is easily identifiable in salmonids up to age 5.

Fin Clips

Fin clipped adult kokanee were recovered for the first time during this study. Recaptures of fin clipped fish at their release site provides the first evidence of imprinting while marked spawners caught elsewhere indicated straying. An estimated 158 adipose clipped age 3 kokanee returned to Sullivan Springs during the 1991 spawn run. These fish were released as fry at Sullivan Springs in 1988. This comprised 0.4% of the original 40,000 fish released with the marks. Hatchery fish contributed an estimated 56% of the age 3 kokanee escapement at Sullivan Springs in 1991. The return of the 1988 release fish at age 4 will provide further information to determine the success of imprinting.

The failure of a spawning run of kokanee up the Clark Fork River may be attributed to straying. Evidence of straying was demonstrated by recaptures of four early Clark Fork River releases and one late Clark Fork River kokanee, all age 3, from Sullivan Springs. In addition, several adipose fin clipped fish were recovered at the Cabinet Gorge Hatchery ladder. Preliminary information indicated the greatest straying occurred with the early Clark Fork River release since none were recovered at the Cabinet Gorge Hatchery. Evidence of straying was not found in a sample of 152 kokanee captured by electrofishing at Hope during the spawning season (no fin clipped fish were found).

Fin clipping of a subsample of 120,000 hatchery fry will also continue in 1992. The first cohort of fin clipped hatchery fry is expected to return as age 4 adult kokanee to egg take stations in 1992 and the second cohort as age 3. Thus, it will be important to age all recaptured fish with fin clips to distinguish year class.

Kokanee Forage and Cladoceran and Shrimp Interaction

Total zooplankton densities in 1991 were the lowest in seven years of study (12.1 organisms/L). Cladoceran densities were extremely low and did not improve until August but were still low (about 2.0 organisms/L) (Figure 26). Mean density of cladocerans have ranged from a high of 1.7 organisms/L in 1987 to the low of 0.6 organisms/L in 1991. Stross (1954) found an average cladoceran density of 6.5 organisms/L and samples as high as 16 organisms/L in 1953, prior to shrimp introduction. Kokanee fry can catch cladocerans much more easily than the faster copepods and they are important food items (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. There is no doubt cladocerans are important food items to kokanee fry, but we were unable to find a statistical relationship ($P = 0.34$) between their abundance and wild fry survival, although graphically there are some positive similarities (Figure 26). Nor was there one when we compared shrimp and wild fry survival ($P = 0.75$) (Figure 26). The role of thermal stratification, precipitation, water level management, and kokanee fry survival needs more detailed study.

The predator/prey interaction of shrimp and cladocerans in Lake Pend Oreille is well documented (Rieman and Falter 1981, Bowles et al. 1987). Shrimp are important predators of cladocerans and have reduced the densities in Lake Pend Oreille (Bowers and Vanderpoeq 1982) and have eliminated cladocerans in some lakes; lakes Tahoe (Goldman et al. 1979), Donner and Fallen, California (Morgan et al. 1981), and Grand Lake, Colorado (Nelson 1981). Shrimp may also be responsible for the elimination of Leptadora. They have yet to be seen in this study but were present in samples collected in 1974 and 1975 (Rieman, unpublished records) and previous years. Shrimp are most effective predators prior to thermal stratification (Rieman and Faiter 1981, Bowles et al. 1988) after which the warmer water (>14°-18°C) segregates them from the zooplankton (Beeton 1960, Nero and Davies 1982). The affect of shrimp on cladoceran populations must have

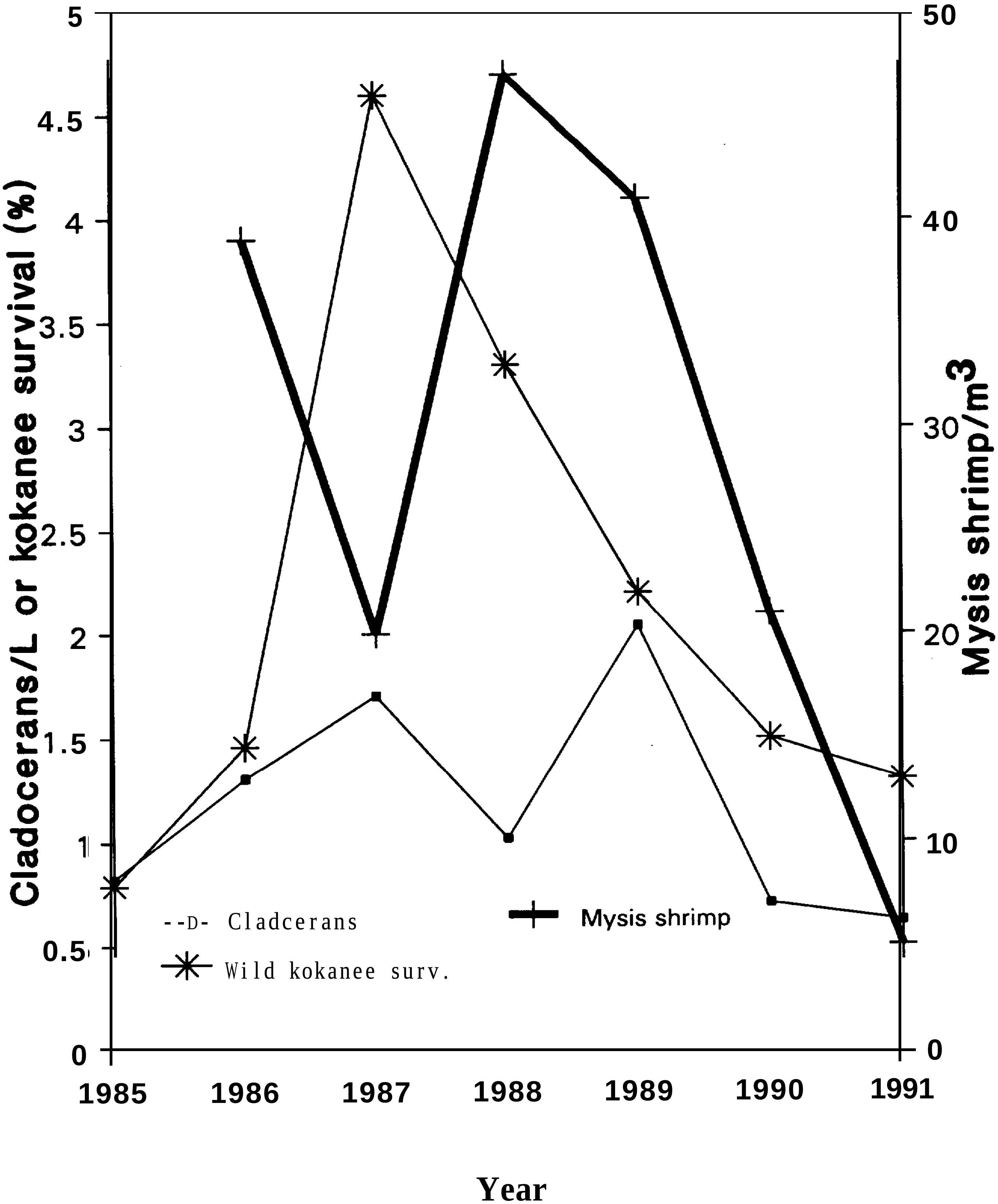

Figure 26. Density of cladcerans (organisms/L), mysis shrimp (organisms/m^3), and survival (X) of wild kokanee, 1985-91, Lake Pend Oreille, Idaho.

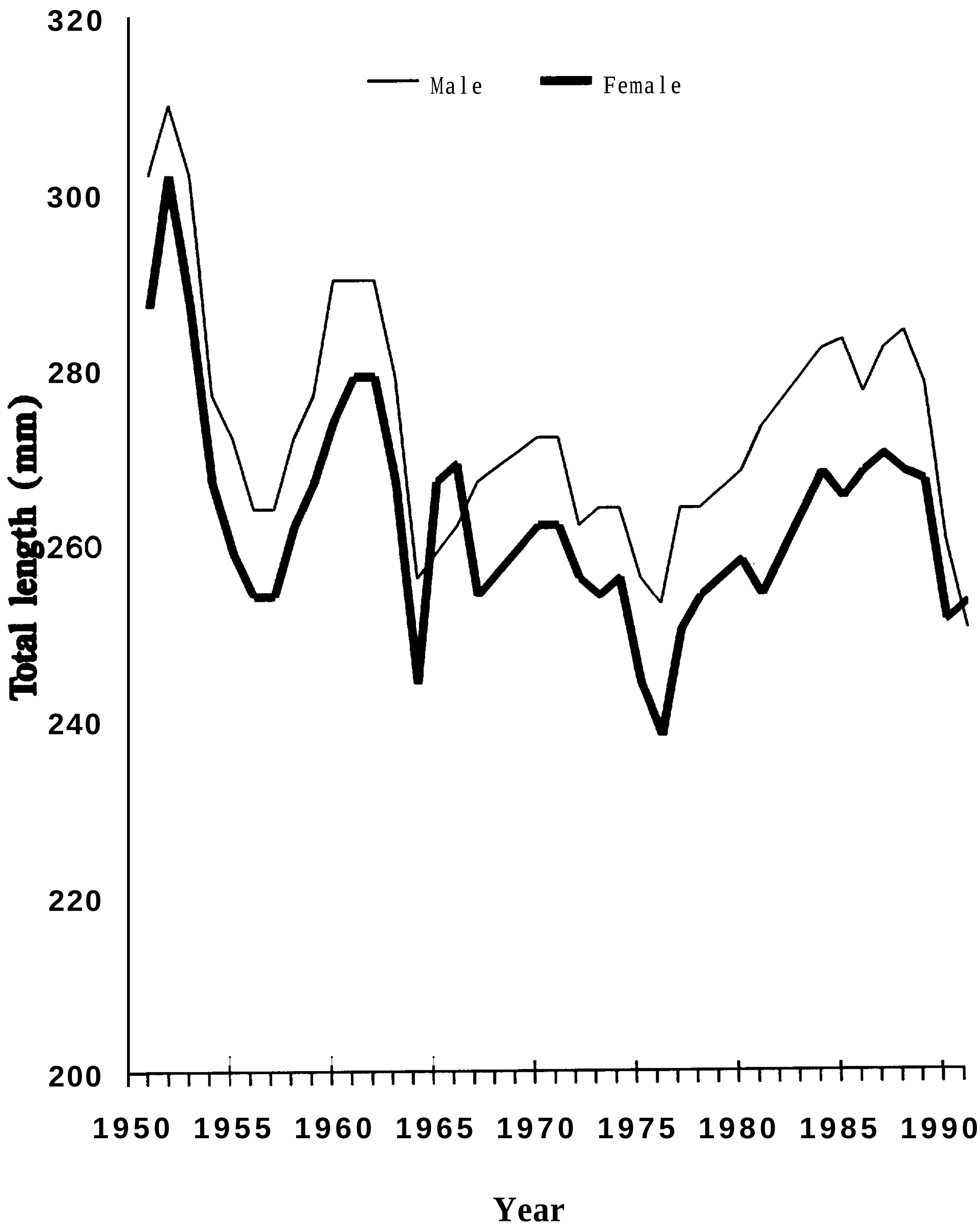

Figure 27. Mean total length (mm) of male and female kokanee spawners from Lake Pend Oreille, Idaho.

occurred soon after establishment in the late 70s. Statistical comparisons of mean shrimp densities (Figure 26) and that of cladocerans (Figure 26) and **copepods** has shown no further evidence of any impacts (**P** = 0.82 and **P** = 0.46, respectively). The persistence of cladocerans in some lakes is explained by the thermal refuge condition previously noted (Threlkeld et al. 1980 and Morgan et al. 1981). The same was true for Lake Granby, Colorado (Martinez and Bergersen **1991),** where several species of cladocerans persisted, but a species that occupied the hypolimnetic layer of the lake disappeared. Kokanee in Lake Granby were found to grow, survive, and return to the fishery at the same rates that they did before the introduction of shrimp (Martinez and Bergersen 1991).

Spawning

The kokanee spawning escapement in 1991 was the second highest since 1986, the first year of this investigation. The highest escapement was 574,500 adult kokanee in 1989 while it was 540,080 in 1991. The increase in the spawning stock was due to several factors: 1) two good year classes of kokanee (1987 and 1988) and 2) improved survival of fish to age 3 and 4 in 1991. The strong 1987 year class was due to the second highest contribution of wild fish in the last decade while the 1988 year class was comprised of the highest contribution of wild and hatchery fish coupled with the highest fry survival rate (29%) during this study.

Earlier maturity of kokanee in Lake Pend Oreille remains a factor of concern as hatchery fish become more important in the spawning escapement and the egg take operation (Table 5 and 6). This concern evolves around two important points; 1) a substantial portion of the kokanee fishery maturing at age 3 or even less desirable age 2 may do so at a size that is not preferred to anglers **(<200 mm).** This never contributes to the fishery **(Rieman** and Meyers 1990); **2)** younger kokanee are less fecund. At Lake Pend Oreille age 4 kokanee comprised about 77% of the spawning escapement from 1987 through 1989 (Bowles et al. 1988, Bowles et al. 1989, and Hoelscher et al. 1990). However, this figure changed in 1990 and 1995 with the contribution **of** mature age 4 fish at 58% (Paragamian et al. 1991) and 622, respectively. Mean lengths of adult kokanee has varied from over 300 mm in 1951 to as small as 237 mm for females in 1976 (Figure 27).

The ratio of kokanee stocked:adult returns as spawners to Sullivan Springs has apparently decreased since the mid 1970s (Appendix E). From 1976 through 1979 the proportion of stocked fry-to-adult returns averaged **11%,** dropped to 4.6% in 1980, and thereafter, averaged 2.4%. The exact reason for this decline is unknown, but it could be due to reduced survival of wild or stocked kokanee, differences in imprinting of kokanee because of size of fry stocked, or an unknown factor. Similar declines in adults returning to hatcheries was documented for nearly all hatcheries rearing Pacific salmon (Hilbom 1992). It would appear that this trend is common among hatcheries supplementing wild populations. Based on this trend, Hilborn questioned the validity of hatchery programs in general.

The Fishery

The kokanee harvest in Lake Pend Oreille is two-thirds lower than the goal **of** 750,000. An estimated 227,000 kokanee were Caught during the **1991 fishing** season (Figure 28). The lower than expected harvest was related to the failure to improve the kokanee population, which included poor egg-to-fry survival of wild kokanee, low fry stocking survival rates (30% less than goal), low egg takes, and low stocking rates. However, substantially more kokanee were caught in 1991 (227,000) than 1985 when the harvest was 72,000 fish (Bowles et al. 1986). The harvest of kokanee in 1991 is similar to that of 1975. The Cabinet Gorge Hatchery kokanee program has improved the fishery to that of the mid-70s

Table 5. Percent mature kokanee by age, trawl samples 1985 through 1991, Lake Pend Oreille, Idaho.

Year	Percent Mature by Age				
	1	2	3	4	5
1985	0	4	85[a]		
1986	0	0	41[a]		
1987	0	0	39	97	
1988	0	0	29	97	
1989	0	0	14	98	100
1990	0	0	52	100	
1991	0	0	35	100	

[a]Age 3 and 4 combined.

KOKCAB.TAB

Table 6. Age structure of kokanee spawner escapement at Sullivan Springs, 1985 through 1991.

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

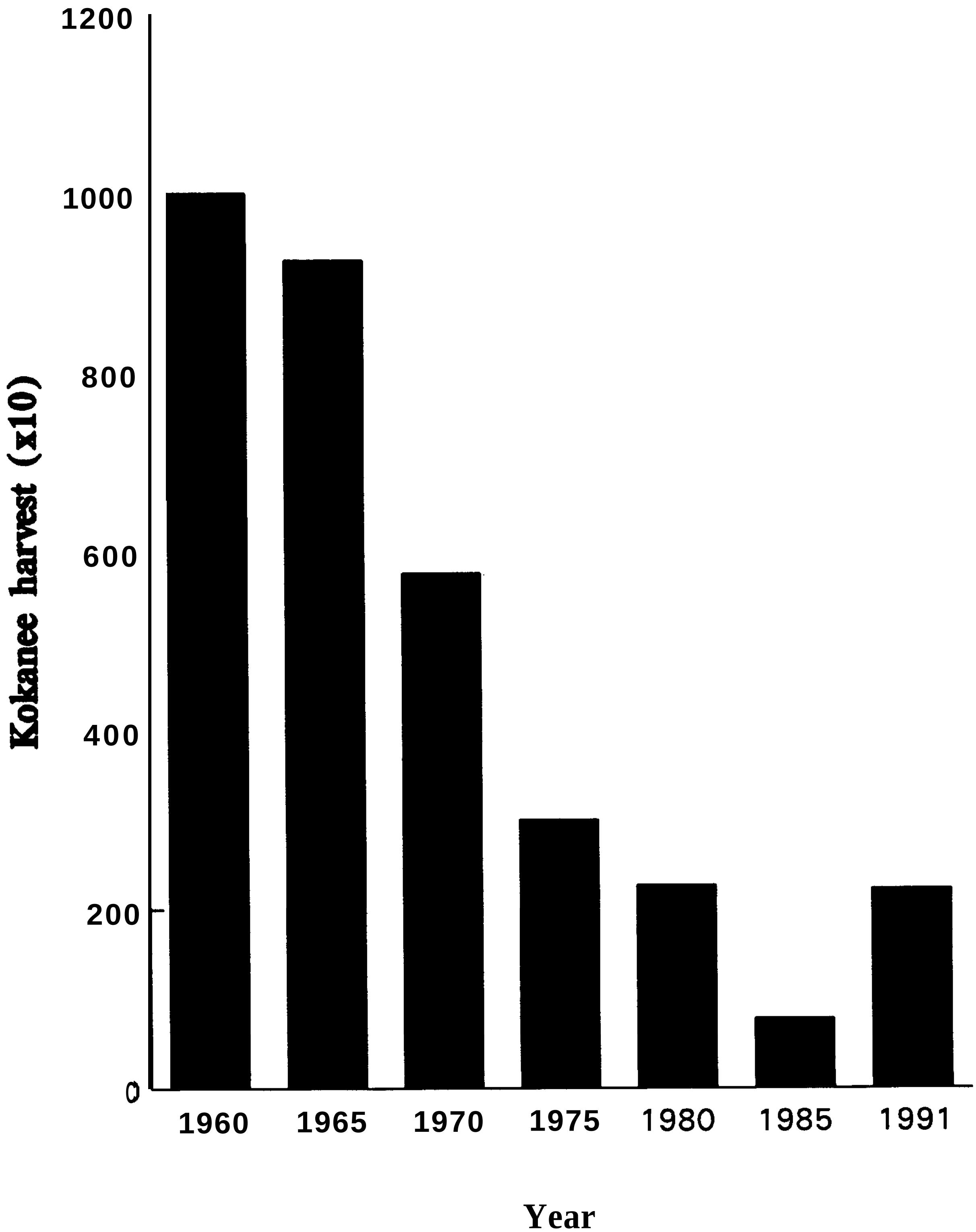

Figure 28. Mean (3-5 years) kokanee harvest in hundreds of thousands from 1960-80; 1985 and 1991 are point estimates.

(Figure 28), but the fishery in the next 3 years (1992-1995) may decline from the 1991 level due to low egg takes and resultant stocking.

Angler catch success of 1.45 kokanee/h during 1991 was better than the 1985 catch rate of 1.03 fish/h (Bowles et al. 1987). Rieman and Meyers (1990) calculated a positive curvalinear relationship between catch effort and age 3 fish/hectare. However, optimum fishing is reached at about 1.4 kokanee/h when kokanee density approaches 50 fish/hectare. At higher densities, after that point, kokanee fishing success remains about the same. Kokanee densities as low as 10 fish/hectare can still provide a fishing success as high as 0.5 kokanee/h. Data from Lake Pend Oreille closely fit Reiman and Myers (1990) curve (1.45 fish/h catch rate and 46 kokanee/hectare age 3 and older). Based on this, it is likely kokanee catch success at Lake Pend Oreille will decline only slightly despite substantial declines in the population.

Mean total length of kokanee in the catch has changed little in the past 11 years. Mean length of kokanee in 1980 was 256 mm (Ellis and Bowler 1980), 250 mm in 1985 (Bowles et al. 1986), 239 mm in 1990 (Paragamian et al. 1991), and 242 mm in 1991. The management goal is 254 mm.

Catch success of large Gerrard rainbow trout in 1991 remains better than it was in 1985, prior to imposition of a 610 mm minimum length limit. Catch success for rainbow over 610 mm in 1985 was 232 h/fish but improved to 84 h/fish in 1990 and was 78 h/fish in 1991. Imposition of the length limit and a 37% voluntary release rate for large fish in 1990 (Paragamian et al. 1991) and 27% in 1991 accounted for the improved fishery. The improved fishing success for large rainbow trout in 1990 may have stimulated greater fishing effort in 1991. An estimated 460,000 h of fishing effort was expended in 1991 compared to about 178,000 in 1985 (Bowles et al. 1987).

Total harvest of rainbow trout has decreased the last six years with the more restrictive regulation (Figure 29). The total estimated harvest was about 6,100 rainbow trout in 1985 with a harvest of 3,456 that were over 432 mm. The total harvest in 1991 with a 610 mm length limit was about 2,157 rainbow trout, and the peak was in 1979 when approximately 10,000 fish were harvested (Bowles et al. 1986).

Harvest of Gerrard rainbow trout by weight was 31% higher in 1991 than 1985 despite the fact numerical harvest was two-thirds lower. Total angler harvest by weight in 1985 was about 9,000 kg (based on unpublished weight-length relationship and mean lengths of rainbow trout in the harvest in 1985 [Bowles et al. 19861) while it was nearly 13,000 kg in 1991. The reason for the improved harvest by weight was due to the increase in mean weight of Gerrard rainbow trout in the harvest, a mean of 1.47 kg in 1985 compared to a mean of 5.7 kg in 1991.

The harvest of bull trout has about doubled since 1985 with a doubling of effort. About 915 bull trout were taken by anglers in 1985 while 1,723 were taken in 1991 (Figure 30). The catch rate for bull trout in 1985 was 12.5 h/fish, 7.6 h/fish in 1990, and 7 h/fish in 1991. From 1985 to 1991 the effort expended toward bull trout doubled with 5,275 h compared to 11,960 h, respectively.

The status of bull trout has declined since the 50s (Figure 30), and management measures to reduce the harvest should improve the stock density. About 50% of the harvest of bull trout in 1991 would have been eliminated with 510 mm length limit. This minimum length limit goes into effect in 1992.

The harvest of lake trout and cutthroat trout has improved since 1985. Lake trout were not reported in the creel of 1985, but 25 were reported in 1990 (Paragamian 1991) and 43 were observed by creel clerks in 1991 (an expanded harvest estimate was not made for lake trout in 1991). Many more lake trout not recorded in the creel survey were reported by anglers targeting this species.

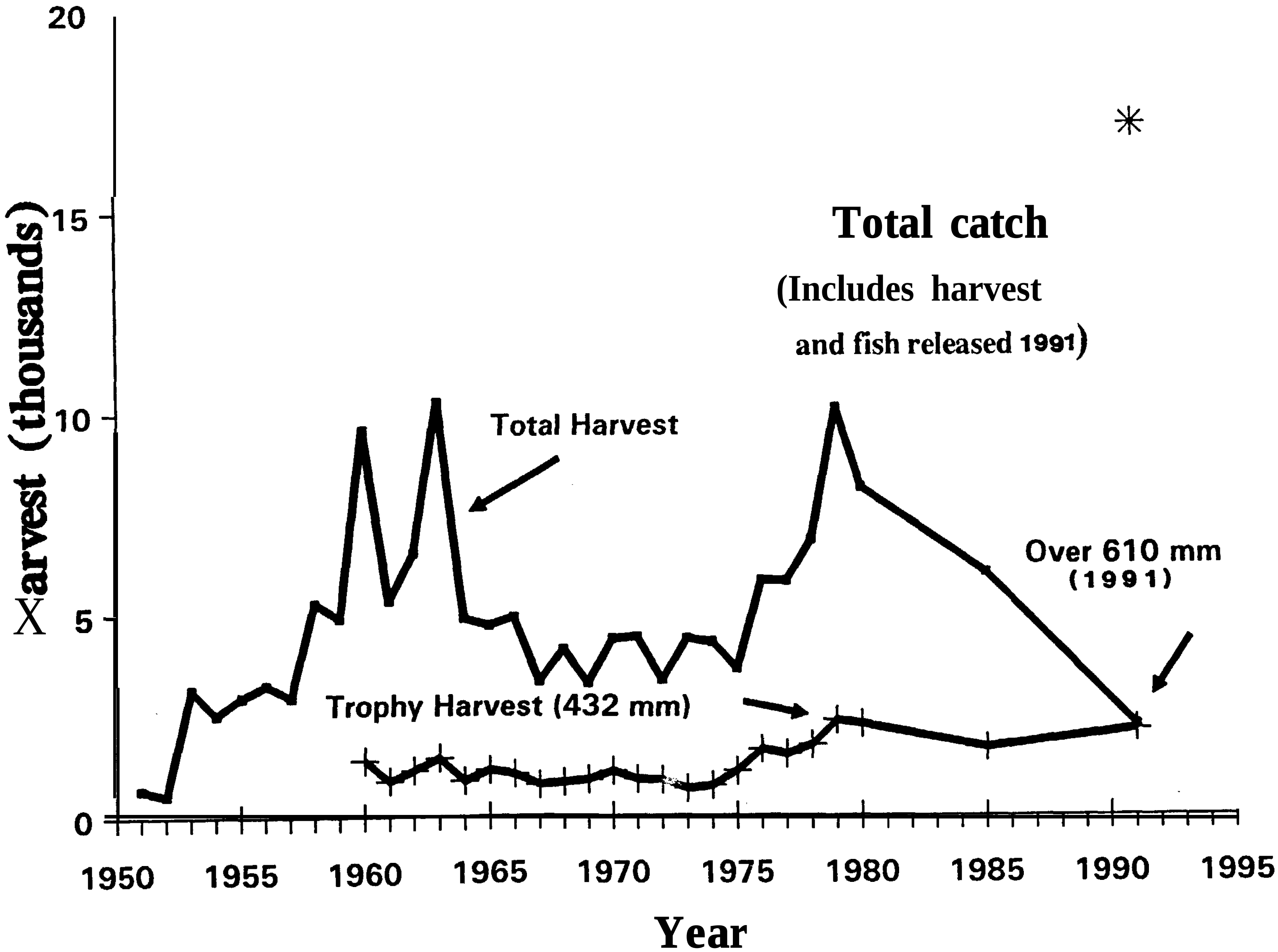

Figure 29. Numerical harvest of rainbow trout from 1951 through 1991; 1980, 1985, and 1991 are point estimates, Lake Pend Oreille, Idaho.

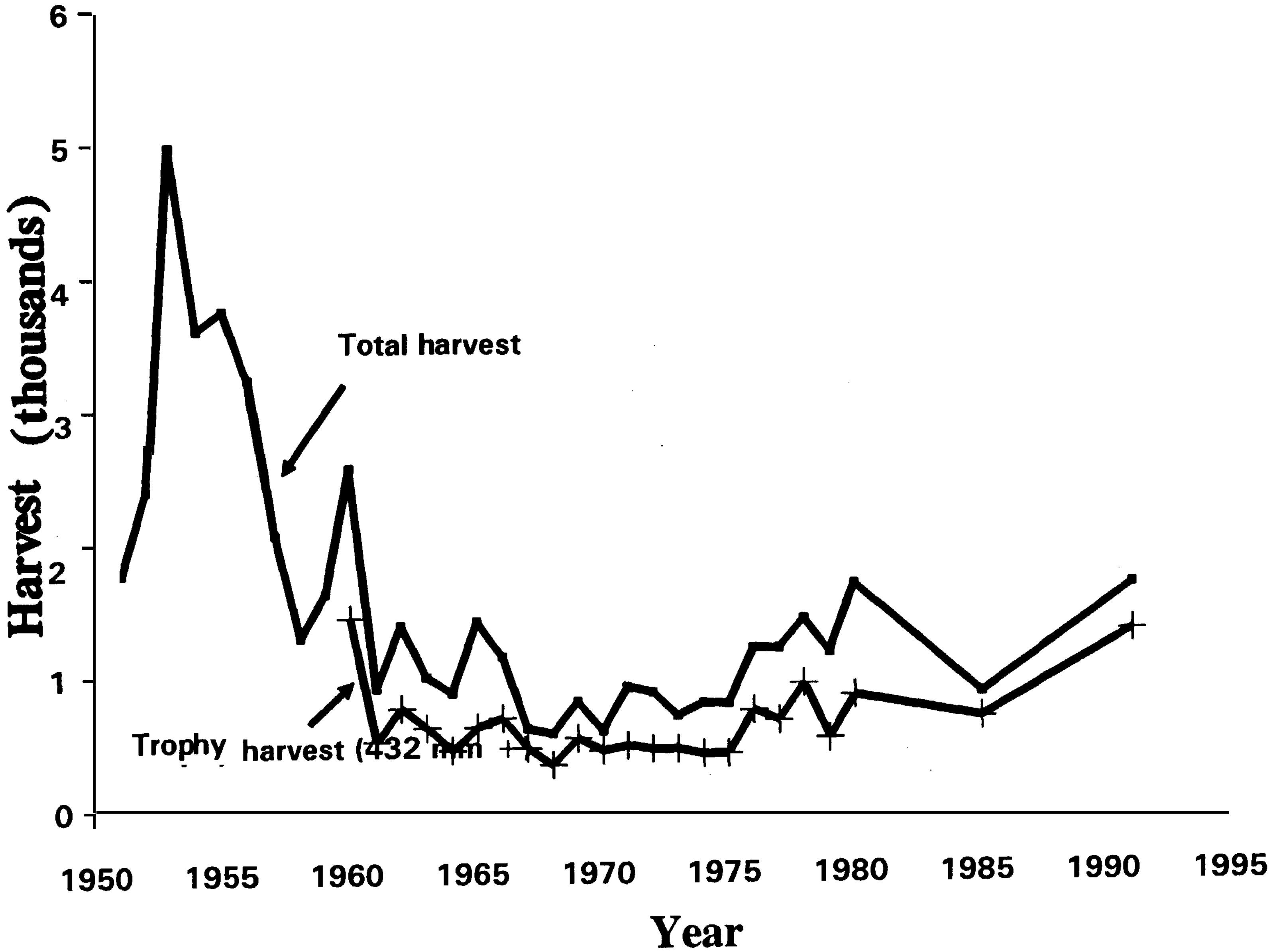

Figure 30 Harvest of bull trout from 1951 through 1991; 1980, 1985, and 1991 are point estimates. Lake Pend Oreille, Idaho.

The harvest of cutthroat trout from Lake Pend Oreille took a dramatic decline from a harvest of over 8,000 fish in the 1950s to about 800 fish in 1967 (Bowles et al. 1987). The degradation of spawning tributaries to poor land management is thought to be the most important factor to the decline in cutthroat trout (Rieman and Myers 1986). Since the late 1960s, the catch of fish has been stable with a catch of 664 fish in 1985 and about 760 cutthroat trout in 1991. It is not known at this time what role the net pen program may have.

An expanded estimate of 56 net pen cutthroat trout (of 138,204 that were released in 1991) were caught in 1991. Many of the fish released in 1990 and 1991 were thought to still be too small to be vulnerable to angling techniques used for kokanee and trout species, but these fish may play a role in providing a shoreline fishery in the future.

RECOMMENDATIONS

1. A minimum of 1.0 million kokanee fry should be released in the Clark Fork River to maintain potential for brood stock return. 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. At least 3.5 million fry should be released into Sullivan Springs Creek each year to maintain an egg supply. 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 1.0 million fry at Garfield Bay during July 1992 to test if the richer environment will improve survival of fry.

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 (260,000 fish) released in Clark Fork River and Sullivan Springs Creek should be fin-clipped to evaluate adult return rates. Small (40 mm) vs. large fry (50 mm) imprinting and early maturation at Sullivan Springs should be continued by differentially fin clipping 30,000 fish from each group.

5. Average fry length at the time of release should be 50 ± 2 mm for production fish with the exception of 30,000 small fry (40 mm) for release at Sullivan Springs. These fish will be used to test early maturation and will receive an RV fin clip.

6. Continue to evaluate the reliability of otoliths for discerning the date-of-release in age 1 and older kokanee. In addition, otoliths of fry should have a passive temperature code according to the procedure of Volk et al. (1990).

7. Evaluation of the predator/prey interaction and bioenergetics of Gerrard rainbow trout should continue. This can be facilitated with a cooperative angler diary program to maintain a record of Gerrard rainbow trout and hatchery/wild origin. This could provide direction for the predator stocking program.

ACKNOWLEDGEMENTS

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 of great help throughout the season and were responsible for all fry marking activities.

WWP provided the maximum possible flows during fry releases into the Clark Fork River. Fred Holm from BPA provided technical and administrative advice throughout the year. Virgil Moore and Melo Maiolie reviewed the draft report.

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APPENDICES

Appendix A. Kokanee age class density (fish/hectare) in Lake Pend Oreille during late summer 1991 A 90% error bound is listed with each estimate.

Class	Origin	Lake section	2	3	4	5	6	Lake average
0+	Hatchery (total	.6 (5 5	20 (7 5	47 7 37 8)	96.5 45 8	43. (10 7	46.9 (4.2	46.5 (10.9)
	Clark Fork River Early summer[a]	0 0 (0.0)	7.8 (2.9)	20.3 (13.9)	46.0 (21.9)	21.5 (5.3)	23.4 (7.0)	21.1 (4.9)
	Sullivan Springs[b]	11.6 (5.5)	12.3 (4.5)	32.9 (23.1)	50.5 (23.9)	21.5 (5.3)	23.4 (7.0)	26.2 (6.1)
	Wild	58.1 (27.8)	68.1 (25.0)	54.6 (36.3)	18.6 (8.8)	21.5 (5.3)	31.2 (9.4)	40.5 (8.5)
	Wild & hatchery	69.9 (31.0)	88.2 (32.5)	102.3 (73.8)	17.0 (54.3)	64.6 16.0)	78.1 (23.5)	87.3 17.8)
1+	Wi ld& hatc hery	27 1 (15.0	6.1 (7 8)	14 8 (8 5)	12.7 (7.9)	3.3 (3.6	20.6 116.6	36.6 (26 9)
2+	Wi ld& hatc hery	146.9 102.0)	38.9 (19.1)	26.3 15.4	63.3 (22.5)	22.2 (69.3)	81.6 (26.8)	78.1 (19.4)
3+	Wi ld& hatchery	107.0 (68.1)	28.4 (14.0)	2.5 (9.5)	20.5 (11.7)	42.7 (26.0)	12.0 (6.3)	33.8 (10.9)
4+	Wi ld& hatchery	31.4 (18.4)	11.3 (6.5)	8.3 (8.6)	8.6 (4.6)	11.0 (6.[illegible]	5.7 (6.1)	11.8 (0.0)
5+	Wi ld& hatcherry	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.[illegible])	0.0 (0.0)	0.0 (0.0)
Total all ag classes		313.7 15.5)	221.5 78.7)	245 8 64.4)	310.0 08.0)	254.6 (95.[illegible])	358.4 (66.9	247.6 74.1)

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

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Appendix B. Maximum single late-run (early run included for Trestle Creek) kokanee counts made during the 1973-78 and 1985-91 spawning seasons on Lake Pend Oreille and its tributaries, excluding the Granite Creek drainage.

Area	1972	1973	1974	1975	1976	1977	1978	1985	1986	1987	1988	1989	1990	1991
Lakeshore														
Bayview	2,626	17, 56	3,588	9,231	525	3,390	798	2,915	720	377[c]	2, 00	875	2,036	530
Farragut	25	0	0	0	0	0	0	--	10	0	4	--	--	--
Idlewild Bay	13	0	25	0	0	0	0	-	--	-	-	--	--	--
Lakeview	4	200	18	0	0	25	0	4	127	59	0	0	75	0
Ellisport Bay and Hope	1	436	975	0	0	0	0	0	0	0	-	-	--	100
Trestle Creek Resorts	0	000	2,250	0	5	75	138	2	35	350	2	2	--	80
Sunnyside	0	25	0	0	0	0	0	0	0	0	--	-	--	--
Fisherman Island	0	0	75	0	0	0	0	--	--	-	--	-	--	--
Anderson Point	0		50	0	0	0	0	-	--	-	--	--	--	--
Camp Bay	0	617	0	0	0	0	0	0	0	0	--	--	-	0
Garfield Bay	0	400	20	0	0	0	0	0	6	0	35	--	0	12
Subtotal	2,669	9,834	7,001	9,231	640	3,490	936	2,921	898	786	2,141	877	2,111	722
Percent of total	29%	62%	25%	64%	33%	40%	19%	32%	10%	20%	14%	19%	25%	28%
Tributaries														
South Gold Creek	030	1,875	1,050	440	0	30	-	235	0.550	2,761	2,390	830	834	120
North Gold Creek	744	1,383	1,068	663	30	426	--	696	0.200	2,750	880	448	458	550
Cedar Creek	0	267	44	16	11	0	0	--	--	--	--	--	--	--
Johnson Creek	0	0	1	0	0	0	0	--	182	0	0	0	0	0
Twin Creek	0	0	135	1	0	0	0	5	0	0	0	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	4,000	,500[d]	9,000	2,400	4,400	2,710
Cascade Creek	--	--	--	--	--	--	--	--		0	019	48	45	0
Trestle Creek	≈93	18	1,210	15	0	40	0	0	0	0	10	0	0	62
Trestle[a]	--	1,100	217	14 555	486	865	1,589	208	1,034	410	22	466	525	995
Garfield Creek	0	0	25	0	0	0	0	--	1	0	40	0	0	0
Subtotal	6,566	2,091	21,513	5,185	3,291	5,186	4,046	6,347	7,098	7,086	2,698	3,726	6,262	4,437
Percent of total[b]	71%	38%	75%	36%	67%	60%	81%	68%	90%	80%	86%	81%	75%	72%
Total[b]	9,235	31,925	28,514	14,416	4,931	8,676	5,000	9,268	18,996	8,872	14,839	4,603	8,373	6,159

[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.

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Appendix C. Statistical comparisons (ANOVA) of zooplankton densities from 1985-91 among lake sections and years, Lake Pend Oreille, Idaho. Lake section abbreviations are: Southern = S, Central = C, and Northern = N. Nonsignificant (P > 0.10) contrasts are delineated by a common line under each contrast. Estimated density and length increase from left to right for lake sections and years.

Zooplankton	P level for Lake section	effect Year	Ma Lake on				> 0 ear			
		Density								
Cyclops	°.926	0.000	N C S	91	86	87	90	85	89	88
Diaptomus	°.784	0.000	N S C	87	86	91	85	89	88	90
Epischura	°.678	0.001	N C S	91	90	8≤	88	89	87	85
Bosmina	°.097	0.000	C N S	91	86	88	90	85	87	89
Diaphonosoma	°.980	0.000	S N C	91	86	87	85	90	88	89
Daphnia	°.446	0.028	C S N	91	85	90	88	89	87	86
Total	°.898	0.000	N C S	91	86	87	90	85	89	88

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Appendix D. Estimated year class (year eggs were deposited) abundance (millions) of kokanee made by midwater trawl in Lake Pend Oreille, Idaho, 1979-91. The two oldest age classes were combined for estimates from 1979-85.

Year class	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979
1990	1.99												
1989	0.83	3.35											
1988	1.77	1.59	4.48										
1987	0.77	1.45	1.17	7.31									
1986	0.27	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.[illegible]1		
1979									0.29	0.64	1.[illegible]6	1.69	
1978										0.87	0.[illegible]9	1.00	2.01
1977											0.[illegible]4	0.96	1.31
1976												1.03	1.70
1975													0.67
Total	5.[illegible]	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	248	306	341	450	266	189	198	249	230	358	230	207	251

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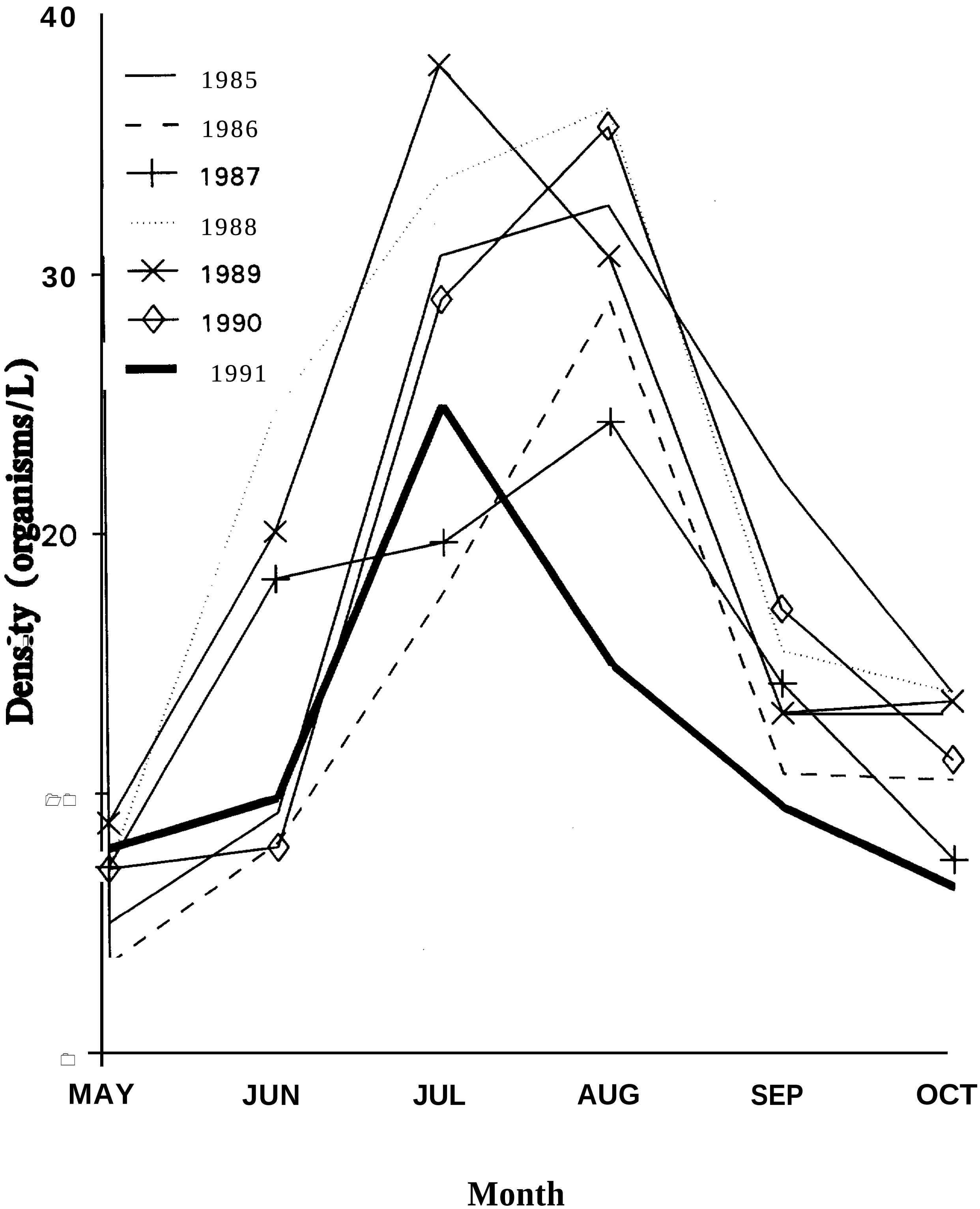
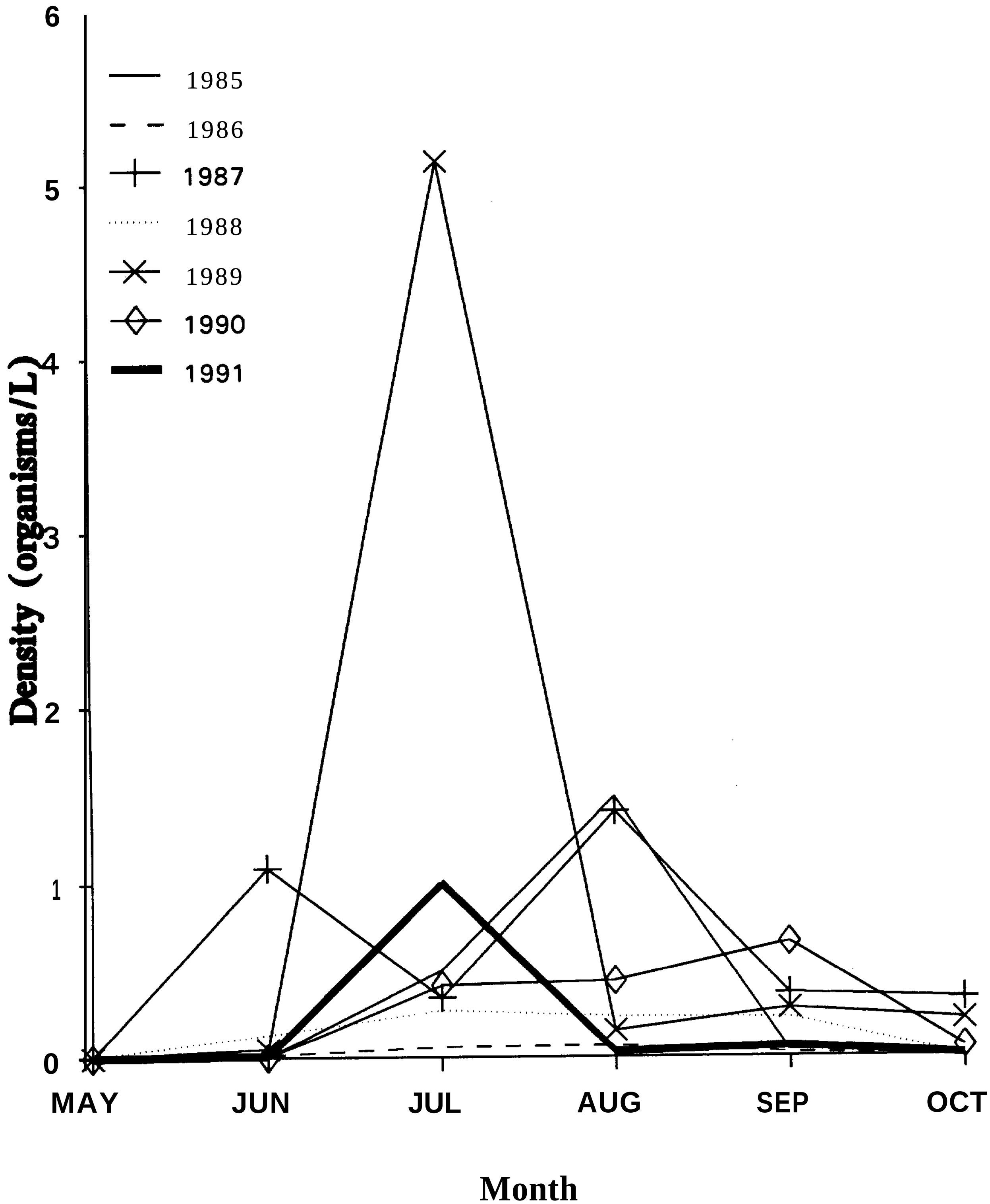
Appendix E. Kokanee spawned from Sullivan Springs Creek from 1976-91, number of eggs collected, subsequent fry released into Sullivan Springs and adult return rate.

Year	Total escapement	Kokanee spawned	Eggs collected	Fry released following year[a]	Estimated adults returning from hatchery releases and year returned		Adult returns as a percent of fry released
1976	10,717	10.200	913,000	757,700	55,500	(1980)	12.89
					42,200	(1981)	
1977	20,075	17,650	2,400,000	1,830,000	135,300	(1981)	10.28
					29,000	(1982)	
1978	----	16,875	1,532,382	1,745,734	118,000	(1982)	10.08
					58,000	(1983)	
1979	_---	12,005	19389,250	1,081,400	42,000	(1983)	10.88
					75,660	(1984)	
1980	55,500	48,760	4,186,664	2,219,796	54,340	(1984)	4.56
					46.810	(1985)	
1981	177,500	112,820	11,653,036	2,487,804	27,935	(1985)	1.93
					20,060	(1986)	
1982	147,000	115,850	11,432,900	3,077,711	22,170	(1986)	3.25
					77,773	(1987)	
1983	100,000	79,850	6,328,924	3,214,512	5,854	(1987)	1.95
					54,500	(1988)	
1984	130.000	122,000	14,973,029	3,428,279	13.600	(1988)	2.20
					61,976	(1989)	
1985	74,745	75,500	10,590,579	1,594,731	14,121	(1989)	3.33
					39,062	(1990)	
1986	42,230	42,230	7,337,000[b]	2,847,345	18,385	(1990)	2.01
					45,425	(1991)	
1987	83,627	83,627	16,600,000[c]	5,138,800	39,428	(1991)	
1988	68.100	60,555	14,058,000[d]	3,538,000	857	(1991)	
1989	79.450	70,600	9,372,000[e]	3,190,700			
1990	57,445	51.445	5,686,000[f]	2,570,264			
1991	85,713	75,624	6,364,209				

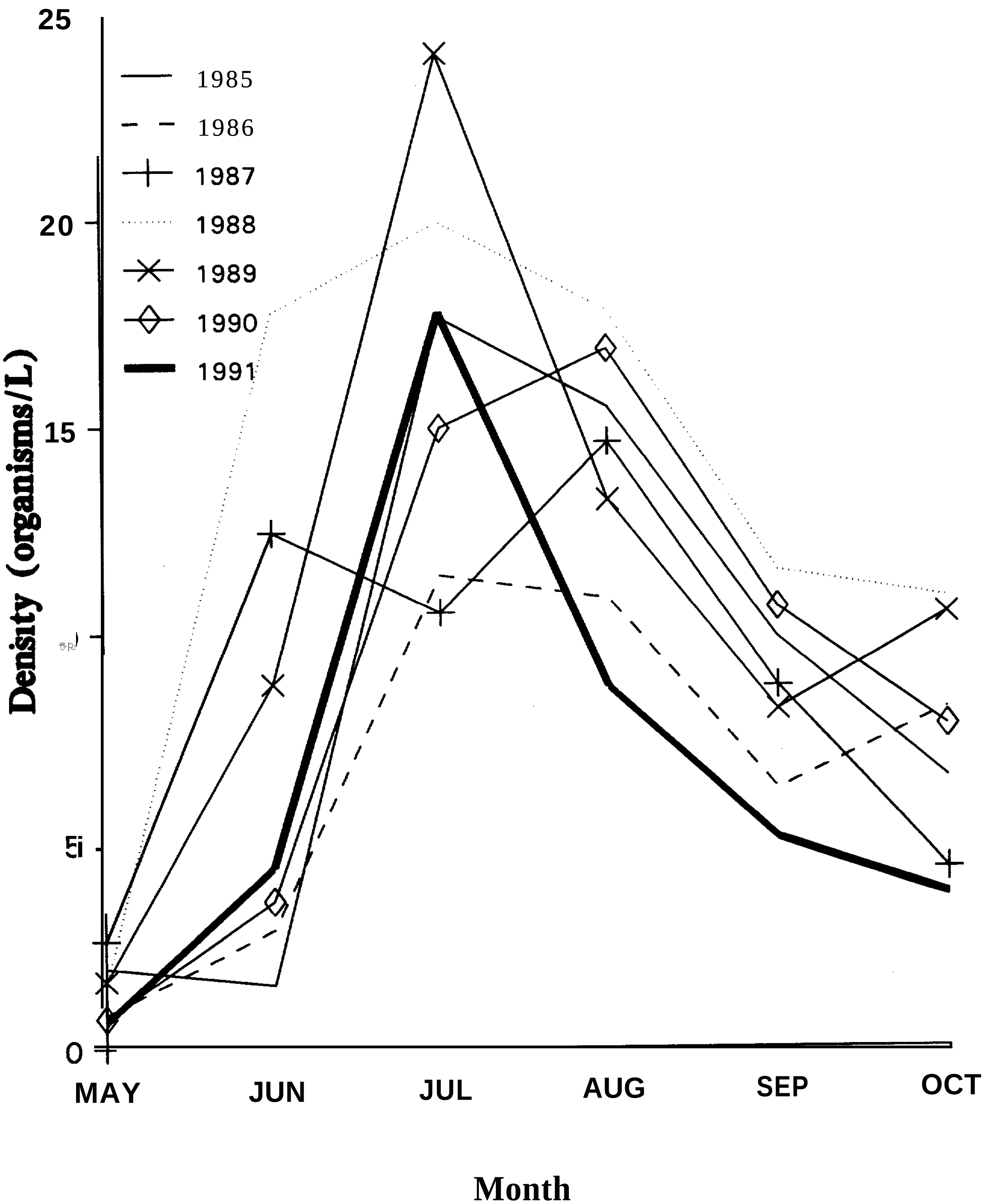
[a] Additional fry were released in other areas.
[b] An additional 1.76 million eggs were collected from Spring Creek and the Clark Fork River, bringing the total egg take to 9.1 million.
[c] An additional 0.61 million eggs were collected from Clark Fork River, bringing the total egg take to 17.22 million.
[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 9.58 million.
[f] An additional 0.30 million eggs were collected from Clark Fork River, bringing the total to 5.6 million.



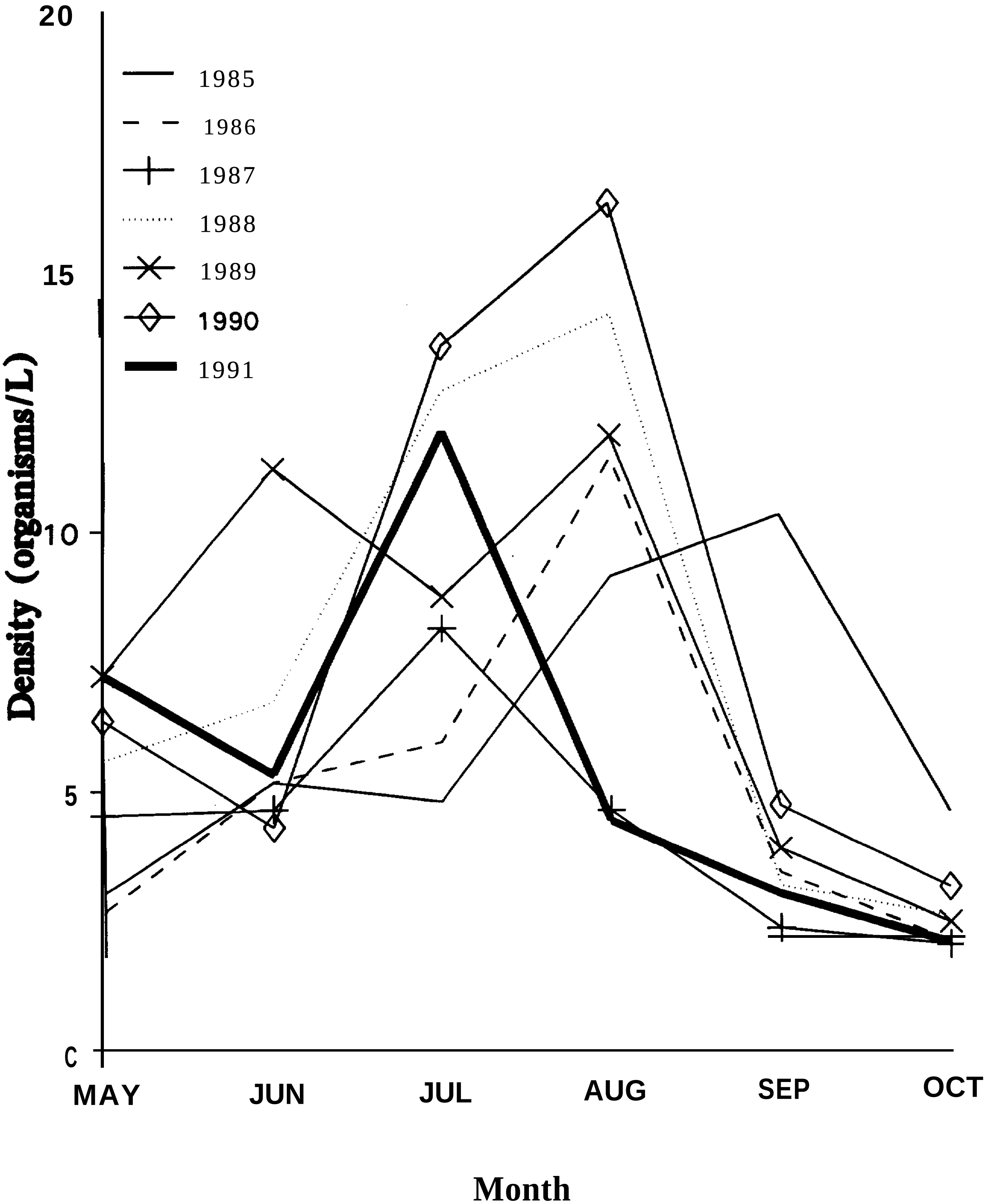
Appendix F. Temporal distribution of mean total densities of zooplankton in Lake Pend Oreille, Idaho, May through October, 1985-91.



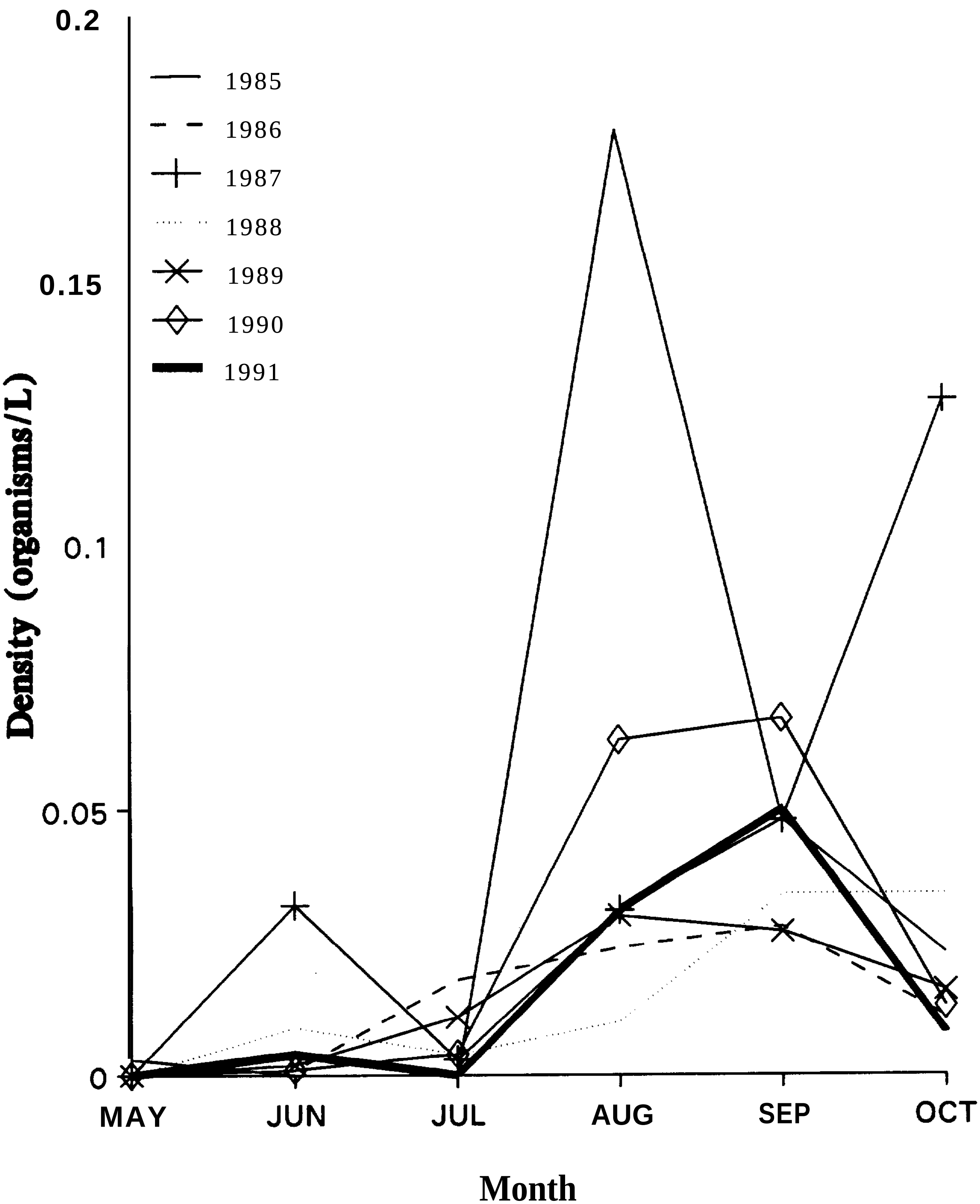
Appendix G. Temporal distribution of mean Bosmina densities in Lake Pend Oreille, Idaho, May through October, 1985-91.



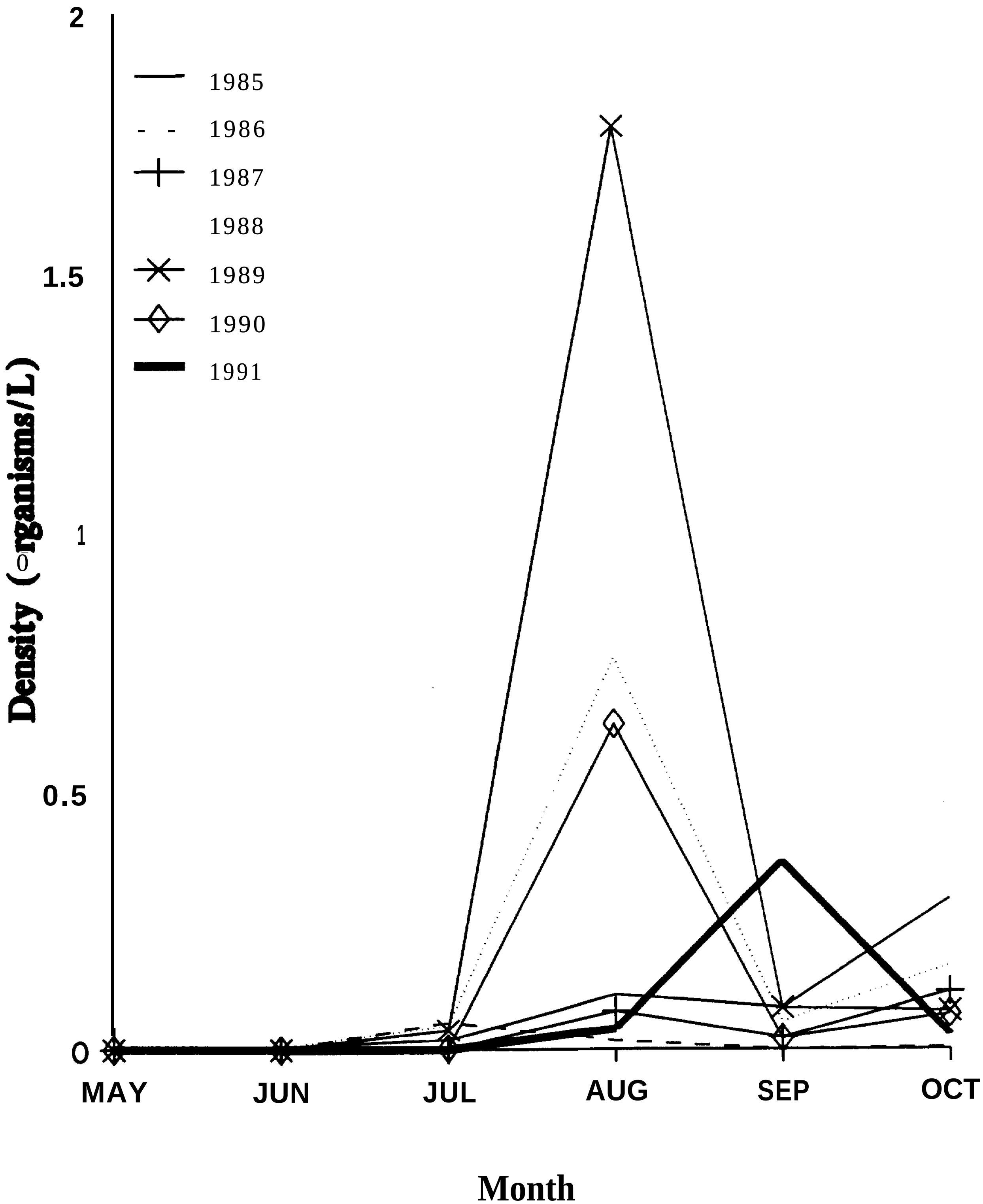
Appendix H. Temporal distribution of mean Cyclops densities in Lake Pend Oreille, Idaho, May through October, 1985-1991.



Appendix I. Temporal distribution of mean Diaptomus densities in Lake Pend Oreille, Idaho, May through October, 1985-91.



Appendix J. Temporal distribution of mean Epischura densities in Lake Pend Oreille, Idaho, May through October, 1985-91.



Appendix K. Temporal distribution of mean Diaphanosoma densities in Lake Pend Oreille, Idaho, May through October, 1985-91.

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