FISHERY RESEARCH

KOKANEE AND RAINBOW TROUT RESEARCH, LAKE PEND OREILLE, 2008

LAKE PEND OREILLE FISHERY RECOVERY PROJECT

ANNUAL PROGRESS REPORT
March 1, 2008—February 28, 2009

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ABSTRACT

During 2008, we examined the response of kokanee *Oncorhynchus nerka* to alterations in winter water levels designed to improve the spawning and incubation success of wild kokanee and to a large-scale predator reduction program aimed at reducing predation by lake trout *Salvelinus namaycush* and rainbow trout *Oncorhynchus mykiss*. We conducted hydroacoustic surveys and trawling during August 2008 to assess the kokanee population and determine the impacts of these experimental alterations. We estimated the total kokanee abundance at 7.0 million (307 kokanee/ha) with a wild fry population of 648,000. We estimated egg-to-fry survival to be 36%, while survival from age-1 to age-2 was 32%. Peak visual counts of spawning wild kokanee were 669 fish on the shoreline, 850 early-run tributary spawners, and 291 late-run tributary spawners. The counts of late-spawning kokanee were still some of the lowest on record, but this marks the first year that early-spawning kokanee were seen in tributaries along the east shore of Lake Pend Oreille. The kokanee population is showing the first signs of rebounding in years, but abundance is low and hatchery-raised fish currently dominate the population. Substrate at monitoring sites indicated gravel composition for wild shoreline-spawning kokanee has decreased since the last full drawdown in 2004.

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INTRODUCTION

Lake Pend Oreille once provided the largest kokanee *Oncorhynchus nerka* fishery in the state of Idaho. Between 1952 and 1966, harvests of kokanee averaged 1 million kokanee/yr with up to 522,692 angler-hours of fishing pressure (Jeppson 1953; Maiolie and Elam 1993). From 1966 to 1985, kokanee harvest dramatically declined, reaching a low of 71,208 kokanee harvested and only 179,229 angler hours in 1985 (Bowles et al. 1987; Maiolie and Elam 1993). Fall and winter drawdowns of the lake for flood control and power production led to much of the kokanee decline (Maiolie and Elam 1993). In 2000, Idaho Department of Fish and Game closed the kokanee fishery because of low adult kokanee abundance. High predation by lake trout *Salvelinus namaycush* and rainbow trout *Oncorhynchus mykiss* on the kokanee stocks led to continued declines in kokanee after 2000 (Maiolie et al. 2002; Maiolie et al. 2006a).

Since 1996, the U.S. Army Corps of Engineers has manipulated the winter drawdown of Lake Pend Oreille to either 625.1 or 626.4 m above mean sea level (MSL) in an attempt to increase kokanee abundance. The lower lake level has allowed wave action to sort gravels and restore kokanee spawning habitat (Maiolie et al. 2004), while kokanee egg-to-fry survival is over 150% higher under the higher winter lake level (see Maiolie et al. 2002). Winter lake level alterations are part of a long-term experiment to enhance kokanee spawning and incubation success. The winter water level of Lake Pend Oreille had been 625.6—626.4 MSL during 2005 to 2008. During the winter of 2007-08, the winter water level of Lake Pend Oreille was lowered to 626.4 MSL with the last full drawdown to 625.1 MSL occurring in 2003 (Figure 1). We monitored the kokanee population to evaluate their response to this experiment. We also examined the quality of potential spawning areas using substrate core sampling to see how lake level changes affected spawning habitat. Additionally, we estimated abundance of the nonnative, zooplanktivorous *Mysis* shrimp *Mysis relicta* to continue expanding the long-term data set and to monitor for potential effects they have on the kokanee population.

While it appears that lake level management has increased kokanee egg-to-fry survival (Maiolie et al. 2006b), the abundance of harvestable-sized kokanee has dropped due to high predation rates. We therefore increased our efforts to monitor predator abundance during the removal efforts. We used both down-looking and up-looking hydroacoustic surveys in an attempt to enumerate large fish in the pelagic area of the lake. Although up-looking hydroacoustics proved mostly unsuccessful in 2006 and 2007, we modified methods during 2008 with hopes of developing this as a useful technique for estimating rainbow trout abundance. If reliable, hydroacoustic surveys would be a less time consuming way to monitor predator abundance than mark-recapture techniques.

STUDY AREA

Lake Pend Oreille is located in the northern panhandle region of Idaho (Figure 2). It is the state’s largest and deepest lake, with a surface area of 32,900 ha, a mean depth of 164 m, and a maximum depth of 357 m. 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 in which thermal stratification typically occurs from late June to September (Maiolie et al. 2002) with epilimnetic temperatures averaging about 9°C (Rieman 1977). Operation of Albeni Falls Dam on the Pend Oreille River keeps the lake level high and stable at 628.7 m above MSL during summer (June-September), followed by lower lake levels of 626.4 m or 625.1 m during fall and winter. Littoral areas are limited and most shorelines areas have steep slopes.

A diverse assemblage of fish species is present in Lake Pend Oreille. Native game fish include bull trout *Salvelinus confluentus***,** westslope cutthroat trout *O. clarkii lewisi*, and mountain whitefish *Prosopium williamsoni.* Native nongame fishes include pygmy whitefish *P. coulterii*, slimy sculpin *Cottus cognatus*, five cyprinid species, and two catostomid species. The most abundant nonnative game fish present are kokanee, Gerrard rainbow trout, lake trout, lake whitefish *Coregonus clupeaformis*, and smallmouth bass *Micropterus dolomieu*. Less abundant introduced sport fishes include northern pike *Esox lucius*, brown trout *Salmo trutta*, largemouth bass *M. salmoides*, and walleye *Sander vitreus* (Hoelscher 1992).

Historically, bull trout and northern pikeminnow *Ptychocheilus oregonensis* were the top native predatory fish in Lake Pend Oreille (Hoelscher 1992). The historical native prey population included mountain whitefish, pygmy whitefish, slimy sculpin, suckers *Catostomus spp*., peamouth *Mylocheilus caurinus*, and redside shiner *Richardsonius balteatus*, as well as juvenile salmonids (bull trout and westslope cutthroat trout). Presently, the predominant predatory species are lake trout, rainbow trout, bull trout, and northern pikeminnow.

PROJECT GOAL

The Lake Pend Oreille Fishery Recovery Project's goal is to recover the sport fisheries in the lake that have been impacted by the federal hydropower system and to enhance the Lake Pend Oreille ecosystem to benefit fish and wildlife, thereby enhancing fishing, recreational opportunities, and other resource values. This is to be accomplished while managing the lake levels for the balanced benefit of fish, wildlife, flood control, and power production.

PROJECT OBJECTIVES

1. Recover kokanee abundance to a population level that can support an average annual harvest of 300,000 fish and catch rates of 1.5 fish per hour by 2015.

2. Have no net decline in the amount of shoreline spawning gravel (maintain 1.7 million sq ft) due to erosion or siltation during this experiment.

3. Have a hatchery stocking program that contributes 375,000 kokanee to the harvest.

METHODS

Kokanee Abundance and Survival

We conducted a lakewide hydroacoustic survey on Lake Pend Oreille to estimate the abundance of kokanee. We performed surveys at night between August 19 and 22, 2008. We used a Simrad EK60 portable scientific echo sounder equipped with a 120 kHz split-beam transducer mounted on a pole located 0.54 m below the surface, off the port side of a 7.3 m boat, with the transducer pointing downward and set to ping at 0.6 s intervals. Prior to the surveys, we calibrated the echo sounder for signal attenuation to the sides of the acoustic axis using Simrad's EK60 software. Calibration settings for the echo sounder are listed in Appendix A.

We used a stratified systematic sampling design in our hydroacoustic surveys. We followed a uniformly spaced, zigzag pattern of transects while traveling from shoreline to shoreline, as described by MacLennan and Simmonds (1992). The starting point of the first transect in each section was chosen randomly. Twenty-one transects were completed in the lake with eight in the southern section, six in the middle section, and seven in the northern section (Figure 2). Transect lengths ranged from 3.6 to 7.7 km and were located using a global positioning system (GPS). For all transects, we maintained a speed of approximately 1.3 m/s (boat speed did not affect our calculations of fish density).

We estimated kokanee abundance with echo integration techniques using Echoview software version 3.10.135.03. Hydroacoustic traces (a single returned echo from a fish) were accepted if they were between -60 and -33 decibels (dB) and the echo length was between 30% and 180% of the original pulse length at a point 6 dB below the peak echo value. Additionally, the correction value returned from the transducer gain model could not exceed a two-way maximum gain compensation of 6 dB (therefore it included all targets within the 3 dB beam width) and the maximum standard deviation of the minor and major axis angles was less than 0.6 degrees.

We used targets that met the above criteria to calculate kokanee density estimates in each transect. In the Echoview software, we drew a box around the kokanee layer on each echogram to define the area sampled (usually between the 10 m and 50 m depths). We integrated the area in the box to obtain the nautical area scattering coefficient (NASC) and analyzed to obtain the mean target strength of all returned echoes. This integration accounted for fish that were too close together for detection as a single target (MacLennan and Simmonds 1992). Pelagic habitat used by kokanee is approximately 22,646 ha, defined by the 91.5 m contour in sections 1 and 2 and the 36.6 m contour in section 3 (Figure 2; Bowler 1978). We calculated densities using the following equation (see Parker-Stetter et al. 2009):

$$\text{Density (fish/ha)} = (\text{NASC} / 4\pi 10^{TS/10})\ 0.00292$$

where:

NASC = the total backscattering in m^2/nautical $mile^2$, and

TS = the mean target strength in dB for the area sampled

To determine a lakewide kokanee population estimate, we first log transformed [log (x+1)] the density estimates to calculate a geometric mean density. We then multiplied the geometric mean density of kokanee in each lake section by the area therein. Finally, we summed abundance in each of the three sections to estimate the total population.

Once density estimates for kokanee were determined, we calculated 90% confidence intervals for lakewide density estimates by standard formulas for stratified sampling designs (Scheaffer et al. 1979) using log transformed data [log (x+1)]:

$$\bar{x} \pm t_{n-1}^{90} \sqrt{\frac{1}{N_{total}^2} \sum_{i=1}^{3} N_i^2 \left(\frac{N_i - n_i}{N_i} \right) \frac{s_i^2}{n_i}}$$

where:

$\bar{x}$ = the estimated mean density of kokanee in the lake (fish/ha),

t = the Student's t value,

N_i = the number of possible samples in a section i,

n_i = the number of samples collected in a section i, and

s_i = the standard deviation of the samples in strata i.

To separate kokanee fry from older age classes, a target-strength frequency histogram was created for all individual fish traces (a single returned echo off a single fish). We used the low point on the histogram as the break between fry and older kokanee.

To partition out age-1 thru age-4 kokanee, we sampled fish using midwater trawling in Lake Pend Oreille from August 26 to 29, 2008. These dates were during the dark phase of the moon, which optimized the capture efficiency of the trawl (Bowler et al. 1979). We randomly selected 12 locations within each section and made hauls in a predetermined, random direction from the selected point (Figure 3).

Rieman (1992) described in detail the sampling procedures for midwater trawling. However, the net used in our study was somewhat different. We used a fixed frame net, measuring 10.5 m long with a 3.0 m tall x 2.2 m wide mouth. This net had a rigid steel frame that kept the mouth of the net open and, therefore, did not have otter boards preceding the net mouth. Mesh sizes (stretch measure) graduated from 32 mm towards the mouth of the net through 25 , 19, and 13 mm in the body of the net and finally to 6 mm in the cod end. We towed the net through the water at a speed of 1.58 m/s using an 8.8 m boat. We determined the vertical distribution of kokanee by using a Furuno Model FCV-585 depth sounder with a 10° hull-mounted transducer. A stepwise oblique tow was conducted along each transect that sampled the entire vertical distribution of kokanee. Each tow consisted of three to six 3-minute steps and represented a 3 m deep portion of the depth zone occupied by kokanee.

We collected kokanee from each trawl transect and placed them on ice until morning when they were processed. Fish were counted, weighed (g), and measured (mm TL). Additionally, we checked all kokanee over 180 mm for maturity. Two independent readers aged fish using scales from 10 to 15 fish in each 10 mm size interval and removed otoliths from these fish. We estimated abundance of age-1 thru age-4 kokanee by partitioning the hydroacoustic survey results into age classes using the proportions of each age captured by trawling in each section. From these proportions, we calculated annual survival between age classes.

Hatchery and Wild Kokanee Abundance

All kokanee produced at the Cabinet Gorge Fish Hatchery since 1997 have been marked by "thermal mass-marking" techniques (or cold branding) described by Volk et al. (1990). Therefore, hatchery kokanee of all ages contain distinct thermal marks. Hatchery personnel initiated thermal treatments five to ten days after fry entered their respective raceways and sacrificed ten fry from each raceway to verify the thermal marking.

To determine hatchery and wild kokanee abundance, we sent otoliths from kokanee captured during the midwater trawl survey to the Washington Department of Fish and Wildlife (WDFW) Otolith Laboratory where WDFW personnel checked them for cold-brand hatchery marks. However, to sample kokanee fry more effectively, we also conducted a survey using a smaller mesh trawl net. Sampling with the fry net began on Lake Pend Oreille in 1999 and has continued annually thereafter. We made eight net hauls per lake section during September 1-2, 2008 (the same new moon period as that year's midwater trawling) using a similar methodology to that of the midwater trawl (Figure 4). The fry net was 1.27 m high by 1.57 m wide across the mouth (2 m^2) and 5.5 m in length. Bar mesh size for the net was 0.8 mm by 1.6 mm. The sampling bucket, on the cod end of the net, contained panels of 1 mm mesh. All kokanee caught in the fry net were immediately frozen on dry ice. Upon return to the dock, the fry were stored in a freezer until analyzed.

Fish were later thawed and measured for length and weight. We removed and sent 88 pairs of otoliths to the WDFW Otolith Laboratory. Additionally, otoliths from 168 kokanee fry and 133 kokanee between ages 1-4 captured in the midwater trawl were sent to the WDFW Otolith Laboratory.

At the WDFW lab, personnel removed one otolith from each vial and oriented it on a glass plate under a fume hood. Then, the otoliths were surrounded with a preformed rubber mold; the molds were filled with clear fiberglass resin and warmed in an oven for approximately 1 h to cure. 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. Finally, the otoliths were examined with a compound microscope at 200- and 400-power magnification. Cold brand patterns within the otolith were compared to reference samples taken from the hatchery during fry rearing. Also, kokanee with hatchery origins were separated out by strain (early or late). For accuracy, two independent readers examined each otolith. Readers settled differences by re-examination.

We calculated the percentage of wild and hatchery kokanee within each 10 mm length group to estimate the percent of wild and hatchery fry in the lake. We then multiplied the percent of wild fish by the hydroacoustic population estimate for each length group. Finally, we summed these values to determine the abundance of wild fish in the lake.

Kokanee Egg to Fry Survival

We used hydroacoustic data to estimate the potential egg deposition (PED) of wild-spawning kokanee. The acoustic estimate of ages 1-4 kokanee (-45.9 dB to –33 dB) in each lake section was multiplied by the percentage of mature kokanee caught in the midwater trawl in that section. We then divided this number by two (assuming a 1:1 ratio of males to females as determined in past years) to obtain the number of females. To obtain the number of wild spawners, we subtracted the number of mature female kokanee collected at the Sullivan Springs Creek fish trap from the population estimate of mature female kokanee. To estimate PED by wild kokanee, we multiplied the wild spawner estimate by mean kokanee fecundity, determined by a total length to fecundity regression developed for Sullivan Springs Creek kokanee over the past ten years (IDFG, unpublished data). Finally, to estimate wild kokanee egg-to-fry survival we divided the estimated number of wild kokanee fry by the previous year's PED.

Historical Trawling Comparisons

In addition to hydroacoustic abundance estimates, we calculated kokanee abundance based on the catch from the midwater trawl and fry trawl samples. These estimates were conducted strictly for comparisons with historic data (kokanee abundance was estimated using trawling alone until 1995), since hydroacoustics provide a more accurate abundance estimate.

Kokanee abundance was calculated by dividing catch per trawl haul by the volume of water filtered by the net (while in the kokanee layer) to obtain density of kokanee at each trawl site. We expanded the age-specific density estimates for each section to a whole-lake population estimate and calculated 90% confidence intervals using standard formulas for stratified sampling designs described previously for hydroacoustic estimates (Scheaffer et al. 1979). Kokanee abundance was estimated using geometric [log (x+1)] means. We calculated the area of the two southern sections along the 91.5 m depth contour and the northern section along the 36.6 m depth contour because of shallower maximum water depth. The 91.5 m contour represents the pelagic area of the lake containing kokanee during late summer (Bowler 1978). For consistency, we have used these same areas (totaling 22,646 ha) each year since 1978.

Predator Abundance

We also used the down-looking hydroacoustics survey to estimate the abundance of large pelagic fish in the open waters of Lake Pend Oreille using echo-counting techniques with Echoview software version 3.10.135.03. We examined hydroacoustic traces (a single returned echo from a fish) if they were over -37 dB and met the previously described criteria used for kokanee traces. Fish tracks (a series of traces returned from the same fish) were defined as a large pelagic fish if they met several criteria: 1) the average target strength of all traces was >-30 dB, 2) it was not aggregated with other similar sized fish, 3) it was between the surface and a depth of 35 m, and 4) it was in water >75 m deep (bottom depth). We totaled the number of traces on each larger fish within the 3 dB beam width, binned them into 1 m depth groups, and calculated the area sampled for each bin by multiplying the number of pings on the transect by the beam width at the center of the bin. Finally, we estimated fish density by dividing the total number of fish traces in each bin by the area sampled.

A weighted (by transect length) average density was calculated for each lake section and multiplied by the area of that section to generate a population estimate. Pelagic habitat used by predators is 21,332 ha and follows the 70 m contour. To estimate the total population size, we summed abundance in each of the three sections. We calculated a 90% confidence interval for the lakewide abundance estimate by standard formulas for stratified sampling designs (Scheaffer et al. 1979) described previously.

Because a substantial portion of acoustic-tagged predators, especially rainbow trout, used water depths that would not be sampled effectively in down-looking hydroacoustic estimates (<10 m; Maiolie et al. 2006a), up-looking hydroacoustic surveys were conducted to estimate large pelagic fish abundance near the surface (portion of the water column in which the down-looking survey finds few fish). Daytime surveys occurred on June 4, 8, 20, and 22, 2008. Weather conditions dictated survey dates. Surface disturbance from winds affected previous up-looking hydroacoustic survey attempts, so we only conducted surveys during calm conditions. The echo sounder used was the same as described for our down-looking survey. We used an 8.8 m boat to tow a 1.9 m torpedo-shaped towed body. The transducer was mounted near the center of the towed body and pointed upward (Figure 5). We lengthened the transducer cable with an additional 100 m of cable equipped with Seacon waterproof connectors at each end. The boat's winch cable deployed and retrieved the towed body. After deploying the towed body, we attached the cable to a large planer board measuring approximately 1.5 m long by 0.5 m high positioned on the starboard side of the boat to move the towed body out and away from the boat's propeller wash to avoid fish disturbance. The weighted towed body ran at a depth of approximately 30 m below the surface when pulled on a 100 m length of cable. This placed the towed body about 95 m behind the boat and provided a clear view of the surface. Because of the depth of the towed body, we only sampled transects where water depths exceeded 75 m. To correct for using the additional 100 m length of transducer cable, the hydroacoustic gear was recalibrated separately. Specific echo sounder settings used for these surveys are in Appendix A. Data were viewed and analyzed using Echoview software in the same manner as for down-looking predator estimates.

Kokanee Biomass, Production, and Yield

We calculated the biomass, production, and yield of the kokanee population in Lake Pend Oreille to determine the effects of predation using hydroacoustic population estimates and kokanee weights from the trawl catch for these calculations. Biomass was the total weight of kokanee within Lake Pend Oreille at the time of our population estimate, calculated by multiplying the population estimate of each kokanee year class by the mean weight of kokanee in that year class. Finally, we summed the year class weights to obtain total kokanee biomass in the lake.

Production is the growth in weight of the kokanee population regardless of whether the fish was alive or dead at the end of the year (Ricker 1975). To determine production of a kokanee age class between years, we subtracted the mean weight of kokanee in each year class of the previous year from the current year's mean weight of the same cohort. We then averaged the population estimates between the two years. Finally, we multiplied the increase in mean weight by the average population estimate for each age class and summed the results for all of the year classes to determine the production for the entire population. These calculations assumed linear rates of growth and mortality throughout the year. Hayes et al. (2007) provides additional details on this summation method for estimating production.

Yield refers to the total biomass lost from the population due to all forms of mortality (e.g., natural, predation) between years (Ricker 1975). To determine annual yield for each age class, we calculated the mean weight per fish between the current and previous year. We then subtracted the population estimate of the current year from the previous year (for each age class) to determine the number of fish that died. Finally, we multiplied the mean weight by the number that died to estimate the yield for each age class. Results were summed across all age classes to estimate total yield for the kokanee population. Again, calculations assumed linear rates of growth and mortality throughout the year.

We plotted both production and yield against kokanee biomass to examine the rate of decline within this population using data from 1996 through 2008. The production to biomass curve was forced through the origin. However, we excluded the flood year of 1997 since significant kokanee mortality occurred that was likely not due to predation.

Kokanee Spawner Counts

We counted spawning kokanee in standard shoreline areas (Appendix B) and tributaries to continue time-series data dating back to 1972. All areas surveyed are historic spawning sites (Jeppson 1960). Nine shoreline areas and seven tributary streams were surveyed approximately weekly during the duration of time that kokanee were present. Shoreline counts occurred November 7-December 21, 2008, and tributary stream counts occurred November 17-December 5. We counted all kokanee, either alive or dead. Seven tributary streams were surveyed by walking upstream, from their mouth to the highest point utilized by kokanee. Streams included South Gold Creek, North Gold Creek, Cedar Creek, Johnson Creek, Twin Creek, Spring Creek, and Trestle Creek. In addition, a survey for the early spawning run of kokanee in Trestle Creek and east shore tributaries (Cedar, North Gold, and South Gold creeks) occurred on September 22 and 26, 2008, respectively.

Kokanee Spawning Habitat

We have sampled six sites annually to assess changes in substrate composition since the last full drawdown event during the winter of 2003-2004. These sites include Twin Creek, Green Bay, Ellisport Bay, Kilroy Bay, south of Evans Landing, and the south side of Ellisport Bay. In July 2008, divers collected six randomly located samples from a gravel band between elevations 624.8 and 625.8 MSL at each site. Divers scooped approximately two liters of substrate into a container and sealed it underwater to eliminate the loss of fine material during transport to the surface. Samples air dried before each sample was screened using soil sieves (sizes 31.5 mm, 6.3 mm, 4.0 mm, and 2.0 mm). We weighed the substrate retained on each sieve and the substrate that fell through the finest screen and calculated a percent of the weight of the total sample. We defined “cobble” as substrates that were 31.5 mm and larger, “gravel” as substrates between 31.5 and 4.0 mm, and “fines” as the substrate smaller than 4.0 mm. We modified these size breaks from several other studies (Chapman and McLeod 1987; Cochnauer and Horton 1979; Irving and Bjornn 1984).

Mysis Shrimp Abundance

We sampled *Mysis* shrimp from June 2-3, 2008 to estimate their density within Lake Pend Oreille. 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 *Mysis* shrimp and for all of our sampling since 1997. From 1997-2003, ten random sites were sampled from each of the three lake sections; however, in 2004-2006, the number of sample sites increased to 15. Because we have been unable to identify any impacts *Mysis* shrimp have on kokanee, we determined that eight random sites were sufficient in each lake section to estimate *Mysis* shrimp abundance for the long-term data set. Therefore, we have sampled eight sites since 2007, and Figure 6 displays the sites used in 2008.

We collected *Mysis* shrimp using a 1 m hoop net equipped with a Kahl Scientific pygmy flow meter with an anti-reversing counter. Net mesh and collection bucket mesh measured 1,000 μm and 500 μm, respectively. Using an electric winch, we lowered the net to a depth of 45.7 m, allowed it to settle for 10-15 seconds, and raised it to the surface at a rate of 0.5 m/s. Collected *Mysis* shrimp were preserved in 50% denatured ethanol until laboratory analysis was performed. This methodology has been standard since 1997.

During laboratory analysis, *Mysis* shrimp were classified as either young-of-the-year (YOY; <11 mm total length) or adult (≥11 mm total length) and counted in each sample. Seven samples were randomly selected to determine sex and length-frequency distributions. We examined *Mysis* shrimp under a dissecting scope to determine sex, and total length was measured from the tip of the rostrum to the end of the telson, excluding setae. *Mysis* shrimp were then classified into five categories according to sexual characteristics: young-of-the-year (YOY), immature male, immature female, mature male, and mature female (Pennak 1978). We based density estimates on the number of *Mysis* shrimp collected in each sample and the volume of water filtered as determined by the flow meter. We calculated the arithmetic means for the immature and adult portion of the *Mysis* shrimp population and for the YOY portion. We also calculated the 90% confidence interval (CI) for the immature and adult estimate.

RESULTS

Kokanee Abundance

In 2008, we estimated the lake contained 7.0 million kokanee (6.2 million to 7.8 million, 90% CI) or 307 fish/ha, based on our standard nighttime hydroacoustic survey. This included 4.8 million kokanee fry (4.2 million to 5.4 million, 90% CI; Table 1) and 2.2 million (2.0 million to 2.5 million, 90% CI) kokanee of ages 1-4 (Table 2). The lake contained an estimated 1.3 million age-1, 754,000 age-2, 111,000 age-3 kokanee, and 39,000 age-4 kokanee. Mean target strengths of kokanee traces showed a separation between kokanee fry and larger fish at –46 dB (Figure 7), or a fish length of about 85 mm. This corresponded closely to the gap in the length-frequency distribution between fry and age-1 kokanee from trawl samples.

We estimated kokanee survival at 14% from fry to age-1, 32% from age-1 to age-2, 40% from age-2 to age-3, and 84% from age-3 to age-4 (Table 3). From 2007 to 2008, survival decreased and increased for fry to age-1 and age-1 to age-2, respectively (Figure 8).

Hatchery and Wild Abundance

During the spring of 2008, Cabinet Gorge Fish Hatchery released 5.9 million thermally marked kokanee fry into Lake Pend Oreille, and 5.1 million fry were of the late spawning strain and the remaining 800,000 were of the early spawning strain. Fry released in 2008 (brood year 2007) received a 15 day pattern on their otoliths created by five single-day coldwater events. The first event was one day of cold water followed by one day of warm and one day of cold. The next four days were warm followed by one day each of cold, warm, and cold. Finally, after another four-day warm period, the final day was cold.

Wild kokanee fry made up 12.9%, 8.3%, and 18.8% of the fry net catch in the southern, middle, and northern sections, respectively (Table 1). Based on these numbers, we estimated the wild fry population at 648,000 (Table 1). Further, we estimated that wild kokanee comprised 26.8%, 44.0%, 81.2%, and 100% of age-1, age-2, age-3, and age-4 abundance estimates, respectively (Table 2). Late-spawning hatchery kokanee were more prevalent than the early-spawning strain, and all age-4 kokanee were wild-origin (Table 2).

Kokanee Egg to Fry Survival

During 2008, we captured five mature kokanee in 36 trawl hauls (two in sections one and two and one in section three). This translates into 3.1%, 2.5%, and 1.7% of the trawl catch being mature in the southern, middle, and northern sections, respectively. Using these percentages to estimate mature kokanee abundance yields an estimate of 49,162 mature kokanee or 24,581 mature female kokanee, assuming a 50:50 ratio of males to females. Hatchery personnel collected 2,112 mature female kokanee at the spawning station at Sullivan Springs Creek. We estimated fecundity of adult female kokanee to be 390 eggs/female. Based on this fecundity estimate, 22,469 naturally spawning adult female kokanee deposited 8.8 million eggs in Lake Pend Oreille and its tributaries.

During 2007, we estimated that wild kokanee deposited 1.8 million eggs in tributaries and along the shoreline of Lake Pend Oreille. Using our estimate of 648,000 wild kokanee fry, we calculated wild kokanee egg-to-fry survival to be 36%.

Historical Trawling Comparisons

Total kokanee abundance based on geometric means of trawl samples was 5.0 million fish (4.3 to 5.7 million, 90% CI) with a density of 219 fish/ha (Table 4). This included 3.1 million kokanee fry, 1.1 million age-1 kokanee, 641,000 age-2 kokanee, 94,000 age-3 kokanee, and 35,000 age-4 kokanee (Figure 9). The total standing stock of kokanee was 3.3 kg/ha (Table 4). Kokanee captured by midwater trawling varied in length from 29 mm to 267 mm (Table 4; Figure 10). Mean weight was 2.3 g for fry, 17.3 g for age-1, 59.1 g for age-2, 84.4 g for age-3, and 111.5 g for age-4 kokanee (Figure 11).

A total of 90 fry were collected using the small-mesh fry net during September 2008. We collected 34 fry in the southern section, 24 fry in the middle section, and 32 fry in the northern section of the lake. Based on this method, and using arithmetic means, we estimated 3.5 million kokanee fry, of which an estimated 500,000 were wild.

Predator Abundance

When analyzed for large pelagic predators, nine fish over -30 dB (590 mm) were identified in the down-looking hydroacoustic survey. Predator abundance estimates in the southern, middle, and northern sections were 1,371, 746, and 4,661 fish, respectively. A total population estimate of large pelagic predator fish by down-looking hydroacoustics was 6,778 fish (5,829 to 7,727 90% CI; 0.32 fish/ha).

Nine large (>-30 dB [>590 mm]) pelagic fish were sampled in our up-looking hydroacoustic survey. Abundance estimates in the southern, middle, and northern sections were 4,266, 2,245, and 2,412 fish, respectively. Based on these observations, the population estimate of pelagic predators >590 mm using up-looking hydroacoustics was 8,922 fish (5,305 to 12,580 90% CI; 0.42 fish/ha).

Kokanee Biomass, Production, and Yield

Kokanee biomass was 91 metric tonnes (t), production was 179 t, and total yield was 165 t (Table 5). We plotted kokanee production and yield against kokanee biomass to examine trends and correlations (Figure 12). Production in 2008 was 14 t higher than yield. This marks the first time since 2003 that production exceeded yield and that biomass increased. Production in 2008 closely fit the curve generated from 1996 through 2007 production estimates (Figure 12).

Kokanee Spawner Counts

In 2008, we observed a peak of 669 kokanee spawning on the lake’s shorelines. Six kokanee were at the Farragut boat ramp; all other shoreline spawning was on the shoreline around Bayview in Scenic Bay (Table 6). We observed a peak of 291 late-run kokanee spawning in tributaries of Lake Pend Oreille, 278 of which were in South Gold Creek (Table 7). Additionally, peak abundance of early-spawning kokanee was 50 in Trestle Creek and 800 in tributaries along the east shore (Table 8).

Kokanee Spawning Habitat

Gravel was the predominant substrate type at all sites except Evans Landing. Between 2007 and 2008, the percent gravel in substrate samples at Evans Landing decreased from 55% to 13% (now 77% cobble), while all other sites had ≥50% gravel (Figure 13). With the exception of Evans Landing, cobble substrate ranged from 2% at the south side of Ellisport Bay to 44.7% at Twin Creek (Figure 13). Fines were ≤11% at all sites except the south side of Ellisport Bay where the substrate was 33% fines (Figure 13).

Mysis Shrimp Abundance

We estimated a total mean density of 893 *Mysis* shrimp/m^2 during June 2008 (Table 9). This included 219 immature and adult *Mysis* shrimp/m^2 (90% CI of ± 40%) and 674 YOY *Mysis* shrimp/m^2. The length-frequency distribution of *Mysis* shrimp cohorts is presented in Figure 14. Overall, total density of *Mysis* shrimp in Lake Pend Oreille increased substantially between 2007 (511 *Mysis* shrimp/m^2) and 2008 (893 *Mysis* shrimp/m^2; Figure 15). A 150% increase in YOY *Mysis* shrimp drove this increase, overcoming a 9% decrease in the density of immature and adult *Mysis* shrimp (Figure 16).

DISCUSSION

Kokanee Abundance

In 2008, kokanee biomass and survival increased for the first time since 2003. The primary driving factor for the higher biomass was an increase in ages 2-4 kokanee, resulting from higher survival rates (see Table 3). Although survival rates increased, they are still well below the desired range of about 60-80%. The extremely low levels of age-1 kokanee and kokanee fry (especially wild fry) likely is explained by record low spawner abundance during 2006 and 2007, which led to reduced recruitment. Egg-to-fry survival (36%) was nearly four times higher than the average since 1998 (9.7%). Like all the estimates we calculate, sample size governs the power of our PED estimates. During 2007, we based PED on only two mature kokanee caught in the midwater trawl, which may have led to error in our estimate. While this potential bias likely influenced the magnitude of the egg-to-fry survival increase, a higher rate was not unexpected given the higher winter lake level during 2007-2008. A higher survival rate in years with a higher winter lake level is consistent with past observations in Lake Pend Oreille and should lead to increased kokanee abundance in future years. However, low abundance is still likely for at least four more years as small cohorts pass through the system. Therefore, the complete loss of this population from Lake Pend Oreille is still possible.

We have been concerned since 1999 that predation will lead to the complete loss of kokanee from Lake Pend Oreille (Maiolie et al 2002). Although the kokanee population has improved since 2007, the continued low abundance of older age classes of kokanee indicates that this population is still at risk of complete collapse. By comparing current trawling data to previous years, we can establish that survival to maturity continues to limit the kokanee population's ability to recover. From 1990 to 1994, an average of 318,000 out of 4.0 million kokanee fry reached age-4 (8.0%; Figure 9). From 2000 to 2004, an average of 24,000 out of 4.5 million kokanee fry reached age-4 (0.5%) and only 418,000 (9%) reached age-2 (Figure 9). In order for the kokanee population to recover, survival to maturity must once again approach 8%. This goal should be met through manipulation of the predator population.

Predator Abundance

As in past years, we used two hydroacoustic methods to estimate large pelagic predator fish in Lake Pend Oreille. Our large (>590 mm) predator estimate (6,778 ± 14%) with the down-looking hydroacoustics was lower than during 2006 (14,600 ± 83%) and 2007 (7,209 ± 21%). Our up-looking hydroacoustic estimate for large pelagic predators (8,922 ± 41%) was significantly higher than during 2006 (no fish found) and 2007 (3,608 ± 18%). Although these estimates may be suggesting a decreasing lake trout population and increase in bull trout and/or rainbow trout (see Maiolie et al. 2006a), they must be interpreted cautiously as the low number of targets can cause hydroacoustics estimates to be unreliable. The small number of fish found (only nine large targets were found in each of the hydroacoustic surveys during 2008) continues to limit our ability to estimate predator abundance using hydroacoustics. Employing different methods, such as increased number of transects, wider transducer beam angle, or multiplexing two transducers should be explored to improve this technique in the future.

Kokanee Biomass, Production, and Yield

Pronounced increases in the production to biomass ratio have been critical to slowing the decline of the kokanee population. We would expect declines in production to cause an increase in the rate of decline in biomass, thus causing a negative feedback loop. The kokanee population production to biomass ratio in 2008 (1.97:1) was lower than in 2007 (2.46:1), but better than from 1996-1999 (1:1 or less). Yield for 2008 was the lowest value recorded in the 13 year history of this metric, possibly indicating a decreased consumptive demand of the predator populations on kokanee. With kokanee biomass at only 91 t, any increase in yield would likely result in sharp decrease in biomass despite high production values. Continued implementation of the predator reduction program should further reduce kokanee yield and lead to population increases.

Kokanee Spawner Counts

Although we noted substantial increases in tributary and shoreline spawner counts since 2007, 2008 values are still the sixth lowest on record. Since nearly all (~99%) shoreline spawning takes place within a small portion of Scenic Bay, disturbance to spawning habitat or incubating eggs poses a risk to the long-term survival of the wild kokanee population. This is of particular concern because kokanee spawning in Scenic Bay occurs in a heavily developed shoreline area with high anthropogenic activity. Thus, anthropogenic activities should be kept to a minimum in this area to ensure they do not threaten kokanee. Kokanee were present along the shoreline in Scenic Bay for seven weeks, much longer than in past years, which may indicate total spawner abundance in 2008 may be even higher than the count suggests. However, we can only speculate because spawner counts provide an index for trend monitoring rather than a measure of total abundance. This was the first time we had a sufficient number of early-run kokanee in east shore tributaries to justify an annual survey. These early-run kokanee were likely returns from the 1.2 million fry stocked in Granite Creek during 2004 (making them age-3 spawners). The majority (>75%) of all tributary-spawning kokanee—both early and late runs—were counted in South Gold Creek. While it was encouraging to see returns of tributary spawners, these fish are not likely to contribute substantially to long-term population recovery goals because of limited tributary spawning habitat relative to lakeshore spawning habitat. Further, tributaries are vulnerable to dynamic flow conditions during egg incubation that can result in higher mortality than would be expected in the lake environment.

Gravel Sampling

The amount of shoreline gravel has decreased since the last drawdown to 625.1 MSL occurred during the winter of 2003-04. During the summer of 2004, the average percent gravel at the six sample locations was 83%, which has now decreased by 31%. Fortunately, sufficient amounts of gravel substrate remained to support the limited number of spawning kokanee in

2008. Previously we recommended that Albeni Falls Dam draw the lake down to a winter elevation of 625.1 MSL every four years to allow wave action to improve spawning habitat (Maiolie et al. 2002). This recommendation still appears valid and is important to follow if kokanee abundance increases in future years in response to predator removal efforts. Therefore, a full drawdown to 625.1 MSL during the winter of 2008-09 (Figure 1) should allow wave action to redistribute substrates and increase gravel composition.

***Mysis* Shrimp Abundance**

Mysis shrimp in Lake Pend Oreille have gone through a cycle of expansion and then decline. *Mysis* shrimp expanded from their introduction in 1966 until 1980, but have since declined from their peak abundance. Immature and adult *Mysis* shrimp (the segments of the population most likely to compete with kokanee) densities have remained relatively stable throughout the last eight years (Figure 16). A similar pattern of expansion followed by decline occurred in other western lakes after *Mysis* shrimp introductions (Richards et al. 1991; Beattie and Clancey 1991).

While it is unclear what limits the *Mysis* shrimp population in Lake Pend Oreille, it does not appear that *Mysis* shrimp are limiting kokanee recovery. *Mysis* shrimp densities have generally stabilized and kokanee survival has continued to fluctuate over the past several years. Maiolie et al. (2002) did not find a correlation between *Mysis* shrimp densities and survival rates of kokanee between the egg and fry stages. This lack of correlation continued in 2008. We recommend continued monitoring of the *Mysis* shrimp population.

RECOMMENDATIONS

1. Continue to monitor kokanee population response to lake level management and reductions in predation.

2. Coordinate with the U.S. Army Corps of Engineers, Bonneville Power Administration, and other agencies to set a winter lake level that benefits kokanee spawning to the extent possible.

3. Continue to reduce predator abundance in an effort to increase kokanee survival.

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Table 1. Population estimates of kokanee fry (millions) based on hydroacoustic surveys of Lake Pend Oreille, Idaho in 2008. Percentage of wild, early-run hatchery (KE), and late-run hatchery (KL) fry was based on the proportions of fry caught using a fry net.

	Southern	**Middle**	**Northern**	**Lakewide Total**	**90% CI**
Total kokanee fry abundance estimate	0.9	1.8	2.0	4.8	4.2 to 5.4
Percent wild fry in fry trawl	12.9	8.3	18.8	—	
Percent KE in fry trawl	9.7	16.7	9.4	—	
Percent KL in fry trawl	77.4	75.0	71.8	—	
Wild fry abundance estimate	0.12	0.15	0.38	0.65	

Table 2. Population estimates for kokanee ages 1-4 in Lake Pend Oreille, Idaho 2008. Estimates were generated from hydroacoustic data that were partitioned into age classes based on the percent of each age class sampled by midwater trawling. Percentage of wild, early-run hatchery (KE), and late-run hatchery (KL) were based on the proportions of each caught in the trawl net.

Area	**Age-1**	**Age-2**	**Age-3**	**Age-4**	**Total**
Southern Section					
Percent of age class in section by trawling	49.7	39.5	7.9	3.0	
Population estimate in section (millions)	0.231	0.184	0.037	0.014	0.466
Middle Section					
Percent of age class in section by trawling	64.6	30.7	3.1	1.2	
Population estimate in section (millions)	0.366	0.174	0.017	0.009	0.566
Northern Section					
Percent of age class in section by trawling	59.7	34.1	4.9	1.3	
Population estimate in section (millions)	0.694	0.396	0.058	0.015	1.163
Total population estimate for lake (millions)	1.291	0.754	0.111	0.039	2.195
90% confidence interval (millions)					2.0 to 2.5
Percent wild	26.8	44.0	81.2	100	
Percent KE	5.2	6.4	8.7	0	
Percent KL	26.8	49.6	10.1	0	

Table 3. Survival rates (%) between kokanee year classes estimated by midwater trawling and hydroacoustics, 1990-2008. Hydroacoustic estimates started in 1996. Year refers to the year the older age class in the survival estimate was collected.

	Age Class							
	Fry to 1		1 to 2		2 to 3		3 to 4	
Year	Trawl	Acoustics	Trawl	Acoustics	Trawl	Acoustics	Trawl	Acoustics
2008[a]	36	14	58	32	15	40	37	84
2007[a]	36	20	4	10	4[b]	11[b]	—[b]	—[b]
2006[a]	29	23	7	13	7[b]	12[b]	6[b]	14[b]
2005[a]	48	46	16	15	31	26	26	28
2004[a]	35	21	33	33	19	28	14	18
2003[a]	31	35	70	55	54	65	—[b]	—[b]
2002[a]	16	30	13	43	—[b]	—[b]	—[b]	—[b]
2001	44	28	25	27	3	6	13	17
2000	66	52	74	22	168	66	107	40
1999	32	24	16	18	61	71	40	49
1998	40	37	29	28	95	94	25	26
1997	21	42	22	59	12	29	6	17
1996	77	44	101	79	57	40	70	46
1995	46	—	307	—	99	—	21	—
1994	12	—	47	—	76	—	38	—
1993	32	—	98	—	256	—	92	—
1992	67	—	94	—	63	—	83	—
1991	25	—	111	—	53	—	82	—
1990	35	—	124	—	27	—	44	—

[a] Data from 2002 to 2008 were based on geometric means transformed by log(x+1).

[b] Too few kokanee caught to provide a reliable estimate of survival.

Table 4. Kokanee population statistics based on geometric ($\log_{10}$ transformed; log[x+1]) means of midwater trawl catches on Lake Pend Oreille, Idaho during August 2008.

	Fry	Age-1	Age-2	Age-3	Age-4	Total (90% CI)
Population estimate (millions)	3.10	1.10	0.64	0.09	0.04	5.0 (4.3 to 5.7)
Density (fish/ha)	136.7	48.6	28.3	4.1	1.6	219.4
Standing stock (kg/ha)	0.30	1.13	1.43	0.30	0.17	3.3
Mean weight (g)	2.3	17.3	59.1	84.4	111.5	-
Mean length (mm)	64.6	142.5	184.9	208.3	243.1	-
Length range (mm)	29-92	113-175	135-247	185-252	227-267	-

Table 5. Biomass, production, and yield (metric tonnes) of kokanee in Lake Pend Oreille, Idaho from 1996-2008.

Year	Biomass	Production	Yield
2008	91.3	178.9	165.3
2007	74.0	182.2	221.1
2006	100.2	206.4	274.2
2005	155.9	231.3	247.2
2004	158.3	217.8	329.2
2003	258.0	236.0	171.7
2002	188.4	262.6	231.3
2001	148.2	249.0	281.3
2000	169.9	194.2	284.1
1999	249.0	256.0	271.4
1998	253.2	230.3	208.5
1997	228.7	220.7	354.3
1996	352.6	278.4	274.7
1995	343.6	NA	NA

Table 6. Counts of kokanee spawning along the shorelines of Lake Pend Oreille, Idaho. The numbers shown indicate the highest weekly count and should be interpreted as an index rather than a total estimate of spawner abundance.

	Bayview	Farragut Ramp	Idlewilde Bay	Lakeview	Hope	Trestle Cr. Area	Sunnyside	Garfield Bay	Camp Bay	Anderson Point	Total
2008	663	6	0	0	0	0	0	0	0	—	669
2007	325	0	0	0	0	0	0	0	0	—	325
2006	1,752	0	0	0	17	0	0	12	0	—	1,781
2005	1,565	0	5	1	0	1	0	66	0	—	1,638
2004	2,342	0	100	1	0	0	0	34	0	—	2,477
2003	940	0	0	0	0	20	0	0	0	—	960
2002	968	0	0	0	0	0	0	0	0	—	968
2001	22	0	0	0	0	0	0	0	1	—	23
2000	382	0	0	2	0	0	0	0	0	—	384
1999	2,736	4	7	24	285	209	0	275	0	—	3,540
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
1993	—	—	—	—	—	—	—	—	—	—	—
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 7. Counts of late-run kokanee spawning in tributaries of Lake Pend Oreille, Idaho. The numbers shown indicate the highest weekly counts at each site.

Year	S. Gold	N. Gold	Cedar	Johnson	Twin	Mosquito	Lightning	Spring	Cascade	Trestle	Total
2008	278	0	2	0	3	—	—	8	—	0	291
2007	0	0	0	0	0	—	—	0	—	0	0
2006	414	61	21	0	0	—	—	60	—	14	570
2005	5,463	615	1	0	1,244	—	—	—[a]	—	76	7,399
2004	721	2,334	600	16	6,012	—	—	3,331[a]	—	0	9,683
2003	591	0	0	0	—	—	—	626	—	9	1,226
2002	79	0	0	0	0	—	—	0	—	0	79
2001	72	275	50	0	0	—	—	17	—	0	414
2000	17	37	38	0	2	0	0	0	0	0	94
1999	1,884	434	435	26	2,378	—	—	9,701	5	423	15,286
1998	4,123	623	86	0	268	—	—	3,688	—	578	9,366
1997	0	20	6	0	0	—	—	3	—	0	29
1996	0	42	7	0	0	—	—	17	—	0	66
1995	166	154	350	66	61	—	0	4,720	108	21	5,646
1994	569	471	12	2	0	—	0	4,124	72	0	5,250
1992	479	559	—	0	20	—	200	4,343	600	17	6,218
1991	120	550	—	0	0	—	0	2,710	0	62	3,442
1990	834	458	—	0	0	—	0	4,400	45	0	5,737
1989	830	448	—	0	0	—	0	2,400	48	0	3,726
1988	2,390	880	—	0	0	—	6	9,000	119	0	12,395
1987	2,761	2,750	—	0	0	—	75	1,500	0	0	7,086
1986	1,550	1,200	—	182	0	—	165	14,000	0	0	17,097
1985	235	696	—	0	5	—	127	5,284	0	0	6,347
1978	0	0	0	0	0	0	44	4,020	0	0	4,064
1977	30	426	0	0	0	0	1,300	3,390	0	40	5,186
1976	0	130	11	0	0	0	2,240	910	0	0	3,291
1975	440	668	16	0	1	0	995	3,055	0	15	5,190
1974	1,050	1,068	44	1	135	0	2,350	9,450	0	1,210	15,308
1973	1,875	1,383	267	0	0	503	500	4,025	0	18	8,571
1972	1,030	744	0	0	0	0	350	2,610	0	1,293	6,027

[a] Cabinet Gorge Hatchery transferred 3000 spawners from the hatchery ladder to Spring Creek.

Table 8. Counts of early-run kokanee spawning in tributaries of Lake Pend Oreille, Idaho. The numbers shown indicate the highest weekly counts at each site. Monitoring early-run kokanee began in 2008; prior to this, only Trestle Creek was counted.

Year	S. Gold	N. Gold	Cedar	Trestle	Total
2008	592	181	27	50	850
2007	—	—	—	124	124
2006	—	—	—	327	327
2005	—	—	—	427	427
2004	—	—	—	682	682
2003	—	—	—	2,251	2,251
2002	—	—	—	1,412	1,412
2001	—	—	—	301	301
2000	—	—	—	1,230	1,230
1999	—	—	—	1,160	1,160
1998	—	—	—	348	348
1997	—	—	—	615	615
1996	—	—	—	753	753
1995	—	—	—	615	615
1994	—	—	—	170	170
1992	—	—	—	660	660
1991	—	—	—	995	995
1990	—	—	—	525	525
1989	—	—	—	466	466
1988	—	—	—	422	422
1987	—	—	—	410	410
1986	—	—	—	1,034	1,034
1985	—	—	—	208	208
1978	—	—	—	1,589	1,589
1977	—	—	—	865	865
1976	—	—	—	1,486	1,486
1975	—	—	—	14,555	14,555
1974	—	—	—	217	217
1973	—	—	—	1,100	1,100
1972	—	—	—	0	0

Table 9. Densities of *Mysis* shrimp (per m^2), by life stage (young of year [YOY], and immature and adult), in Lake Pend Oreille, Idaho June 2-3, 2008. Sample locations within each lake section are shown in Figure 6.

Section	**YOY/m^2**	**Immature & Adults/m^2**	**Total *Mysis* Shrimp/m^2**
Section 1	826.9	273.8	1100.7
Section 2	1076.0	322.2	1398.2
Section 3	184.9	81.6	266.5
Whole lake means	**674.1**	**219.3**	**893.1**

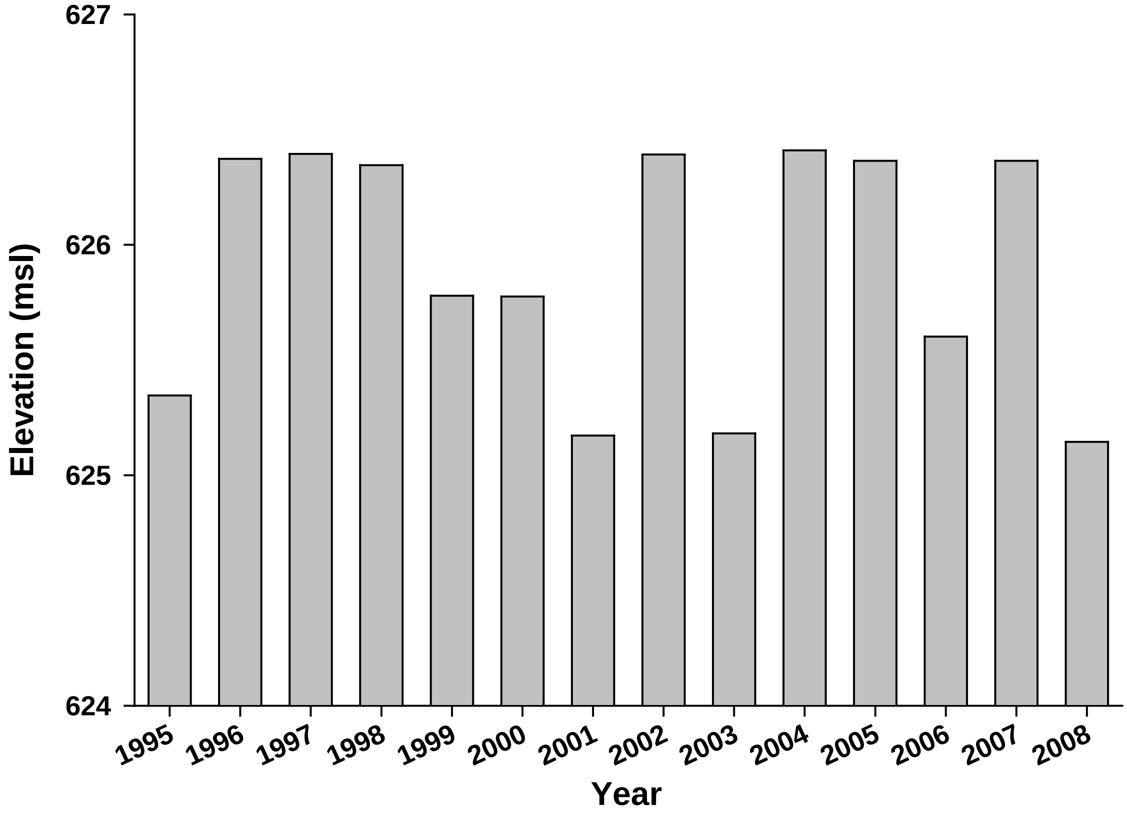
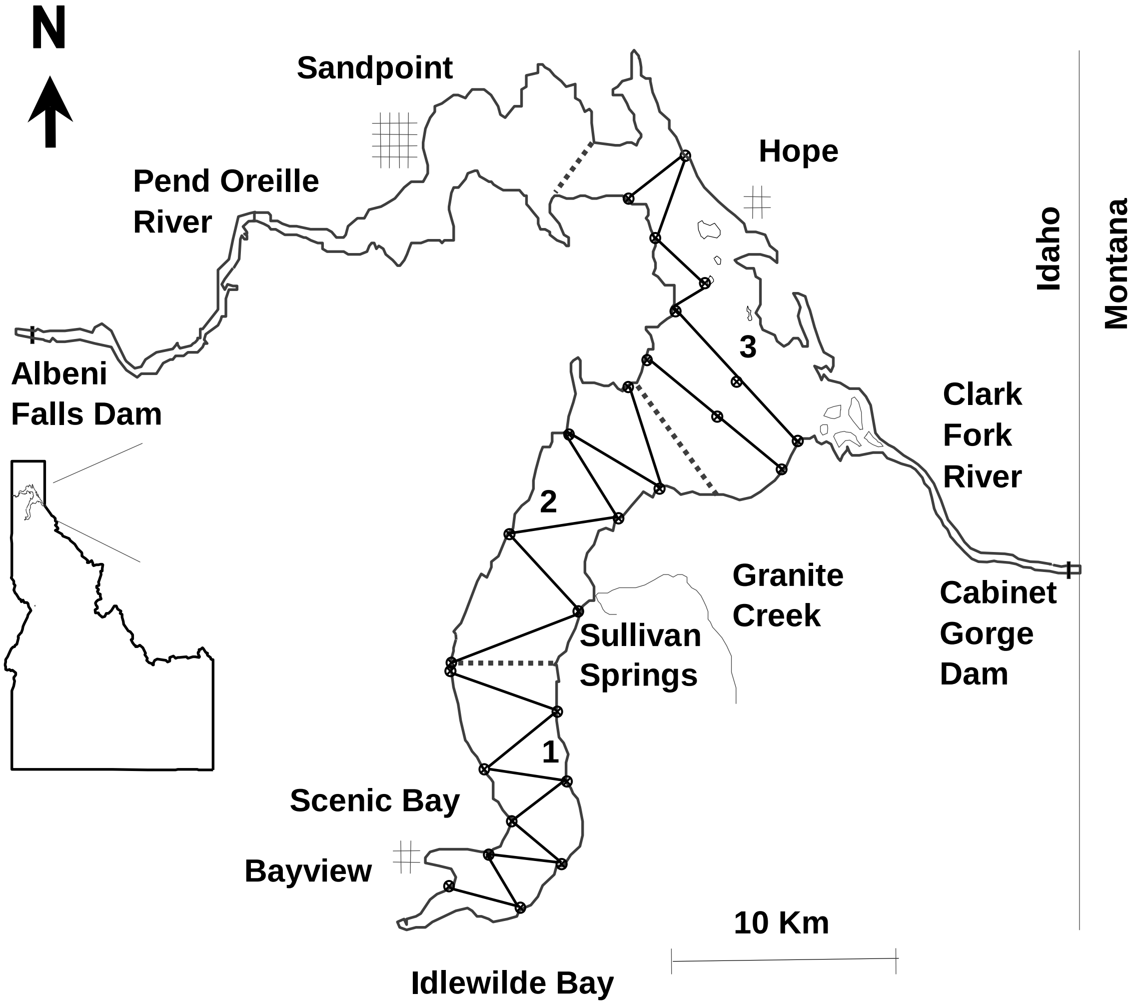


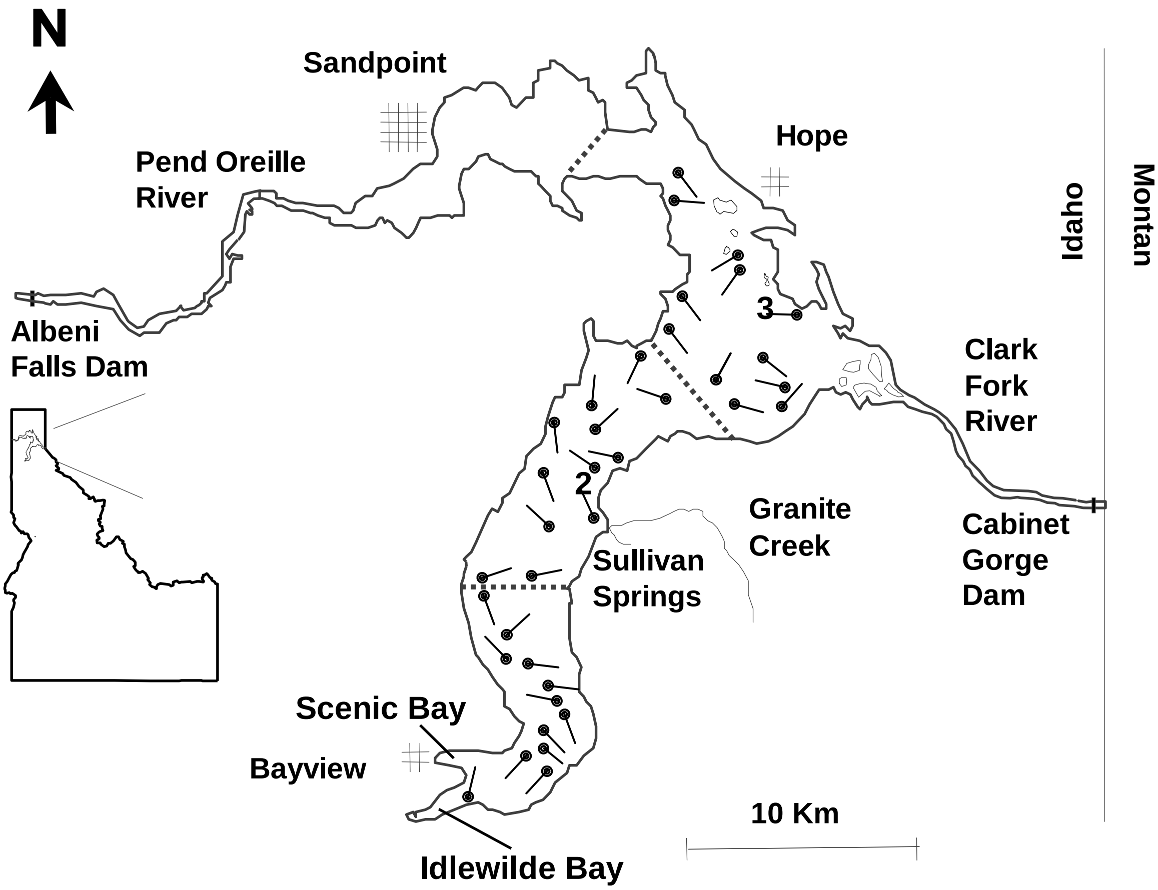
Figure 1. Winter pool surface elevation during years of lake level experiment in Lake Pend Oreille, Idaho. Year shown represents the year the lake was drawn down (i.e. 1995 for winter of 1995-1996).



Section	Area (hectares)
1	6,486
2	7,776
3	8,384

⊗ - Start and stop of transects

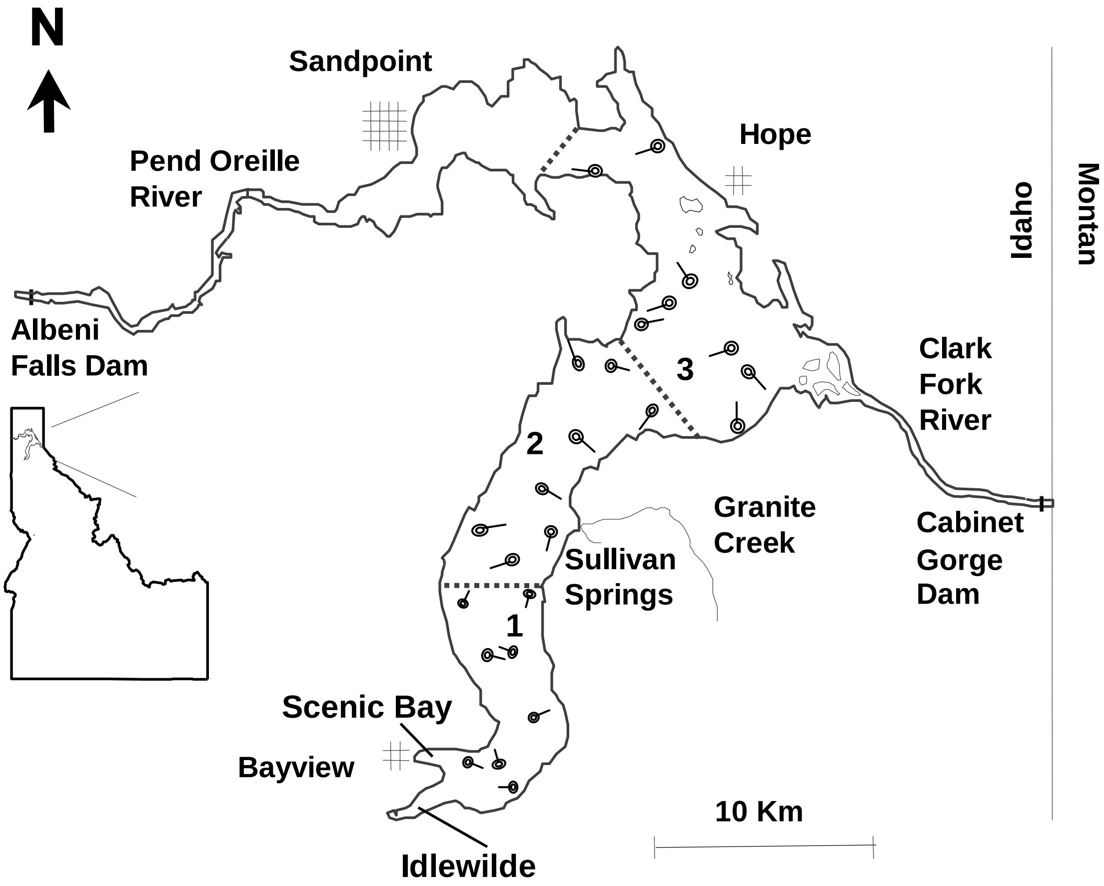
Figure 2. Map of Lake Pend Oreille, Idaho showing prominent landmarks, and the three lake sections marked with dashed lines. The dark lines mark the location of hydroacoustic transects in 2008. The inserted table depicts the area of kokanee habitat in each section.



Section	Area (hectares)
1	6,486
2	7,776
3	8,384

- Transect location and direction

Figure 3. Map of Lake Pend Oreille, Idaho showing the locations of kokanee trawling transects used in 2008.



Section	Area (hectares)
1	6,486
2	7,776
3	8,384

- Transect location and direction

Figure 4. Map of Lake Pend Oreille, Idaho, showing the locations of kokanee fry trawling transects used in 2008.

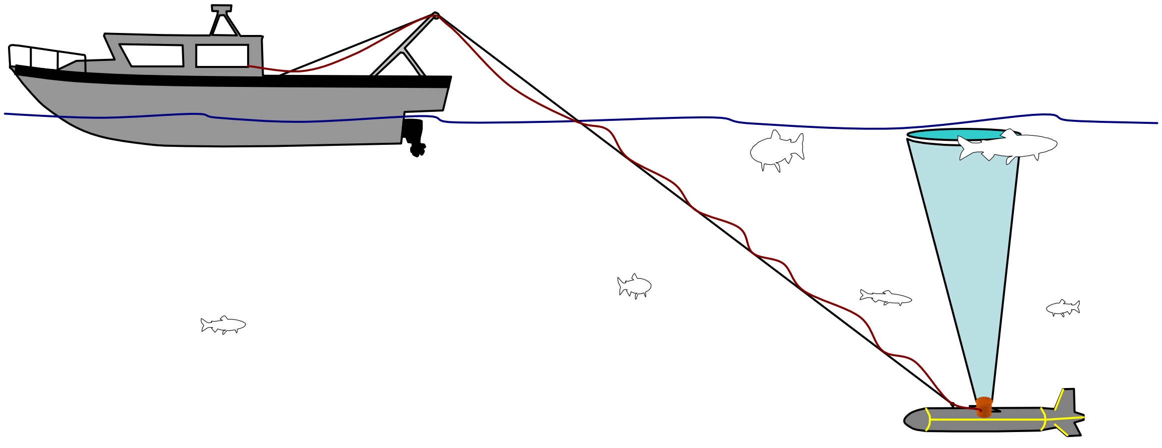


Figure 5. Illustration of towed body, hydroacoustic transducer arrangement, and towing vessel used during up-looking hydroacoustic surveys for predatory salmonids on Lake Pend Oreille, Idaho during June 2008.

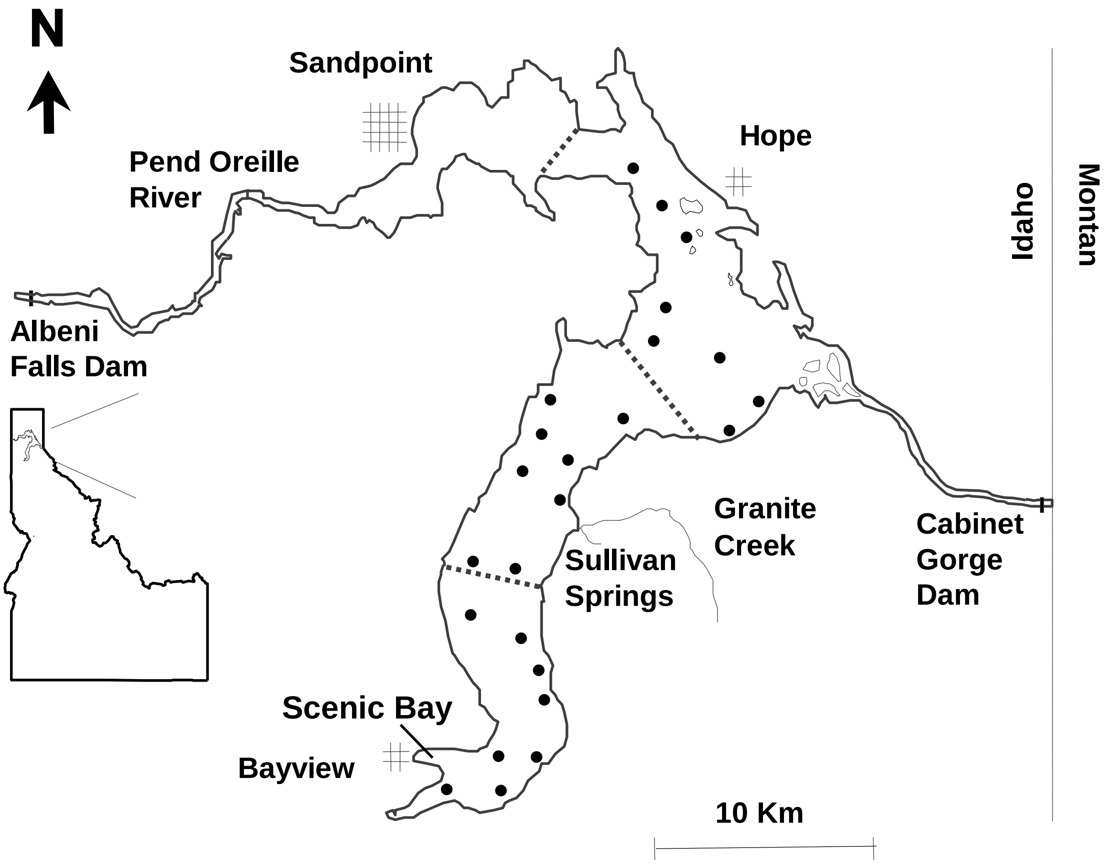


Figure 6. Map of Lake Pend Oreille, Idaho showing *Mysis* shrimp sampling locations within each lake section. Sampling occurred from June 2-3, 2008.

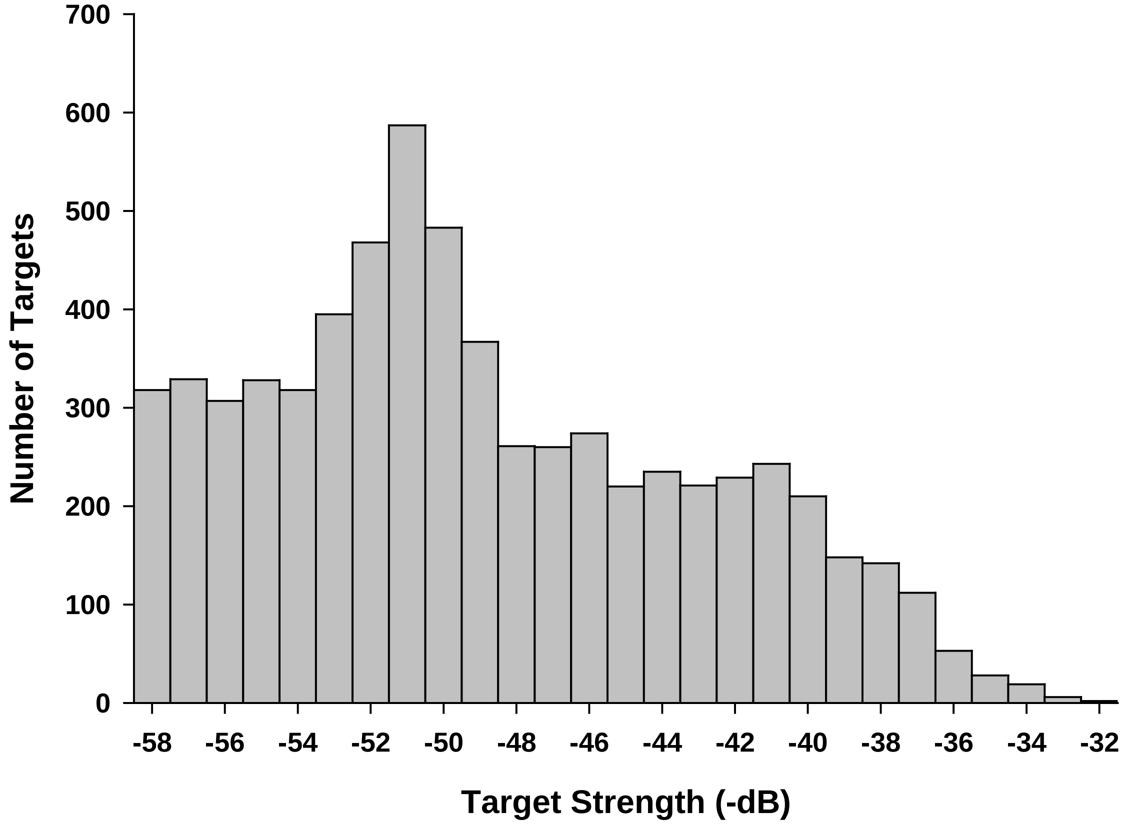


Figure 7. Target strengths of 42,148 fish recorded in Lake Pend Oreille from hydroacoustics in August 2008. Distribution was created to define the target strength between kokanee fry and ages 1-4 kokanee (>-46 dB).

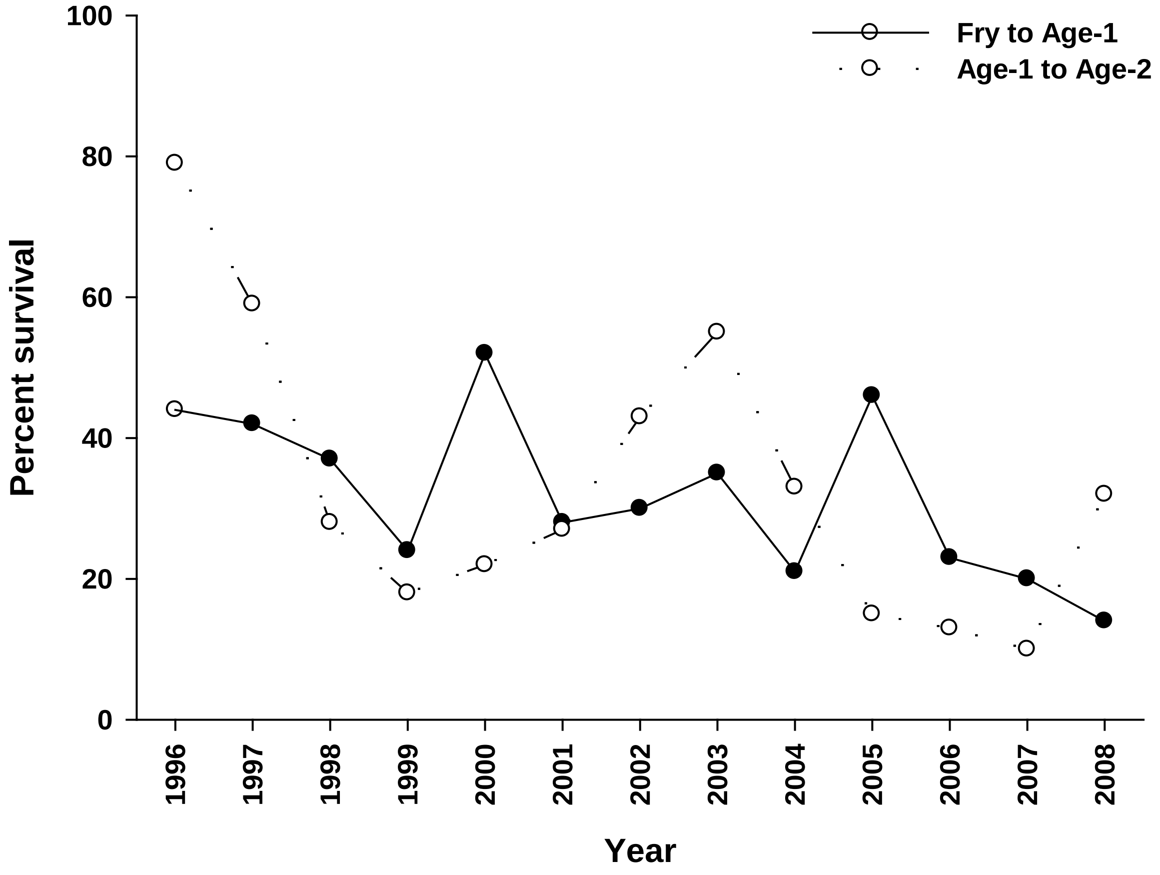


Figure 8. Survival rates of kokanee from fry to age-1 and age-1 to age-2 in Lake Pend Oreille, Idaho. Estimates were generated from hydroacoustic surveys conducted between 1996 and 2008.

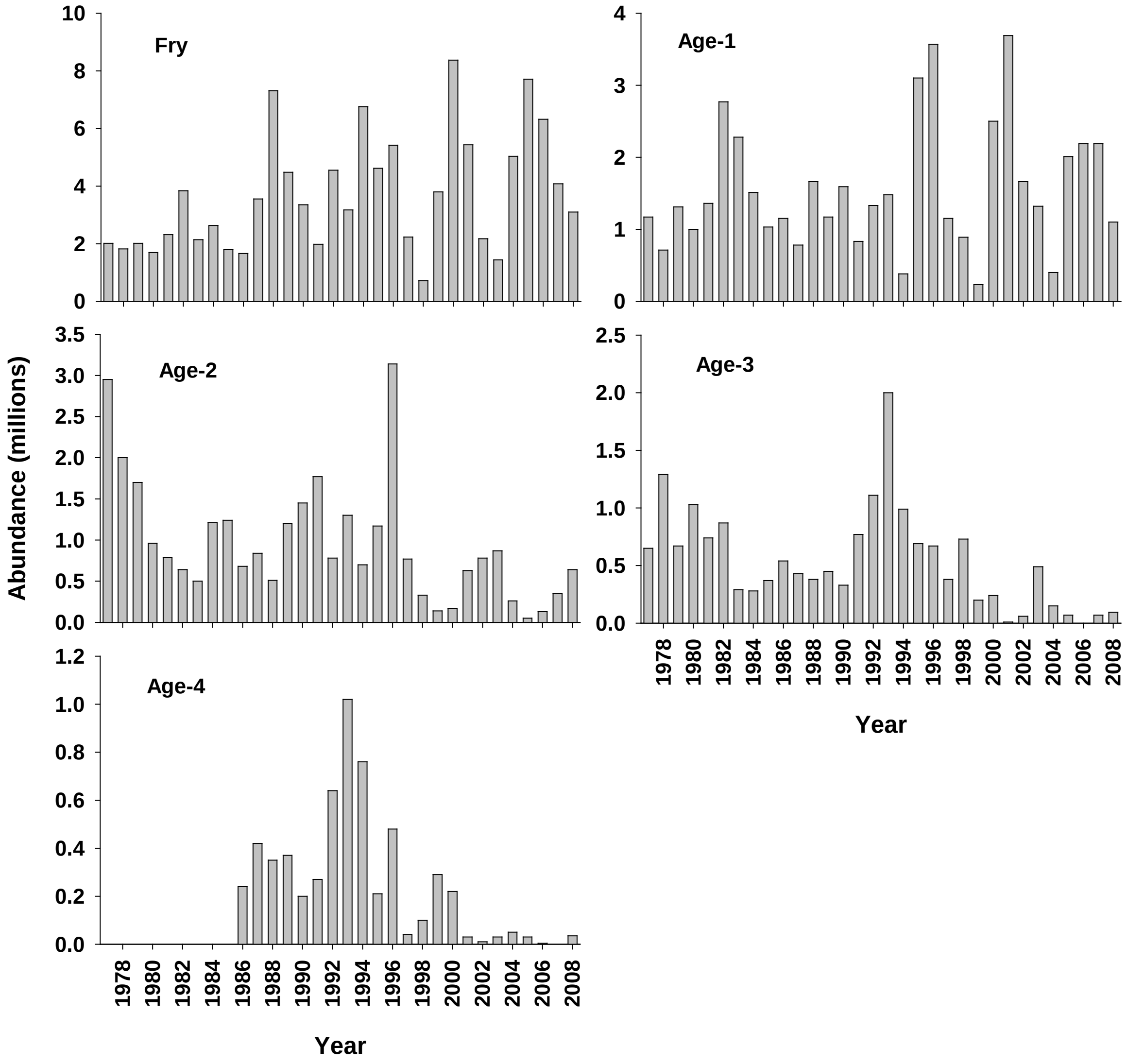


Figure 9. Kokanee age-specific population estimates based on midwater trawling between 1978 and 2008. Age-3 and -4 kokanee were not separated prior to 1986.

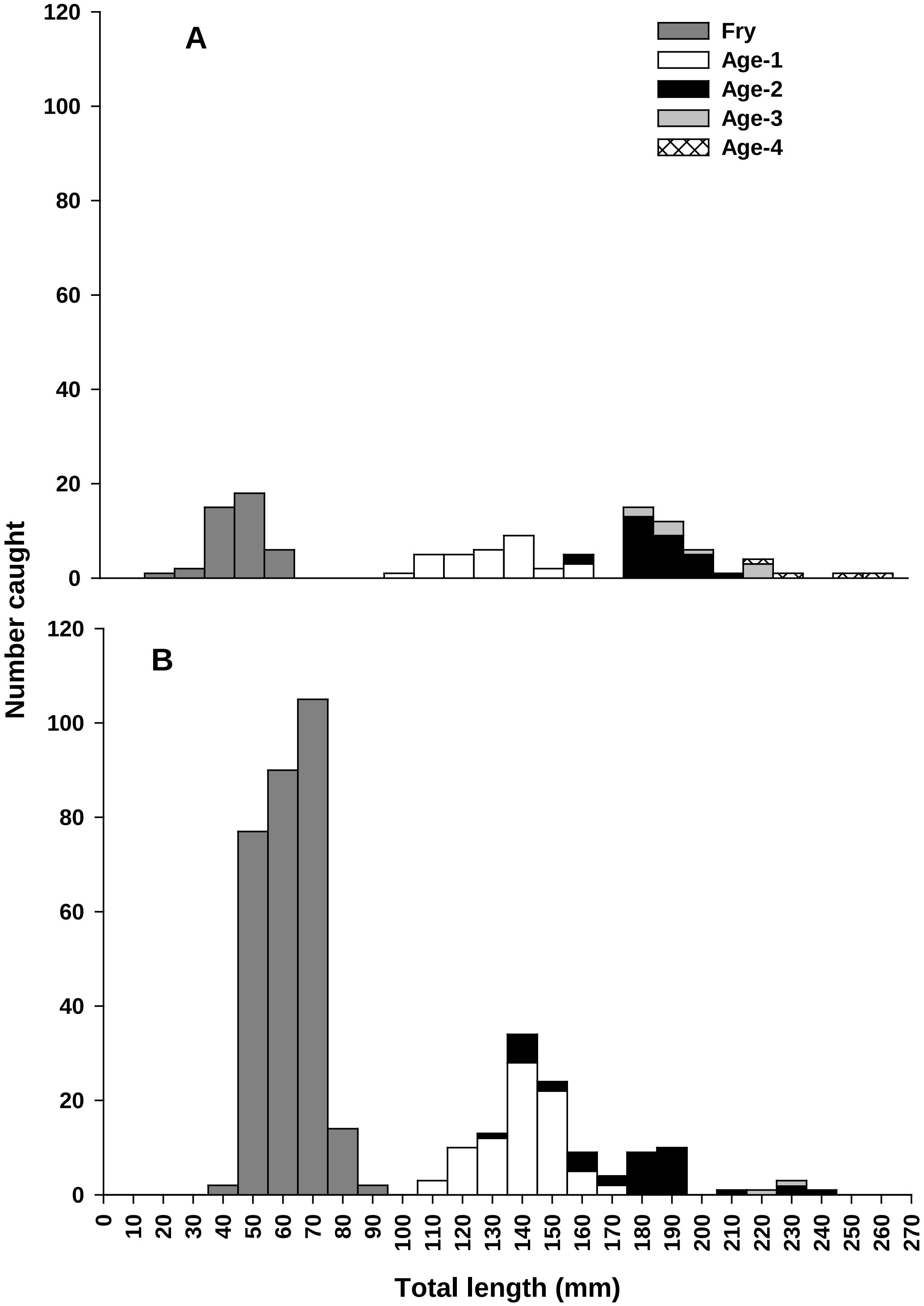


Figure 10. Length-frequency distribution of individual age classes of wild (A) and hatchery (B) kokanee caught by midwater trawling in Lake Pend Oreille, Idaho during August 2008.

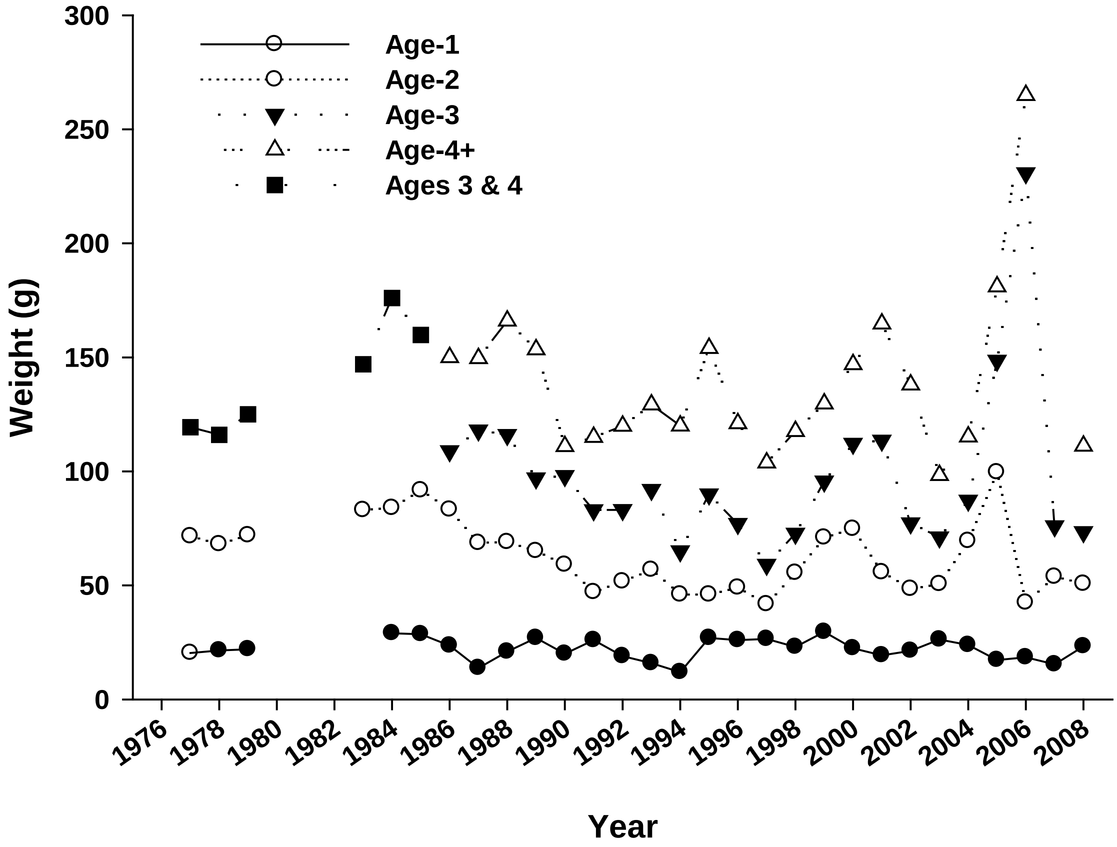


Figure 11. Mean weight (g) of kokanee by age class since midwater trawling began on Lake Pend Oreille, Idaho in 1977.

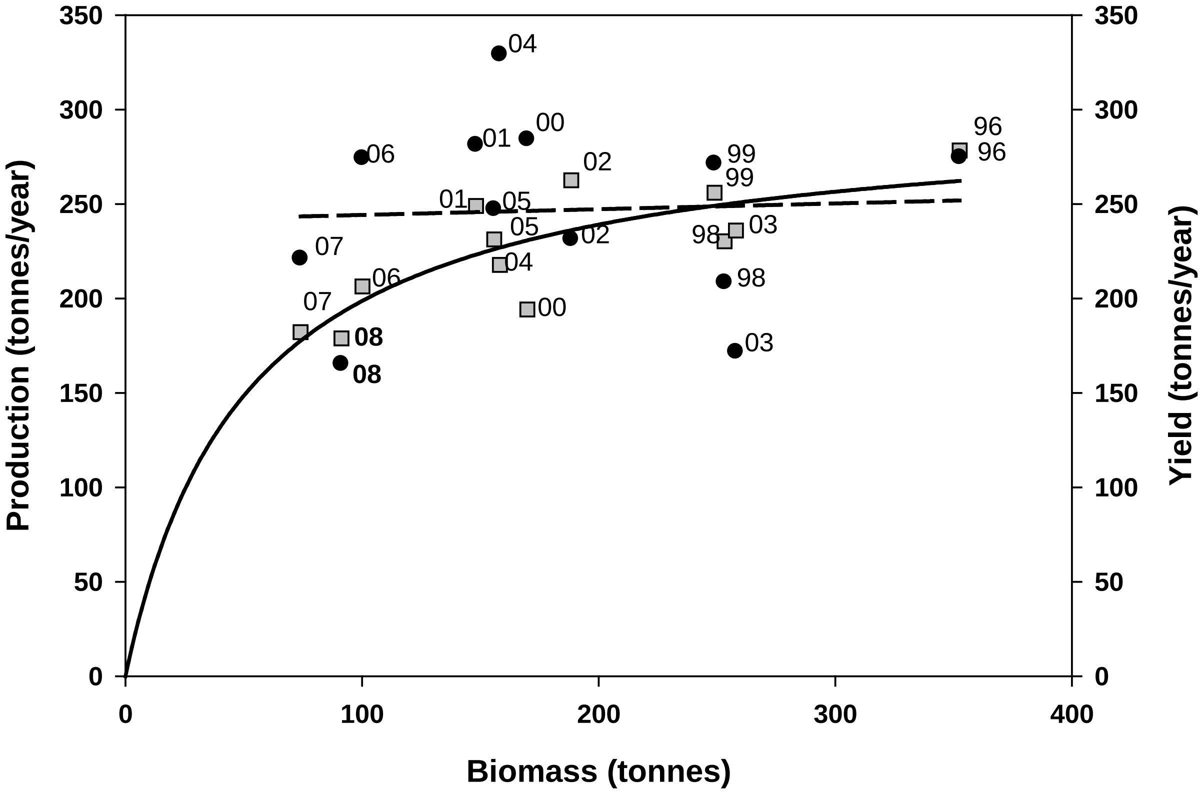


Figure 12. Kokanee biomass, production, and yield (metric tonnes) in Lake Pend Oreille, Idaho from 1996-2008, excluding 1997 due to 100 year flood. Kokanee biomass was measured at the start of the year. Gray squares indicate production and black circles indicate yield. The solid black line represents the production curve, and the dashed line is the yield trend line.

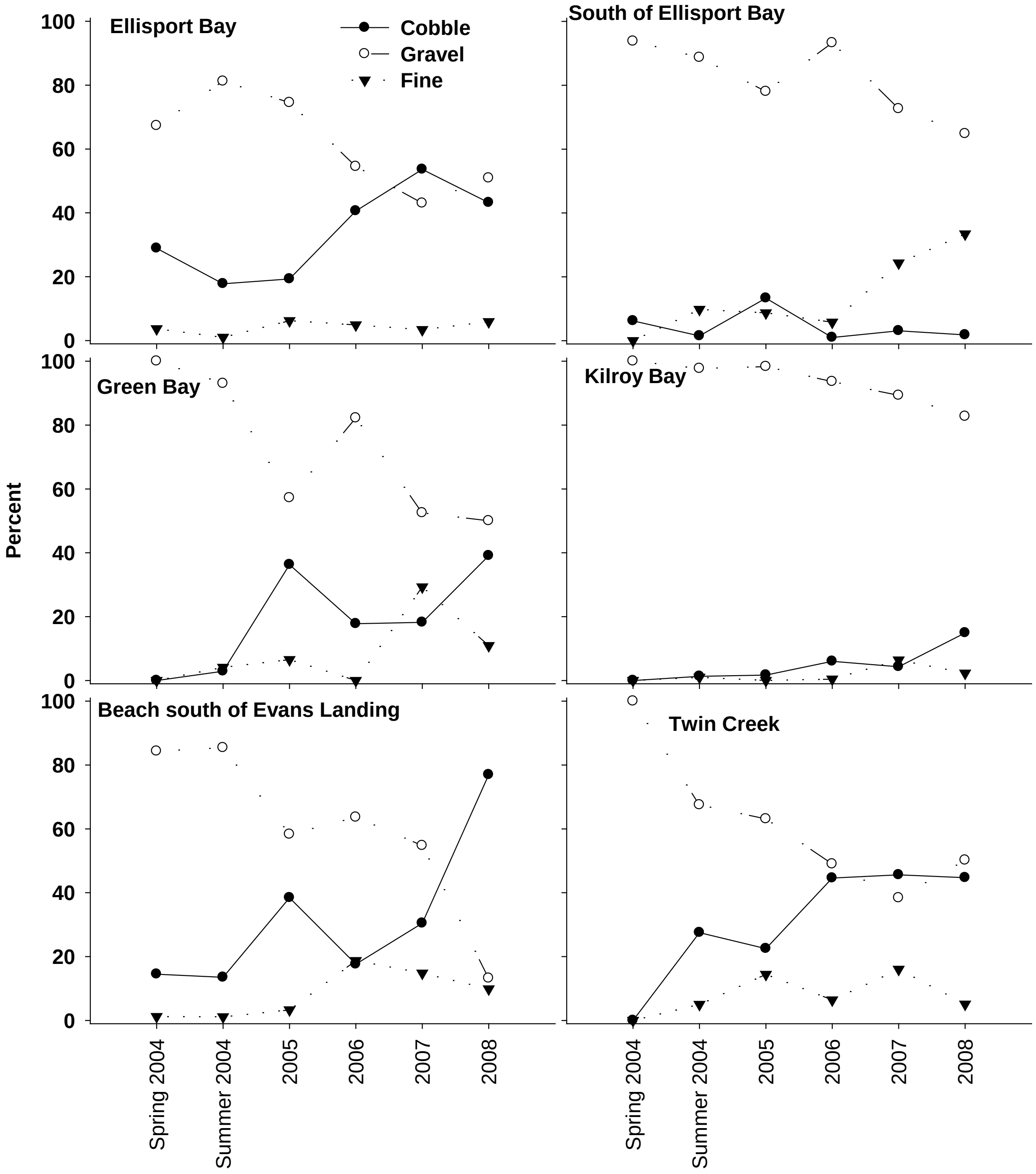


Figure 13. Substrate composition at potential kokanee spawning beaches in Lake Pend Oreille, Idaho. Sampling during spring 2004 was conducted above the water line at an elevation of 625.1 to 625.8 m while lake was at its low pool level. Other samples were collected at the same elevation by scuba diving during summer.

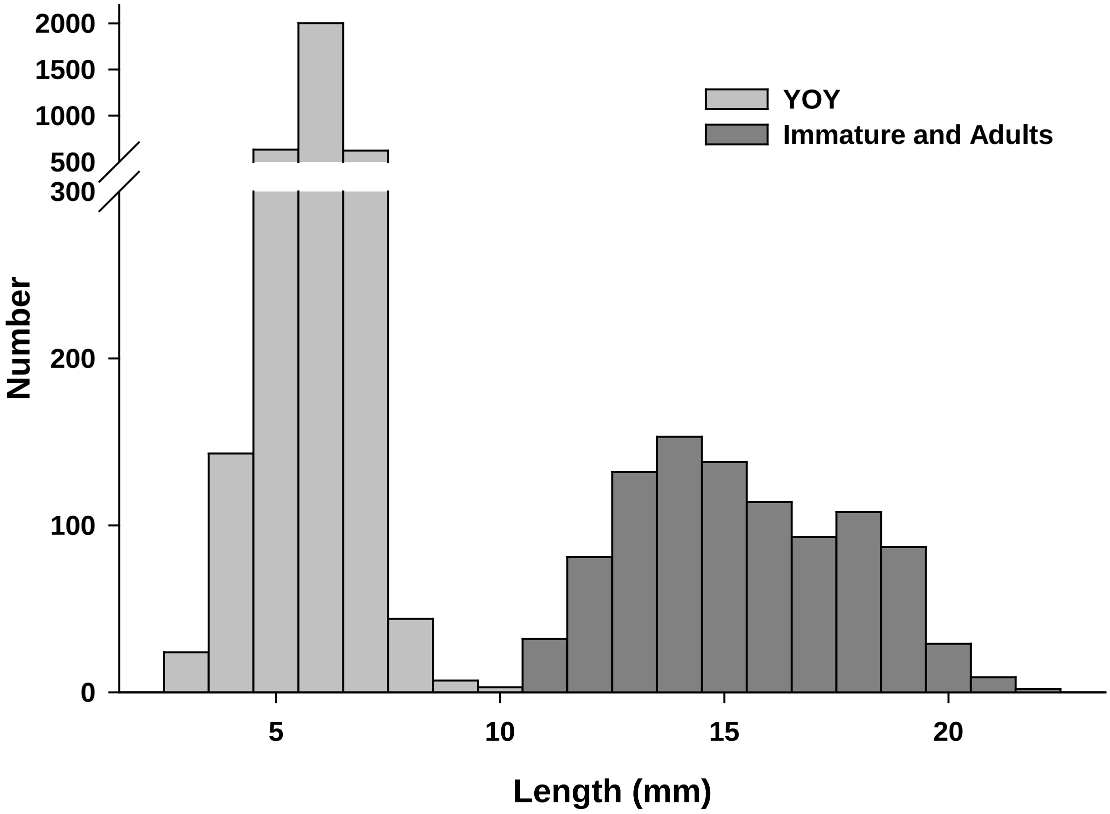


Figure 14. *Mysis* shrimp length-frequency distribution during June 2008 on Lake Pend Oreille, Idaho.

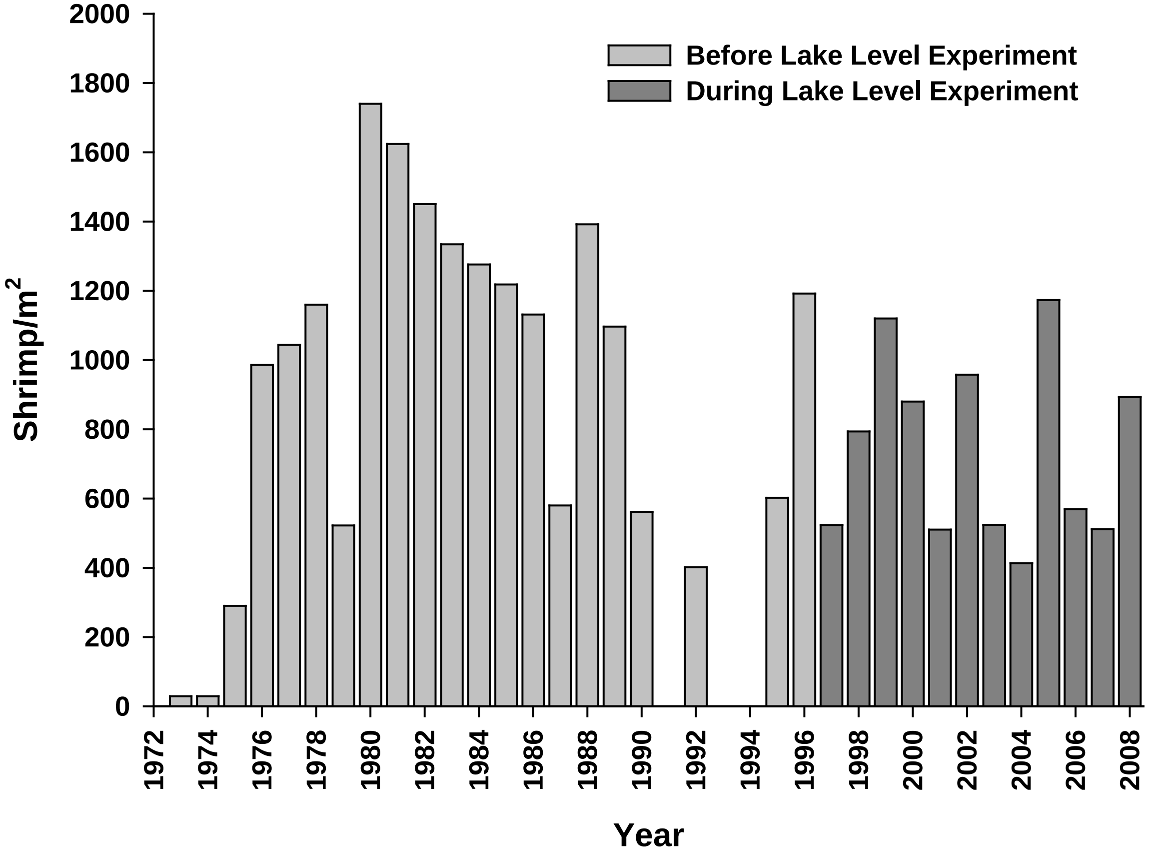


Figure 15. Annual mean density of *Mysis* shrimp in Lake Pend Oreille, Idaho from 1973-2008. Data collected before 1989 were obtained from Bowles et al. (1991), and data from 1995 and 1996 were from Chipps (1997). *Mysis* shrimp densities from 1992 and earlier were converted from Miller sampler estimates to vertical tow estimates by using the equation y = 0.5814x (Maiolie et al. 2002). Gaps in the histogram indicate no data were collected that year.

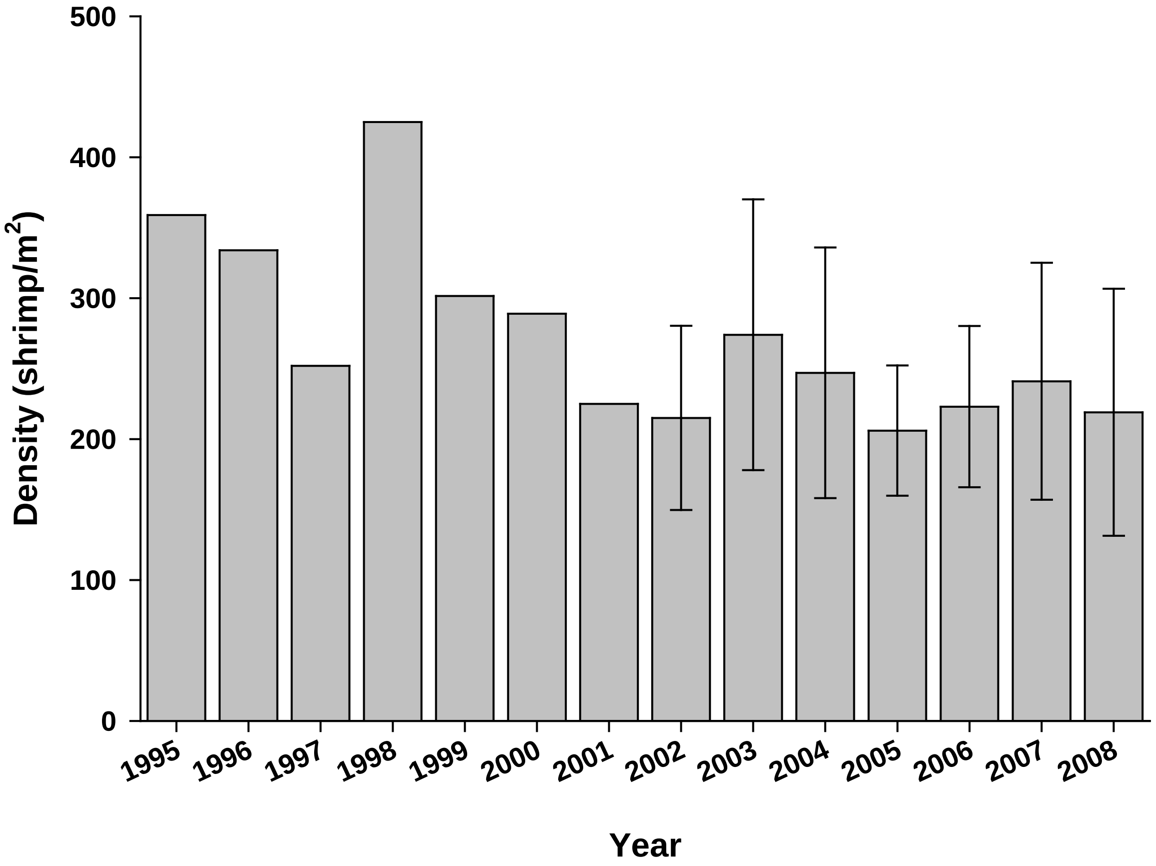


Figure 16. Density estimates of immature and adult *Mysis* shrimp in Lake Pend Oreille, Idaho for the past 14 years (1995-2008). Error bounds were added to the recent population estimates to identify 90% confidence intervals around the estimate.

APPENDICES

Appendix A. Transceiver settings for the Simrad EK 60 echo sounder used for down-looking (short cord) and up-looking (long cord) surveys on Lake Pend Oreille, Idaho during 2008.

Calibration date:	**May 22, 2008**	**May 27, 2008**
Setting	**Short Cord**	**Long Cord**
Transducer: Simrad	Split Beam 120-7C	Split Beam 120-7C
Absorption Coefficient (dB/m)	.005100	.004613
Sound Speed (m/s)	1433	1443
Transmitted Power (w)	200	200
Two-way Beam Angle (dB re: 1 steradian)	-21.00	-21.00
Transducer Gain (dB)	27.41	24.69
SA Correction (dB)	-0.61	-0.52
Transmitted Pulse Length(ms)	0.256	0.256
Frequency (kHz)	120 kHz	120 kHz
Minor-Axis Angle Offset (degrees along)	-0.02	-0.01
Major- axis Angle Offset (degrees Athwart)	-0.01	-0.01
Major Axis 3 dB Angle (degrees)	6.57	6.34
Minor Axis 3 dB Angle (degrees)	6.56	6.36
Athwart Angle Sensitivity	23.00	23.00
Along Angle Sensitivity	23.00	23.00
Depth of Calibration Sphere (m)	19.3 m	25 m
Depth of Transducer (m)	0.75	0.75
Receiver Band (kHz)	8.71	8.71
Water Temp at Mid-depth (°C)	6.5°	9.0°

Appendix B. Location 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, and all areas between).

Farragut State Park

- From state park boat ramp go both left and right approximately 1/3 km.
- Idlewilde 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 Lighthouse 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 basin area.

Sunnyside

- From Sunnyside Resort go east approximately 1/2 km.

Garfield Bay

- Along docks at Harbor Marina on east side of bay.
- From the public boat ramp go southwest 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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