Lake Pend Oreille Fishery Recovery Project

Annual Report
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Lake Pend Oreille Fishery Recovery Project

Annual Progress Report for 1998
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LAKE PEND OREILLE FISHERY RECOVERY PROJECT

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ABSTRACT

The elevation of Lake Pend Oreille was kept 1.2 m higher during the winter of 1997-1998 in an attempt to recover the impacted kokanee fishery. This was the second winter of a scheduled three-year test. Hydroacoustic surveys and trawling were conducted in the fall of 1998 to assess the kokanee population. We estimated the abundance of wild and hatchery fry in the lake at 3.71 million by hydroacoustics. These originated from an estimated 11.2 million eggs spawned during the fall of 1997. The survival from wild spawned eggs to wild fry was 9.7%, which is the highest egg-to-fry survival rate on record. This is the strongest indication to date that higher lake levels were having a direct benefit to the kokanee population. By trawling, we found that total kokanee abundance in the lake dropped to a new record low of 2.8 million fish. The number of adult kokanee in the lake was below average: 100,000 age 4 kokanee (100% mature) and 730,000 age 3 kokanee (29% mature). These fish laid an estimated 52.1 million eggs in 1998. Hatchery personnel collected 9.0 million eggs which were cultured, marked by cold branding the otoliths, and the resulting fry stocked into the lake in 1999. Peak counts of spawning kokanee were 5,100 fish on the shoreline and 9,700 fish in tributary streams; unusually high considering the low population in the lake. Opossum shrimp *Mysis relicta* declined in the southern two sections of the lake but increased in the northern end. Immature and mature shrimp (excluding young-of-the-year [YOY] shrimp) densities averaged 426 shrimp/m^2. The number of waterfowl using the lake in the winter of 1998-1999 increased from the previous three years to over 30,000 ducks, geese, and swans.

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INTRODUCTION

The decline of the kokanee *Oncorhynchus nerka* population in Lake Pend Oreille has been largely attributed to the current operation of Albeni Falls Dam (Maiolie and Elam 1993; Paragamian and Ellis 1994). Historical population trends and harvest data indicated winter pool elevation affected kokanee abundance and harvest. Drawdowns of the lake below the elevation needed for flood control exposed most of the shoreline gravel that limited kokanee spawning. In an attempt to recover the kokanee population, the Idaho Department of Fish and Game (Department) proposed that the lake be drawn down only to a winter lake level of 626.7 m (2,056 ft) above mean sea level, approximately 1.5 m above the minimum level used from 1966 to 1995. Gravel surveys conducted in 1994 determined this would increase the amount of suitable kokanee spawning gravel by 560 percent (Fredericks et al. 1995).

The Northwest Power Planning Council directed the U.S. Army Corps of Engineers to change the winter elevation of Lake Pend Oreille beginning in the winter of 1996. The lake was to be kept above an elevation of 626.4 m (2,055 ft, 1.2 m higher) for three winters. They also directed the Bonneville Power Administration (BPA) to fund the Department to investigate the effect of lake level changes on kokanee production; possible movements of shoreline gravel and sediment; a lake energy budget including zooplankton, predation levels and predator abundance, *Mysis* shrimp and food availability for fry and adult kokanee, changes in the abundance of warm water fish species, concerns about Eurasian water milfoil, and effects on wildlife and waterfowl. These studies were to be conducted between 1996 and 2001. After this time, fishery managers were to meet and discuss options for managing the lake levels on a long-term basis. This report covers the second year of findings on this study. Conclusions on the effect of lake levels would be premature at this point.

OBJECTIVE

To return kokanee harvest to 750,000 fish annually with a mean length of 250 mm. This will be possible once the abundance of harvestable-sized kokanee reaches 3.75 million fish.

STUDY AREA

Lake Pend Oreille is located in the northern panhandle of Idaho (Figure 1). It is the state's largest lake and has a surface area of 38,300 ha, a mean depth of 164 m, and a maximum depth of 351 m. Summer pool elevation of Lake Pend Oreille is 628.7 m. Pelagic habitat used by kokanee is considered to be 22,546 ha (Figure 1) (Bowler 1978). The Clark Fork River is the largest tributary to the lake. Outflow from the lake forms the Pend Oreille River.

Lake Pend Oreille is a temperate, oligotrophic lake. Summer temperatures (May to October) averaged approximately 9°C in the upper 45 m (Rieman 1977; Bowles et al. 1987, 1988, 1989). Thermal stratification typically occurs from late June to September. Operation of Albeni Falls Dam on the Pend Oreille River keeps the lake level high and stable at 628.7 m during summer (July-September) followed by reduced lake levels of 625.1 m during fall and winter (typical dam operation between 1966 and 1996). During the first two winters of this study, the winter lake level was held above 626.4 m. A similar reduction in drawdown is scheduled for the winter of 1998-1999 (Figure 2).

A wide diversity of fish species is present in Lake Pend Oreille. Kokanee entered the lake in the early 1930s from Flathead Lake, and were well established by the 1940s. Other game fish include: Gerrard rainbow trout *Oncorhynchus mykiss,* bull trout *Salvelinus confluentus*, westslope cutthroat trout *Oncorhynchus clarki lewisi*, lake whitefish *Coregonus clupeaformis*, mountain whitefish *Prosopium williamsoni*, and lake trout *Salvelinus namaycush,* in addition to several other cool and warm water species.
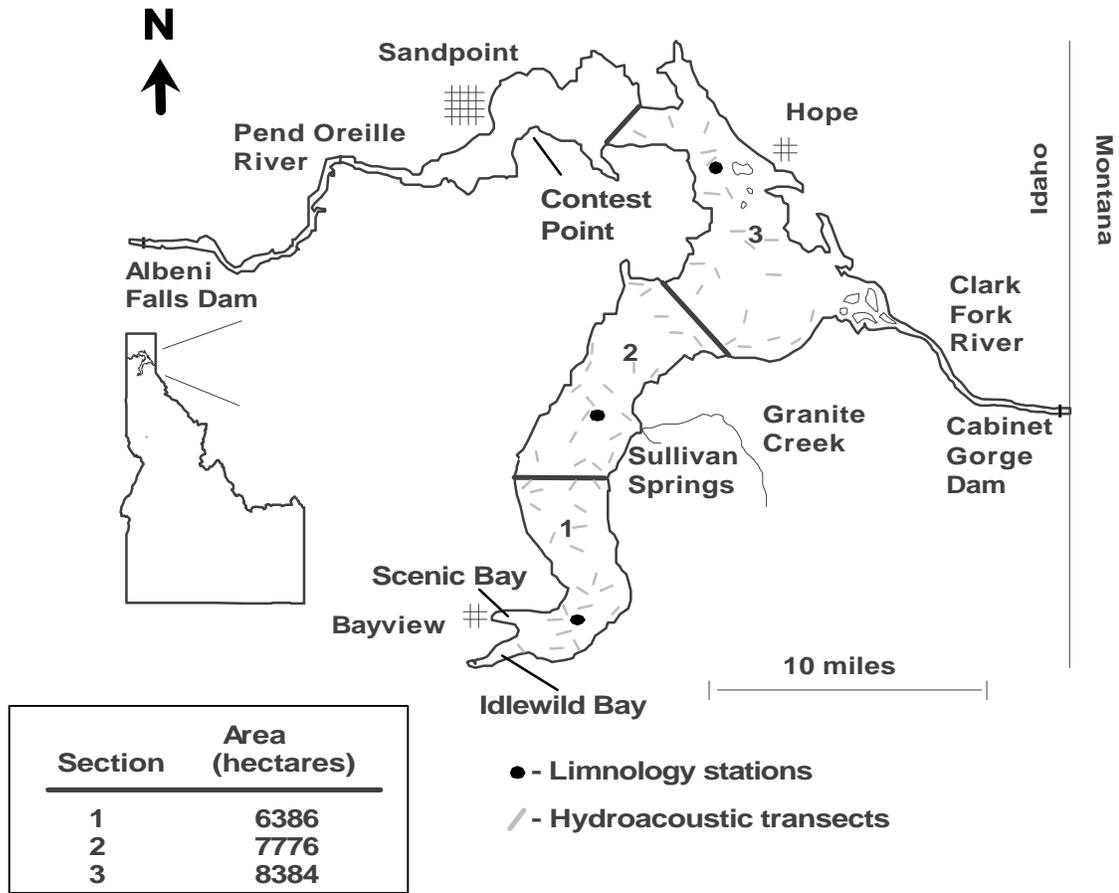
Figure 1. Map of Lake Pend Oreille, Idaho showing prominent landmarks, the three sections used for estimating kokanee and shrimp abundance, and limnology stations. Grey lines mark the location of hydroacoustic transects in 1998. Inserted table depicts the area of kokanee habitat in each section.
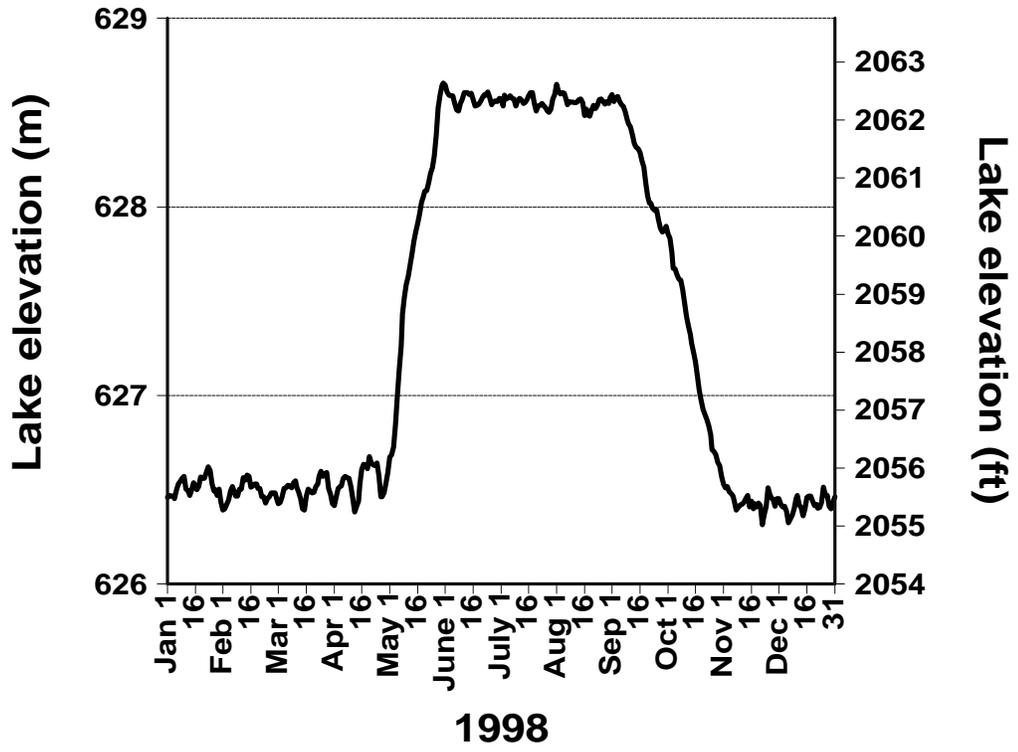
Figure 2. Surface elevation of Lake Pend Oreille, Idaho 1998.

METHODS

Midwater Trawling

We conducted standardized midwater trawling in Lake Pend Oreille from August 17 to August 24, 1998. These dates were during the dark phase of the moon, which optimized the capture efficiency of the trawl (Bowler et al. 1979).

The lake was divided into three sections (Figure 1), and a stratified random sampling scheme was used to estimate kokanee abundance and density. Twelve transects were randomly selected within each section and one haul was made along each transect. We located each trawl site using the Global Positioning System (GPS).

The midwater trawl equipment and sampling procedures were described in detail by Rieman (1992). The net was 13.7 m long with a 3 m x 3 m mouth. Mesh sizes (stretch measure) graduated from 32, 25, 19 and 13 mm in the body of the net to 6 mm in the cod end. The trawl net was towed at a speed of 1.5 m/s by an 8.5 m boat. We determined the vertical distribution of kokanee by using a Raytheon Model V850 depth sounder with a 20° hull mounted transducer. A step-wise oblique tow was conducted along each transect which sampled the entire vertical distribution of kokanee.

Fish from each trawl sample were counted and placed on ice until morning. Length and weight of individual kokanee was recorded and all fish over 170 mm were checked for maturity. Scales were taken from 10 fish in each 10 mm size interval for aging. Otoliths were removed from age 0 and age 1 kokanee. One hundred otoliths from each age group were sent to Washington Department of Fisheries for analysis.

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 formulas for stratified sampling designs (Scheaffer et al. 1979). The area of each section was calculated for the 91.5 m contour; however, the northern section 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). For consistency, these same areas have been used each year since 1978. Ninety-percent confidence intervals were calculated on the kokanee abundance estimates (Scheaffer et al. 1979).

Potential egg deposition (PED) was calculated by determining the percent maturity of age 3 and age 4 kokanee in the trawl catch (by dissection). Percent maturity was then multiplied by the population estimate for that age class and divided by two to obtain the number of mature females. Number of mature females in the lake was then multiplied by the mean fecundity seen at the Granite Creek spawning station to estimate potential egg deposition. We then subtracted the number of eggs collected by hatchery personnel at the Cabinet Gorge Hatchery and Granite Creek egg-take stations to determine the number of eggs spawned by wild fish (wild PED).

Hydroacoustics

We conducted hydroacoustic surveys on Lake Pend Oreille at night between August 10 and 13, 1998. Twenty transect locations were randomly chosen in each of three lake sections for a total of 60 transects. We also randomly selected a compass bearing for the direction of each transect (Figure 1). Sampling sites were located by using GPS.

At each location, a 10-minute hydroacoustic survey was conducted using a Simrad EY500 portable scientific echosounder. Boat speed was approximately 1 m/s (boat speed did not affect our calculations of fish density). Echosounder was set to ping at 1.0 s intervals. Calibration of the echosounder was checked using a copper calibration sphere before the start of surveys and gains adjusted to achieve the correct target strengths. Echosounder was annually calibrated to correct for signal attenuation to the sides of the acoustic axis using Simrad's Lobe program. We analyzed the survey information using Simrad EP500 software version 5.2.

Three hundred-eighty kokanee were "trace tracked" to determine the target strengths of fish which would be used to separate age classes of kokanee. To be considered a fish in the trace track, it had to be detected (pinged) at least twice, not move more than 30 cm vertically between detections, and not be missed by more than 1 ping during the tracking. A bar graph of target strength versus frequency was then drawn. We used the low points on the graph to define the breaks between age classes of fish.

To estimate abundance of hatchery and wild fry, we took the total estimate of fry in each section of the lake based on hydroacoustics and multiplied it times the proportion of each type of fry collected in the trawl samples for that section. Section totals were summed to get lake-wide abundance estimates of hatchery and wild fry.

Spawner Counts and Surveys

We walked standard shoreline areas (Appendix A) and tributaries and counted spawning kokanee to continue this data set. All areas surveyed have been documented as historical spawning sites (Jeppson 1960). Nine shoreline areas were surveyed once a week for three straight weeks starting with the third week in November 1998. All kokanee, either alive or dead, were counted. The highest count at each site was reported.

Seven tributary streams were surveyed by walking upstream from the mouth to the highest point utilized by kokanee during the same period as shoreline counts. Trestle Creek, which supports a run of early spawning kokanee, was also surveyed on September 21, 1998 for spawners.

Hatchery Fry Marking

All kokanee fry released from the Cabinet Gorge Fish Hatchery in 1997 and 1998 were marked by "cold branding" their otoliths (Volk et al. 1990). This was the second year that fry released into Lake Pend Oreille were cold branded. The intent of this marking was to be able to separate hatchery and wild kokanee throughout their life cycle by comparing growth patterns on saggital otoliths. In addition, 99,000 kokanee fry from an early spawning strain were reared at the Clark Fork Hatchery and stocked into Spring Creek. These fish were unmarked, but were considerably larger than wild fry; 90–100 mm by August sampling versus 20-60 mm for wild fry.

Cold branding of the otoliths was done at the Cabinet Gorge Fish Hatchery. Fry within an individual raceway were from eggs collected within ten days of each other. Thermal treatments were initiated five to ten days after fry entered their respective raceways. Fry from 1997 and 1998 were treated to create unique banding pattern on their otoliths. Fry in 1997 were given 5 evenly spaced bands by placing them on cool water ($5^{o}C$) for 24 h and then returning them to normal ($10^{o}C$) rearing temperatures for 24 h and repeating this five times. Fry in 1998 were again marked with five cool water events, however, the number of days between cool water events changed. Between the first and last two cool water events the fry were returned to normal rearing temperatures for three days. Only one day of normal temperatures was given between the 2nd, 3rd, and 4th bands. Twenty fry from each raceway were sacrificed to verify the thermal marking. These fry were sent to the Washington Department of Fish and Wildlife Otolith Laboratory, in Olympia Washington. Recognizable otolith marks were verified on all thermally treated individuals. All 2.484 million fry were stocked in Lake Pend Oreille at Sullivan Springs on June 16, 1998.

We sent otoliths from 200 age 0 and age 1 kokanee collected during the August trawling to the Washington Department of Fish and Wildlife for analysis. Before shipment, we catalogued each fish, recorded total length and weight, and removed, cleaned and catalogued the saggital otoliths.

Washington Fish and Wildlife personnel removed one sagitta from each of the 200 vials and oriented it on a glass plate labeled to associate the otolith with the specimen vial. Under a fume hood, otoliths were positioned on a glass plate and surrounded with a preformed rubber mold. Rubber molds were then filled with clear fiberglass resin and warmed in an oven for approximately 1 h for curing. The resulting blocks of resin containing the otoliths were cut into groups of four otoliths per block for sectioning and polishing. Blocks of four otoliths were lapped on a rotating disc of 500 grit carborundum paper until the nucleus of each otolith was clearly visible. The otoliths were then polished using a rotating polishing cloth saturated with one micron deagglomerated alpha alumina and water slurry. After lapping and polishing, the otoliths were examined with a compound microscope at 200 power and/or 400 power magnification. Patterns within the otolith were compared to those on reference samples taken from the hatchery during fry incubation. For accuracy, two independent readers examined each otolith. Differences between the readers were settled by re-examining the otolith.

Shrimp Abundance

Opossum shrimp *Mysis relicta* (locally known as Mysis shrimp), were sampled from June 24 to 26, 1998 to estimate their abundance and determine whether changes in shrimp abundance could influence the outcome of the lake level experiment. All sampling occurred at night during the dark phase of the moon. The new moon during June has been the standard sampling date for most of the previous work on shrimp, and for all of our sampling since 1997. Eight sampling sites were randomly located in each of three sections of the lake (Figure 1). We used GPS coordinates to locate each sampling site.

We collected shrimp using a hoop net that was 1 m in diameter and equipped with a flowmeter. Net mesh and cod-end bucket mesh measured 1,000 µm and 500 µm, respectively. We lowered the net to a depth of 45.7 m (150 ft) and raised it to the surface at a rate of 0.5 m/s using an electric winch. Shrimp were immediately placed in denatured ethanol for preservation. This methodology has been used since 1995 to assess the population.

Mysids were measured from the tip of the rostrum to the end of the telson, excluding setae, and classified into five categories according to sex characteristics, young of year, immature males and females, and mature males and females (Gregg 1976, Pennak 1978).

Limnology

We measured water temperature, dissolved oxygen, and water clarity (Secchi transparency) monthly from January through December 1998. Data were collected at three standardized stations that represented the southern, middle, and northern sections of the lake (Figure 1). Sample dates were approximately the middle of each month. We used a Yellow Springs Instrument Company model 57 meter to measure temperature and dissolved oxygen from the surface to a depth of 59 m. The meter was calibrated before each survey using the "water saturated air" method suggested by the manufacturer. Water clarity was monitored at each station using a 20 cm diameter Secchi disc during each survey.

Waterfowl Counts

On January 5, 1998 wildlife biologists flew in a fixed-wing aircraft and counted waterfowl in the vicinity of the lake. Areas surveyed included the Clark Fork River (Idaho portion), the Pend Oreille River (Idaho portion), and Lake Pend Oreille.

Gravel Sampling

Five areas of shoreline were sampled in 1998 to determine if potential spawning gravel is increasing in silt content or becoming unusable to kokanee spawners. Areas surveyed included the lake's shoreline at a site in Garfield Bay, at Trestle Creek, just north of the mouth of North Gold Creek, at Hope, and at Ellisport Bay. Each of these sites was surveyed in 1992 (Maiolie and Elam 1993), and was a historic location for kokanee spawning (Jeppson 1960).

Sampling was conducted from July 15 to 29, 1998. At this time the lake was at its summer full pool level and all gravel samples were collected while scuba diving. We tied a rope to the shoreline at each transect location and stretched it out into the lake perpendicular to the shore. Flagging was tied to the rope to mark the distances to the top and bottom of the gravel bands as seen in the 1992 study. Two random samples were collected in each substrate band. Samples were collected by scooping approximately 2 liters of substrate into a container and sealing it underwater so fine material would not be lost during transport to the surface.

At Garfield Bay, we collected a sample every 1.2 m along the transect that extended from the 624.8 m elevation (2,049.8 feet) to the summer pool level of 628.5 m (2,062.2 feet). Each sample was individually bagged, labeled, and oven-dried. We then screened each substrate sample through soil sieves of the following sizes: 63.5 mm, 31.8 mm, 15.9 mm, 9.5 mm, 6.3 mm, 2 mm, and 0.84 mm. The substrate retained on each screen, and the substrate which fell through the finest screen, was then weighed and calculated as a percent of the weight of the total sample. We defined "cobble" as substrates that were 31.8 mm and larger, "gravel" as substrates between 31.8 and 6.3 mm, and "fines" as the substrate smaller than 6.3 mm.

Riparian Areas

We monitored the shoreline riparian areas of the lake to determine if riparian vegetation would colonize the drawdown zone. At four selected sites, we photographed the shoreline vegetation when water level was at the low pool elevation. Sites included: Denton Slough, the mouth of Trestle Creek, Farragut State Park, and the shoreline near Hope. If increases in vegetation occurred, we were requested to conduct further studies on its benefits to wildlife.

RESULTS

Midwater Trawling

In 1998, we estimated total kokanee abundance at 2.8 million fish and the density of age 4 fish at 4 fish/ha. Kokanee fry abundance was estimated at 725,000 (+/-21%, 90% confidence interval). We estimated the lake also contained 891,000 age 1 kokanee (+/- 68%), 330,000 age 2 kokanee (+/- 46%), 728,000 age 3 kokanee (+/- 52%), and 95,000 age 4 kokanee (+/- 50%) (Table 1). No age 5 fish were sampled. Total standing stock for kokanee was 4.6 kg/ha.

All of the age 4 kokanee and 29% of the age 3 kokanee in the trawl samples were found to be mature. Therefore, we estimated the lake contained 306,000 mature fish, of which 51% were estimated to be female. Fecundity averaged 333 eggs per female kokanee as determined at the Sullivan Springs egg station in 1998. Therefore, potential egg deposition was estimated at 52.1 million eggs. Hatchery crews collected 9.0 million eggs at Sullivan Springs and Cabinet Gorge Fish Hatchery Ladder. This left 43.1 million eggs to be naturally spawned on the lakeshore and in tributary streams during the fall of 1998.

Survival rates between age classes of kokanee were: 40% from age 0 to age 1, 29% from age 1 to age 2, 92% from age 2 to age 3, and 25% for age 3 to age 4 fish (Table 2). Survival of eggs laid in 1994 (246 million) to age 3 fish in 1998 (0.73 million) was 0.30%.

Table 1. Kokanee population statistics based on trawling Lake Pend Oreille, Idaho during August 1998.

| | **Age** | | | | | |
	0	1	2	3	4	Total
Population estimate (millions)	0.72	0.89	0.33	0.73	0.10	2.8
+/- 90% CI	21%	68%	46%	52%	50%	
Density (fish/ha)	32	40	15	32	4	123
Mean weight (g)	1.3	22.7	55.2	72.3	117.6	
Standing stock (kg/ha)	0.04	0.90	0.82	2.33	0.5	4.6
Mean length (mm)	57	141	169	209	245	
Length range (mm)	20-89	90-189	160-209	180-239	220-259	

Table 2. Estimated survival rates (%) for kokanee year classes (by age), in Lake Pend Oreille, Idaho. Year class is the year eggs were laid.

Year Class	Age Class				
	0 to 1	1 to 2	2 to 3	3 to 4	Eggs to 3
1996	40				
1995	21	29			
1994	78	22	92		0.30
1993	42	110	12	25	0.17
1992	12	400	44	7	0.40
1991	32	47	106	59	0.80
1990	67	98	76	15	1.55
1989	25	94	256	38	1.70
1988	35	111	63	92	0.94
1987	16	124	53	83	0.66
1986	47	72	27	82	0.48
1985	47	65	88	44	0.37
1984	64	73	45	97	0.43
1983	39	66	63	81	1.26
1982	70	70	43	77	2.49
1981	59	53	[a]		
1980	119	18	[a]		
1979	80	47	[a]		
1978	50	79	[a]		
1977	72	73	[a]		

[a] Unable to calculate survival rate since age 3 and 4 kokanee were not separated prior to 1986.

Hydroacoustics

We estimated the lake contained 8.7 million ($\pm$ 12%) kokanee in 1998 based on hydroacoustic surveys. This included 3.71 million fry ($\pm$ 12%), and 5.03 million ($\pm$ 17%) kokanee from age 1 to age 4.

Mean target strengths of "trace tracked" kokanee showed a clear separation between age 0 kokanee and larger fish at the –46 dB level (Figure 4). This corresponded to a fish length of 100 mm (Love 1971). Separation of age 0 fish from the other size groups at the 100-mm size was also seen in the trawl samples (Figure 3). We could therefore separate kokanee fry from older kokanee based on their target strengths. No separation between older age classes (ages 1 to 4) could be defined based on target strengths.

We separated the hydroacoustic estimate of age 1 to age 4 fish based on the percent frequency of kokanee age classes in trawl samples for each section of the lake. Therefore, based on hydroacoustics, we estimated the lake contained 3.708 million age 0, 2.241 million age 1, 0.821 million age 2, 1.745 million age 3, and 0.220 million age 4 kokanee (Table 3).

The hydroacoustic estimate of fry was separated into abundance estimates of wild and hatchery fry. Wild kokanee fry ranged from 20 to 60 mm in total length and had no temperature mark on their otoliths. They made up 42% (n=38) of the total fry number in the southern end of the lake, 24% (n=34) of the fry in the middle section of the lake, and 24% (n=21) of the fry in the northern end of the lake. These percentages were multiplied by the hydroacoustic estimate of age 0 fish in each section to obtain a population estimate of wild fry of 1.026 million. These fry came from an estimated 10.6 million wild-spawned eggs that were laid in the lake and in tributaries in 1997. Survival of naturally deposited eggs to wild fry was therefore 9.7% (Table 4).

Age 1 kokanee from wild origin ranged from 100 mm to 160 mm; lacked the temperature mark on their otoliths and showed one annuli on their scales. Wild age 1 fish made up 0% of the total number in the southern end of the lake, 80% in the middle section of the lake, and 62% in the northern end of the lake. Multiplying the percent times the number of age 1 kokanee in the hydroacoustic estimate, by section, yielded an estimate of 1.400 million (64%) wild and 0.779 million (36%) hatchery age 1 kokanee (Figure 5).

None of the age 2, age 3 or age 4 kokanee had temperature marks on their otoliths in 1998. Therefore, no differentiation between wild and hatchery fish could be made.

Spawner Counts and Surveys

Counts of kokanee spawning along the shoreline in 1998 totaled 5,104 fish, the highest in over 10 years. Nearly all of these fish were seen in Scenic Bay (Table 5).

Counts of kokanee spawning in tributary streams totaled 9,714 fish (Table 6). Most tributary spawning occurred in South Gold and Spring creeks.
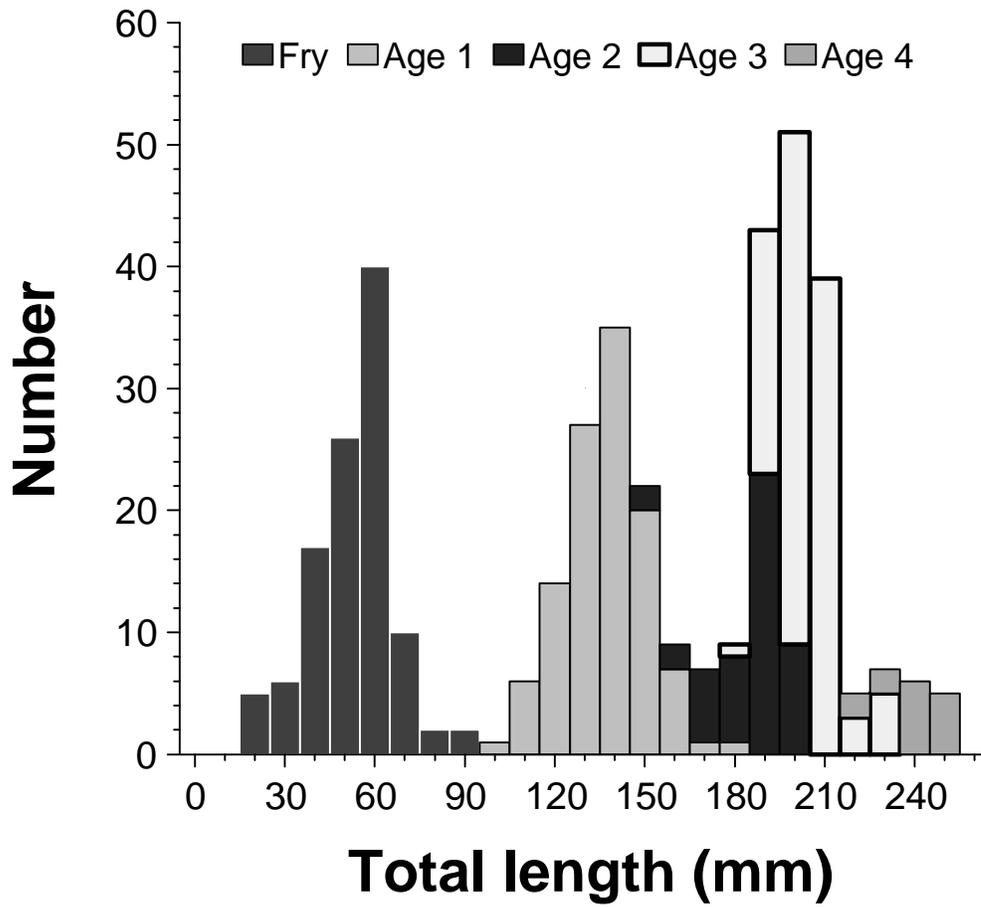
Figure 3. Length-frequency distribution of kokanee caught by mid-water trawling in Lake Pend Oreille, Idaho 1998. Ages were based on reading scales.
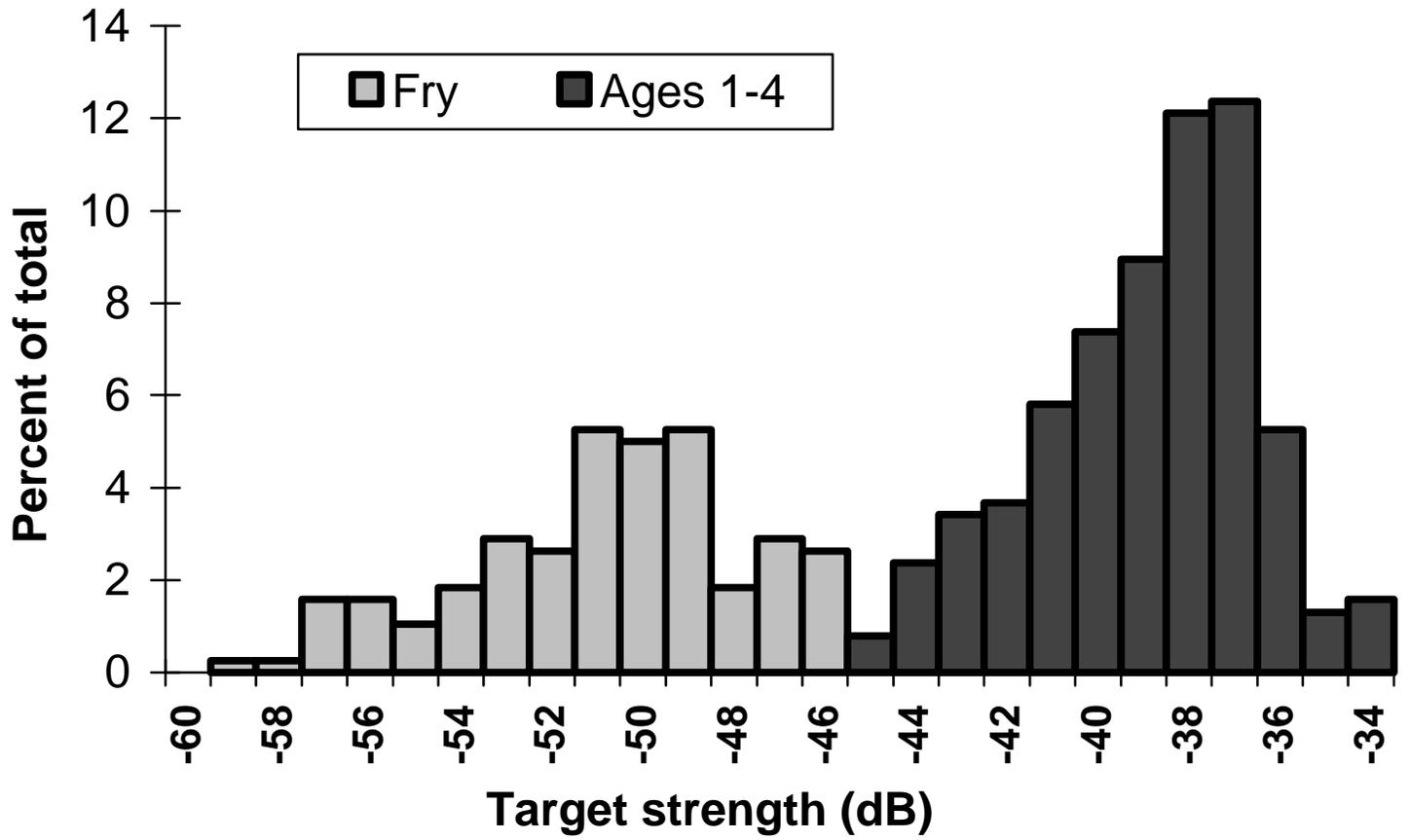
Figure 4. Target strengths of 380 kokanee recorded during hydroacoustic surveys on Lake Pend Oreille, Idaho during August 1998.

Table 3. Kokanee population estimates in Lake Pend Oreille, Idaho based on hydroacoustic surveys. Hatchery and wild fish were differentiated by otoliths or size frequency distributions. Wild potential egg deposition (PED) was based on trawling and excludes the number of eggs collected for the hatchery program. Numbers are in millions.

Year	Age 0	Age 0	Age 1	Age 1	Age 1	Age 2	Age 3	Age 4
	Wild	Hatchery	Wild	Hatchery	Undifferentiated			
1998	1.026	2.682	1.441	0.800	-	0.821	1.745	0.220
1997	2.590	3.496	-	-	2.905	1.857	0.863	0.115
1996	2.058	3.296	-	-	3.662	3.443	0.747	0.490
1995	2.765	4.514	-	-	3.418	2.082	1.120	0.248
1994	-	-	-	-	-	-	-	-

Table 4. Potential egg deposition (PED) for wild spawned eggs and calculated survival rates of wild kokanee fry in Lake Pend Oreille, Idaho. Minimum lake elevation is the low point for water levels while that year class of fry was incubating.

Year	Wild PED from previous year	Wild fry abundance (millions)	Percent survival	Minimum lake elevation
1998	10.6	1.026	9.7	2055.1
1997	142.0	2.590	1.8	2055.0
1996	61.6	2.058	3.3	2051.7
1995	229.4	2.765	1.2	2051.1
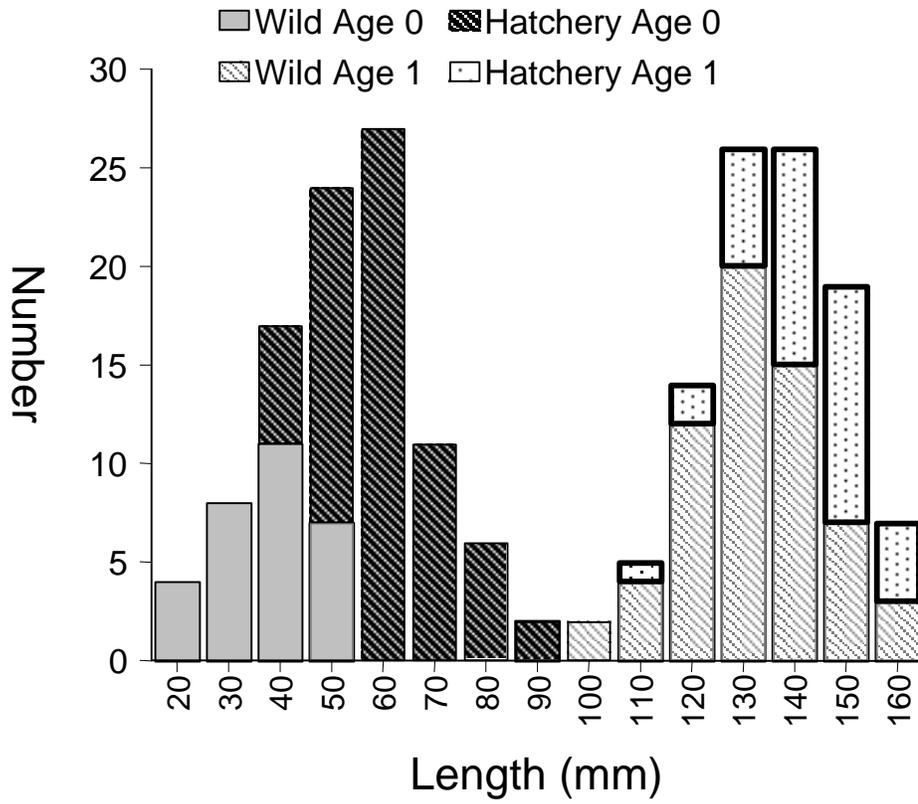
Figure 5. Length-frequency distribution of age 0 and age 1 kokanee caught by trawling in Lake Pend Oreille, Idaho 1998. Age classes were divided into hatchery and wild fish based on otolith marks.

Table 5. Counts of kokanee spawning along the shorelines of Lake Pend Oreille, Idaho. The numbers shown indicate the highest weekly count.

Year	Bayview	Farragut Ramp	Idlewild Bay	Lakeview	Hope	Trestle Cr. Area	Sunnyside	Garfield Bay	Camp Bay	Anderson Point	Total
1998	5,040	2	0	0	22	6	0	34	0	-	5,104
1997	2,509	0	0	0	0	7	2	0	0	-	2,518
1996	42	0	0	4	0	0	0	3	0	-	49
1995	51	0	0	0	0	10	0	13	0	-	74
1994	911	2	0	1	0	114	0	0	0	-	1,028
1992	1,825	0	0	0	0	0	0	34	0	-	1,859
1991	1,530	0	-	0	100	90	0	12	0	-	1,732
1990	2,036	0	-	75	0	80	0	0	0	-	2,191
1989	875	0	-	0	0	0	0	0	0	-	875
1988	2,100	4	-	0	0	2	0	35	0	-	2,141
1987	1,377	0	-	59	0	2	0	0	0	-	1,438
1986	1,720	10	-	127	0	350	0	6	0	-	2,213
1985	2,915	0	-	4	0	2	0	0	0	-	2,921
1978	798	0	0	0	0	138	0	0	0	0	936
1977	3,390	0	0	25	0	75	0	0	0	0	3,490
1976	1,525	0	0	0	0	115	0	0	0	0	1,640
1975	9,231	0	0	0	0	0	0	0	0	0	9,231
1974	3,588	0	25	18	975	2,250	0	20	0	50	6,926
1973	17,156	0	0	200	436	1,000	25	400	617	0	19,834
1972	2,626	25	13	4	1	0	0	0	0	0	2,669

Table 6. Counts of kokanee spawning in tributaries of Lake Pend Oreille, Idaho. The numbers shown indicate the highest weekly count at each site.

Year	South Gold	North Gold	Cedar	Johnson	Twin	Mosquito	Lightning	Spring	Cascade	Trestle[a]	Trestle	Total
1998	4,123	623	86	0	268	--	--	3,688	--	348	578	9,714
1997	0	20	6	0	0	--	--	3	--	615	0	644
1996	0	42	7	0	0	--	--	17	--	753	0	819
1995	166	154	350	66	61	--	0	4,720	108	615	21	6,261
1994	569	471	12	2	0	--	0	4,124	72	170	0	5,420
1992	479	559	--	0	20	--	200	4,343	600	660	17	6,878
1991	120	550	--	0	0	--	0	2,710	0	995	62	4,437
1990	834	458	--	0	0	--	0	4,400	45	525	0	6,262
1989	830	448	--	0	0	--	0	2,400	48	466	0	4,192
1988	2,390	880	--	0	0	--	6	9,000	119	422	0	12,817
1987	2,761	2,750	--	0	0	--	75	1,500	0	410	0	7,496
1986	1,550	1,200	--	182	0	--	165	14,000	0	1,034	0	18,131
1985	235	696	--	0	5	--	127	5,284	0	208	0	6,555
1978	0	0	0	0	0	0	44	4,020	0	1,589	0	5,653
1977	30	426	0	0	0	0	1,300	3,390	0	865	40	6,051
1976	0	130	11	0	0	0	2,240	910	0	1,486	0	4,777
1975	440	668	16	0	1	0	995	3,055	0	14,555	15	19,740
1974	1,050	1,068	44	1	135	0	2,350	9,450	0	217	1,210	15,525
1973	1,875	1,383	267	0	0	503	500	4,025	0	1,100	18	9,671
1972	1,030	744	0	0	0	0	350	2,610	0	0	1,293	6,027

(a) September count of early spawning kokanee

Shrimp Abundance

The estimated total mean density of shrimp during June 1998 was 793 shrimp/m^2 (Table 7). This included 367 young-of-the-year (YOY) shrimp/m^2 (<12 mm in total length) and 426 immature and adult shrimp/m^2. Density of immature and adult shrimp at the southern end of the lake declined from 380 in 1997 to 149 shrimp/m^2 in 1998, and declined from 273 to 199 shrimp/m^2 in the center of the lake. At the north end of the lake, densities increased from 102 shrimp/m^2 in 1997 to 930 shrimp/m^2 in 1998. The whole-lake average of immature and adult shrimp (excluding YOY) increased from last year's mean of 252 shrimp/m^2 to this year's mean of 426 shrimp/m^2 (90% confidence interval was ± 93%) (Figure 6).

Limnology

Secchi transparencies averaged 5.4 m at the northern end of Lake Pend Oreille verses 7.3 m and 7.5 m at the middle and southern sections, respectively (Table 8). During spring run-off in June, transparency dropped to its lowest point of 1.2 m at the northern station. The maximum Secchi depth of 11.5 m was recorded at the mid-lake station during August.

Water temperatures in the lake ranged from a low of 3.4^{o}C at the surface during January to a high of 25°C at the surface during August 1998 (Figure 7). Stratification began in early July with water temperatures exceeding 15.8^{o}C. Stratification broke down in late October. Water over 14°C (the upper maximum temperature for shrimp) reached a depth of 17 m in the northern section, 13 m in the middle section, and 15 m in the southern section during the September 16 survey.

Dissolved oxygen concentrations were similar among all three stations in 1998. Concentrations ranged from 12.6 mg/l in May to 8.0 mg/l in September on the south end of the lake; from 12.0 mg/l in April to 7.8 in August at the mid-lake station; and from 12.9 mg/l in April to 7.9 in September at the northern station. As expected, dissolved oxygen declined as temperature increased.

Waterfowl Counts

On January 5, 1999, wildlife biologists recorded seeing only one diving duck on the Idaho portion of the Clark Fork River. They reported 550 dabbler ducks, 9,756 diving ducks, 63 mergansers, 288 Canada geese, 18 tundra swans and 105 coots on the Idaho portion of the Pend Oreille River. On Lake Pend Oreille the counts were: 2,050 dabbler ducks, 17,790 diving ducks, 577 mergansers, 347 Canada geese, 80 tundra swans, and 18,935 coots. The total waterfowl count was 31,520, which does not include 19,040 coots (Figure 8).

Table 7. Densities (per m^2) of opossum shrimp in Lake Pend Oreille, Idaho
June 24-26, 1998. Sections are shown in Figure 1.

| Section - transect	YOY / m^2	Immature & Adults / m^2	Total shrimp / m^2
1-04	232	137	369
1-06	813	495	1308
1-10	470	188	657
1-18	145	81	226
1-21	135	36	172
1-28	292	59	350
1-32	225	42	266
1-49	140	151	291
Section 1 means	306.5	148.6	455.2
2-02	230	105	335
2-03	232	127	359
2-15	408	225	633
2-27	940	153	1,093
2-42	692	265	957
2-52	145	285	430
2-53	846	244	1,090
2-56	1,033	186	1,219
Section 2 means	565.8	198.9	764.7
3-05	309	131	440
3-14	245	414	659
3-38	76	140	216
3-48	126	182	308
3-57	83	165	248
3-67	116	54	170
3-74	450	5,194	5,644
3-86	436	1,160	1,596
Section 3 means	230.3	929.8	1,160
Whole lake means	367.5	425.8	793.3
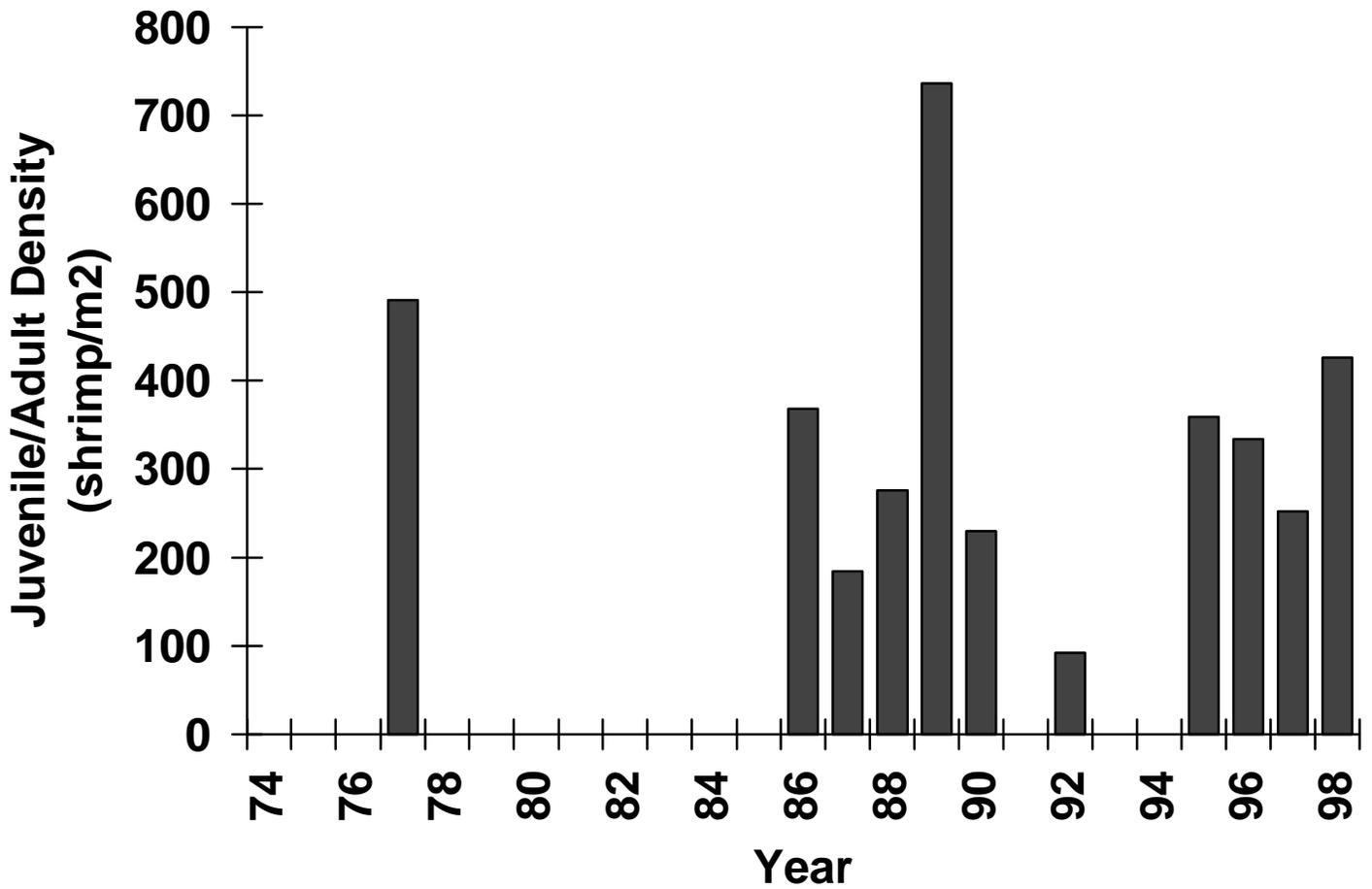
Figure 6. Density of immature and mature opossum shrimp (excluding young-of-the-year shrimp) in Lake Pend Oreille, Idaho. Gaps in the bar chart indicate no data were collected or that the young-of-the-year fraction could not be determined.
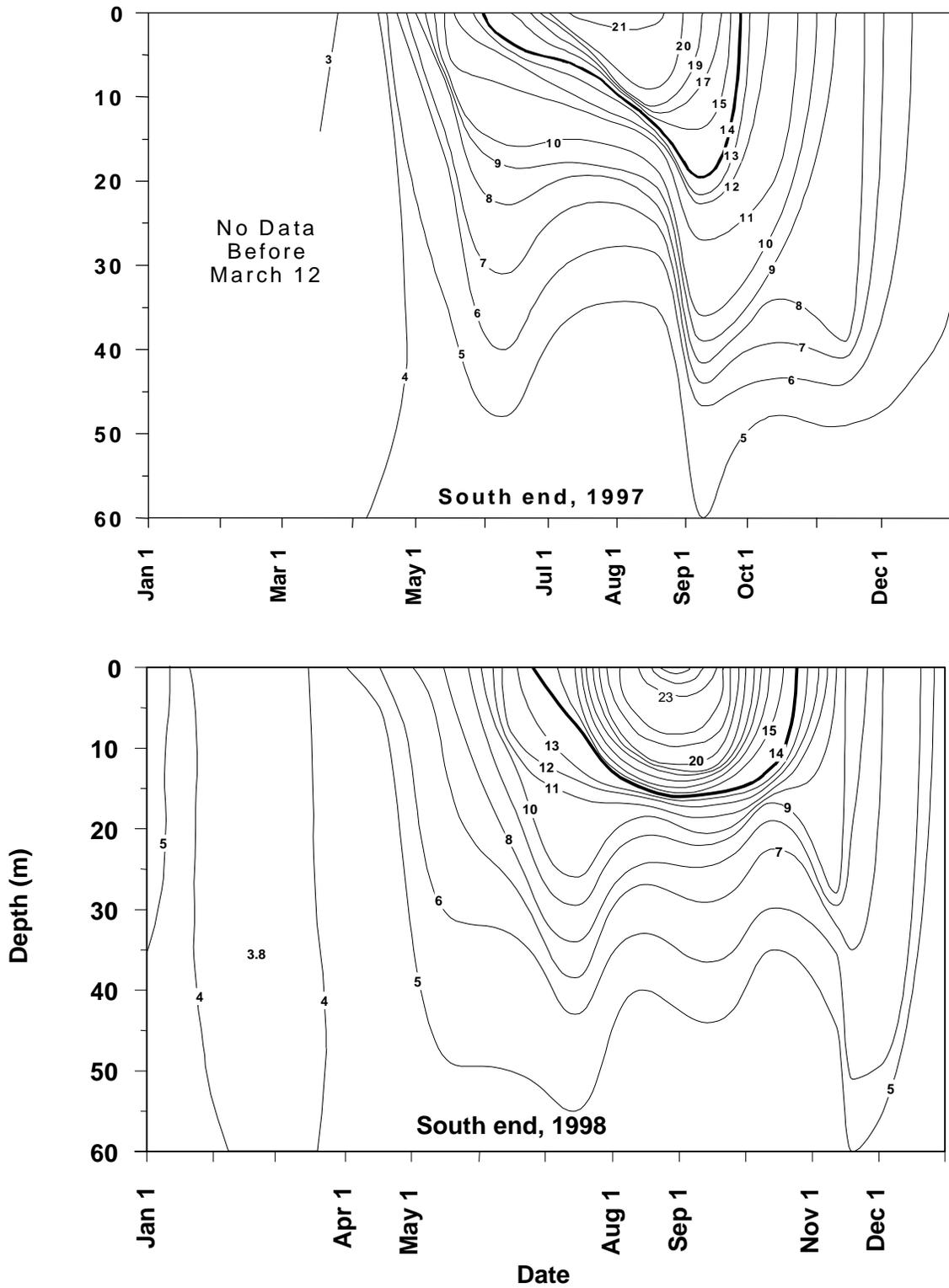
Figure 7. Isopleths of water temperature (C°) in Lake Pend Oreille, Idaho in 1997 and 1998.

Table 8.   Secchi disk transparencies (m) at three locations in Lake Pend Oreille, Idaho
          1953, 1974, 1997, and 1998.

|	April	May	June	July	Aug.	Sept.	Oct.	Mean
Southern station								
1953	11.9	8.0	3.7	6.1	11.6	8.5	12.8	8.9
1974	8.8	7.6	3.7	3.9	9.2	9.1	9.3	7.4
1997	12.5	4.0	2.7	6.5	8.2	9.0	6.2	7.0
1998	9.0	6.0	4.0	5.5	11.0	9.5	7.75	7.5
Mid-lake station								
1953	--	--	3.7	6.1	10.7	12.2	12.2	--
1974	--	5.5	2.3	4.7	9.8	9.4	11.6	--
1997	16.5	5.2	2.0	5.0	7.9	6.8	8.0	7.3
1998	9.0	4.5	3.5	6.0	11.5	10.0	7.0	7.3
Northern station								
1953	3.0	3.7	0.9	6.4	9.4	11.0	10.4	6.4
1974	4.0	0.9	0.4	2.8	9.4	10.2	11.6	5.6
1997	5.3	0.7	1.0	4.0	8.5	5.8	5.5	4.4
1998	5.5	3.2	1.2	4.1	10.0	7.5	6.5	5.4
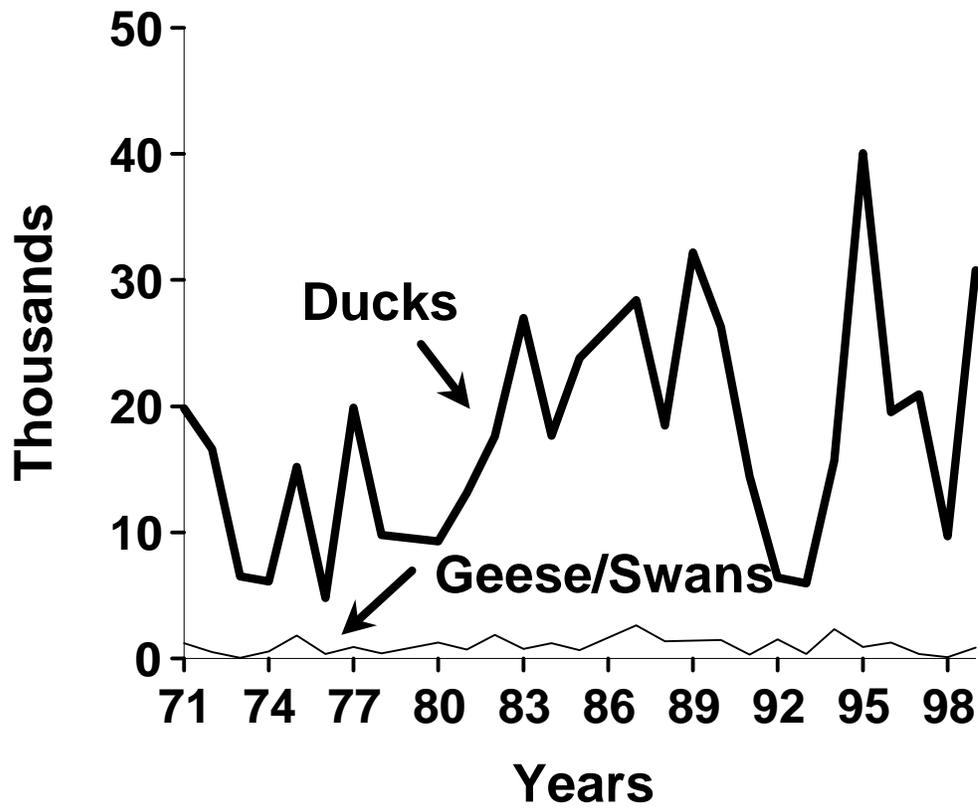
Figure 8. Estimates of waterfowl abundance on Lake Pend Oreille, the Pend Oreille River, and the Clark Fork River, Idaho.

Gravel Sampling

Seventy-one samples of gravel were collected and analyzed at five separate locations. At each site substrates were sorted into bands which were parallel with the shoreline. Substrates varied from very poor spawning potential (99.7% cobble in Garfield Bay) to very high quality spawning gravel (81% gravel with 2% fines in Ellisport Bay)(Figures 9 to 13). Gravel quality varied substantially between sites and between elevations at an individual site.

Riparian Areas

No change was noted in riparian areas of Denton Slough, Trestle Creek, Farragut State Park or Hope (Figures 14-17). Riparian vegetation did not colonize this drawdown zone in any significant amounts.

DISCUSSION

Kokanee Abundance

In previous studies we made several key findings that suggested that higher fall-winter lake levels would improve kokanee abundance (Maiolie et al. 1999). Kokanee readily utilized the new gravels that were made available by higher lake levels. These gravels were cleaner which should have improved the survival of incubating eggs by providing them with more oxygen and allowing waste products to be carried away (Bjornn 1969). Kokanee also appeared to utilize much of the southern half of the lake for spawning. Although not previously mapped, most kokanee were thought to be spawning in the Scenic Bay area as evident in the spawner counts (Table 5). The spreading of spawning activities would have dispersed kokanee redds and minimized their superimposition. This also could have dispersed the fry around the lake, which would minimize the potential for intra-specific competition and may have reduced the potential for predators to key in on kokanee fry.

We noted additional changes in 1998, which indicated that a higher winter lake level was a benefit to the kokanee population. During 1997, the number of eggs laid on the shoreline and in tributary streams was 10.6 million (Table 4). These became 1.026 million wild fry (Table 4) for a survival rate of 9.7%. This was a marked improvement over the three previous years. Egg-to-fry-survival was 1.2% in 1995, two years before the start of the test. In 1996, fry survival was 3.3%. This was the year before the experiment began, but the USACE raised the lake level to 626.5 m (2,055.6 feet) on December 5 as kokanee were spawning. This may have benefited fish spawning at the end of the spawning season. During 1997 egg to fry survival was 1.8% even though the lake was held higher. We attributed the poor survival in 1997 to having the wettest spring on record. This caused sharp declines in all age classes of kokanee including fry (Maiolie et al. 1999). The mechanism for this decline is unclear, but high flows may have caused kokanee to move downstream out of the lake or high dissolved gases may have caused mortalities.

Trestle Creek
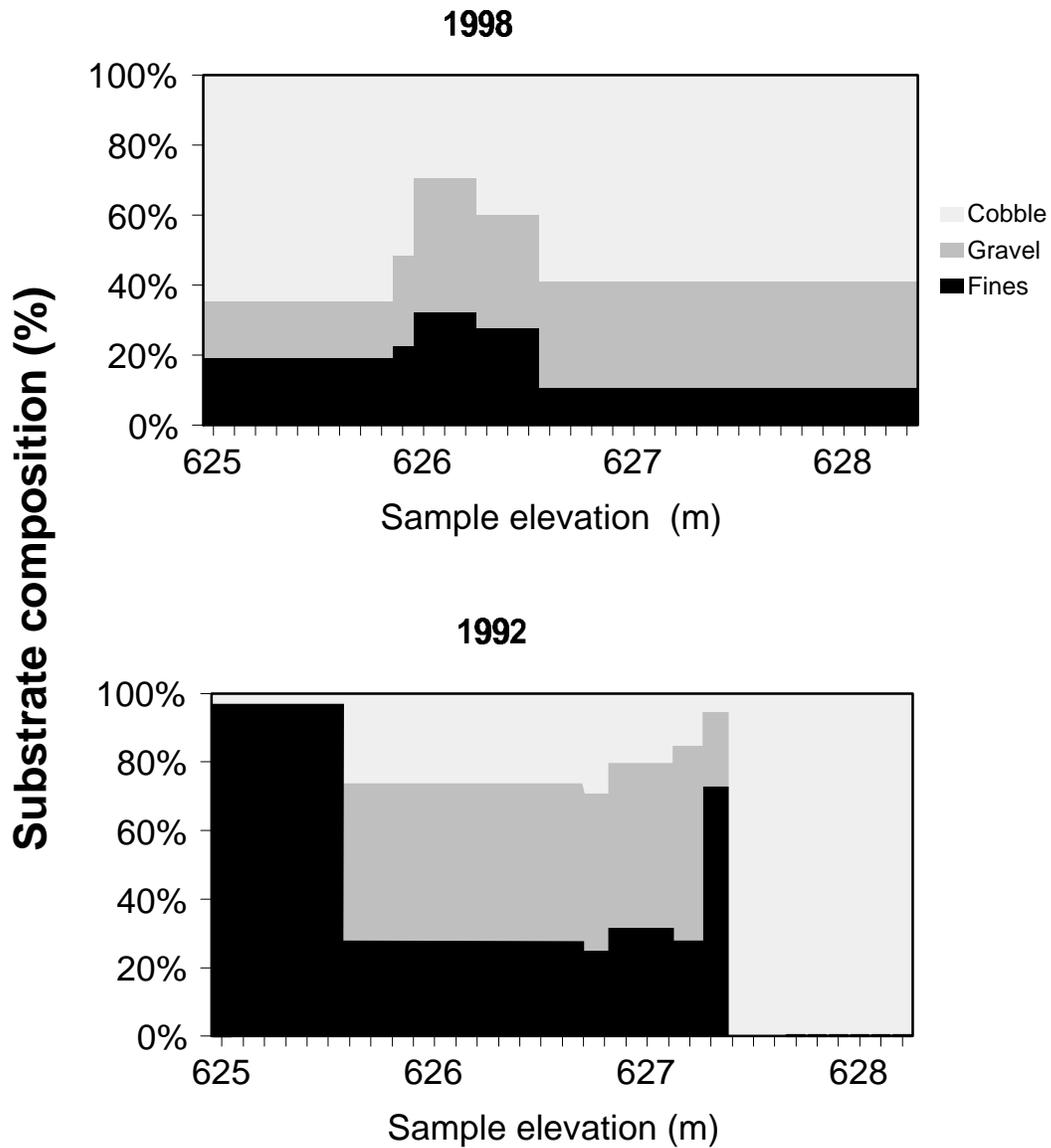
1998

1992

Figure 9. Comparison of substrate composition between two samples taken on the shore of Lake Pend Oreille near Trestle Creek, Idaho in 1992 and 1998.

Hope
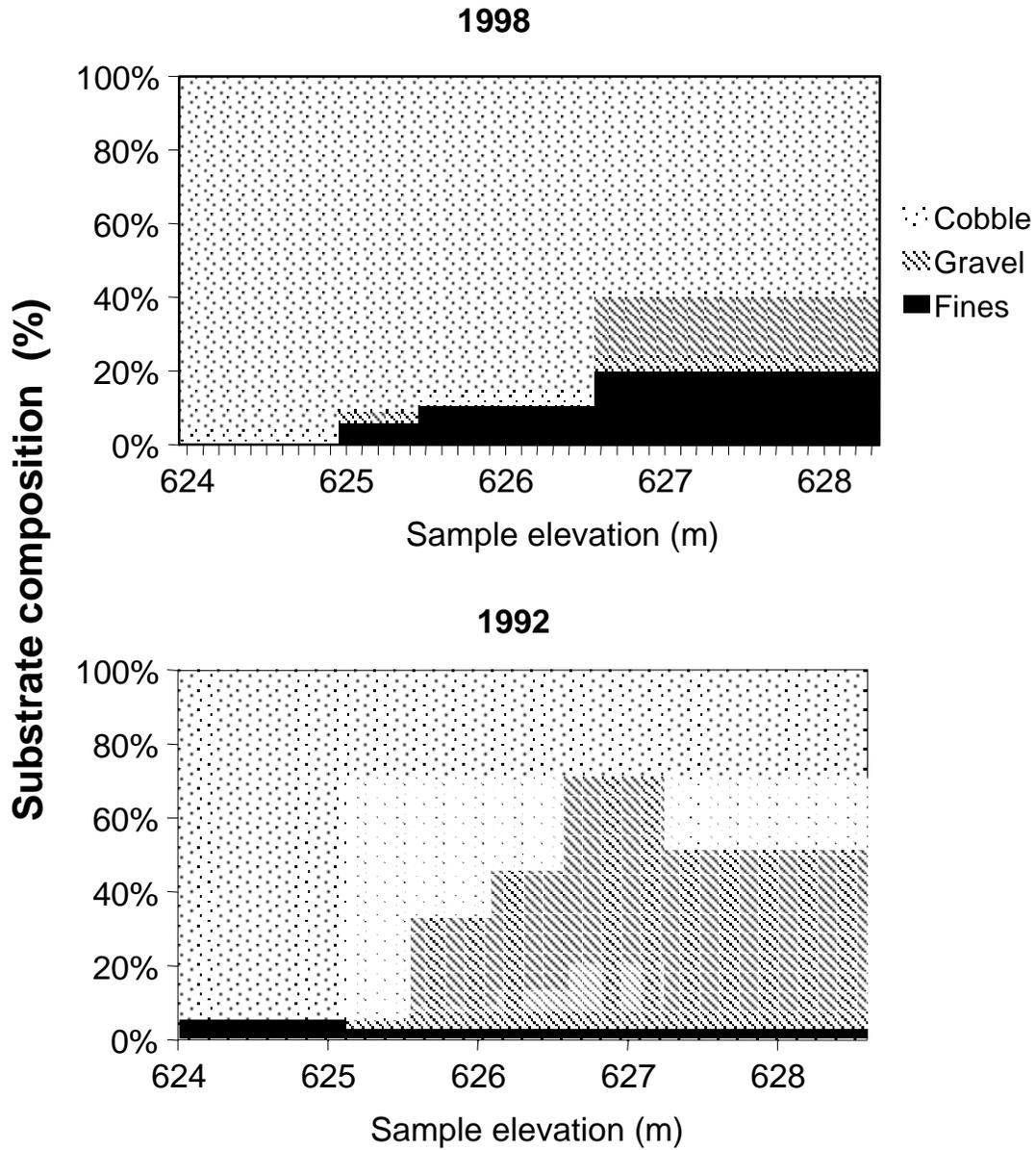
1998

1992

Figure 10. Comparison of substrate composition between two samples taken on the shore of Lake Pend Oreille near Hope, Idaho in 1992 and 1998.

North Gold
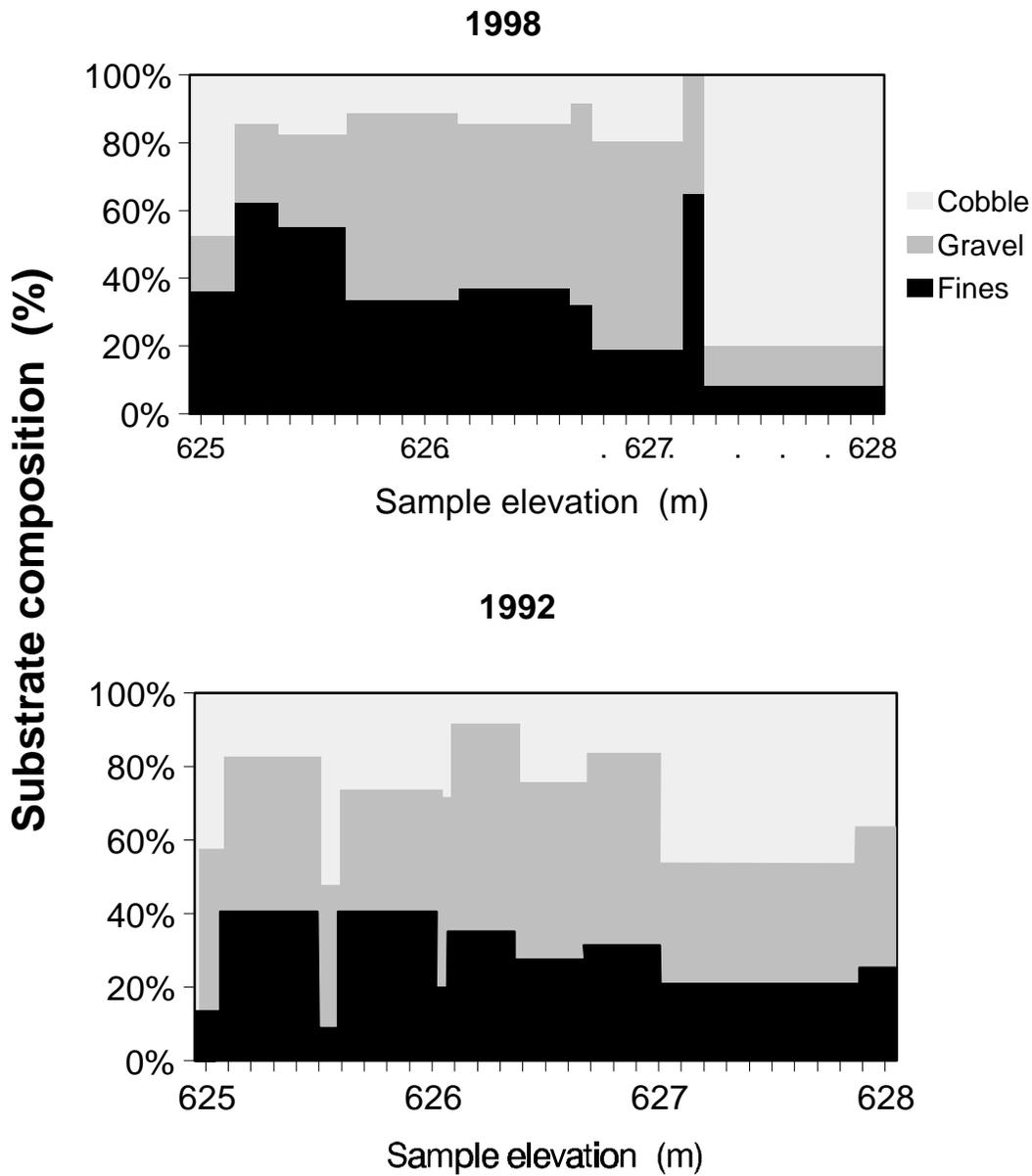
1998

1992

Figure 11. Comparison of substrate composition between two samples taken on the shore of Lake Pend Oreille near North Gold Creek, Idaho in 1992 and 1998.

31

# Ellisport Bay
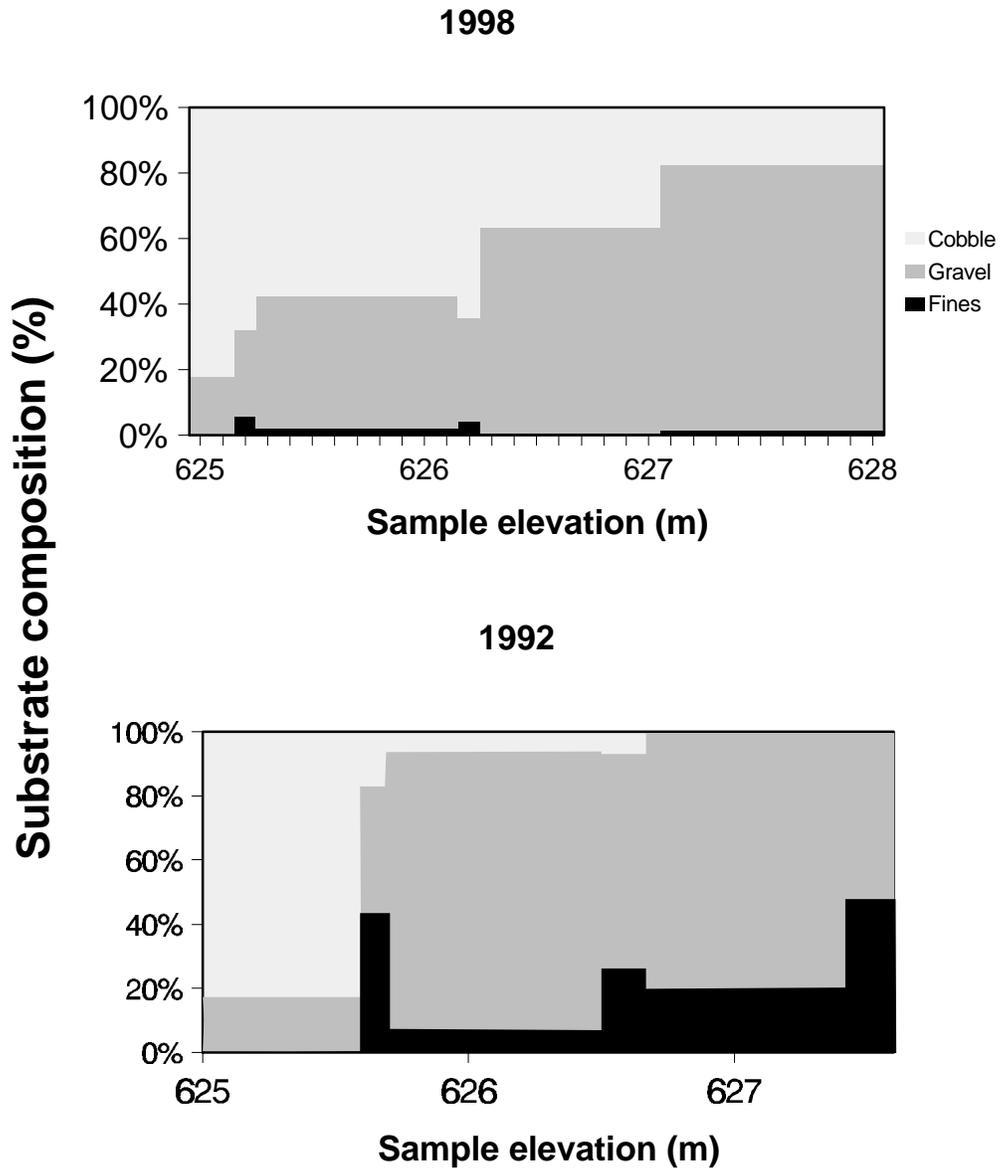
1998

1992

Figure 12. Comparison of substrate composition between two samples taken on the shore of Lake Pend Oreille near Ellisport Bay, Idaho in 1992 and 1998.

Garfield Bay
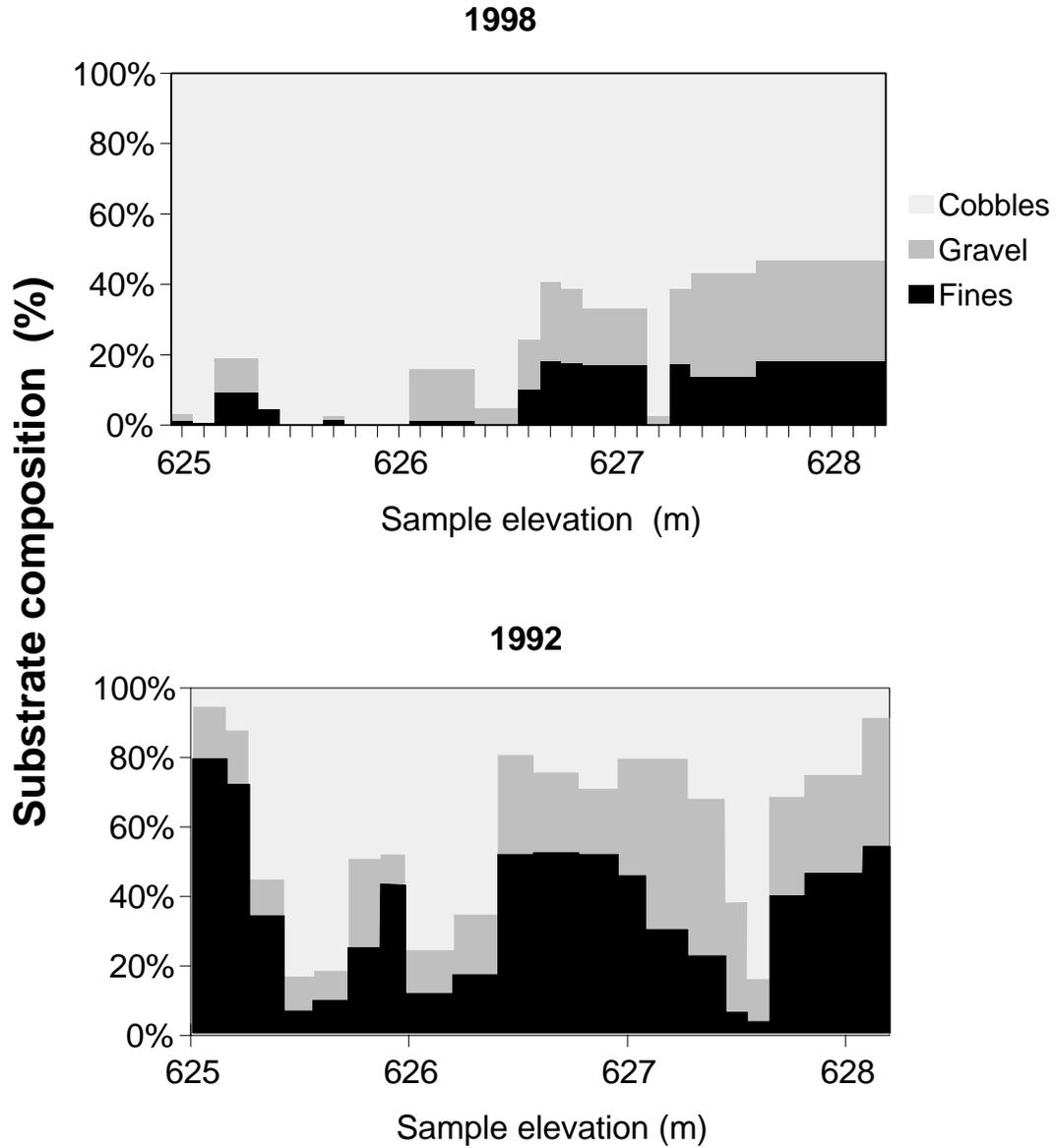
1998

1992

Figure 13. Comparison of substrate composition between two samples taken on the shore of Lake Pend Oreille at Garfield Bay, Idaho in 1992 and 1998.

Figure 14. Shoreline of Lake Pend Oreille, Idaho in Denton Slough with lake elevation at 626.4 m (2,055 feet).

Figure 15. Shoreline of Lake Pend Oreille, Idaho near the mouth of Trestle Creek with lake elevation at 626.4 m (2,055 feet).

Figure 16. Shoreline of Lake Pend Oreille, Idaho near Farragut State Park boat ramp with lake elevation at 626.4 m (2,055 feet).

Figure 17. Shoreline of Lake Pend Oreille, Idaho near Hope with lake elevation at 626.4 m (2,055 feet).

Unfortunately, high run-off in 1997 reduced the numbers of adult kokanee in the lake to their lowest point on record. Consequently, the number of eggs laid in 1997 was at its lowest point on record. Thus, even with the improved wild egg-to-fry survival rate, the number of fry in the lake declined. To this point in the study it appears that higher winter lake levels are causing positive changes in the kokanee population. Additional years of testing are needed before any conclusions should be drawn.

The low kokanee survival rates in 1997 were attributed to the highest spring run-off on record. Survival rate of all year classes improved to varying degrees in 1998 (Table 2). Survival rates from age 0 to age 1 and age 2 to age 3 have returned to about average, however, survival from age 1 to age 2 and age 3 to age 4 remain below average.

This study will also give us a unique opportunity to evaluate the survival of wild and hatchery kokanee as they move into older age classes. Based on hydroacoustics, wild age 0 kokanee in 1997 (2.590 million) became 1.400 million wild age 1 fish in 1998 for a survival rate of 54%. Hatchery produced fry in 1997 (3.496 million) became 0.800 million age 1 kokanee in 1998 for a survival rate of 23%. This indication of poorer survival for hatchery kokanee will be examined annually in future years. Prior to this study, the assumption was that hatchery kokanee would survive as well as wild fish once the initial mortality of stocking them had passed.

The most realistic estimate of the number of kokanee fry in the lake was made by using the hydroacoustic estimate of small fish in each lake section and multiplying it times the percent of hatchery and wild kokanee fry caught in the trawl net in each lake section. By this method the problem of fish avoiding the net could be minimized. Since the trawl net contained panels of mesh that graduated from 32 to 25 to 19 to 13 to 6 mm, we suspect that the trawl was relatively less effective at catching the smaller wild fish which were more likely to pass through the panels. This would have the effect of underestimating wild fry abundance and survival and overestimating these parameters on hatchery fish. A solution to this potential problem would be to sample the lake with a large net (2m2) with small mesh (2 mm) and compare the results to the trawl catch. If a size bias is determined, the percent of hatchery and wild fry in the new net could be used to characterize the hydroacoustic estimates.

Shrimp Abundance

We monitored the shrimp population to determine if changes in shrimp abundance could be affecting kokanee survival. If large changes in the shrimp population occur, then it could have an effect on the experiment's outcome. At the end of the test, kokanee survival rates will be regressed against shrimp abundance to look for correlation.

Young-of-the-year shrimp in Lake Pend Oreille exert little predation mortality on crustacean zooplankton and do not become potential competitors with kokanee until they reach a length of >8 mm (Chipps 1997). Accordingly, the density of immature and mature shrimp provides the best guideline for interpreting potential competition. Immature and mature shrimp in Lake Pend Oreille reached $426/m^2$ in 1998 (Figure 6). This is an increase in the average density over the past three years, but all of the increase occurred in the northern section of the lake.

Limnology

We monitored basic parameters of physical limnology to determine if they influenced the outcome of the lake level experiment. Unusually cold or warm years, for example, could affect survival of fry and possibly bias the test results. Surface temperatures in 1998 were unusually warm and reached 25°C (Figure 7). Warm water (over 14°C) persisted well into October, which may have extended the growing season for zooplankton and kokanee. Limnological results will be more meaningful once the five years of this study are completed and individual years can be compared to the survival of kokanee fry.

Waterfowl Counts

Lake Pend Oreille is an important area for migrating waterfowl as evidenced by the 30,000 waterfowl counted there in January. Higher winter lake levels allow for a significant expansion of aquatic marcophytes around the perimeter of the lake that could be a benefit to their feeding. Numbers of waterfowl on the lake appear to be rather variable and may not be a precise indicator of habitat quality. Their abundance was expected to fluctuate with changes in migration timing, the freezing of other water bodies in northern Idaho, and the nesting success from the previous spring. Counts of waterfowl increased during January 1999 possibly reflecting some improvement in habitat.

Gravel Sampling

We compared gravel samples collected in 1998 with those collected at the same locations in 1992 (Maiolie and Elam 1993). Of particular importance were the amount of fines between 625.1 m (2,051 ft) and 626.7 m (2,056 ft). This is the range of elevations between which the USACE can hold the winter pool level. Between these elevations the amount of fine material declined at the Trestle Creek, Garfield Bay, and Ellisport Bay sites. The amount of fine material remained about the same at the Hope and the North Gold sites. On this basis it does not appear that areas inundated by higher winter lake levels are declining in quality due to sedimentation.

We did note that the composition of shoreline substrates was changing. At some sites such as Garfield Bay and Ellisport Bay, the amount of gravel declined along with the amount of fine material (Figures 12 and 13). At all sites except the North Gold Creek site, there was a general trend for the amount of cobble to increase. This trend needs to be closely monitored in future years.

Riparian Areas

No change was seen in the riparian areas around the lake. Since the drawdown zone is inundated during the growing season and exposed above the water during the winter, the area has not been colonized by vegetation. Lessening the amount of drawdown during this study did not change this fact.

RECOMMENDATIONS

1. We recommend continuing the lake level experiment, as planned.
2. Shoreline spawning gravel should be monitored on an annual basis. The amount of fine material and gravels should be closely examined.
3. Developing a large, fixed-frame, small mesh net should more closely monitor kokanee fry abundance. This could be used in conjunction with the hydroacoustic estimates to get a better estimate of the abundance of hatchery and wild fry.

ACKNOWLEDGMENTS

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Appendix A.   Definition of areas surveyed for shoreline spawning kokanee in Lake Pend Oreille since 1972.

Scenic Bay
- From Vista Bay Resort to Bitter End Marina (the entire area within the confines of these two marinas).
-
Farragut State Park
- From state park boat ramp go both left and right approximately 1/3 km.
- Idlewild Bay, From Buttonhook Bay north to the north end of the swimming area parking lot.
-
Lakeview
- From mouth of North Gold Creek go north 100 meters and south 1/2 km.
Hope/East Hope

- Start at the east end of the boat launch overpass and go west 1/3 km.
- From Strong Creek go west and stop at Highway 200. Go east to Litehouse Restaurant.
- Start at East Hope Marina and go west stopping at Highway 200.
-
Trestle Creek Area
- From the Army Corps of Engineers recreational area boat ramp go west to mouth of Trestle Creek, including Jeb and Margaret's RV boat launch area.
-
Sunnyside
- From Sunnyside Resort go east approximately 1/2 km.
-
Garfield Bay
- Along docks at Harbour Marina on east side of bay.
- From the Idaho Fish and Game managed boat ramp go toward Garfield Creek. Cross Garfield Creek and proceed 1/4 km.
- Survey Garfield Creek up to road culvert.
-
Camp Bay
- Entire area within confines of Camp Bay.
-
Fisherman's Island
- Entire Island Shoreline - not surveyed since 1978.
-
Anderson Point
- Not surveyed since 1978.

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