FISHERY RESEARCH

# KOKANEE AND RAINBOW TROUT RESEARCH EFFORTS, LAKE PEND OREILLE, 2007

## LAKE PEND OREILLE FISHERY RECOVERY PROJECT

**ANNUAL PROGRESS REPORT**
**March 1, 2007—February 28, 2008**


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## ABSTRACT

Since 1996, the winter water level of Lake Pend Oreille has been managed as part of a multi-year study to improve the spawning and incubation success of wild kokanee *Oncorhynchus nerka*. During the winter of 2006-2007, the lake level was lowered to 626.4 m above mean sea level (msl). We conducted hydroacoustic surveys and trawling during August 2007 to assess the kokanee population and determine the impacts of lake level changes on wild fry recruitment. We estimated the total kokanee abundance at 11.8 million based on hydroacoustics (520 kokanee/ha). Based on this number, we estimated the wild fry population at 1.98 million. Due to low adult kokanee numbers, we were unable to estimate the number of spawners and potential egg deposition in 2006, and therefore were unable to calculate egg-to-fry survival for 2007. Peak visual counts of spawning wild kokanee were 325 fish on the shoreline and 124 fish in tributary streams. This is the lowest total spawner count recorded. We also examined substrate at potential spawning areas to determine changes in substrate composition in relation to lake level changes. At most sites, the percent gravel of the total substrate composition has decreased and been replaced by fine sediments.

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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 and provided 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). Much of the kokanee decline was related to fall drawdowns of the lake for flood control and power production (Maiolie and Elam 1993). During 2000, the kokanee fishery was closed because of low adult kokanee abundance. Continued declines in kokanee occurred after 2000 and were attributed to high predation levels on the reduced kokanee stocks (Maiolie et al. 2002; Maiolie et al. 2006a).

Since 2006, 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 150% higher under the higher winter lake level (Maiolie et al. 2002). During the winter of 2006-07, the winter water level of Lake Pend Oreille was lowered to 626.4 msl (Figure 1) as part of a long-term experiment to enhance kokanee spawning and incubation success. We monitored the kokanee population to evaluate their response to this experiment. We also monitored the quality of potential spawning areas using substrate core sampling to see how lake level changes affected spawning habitat. Additionally, we have estimated abundance of the nonnative, zooplanktivorous *Mysis* shrimp *Mysis relicta* to continue expanding the long-term data set.

While it appears that changing lake levels have increased the abundance of kokanee fry (Maiolie et al. 2006b), the abundance of harvestable-sized kokanee has dropped, likely due to high predation rates. We therefore increased our efforts to monitor predator abundance and help guide 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. We continued to modify up-looking hydroacoustic techniques during 2007 to estimate rainbow trout abundance. If proven reliable, hydroacoustic surveys would be a much easier way to monitor predator abundance than mark-recapture estimates.

All work on this project was funded by the Bonneville Power Administration to mitigate for the construction of Albeni Falls Dam.

## STUDY AREA

Lake Pend Oreille is located in the northern panhandle 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 epilimnion temperatures averaging approximately 9°C (Rieman 1977). Operation of Albeni Falls Dam on the Pend Oreille River keeps the lake level high and stable at 628.7 msl during summer (June-September), followed by lower lake levels of 626.4 m to 625.1 msl during fall and winter. Littoral areas are limited and mostly characterized by having a very steep bottom.

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 fish include pygmy whitefish *P. coulterii*, slimy sculpin *Cottus cognatus*, five cyprinids, and two catostomids. Kokanee entered the lake in the early 1930s via downstream dispersal from Flathead Lake, Montana and were well established by the 1940s. Since this time, kokanee have been the primary pelagic forage species in Lake Pend Oreille. Other introduced game fish include Gerrard rainbow trout *O. mykiss,* lake whitefish *Coregonus clupeaformis*, and lake trout *S. namaycush*. Additionally, several other cold, cool, and warmwater species are present. Pelagic habitat used by kokanee is approximately 22,646 ha (Figure 2; Bowler 1978), while pelagic habitat used by rainbow trout was measured at 21,332 ha.

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. Other less abundant predators include: northern pike *Esox lucius*, brown trout *Salmo trutta*, smallmouth bass *Micropterus dolomieu*, largemouth bass *M. salmoides*, and walleye *Sander vitreus* (Hoelscher 1992), all of which were introduced.

## PROJECT GOAL

The Lake Pend Oreille Fishery Recovery Project goal is to recover the sport fisheries of 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

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

Objective 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.

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

## METHODS

### Down-looking Hydroacoustic Survey

We conducted lakewide hydroacoustic surveys on Lake Pend Oreille to monitor the kokanee population and provide an estimate of large pelagic fish likely to be kokanee predators. Surveys were performed at night between August 27 and August 30, 2007. A Simrad EK60 portable scientific echo sounder equipped with a 120 kHz split-beam transducer set to ping at 0.6 s intervals was used to perform mobile hydroacoustic surveys. The pole-mounted transducer was located 0.75 m below the surface, off the port side of the boat, with the transducer pointing downward. Prior to the surveys, the echo sounder was calibrated 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, following a uniformly-spaced, zigzag pattern of transects 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 km to 7.7 km and were located using a global positioning system (GPS). For all transects, we utilized a 7.3 m boat and maintained a speed of approximately 1.3 m/s (boat speed did not affect our calculations of fish density).

We estimated kokanee abundance using echo integration techniques. We used Echoview software version 3.10.135.03 to view and analyze collected data. 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.

Once kokanee targets met the above criteria, we calculated density estimates of kokanee in each transect using the Echoview software. A box was drawn around the kokanee layer on each echogram to define the area sampled (usually between the 10 m and 50 m depths). The area in the box was integrated 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 to be detected as a single target (MacLennan and Simmonds 1992). We calculated densities using the following equation:

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

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 population estimate for kokanee, 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 for each lake section by the area of each lake section. Abundance in each of the three sections was then summed to estimate the total population.

We used *in-situ* target strengths to separate fry from older age classes of kokanee using Echoview software. Fish traces (a single returned echo off a single fish) were plotted on a frequency histogram of target strength versus frequency. We used the low point on the graph to define the size break between fry and older age classes of kokanee and checked this against the sizes of kokanee caught in our midwater trawl samples. Kokanee of ages 1 to 4 were not separated based on their target strengths, but rather were based on the percentages of each age class collected by trawling in that section.

Once density estimates for kokanee were determined, we calculated 90% confidence intervals for lake-wide 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 estimate abundance of hatchery and wild fry, we used two different methods to ensure data were comparable to previous methods and to utilize a potentially more accurate technique. First, we took the total hydroacoustic estimate of fry in each section of the lake and multiplied it by the proportions of wild and hatchery fry collected in midwater trawl samples for that section (trawling described below). As a second approach, hydroacoustic fry abundance in each section was multiplied by the proportions of wild and hatchery fry collected with a smaller fry net (described below) in that section. For both methods, estimates of wild and hatchery fry in each lake section were summed to get lakewide abundance estimates of fry. Pelagic targets between -58.0 and -46.0 dB (20 mm to 85 mm, based on Love 1971) were considered kokanee fry. Hatchery fry collected by netting were identified based on the presence of cold brand marks on their otoliths (Volk et al. 1990). Examination for the cold brands was conducted at the Washington Department of Fish and Wildlife (WDFW) Otolith Laboratory in Olympia, Washington.

To estimate abundance of age-1 thru age-4 kokanee, we partitioned the hydroacoustic survey results into age classes based on the percent of each age class collected by trawling in that section (Table 1). Based on hydroacoustics with kokanee age classes estimated by trawl percentages, we calculated the survival rate of each year class of kokanee between 2006 and 2007. The abundance of wild fry was estimated by multiplying the percentage of wild fry caught in our fry net in each section by the hydroacoustic estimate of all fry. We also used the hydroacoustic data to estimate the potential egg deposition (PED) by wild kokanee. The acoustic estimate of age 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 to obtain the number of females. The number of mature female hatchery kokanee collected at the Sullivan Springs Creek fish trap was subtracted from the population estimate of mature female kokanee to obtain the number of wild spawners. The wild spawner estimate was then multiplied by kokanee fecundity to obtain wild PED. In previous years of the study, mean fecundity was determined by dissecting 20 female kokanee from the beginning, middle, and end of the spawning run (n = 60). During 2007, fecundity was determined by dissecting only nine female kokanee because of the low number of adult kokanee returning to Sullivan Springs Creek. The number of wild kokanee fry was divided by the previous year's wild PED to estimate wild egg-to-fry survival.

The same down-looking survey was used to estimate the abundance of large pelagic fish in the open waters of Lake Pend Oreille. Density estimates of large fish were determined using echo-counting techniques. Echoview software version 3.10.135.03 was used to view and analyze the collected data. Hydroacoustic traces (a single returned echo from a fish) were examined 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). The number of traces on each larger fish within the 3 dB beam width was binned into 1 m depth intervals and divided by the area sampled at that depth to calculate fish density. Sampled area for each bin was calculated by multiplying the number of pings on the transect by the 3 dB beam width at the center of the bin.

To determine a population estimate, a weighted (by transect length) average density was calculated for each lake section and multiplied by the area of that section. Abundance in each of the three sections was then summed to estimate the total population. We calculated a 90% confidence interval for the lakewide abundance estimate by standard formulas for stratified sampling designs (Scheaffer et al. 1979) described above.

## Up-looking Hydroacoustic Survey

Maiolie et al. (2006a) determined that a substantial portion of acoustic-tagged predators, especially rainbow trout, utilized water depths that would not be sampled effectively in down-looking hydroacoustic estimates (<10 m) due to small beam width at that depth. Therefore, up-looking hydroacoustic surveys were conducted to estimate large (>590 mm) pelagic fish abundance near the surface. Daytime surveys were conducted on June 4, 8, 20, and 22, 2007. Survey dates were dictated by weather conditions. Surface disturbance from winds affected previous up-looking hydroacoustic survey attempts, so surveys were only conducted during calm conditions. The same echo sounder was used as described in 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 3). The transducer cable was lengthened with an additional 100 m length of cable equipped with Seacon waterproof connectors at each end. The towed body was deployed and retrieved using the boat's winch cable. After deploying the towed body, the cable was attached to a large planer board measuring approximately 1.5 m long by 0.5 m high. The planer board was deployed on the starboard side of the boat to move the towed body out and away from the boat's propeller wash. The towed body was weighted and 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. A separate calibration was run for the hydroacoustic gear to correct for using the additional 100 m length of transducer cable. Specific echo sounder settings used for these surveys are in Appendix A.

We followed the transects such that water depths of 75 m or less were avoided. Transects were viewed and analyzed using Echoview software. Density estimates were made using echo counting techniques, where the number of individual traces in 1 m depth bins was divided by total area sampled by the acoustic beam at each depth. Target depths were calculated with reference to the distance from the lake surface. Targets larger than -30 dB (>590 mm) were assumed to be pelagic predators. We used the up-looking survey to calculate densities of large pelagic fish in the top 10 m of water and used the down-looking survey to calculate densities between the 10 and 35 m depths.

## Midwater Kokanee Trawling

We conducted midwater trawling in Lake Pend Oreille from September 6 to 8, 2007. These dates were during the dark phase of the moon, which optimized the capture efficiency of the trawl (Bowler et al. 1979). We used a stratified random sampling scheme to estimate kokanee abundance and density within the three lake sections. We randomly selected 12 locations within each section and made hauls in a predetermined, random direction from the selected point (Figure 4). We located each trawl site using GPS coordinates.

Rieman (1992) described in detail the sampling procedures for midwater trawling. However, the net used in our study was somewhat different. For the fifth straight year, 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 to 25 to 19 to 13 mm in the body of the net 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-582 depth sounder with a 10° hull-mounted transducer. A stepwise oblique tow was conducted along each transect, consisting of 3 to 6 steps, which sampled the entire vertical distribution of kokanee. Each step lasted for 3 minutes and represented a 3 m deep portion of the depth zone occupied by kokanee.

Kokanee from each trawl sample were counted and placed on ice until morning, when they were processed without being frozen. Length and weight were recorded for individual fish, and all kokanee over 180 mm were checked for maturity. Scales and otoliths were taken from 10 to 15 fish in each 10 mm size interval for ageing. The otoliths from 122 kokanee were sent to the WDFW Otolith Laboratory for ageing and identification of cold brands to document wild or hatchery origins of individual fish.

Kokanee catch per trawl haul was divided by the volume of water filtered by the net (while in the kokanee layer) to obtain density of kokanee at each trawl site. The age-specific density estimates for each section were expanded to a whole-lake population estimate, and 90% confidence intervals were calculated using standard formulas for stratified sampling designs (Scheaffer et al. 1979; see earlier equation). Kokanee abundance was estimated using geometric [log (x+1)] means. The geometric means provided a more accurate estimate of kokanee abundance than the arithmetic means that were calculated during previous years. The area of each section was calculated for the 91.5-m depth contour; however, the northern section was calculated from the 36.6 m depth contour because of shallower maximum water depth. The 91.5 m contour was selected because it represents the pelagic area of the lake where kokanee were found during late summer (Bowler 1978). For consistency, these same areas (totaling 22,646 ha) have been used each year since 1978.

## Kokanee Fry Netting

Because the midwater trawl has large enough mesh that some kokanee fry, especially smaller wild fish, may pass through the net, we sampled Lake Pend Oreille with a small mesh trawl net as an additional method to estimate kokanee fry abundance. We also used the proportions of hatchery and wild fish captured in each section to determine total wild fry abundance. Sampling with the fry net began on Lake Pend Oreille in 1999 and has continued annually thereafter. Net hauls were made during the same new moon period as that year's midwater trawling to make the results comparable. Eight net hauls were made in each lake section during September 11-12, 2007 (Figure 5).

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.

We made stepwise oblique tows through the layer of kokanee seen on the boat's echo sounder. The net was towed at depths ranging from 13 m to 35 m. The fry net was towed for three minutes at each "step" (a step corresponded to a 3 m depth stratum) until the entire kokanee layer had been sampled. The average boat speed was 1.7 m/s.

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 for later analysis. The fish were later thawed and measured for length and weight. We removed and sent 112 pairs of otoliths to the WDFW Otolith Lab to determine the origin (hatchery vs. wild) of kokanee fry captured during fry trawling. We removed otoliths from 44 fry in section 1, 35 fry in section 2 and 33 fry in section 3.

The percentage of wild and hatchery kokanee within each 10 mm length group was identified by otolith examination. Percent wild fish was multiplied by the population estimate within each length group and then summed to determine the abundance of wild fish.

Density of fry (fish/ha) in the kokanee layer was calculated for each net tow based on the volume of water sampled by the net (boat speed [m/s] x time [s] x the area of the net mouth [$m^2$]) as it passed through the kokanee layer, multiplied by the thickness of the kokanee layer (m), and multiplied by 10,000 to convert estimates to fish/ha. Density estimates were averaged per section and expanded by the area of the section. Estimates of fry within each section were summed to determine the lake-wide population estimate of fry.

## <u>Hatchery Kokanee Marking</u>

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 should contain distinct thermal marks. Thermal treatments were initiated five to ten days after fry entered their respective raceways. Fry released in 2007 (brood year 2006) received a 12 day pattern created by five single-day coldwater events. The first event was one day of cold water followed by a four-day warm water event. The subsequent three marking events consisted of alternating between cold and warm water for one day each. The last warmwater event was followed by a final coldwater mark. Ten fry from each raceway were sacrificed to verify the thermal marking. Recognizable otolith marks were verified on all thermally treated individuals.

During the spring of 2007, Cabinet Gorge Fish Hatchery released 11.26 million thermally marked kokanee fry into Lake Pend Oreille. Out of this total, 9.08 million fry were of the late spawning strain and the remaining 2.18 million were of the early spawning strain. We sent 234 otoliths from all kokanee age classes collected during the 2007 trawling to the WDFW lab to determine origin. Before shipment, we catalogued each fish, recorded total length and weight, and removed, cleaned, and numbered the otoliths. One otolith was removed from each of the 327 vials by WDFW personnel and oriented 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 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. 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 reference samples taken from the hatchery during fry rearing since 1996. For accuracy, two independent readers examined each otolith. Differences between the readers were settled by re-examination.

## 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. Hydroacoustic population estimates and kokanee weights from the trawl catch were used 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. The year class weights were then summed to obtain total kokanee biomass in the lake.

Production was defined as 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 an age class of kokanee between two 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 (to get the increase in weight of each year class). Next, we averaged the population estimates between the two years. Lastly, we multiplied the increase in mean weight by the average population estimate for each age class. We then summed the results for all of the year classes to determine the production for the entire population. These calculations assume 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 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. Lastly, we multiplied the mean weight by the number that died to estimate the yield for each age class. Results were summed across all year 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. Data from 1996 through 2007 were used to plot the trend lines. The production to biomass curve was forced to go 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 this time-series data set dating back to 1972. All areas surveyed were documented as historic spawning sites (Jeppson 1960). Nine shoreline areas and seven tributary streams were surveyed the third week of November. We counted all kokanee, either alive or dead.

The 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 (which supports both an early and late run of kokanee). In addition, the early spawning run of kokanee in Trestle Creek was surveyed on September 20, 2007 to assess this stock.

## Kokanee Spawning Habitat Sampling

Six sites (Twin Creek, Green Bay, Ellisport Bay, Kilroy Bay, south of Evans Landing, and the south side of Ellisport Bay) were sampled in July 2007 to document changes in substrate composition after being flooded by higher summer pool levels. Scuba divers identified a gravel band between elevation 624.8 msl and 625.8 msl and collected 4-5 randomly located samples from each of the six sites. 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 were allowed to dry before each sample was screened using soil sieves (sizes 31.5 mm, 6.3 mm, 4.0 mm, and 2.0 mm). Sieved samples were weighed to determine the composition. The substrate retained on each screen, and the substrate that 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 31.5 mm and larger, "gravel" as substrates between 31.5 and 4.0 mm, and "fines" as the substrate smaller than 4.0 mm.

## *Mysis* Shrimp Abundance

We sampled *Mysis* shrimp *Mysis relicta* from June 12-13, 2007 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; in 2004 and 2005, the number of sample sites was increased to 15. However, during 2007, we determined eight random sites were sufficient in each lake section (Figure 6). GPS coordinates were used to locate all sampling locations.

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. The net was lowered to a depth of 45.7 m, allowed to settle for 10-15 seconds, and raised to the surface at a rate of 0.5 m/s using an electric winch. Collected mysids were placed in denatured ethanol for preservation until laboratory analysis was performed. This methodology has been the standard since 1997.

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

## RESULTS

### Down-looking Hydroacoustic Survey

In 2007, we estimated the lake contained 11.8 million kokanee (10.8 million to 12.8 million, 90% CI) or 520 fish/ha, based on our standard nighttime hydroacoustic survey. This included 9.1 million age-0 kokanee (8.4 million to 9.9 million, 90% CI; Table 2) and 2.7 million (2.4 million to 3.0 million, 90% CI) kokanee of ages 1-4 (Table 1). The lake contained an estimated 2.4 million age-1, 279,000 age-2, and 46,000 age-3 kokanee. Age-4 kokanee abundance was too low to calculate. 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 as 20% from age-0 to age-1, 10% from age-1 to age-2, and 11% from age-2 to age-3 (Table 3). We were unable to calculate survival from age-3 to age-4 due to the lack of kokanee collected in these age classes.

Wild kokanee fry made up 27.3%, 28.6%, and 15.2% of the fry net catch in the southern, middle, and northern sections, respectively (Table 2). Based on these numbers, we estimated the wild fry population at 2.0 million (Table 2). During 2006, we were unable to accurately estimate the number of spawning kokanee and potential egg deposition (PED), and therefore were unable to calculate egg-to-fry survival for 2007.

In the down-looking hydroacoustic survey, eight fish over -30 dB (590 mm) were recorded. Abundance estimates in the southern, middle and northern sections were 2,408, 2,828, and 1,974 fish, respectively. A total population estimate of large pelagic predator fish by down-looking hydroacoustics (fish >10 m deep) was 7,209 fish ± 21% (0.34 fish/ha).

### Up-looking Hydroacoustic Survey

Four large (> -30 dB [>590 mm]) pelagic fish were seen in our up-looking hydroacoustic survey. Abundance estimates in the southern, middle, and northern sections were 1,530, 0, and 2,078 fish, respectively. Based on these observations, the population estimate of pelagic predators >590 mm using up-looking hydroacoustics (fish < 10 m deep) was 3,608 fish ± 18% (0.17 fish/ha).

### Midwater Trawling for Kokanee

Total kokanee abundance based on geometric means of trawl samples was 6.7 million fish (± 0.57, 90% CI) with a density of 296 fish/ha (Table 4). This included 4.1 million kokanee fry, 2.2 million age-1 kokanee, 347,000 age-2 kokanee, and 73,000 age-3 kokanee. No age-4 kokanee were captured in the midwater trawl; therefore, we were unable to estimate abundance for this portion of the kokanee population. The total standing stock of kokanee was 2.9 kg/ha (Table 4). Kokanee captured by midwater trawling varied in length from 26 mm to 236 mm (Table 4; Figure 8). Mean weight was 2.1 g for age-0, 15.4 g for age-1, 53.8 g for age-2, and 76.0 g for age-3 kokanee (Figure 9).

During 2007, only two mature kokanee were caught in 36 trawl hauls (both fish were caught in section one). This translates into 0.7% of the trawl catch in the southern section being mature, with 0% mature in the middle and northern sections. Using these percentages to estimate mature kokanee abundance yields an estimate of 9,511 mature kokanee or 4,755 mature female kokanee assuming a 50:50 ratio of males to females. Hatchery personnel collected 1,133 mature female kokanee at the spawning station at Sullivan Springs Creek. Fecundity of adult female kokanee collected at Sullivan Springs Creek was 496 eggs/female. Based on this fecundity estimate, 3,622 naturally spawning adult female kokanee deposited 1.8 million eggs in Lake Pend Oreille and its tributaries.

## Kokanee Fry Netting

A total of 112 fry were collected using the small-mesh fry net during September 2007. We collected 44 fry in the southern section, 35 fry in the middle section, and 33 fry in the northern section of the lake. Based on this method, and using arithmetic means, we estimated 4.7 million kokanee fry, of which an estimated 1.1 million were wild.

## Kokanee Biomass, Production, and Yield

We calculated estimates of kokanee biomass, production, and yield based on the hydroacoustic estimates of kokanee abundance. Kokanee biomass was 74 metric tonnes (t), and kokanee production was 182 t (Table 5). Total yield of kokanee was 221 t (Table 5).

We plotted kokanee production and yield against kokanee biomass to examine trends and correlations (Figure 10). Yield in 2007 was 39 t higher than production, and biomass declined considerably from 2006. Production in 2007 was again near the trend line fitted to the production data from 1996 through 2006 (Figure 10).

## Kokanee Spawner Counts

In 2007, we observed 325 kokanee spawning on the lake's shorelines. All shoreline spawning was observed in Scenic Bay; no shoreline spawning kokanee were observed at other historical spawning locations (Table 6). We observed 124 early-spawning kokanee in Trestle Creek; no other kokanee (late or early spawning) were observed in other tributaries to Lake Pend Oreille (Table 7).

## Kokanee Spawning Habitat Sampling

The largest changes in substrate composition between 2007 and 2006 were observed at Green Bay, the south side of Ellisport Bay, and Evans Landing, where the percent of gravel in substrate samples decreased by 29.7%, 20.7%, and 19.9%, respectively (Figure 11). At Green Bay and the south side of Ellisport Bay, increased fines (+29.3 and +18.5%, respectively) replaced the majority of gravel losses. The decrease in gravel at the Evans Landing sample site was replaced by increases in cobble (+12.8%) and fines (+7.2%).

## *Mysis* Shrimp Abundance

We estimated a total mean density of 511 *Mysis* shrimp/m$^2$ during June 2007 (Table 8). This included 241 immature and adult *Mysis* shrimp/m$^2$ (90% CI of $\pm$ 35%) and 270 YOY *Mysis* shrimp/m$^2$. The length-frequency distribution of cohorts is presented in Figure 12. Overall, total density of *Mysis* shrimp in Lake Pend Oreille remained relatively stable between 2006 (569 shrimp/m$^2$) and 2007 (511 shrimp/m$^2$) (Figure 13). From 2006 to 2007, the density of YOY *Mysis* shrimp decreased by 22%, while the density of immature and adult *Mysis* shrimp increased by 8% (Figure 14).

## DISCUSSION

### Kokanee Population Dynamics

In previous years of the Lake Pend Oreille Fishery Recovery Project, we documented improvements in wild kokanee egg-to-fry survival with changes in the winter water level. Due to the limited amount of adult kokanee observed in the trawl catch in 2006, we were unable to estimate potential egg deposition in 2006 and, in turn, were unable to estimate egg-to-fry survival in 2007. Survival rates between other ages, particularly between ages 0 to 1 and ages 1 to 2, continued to decline (Figure 15). The limited number of age-3 and age-4 kokanee captured made accurate estimates of survival rates for these age classes difficult.

Since 1999, we have been concerned that predation will cause the complete loss of kokanee from Lake Pend Oreille (Maiolie et al 2002). Continued declines in survival rates (Table 3; Figure 15) and the loss of older age classes of kokanee indicate that this situation is worsening. Age-specific population estimates of kokanee show increased age-0 abundance, potentially due to increased stocking. However, abundance of kokanee ages 2-4 are severely depressed (Figure 16). Tributary spawner counts are the lowest on record, while shoreline spawners are down 82% from 2006. It is unlikely that this population will persist if the current survival rates do not improve. During 2007, 23,006 lake trout and 8,141 rainbow trout were removed from Lake Pend Oreille through commercial netting and an angler incentive program in an attempt to reduce predator abundance and increase kokanee survival. At this point, it is too early to determine if predator removal efforts have had the desired effect. Predator removal efforts are ongoing, and future kokanee population monitoring and survival rate estimates will determine the effectiveness of these efforts.

One factor which has kept this population from complete extirpation from the lake has been the pronounced increases in the production:biomass ratio. In 2007, the kokanee population produced 182 t of fish flesh from a population with a biomass of 74 t for a ratio of 2.46:1. This ratio was about 1:1 or less in 1996 through 1999. Increases in the production to biomass ratio helped to slow the decline, but with yield exceeding production, a decline in biomass was still observed. Any future declines in kokanee biomass are likely to cause a decrease in kokanee production (Figure 10). Declines in production would be expected to cause an increase in the rate of decline in biomass, thus causing a negative feedback loop. Yield for 2007 fell much below the trend line and was the second lowest yield recorded since 1998.

We have shown throughout the years that discrepancies, sometimes two-fold, arise between trawl and hydroacoustic estimates of the kokanee population, but the hydroacoustic estimate is a more accurate representation of kokanee abundance. However, because we have historical kokanee abundance calculated via trawling back to 1978, we will continue to calculate trawl estimates to use as an index when comparing to historical data or until sufficient data exist that a conversion can be created. Similarly, we will continue to sample fry with both trawl nets.

## Predator Abundance

In 2007, we tried two different methods of hydroacoustics to estimate large pelagic predator fish in Lake Pend Oreille. Our large predator estimate of 3,608 ± 18% with the up-looking hydroacoustics and 7,209 ± 21% with the down-looking hydroacoustics were both lower than the 2006 combined estimate of 14,600 ± 83%. We were not able to combine the two estimates during 2007 because the duration of time between estimates (up-looking was conducted in June; down-looking in August) causes them to become independent of one another due to potential fish dispersal. Estimating predator abundance using hydroacoustics continues to be limited by the small number of fish found (only four fish were found in 21 transects of the 2007 up-looking hydroacoustics). Thus, these estimates must be interpreted with caution as the low number of targets can make these estimates of large predators unreliable due to an increased likelihood of inaccuracy. Employing different methods such as increased number of transects, wider transducer beam angle, or multiplexing two transducers may be able to improve this issue in the future.

During 2006, boat propeller wash near the surface during the up-looking hydroacoustic surveys masked the presence of fish in the top few meters of water and led to problems with analyzing the data. Therefore, for 2007, a large planer board was designed to pull the towed body out away from the boat and past the effects of the propeller wash. The planer board successfully alleviated the majority of the propeller wash problem. However, a light wind during several transects caused disturbance reaching two to three meters below the surface, and once again shrouded targets. For future surveys, weather will play a larger role in determining when up-looking surveys are executed.

## Gravel Sampling

The amount of shoreline gravel has decreased since 2004, but substrate remains in good quality to support the limited amount of kokanee spawning anticipated in 2008. The last drawdown of the lake to its low pool elevation was during the winter of 2003-04, which allowed wave action to clean and redistribute shoreline gravel. During the summer of 2004, the average percent gravel at the six sample locations was 83%; the average percent gravel in 2007 has decreased to 57%. Previously we had recommended that the lake be drawn down after 3 years of higher winter levels to allow wave action to improve spawning habitat (Maiolie et al. 2002). This recommendation still appears valid and will be important to follow if kokanee abundance increases in future years in response to predator removal efforts.

## *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 (Figure 13). Immature and adult *Mysis* shrimp densities (the segment of the population most likely to compete with kokanee) have remained relatively stable throughout the last eight years (Figure 14). A similar pattern of expansion followed by decline was observed 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 remained in 2007. Continued monitoring of *Mysis* shrimp is recommended.

## 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, BPA, 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 for kokanee age classes 1 through 4 in Lake Pend Oreille, Idaho, 2007. Estimates were generated from hydroacoustic data that were partitioned into age classes based on the percent of each age class sampled by midwater trawling.

| Area | Age 1 | Age 2 | Age 3 | Age 4 | Total |
|---|---|---|---|---|---|
| **Southern Section** | | | | | |
| Percent of age class in section by trawling | 58.8 | 31.7 | 9.5 | 0 | |
| Population estimate in section (millions) | 0.257 | 0.139 | 0.041 | NA | 0.437 |
| **Middle Section** | | | | | |
| Percent of age class in section by trawling | 92.5 | 7.2 | 0.3 | 0 | |
| Population estimate in section (millions) | 0.821 | 0.064 | 0.002 | NA | 0.887 |
| **Northern Section** | | | | | |
| Percent of age class in section by trawling | 94.2 | 5.6 | 0.2 | 0 | |
| Population estimate in section (millions) | 1.290 | 0.076 | 0.002 | NA | 1.369 |
| **Total population estimate for lake (millions)** | 2.369 | 0.279 | 0.046 | NA | 2.694 |

Table 2. Population estimates of kokanee fry (millions) based on hydroacoustic surveys of Lake Pend Oreille, Idaho in 2007. Percentage of wild fry was based on the proportion of wild fry caught using a fry net and by midwater trawling.

| | Southern | Middle | Northern | Lakewide Total | 90% CI |
|---|---|---|---|---|---|
| Total kokanee fry abundance estimate | 1.7 | 2.9 | 4.4 | 9.1 | 8.4 to 9.9 |
| Percent wild fry in fry trawl | 27.3 | 28.6 | 15.2 | — | |
| Wild fry abundance estimate | 0.5 | 0.8 | 0.7 | 2.0 | |

Table 3. Survival rates (%) between kokanee year classes estimated by midwater trawling and hydroacoustics, 1990-2007. Hydroacoustic estimates started in 1996. Year refers to the year the older age class in the survival estimate was collected.

| | Age Class | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 to 1 | | 1 to 2 | | 2 to 3 | | 3 to 4 | |
| **Year** | **Trawl** | **Acoustics** | **Trawl** | **Acoustics** | **Trawl** | **Acoustics** | **Trawl** | **Acoustics** |
| 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 2007 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 2007.

| | **Age 0** | **Age 1** | **Age 2** | **Age 3** | **Age 4** | **Total (90% CI)** |
|---|---|---|---|---|---|---|
| Population estimate (millions) | 4.1 | 2.2 | 0.3 | 0.1 | NA | 6.7 (6.1 to 7.3) |
| Density (fish/ha) | 180.3 | 96.8 | 15.3 | 3.2 | - | 295.6 |
| Standing stock (kg/ha) | 0.38 | 1.49 | 0.82 | 0.24 | - | 2.93 |
| Mean weight (g) | 2.1 | 15.4 | 53.8 | 76.0 | - | - |
| Mean length (mm) | 63.7 | 125.3 | 192.1 | 213.8 | - | - |
| Length range (mm) | 26-109 | 93-162 | 148-214 | 199-236 | - | - |

Table 5. Biomass, production, and yield (metric tons) of kokanee in Lake Pend Oreille, Idaho from 1996-2006.

| Year | Biomass | Production | Yield |
|---|---|---|---|
| 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 kokanee spawning in tributaries of Lake Pend Oreille, Idaho. The numbers shown indicate the highest weekly counts at each site and should be interpreted as an index rather than a total estimate of spawner abundance.

| Year | S. Gold | N. Gold | Cedar | Johnson | Twin | Mosquito | Lightning | Spring | Cascade | Trestle[a] | Trestle | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2007 | 0 | 0 | 0 | 0 | 0 | — | — | 0 | — | 124 | 0 | 124 |
| 2006 | 414 | 61 | 21 | 0 | 0 | — | — | 60 | — | 327 | 14 | 897 |
| 2005 | 5,463 | 615 | 1 | 0 | 1,244 | — | — | —[b] | — | 427 | 76 | 7,826 |
| 2004 | 721 | 2,334 | 600 | 16 | 6,012 | — | — | 3,331[b] | — | 682 | 0 | 13,696 |
| 2003 | 591 | 0 | 0 | 0 | — | — | — | 626 | — | 2,251 | 9 | 3,477 |
| 2002 | 79 | 0 | 0 | 0 | 0 | — | — | 0 | — | 1412 | 0 | 1,491 |
| 2001 | 72 | 275 | 50 | 0 | 0 | — | — | 17 | — | 301 | 0 | 715 |
| 2000 | 17 | 37 | 38 | 0 | 2 | 0 | 0 | 0 | 0 | 1,230 | 0 | 1,324 |
| 1999 | 1,884 | 434 | 435 | 26 | 2,378 | — | — | 9,701 | 5 | 1,160 | 423 | 16,446 |
| 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] Trestle Creek early spawners.
[b] Cabinet Gorge Hatchery transferred 3,000 spawners from the hatchery ladder to Spring Creek.

Table 8. Densities of *Mysis* shrimp (per m$^2$), by life stage (young of year [YOY], and immature and adult), in Lake Pend Oreille, Idaho, June 12-13, 2007. 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 | 364.1 | 176.5 | 540.6 |
| Section 2 | 348.3 | 303.3 | 651.6 |
| Section 3 | 125.0 | 233.7 | 358.7 |
| **Whole lake means** | **269.7** | **241.2** | **511.2** |

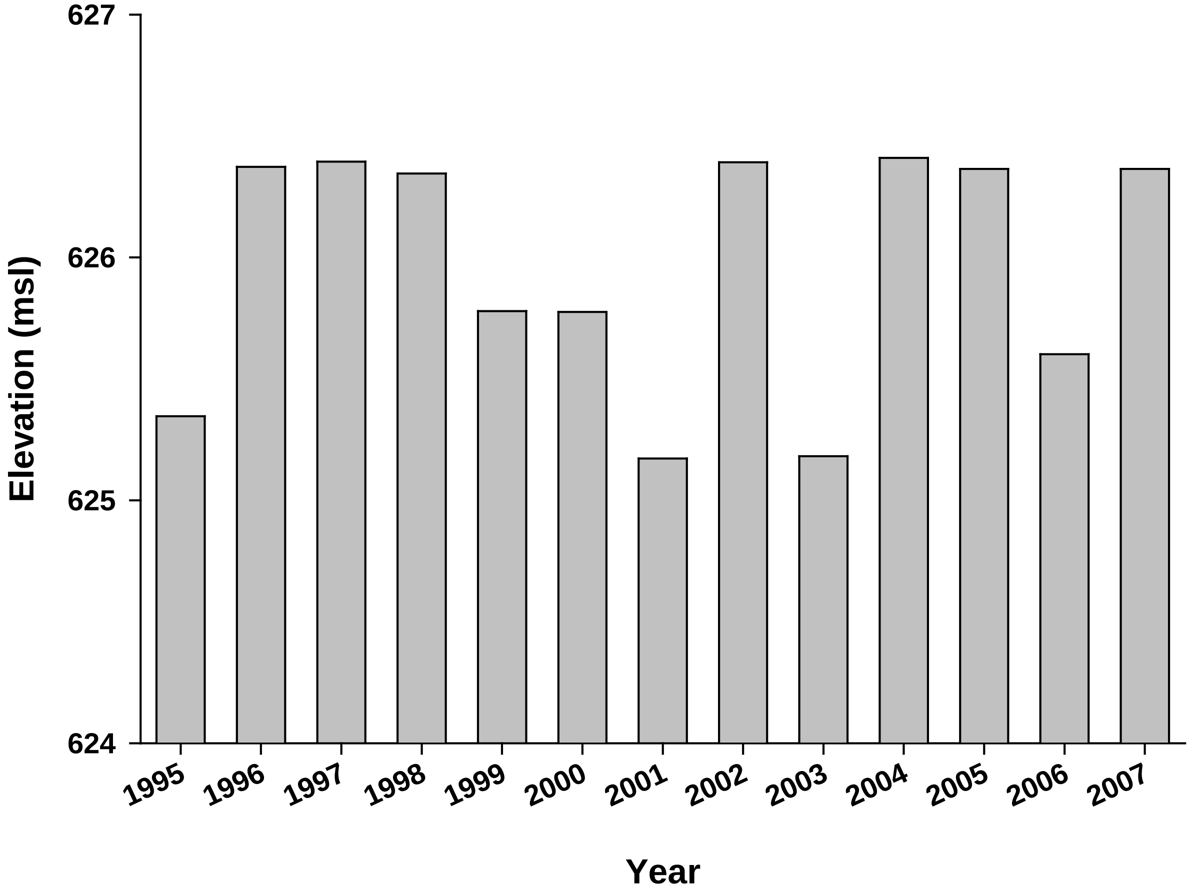
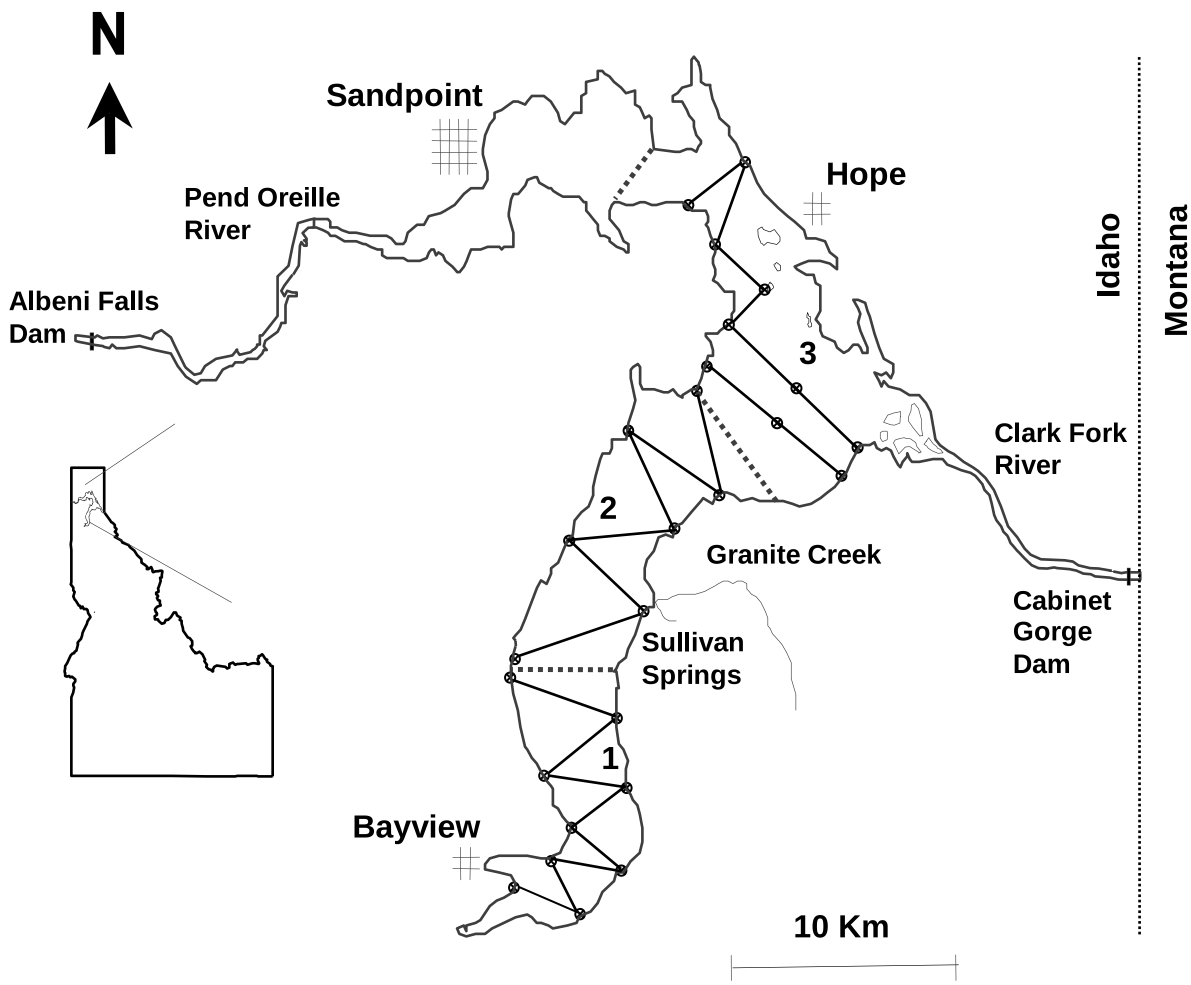



Figure 1. Winter pool surface elevation during years of lake level experiment in Lake Pend Oreille, Idaho. Year shown represents the year the lake was drawn down (i.e. 1995 for winter of 1995-1996).




| 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 2007. The inserted table depicts the area of kokanee habitat in each section.

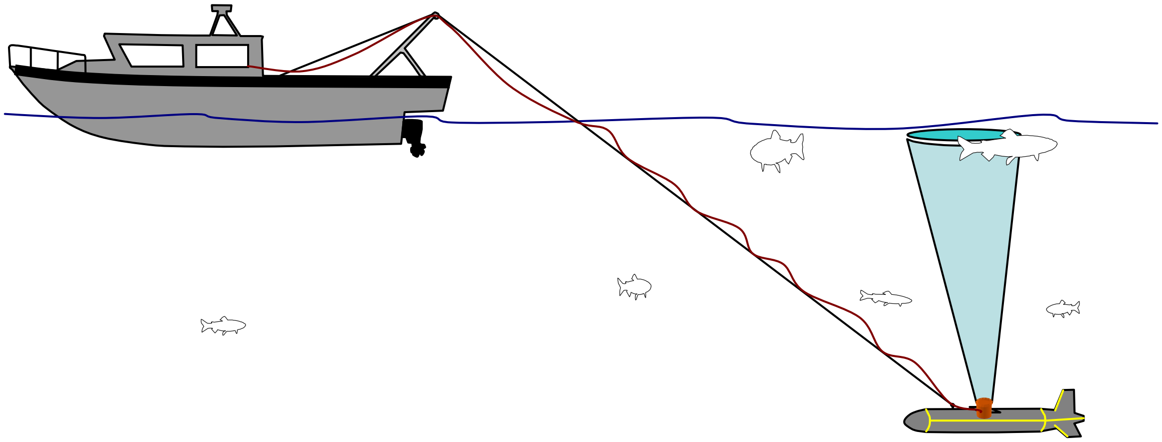


Figure 3. Illustration of towed body, hydroacoustic transducer arrangement, and towing vessel used during up-looking hydroacoustic surveys for predatory salmonids on Lake Pend Oreille, Idaho during June 2007.

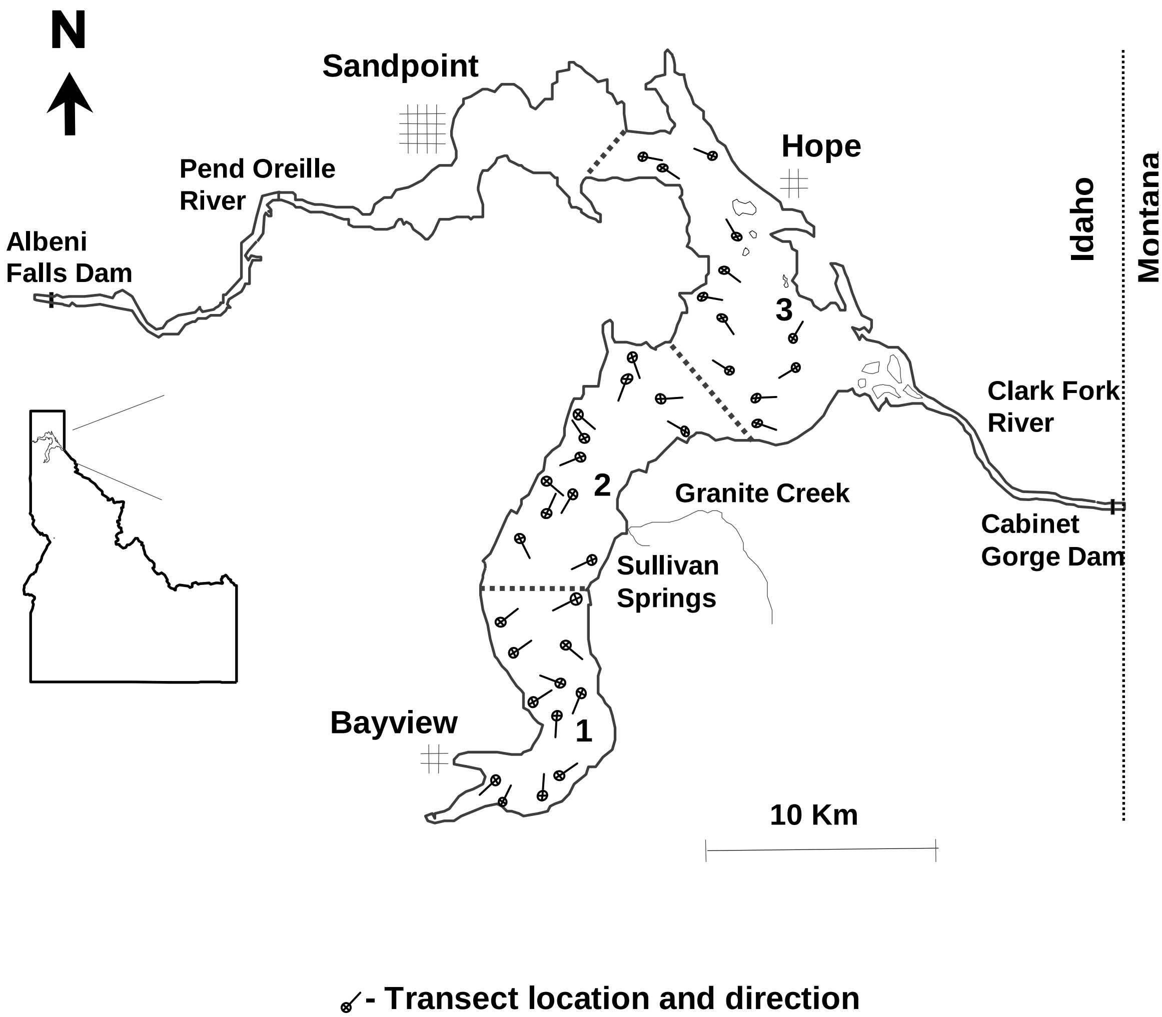



Figure 4. Map of Lake Pend Oreille, Idaho showing the locations of kokanee trawling transects used in 2007.

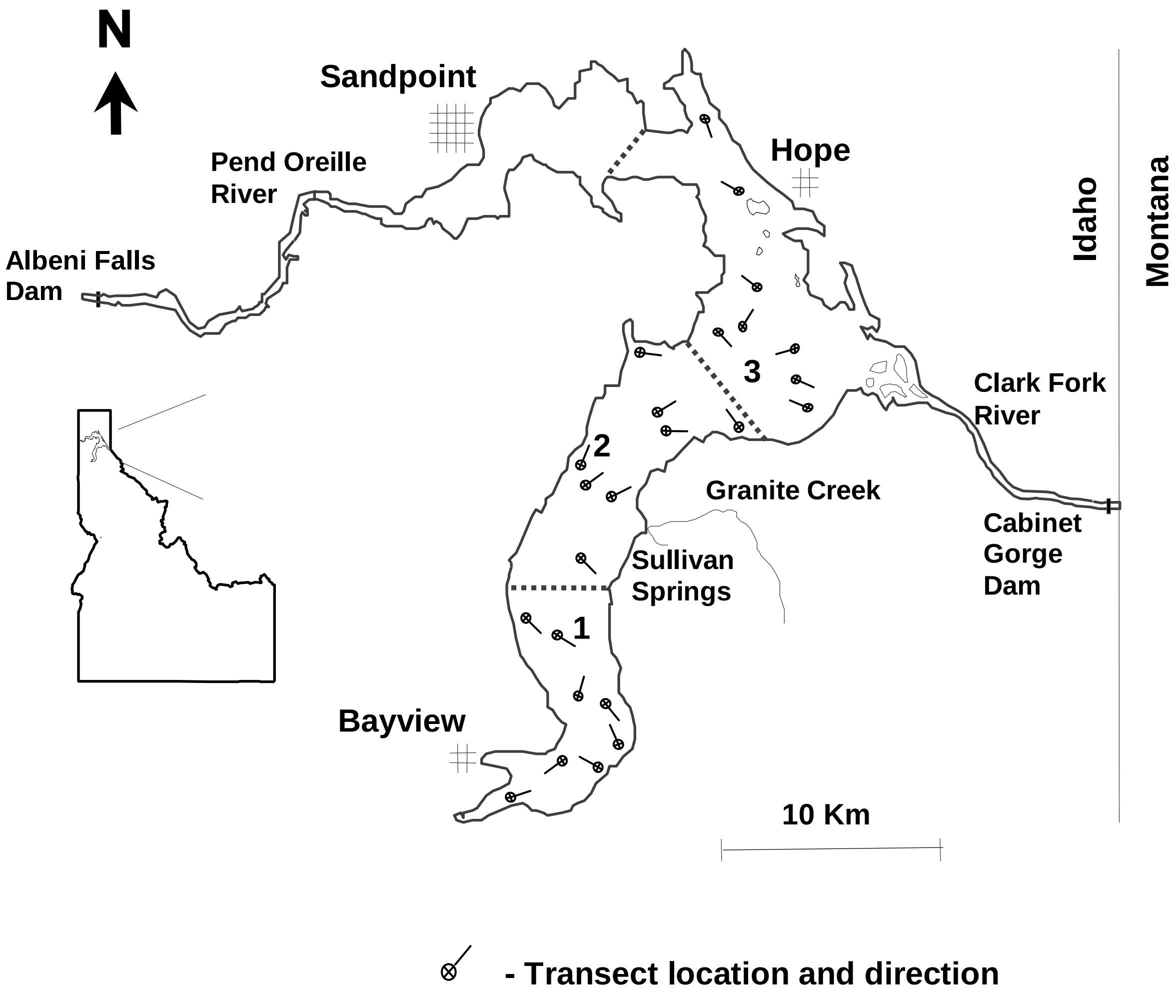



Figure 5. Map of Lake Pend Oreille, Idaho, showing the locations of kokanee fry trawling transects used in 2007.

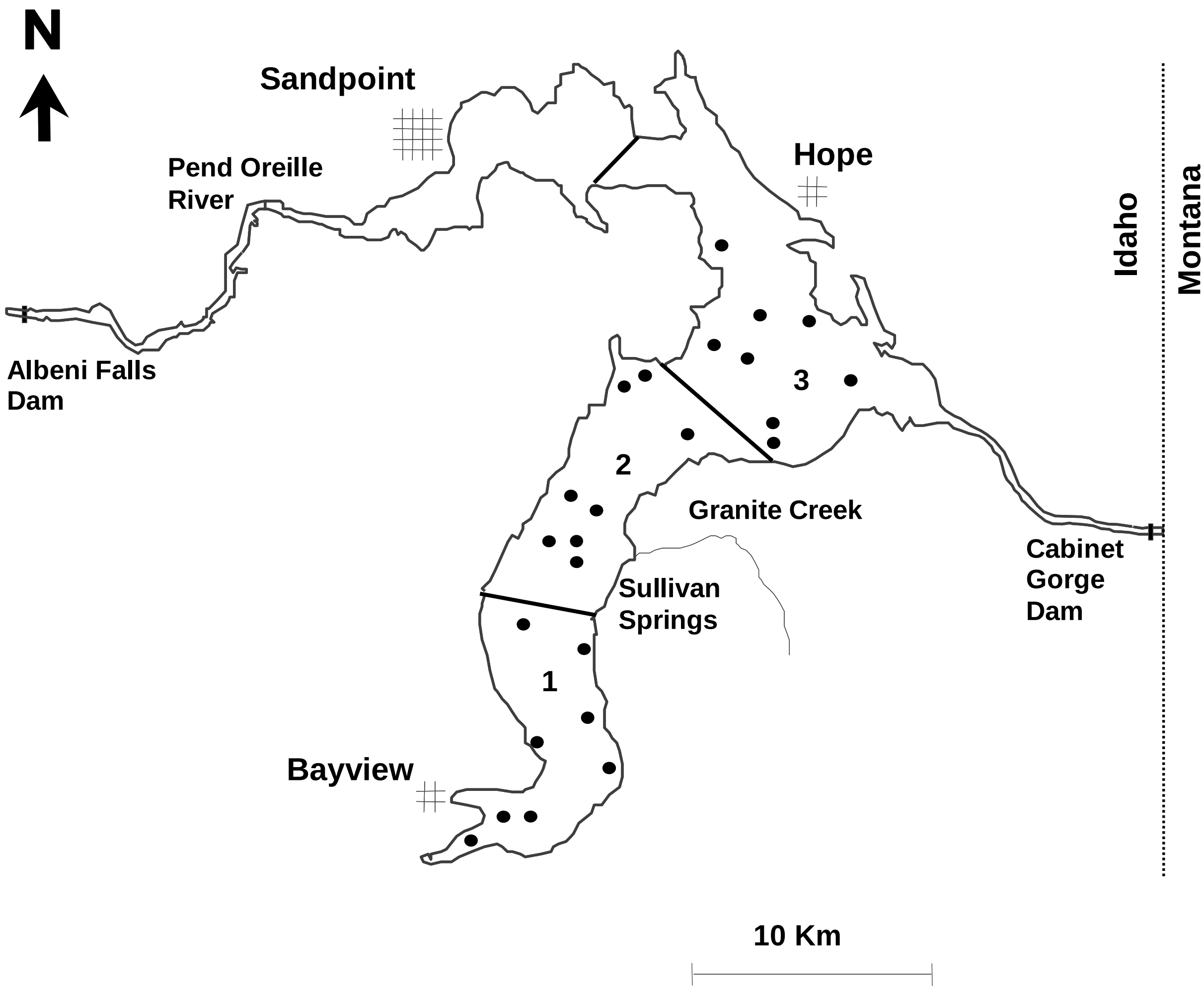



Figure 6. Map of Lake Pend Oreille, Idaho showing *Mysis* shrimp sampling locations within each lake section. Sampling occurred from June 12-13, 2007.

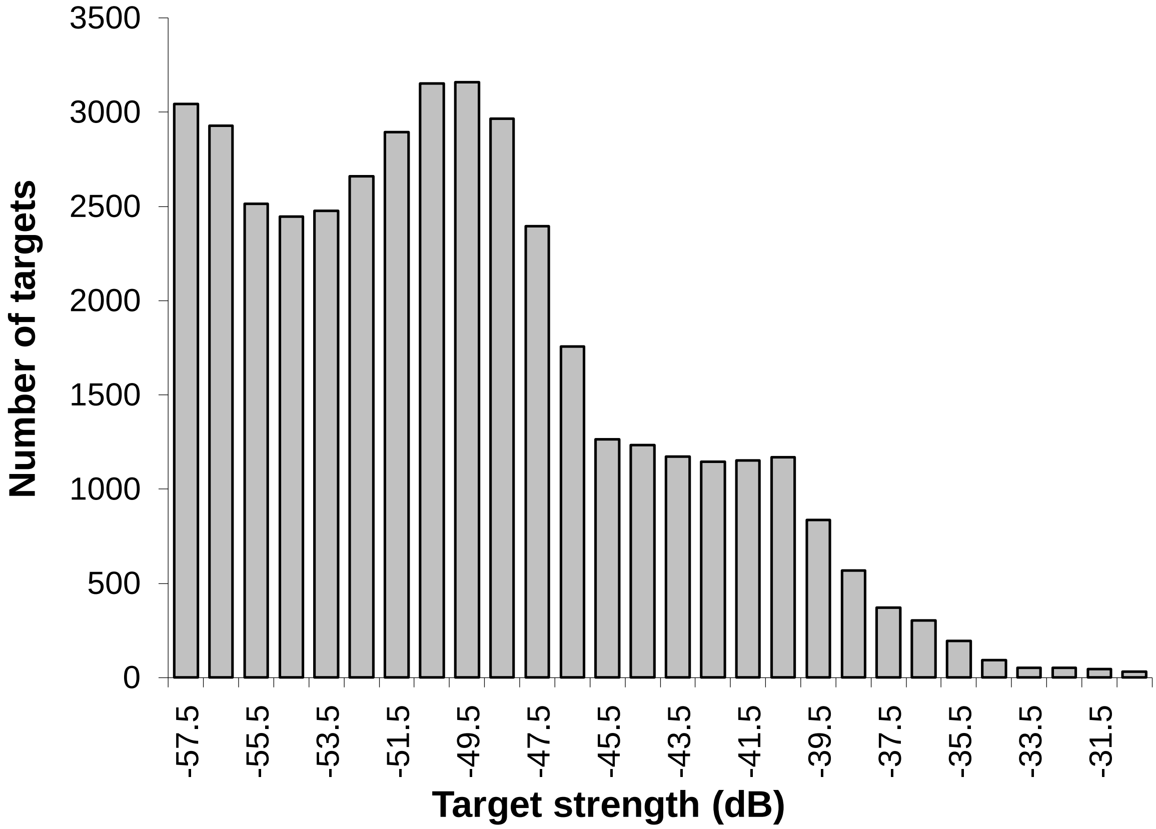



Figure 7. Target strengths of 42,148 fish recorded in Lake Pend Oreille from hydroacoustics in August 2007. Distribution was created to define the target strength between kokanee fry and age-1 and older kokanee (>-46 dB).

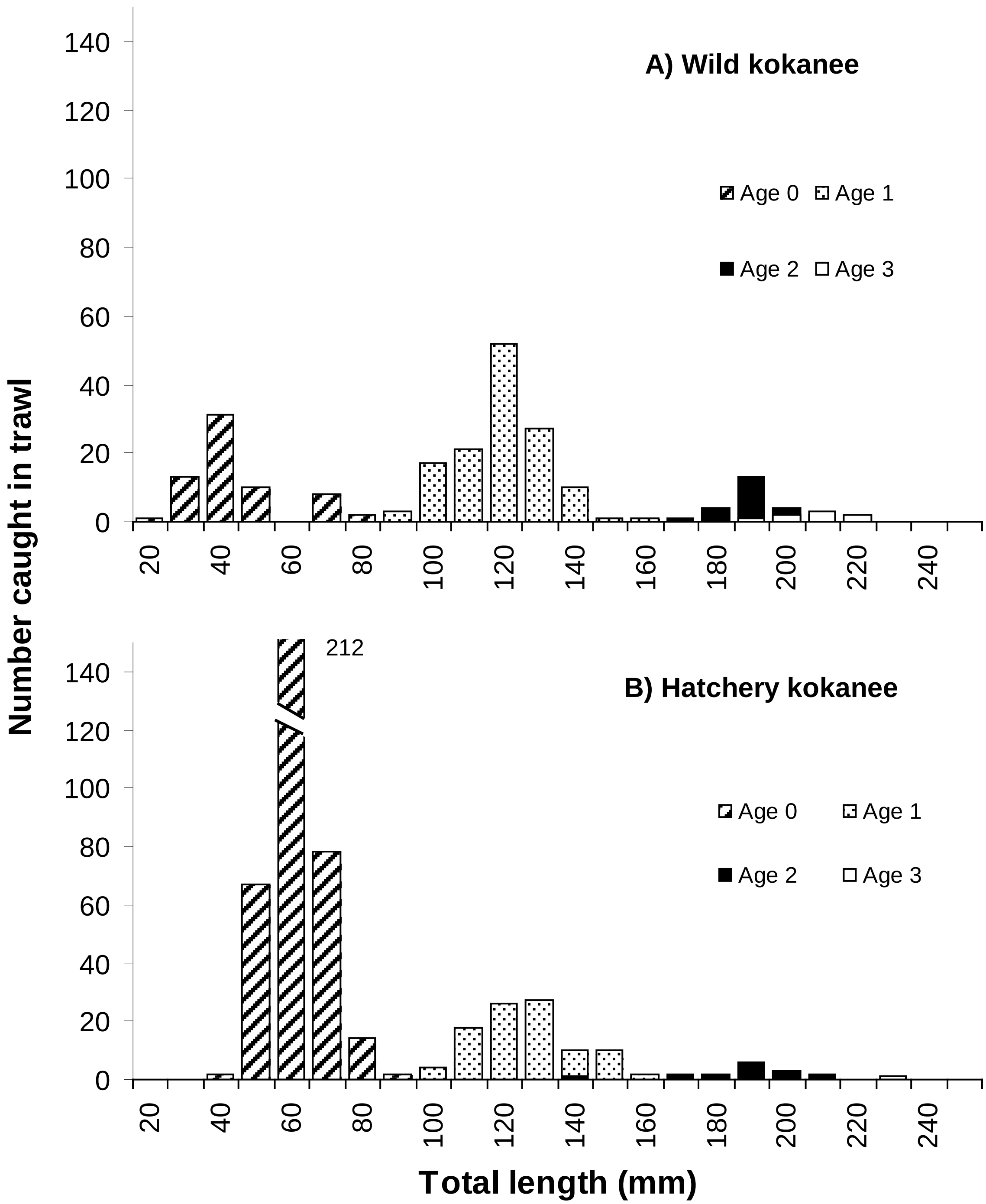



Figure 8. Length-frequency distribution of individual age classes of wild (A) and hatchery (B) kokanee caught by midwater trawling in Lake Pend Oreille, Idaho during August 2007.

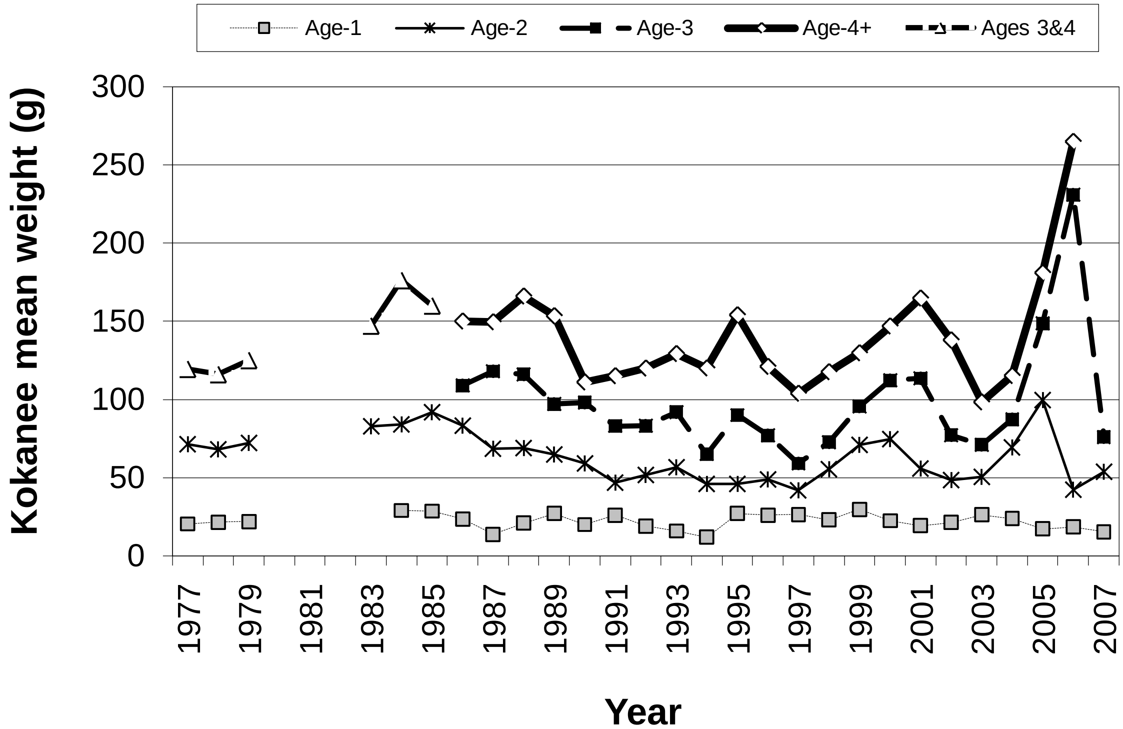



Figure 9. Mean weight (g) of kokanee by age class since midwater trawling began on Lake Pend Oreille, Idaho in 1977.

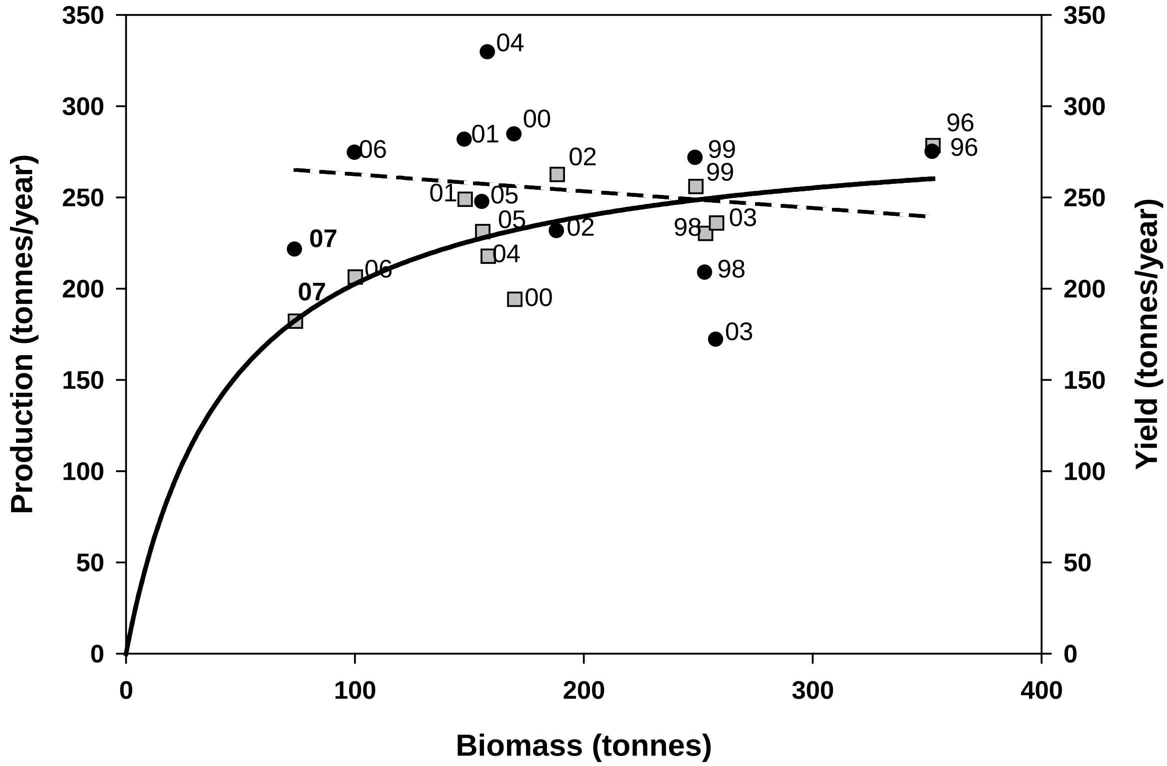



Figure 10. Kokanee biomass, production, and yield (metric tonnes) in Lake Pend Oreille, Idaho from 1996-2007, excluding 1997 due to 100 year flood. Kokanee biomass was measured at the start of the year. Gray squares indicate production and black circles indicate yield. The solid black line represents the production curve, and the dashed line is the yield trend line. Numeral by each point represents the year of the estimate.

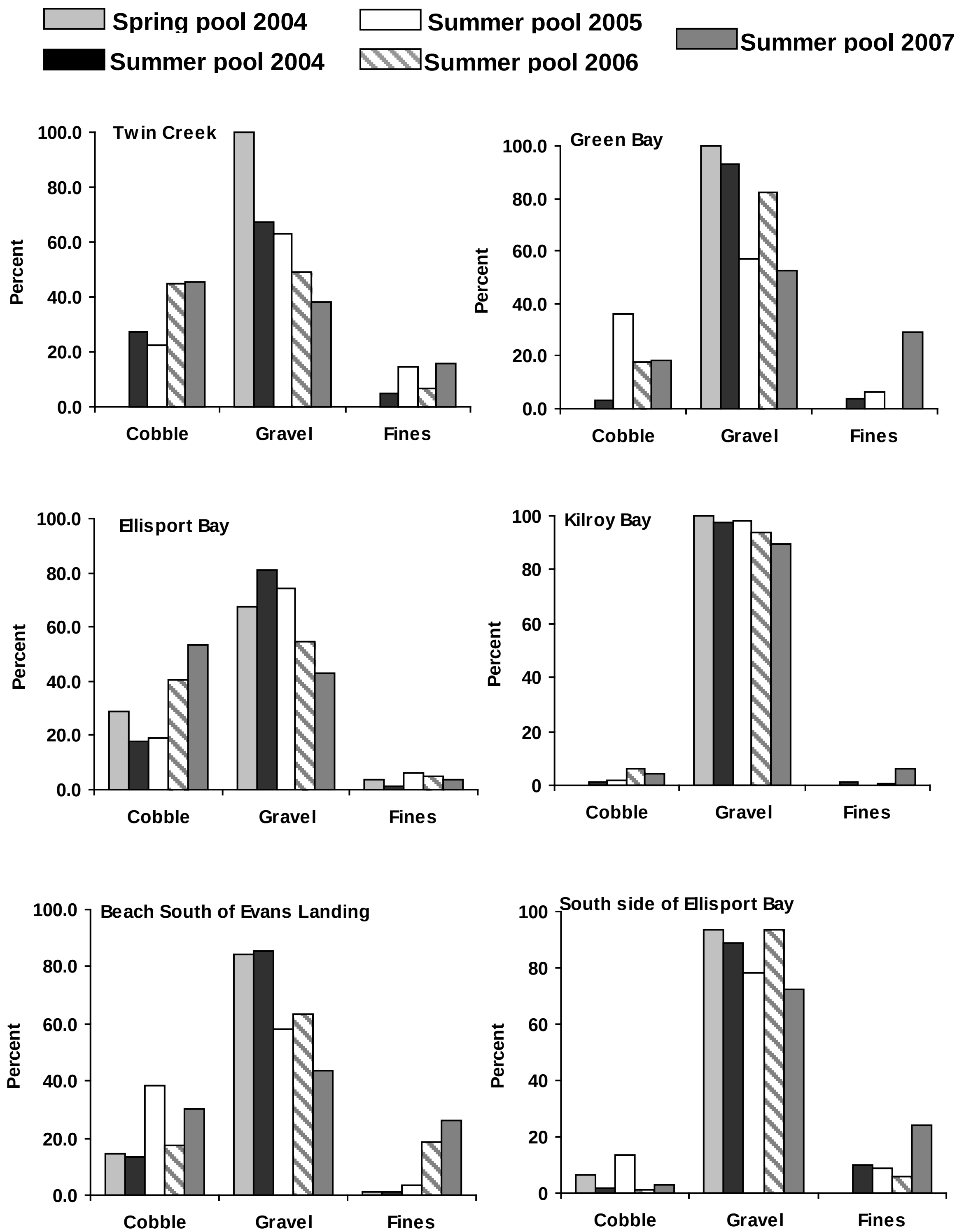



Figure 11. Substrate composition at potential kokanee spawning beaches in Lake Pend Oreille, Idaho. Sampling during spring 2004 was conducted above the water line at an elevation of 625.1 to 625.8 m while lake was at its low pool level. Other samples were collected at the same elevation by scuba diving during summer.

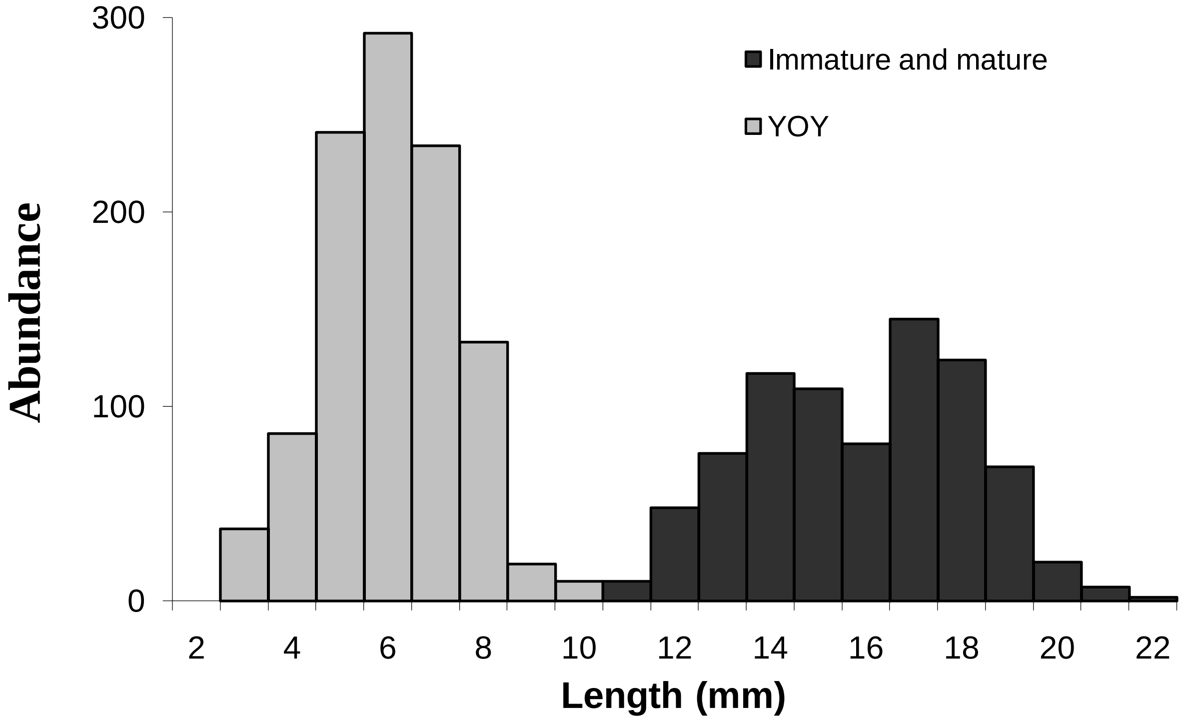



Figure 12. Length-frequency distribution of young-of-the-year (YOY) and immature and mature *Mysis* shrimp during June 2007 on Lake Pend Oreille, Idaho.

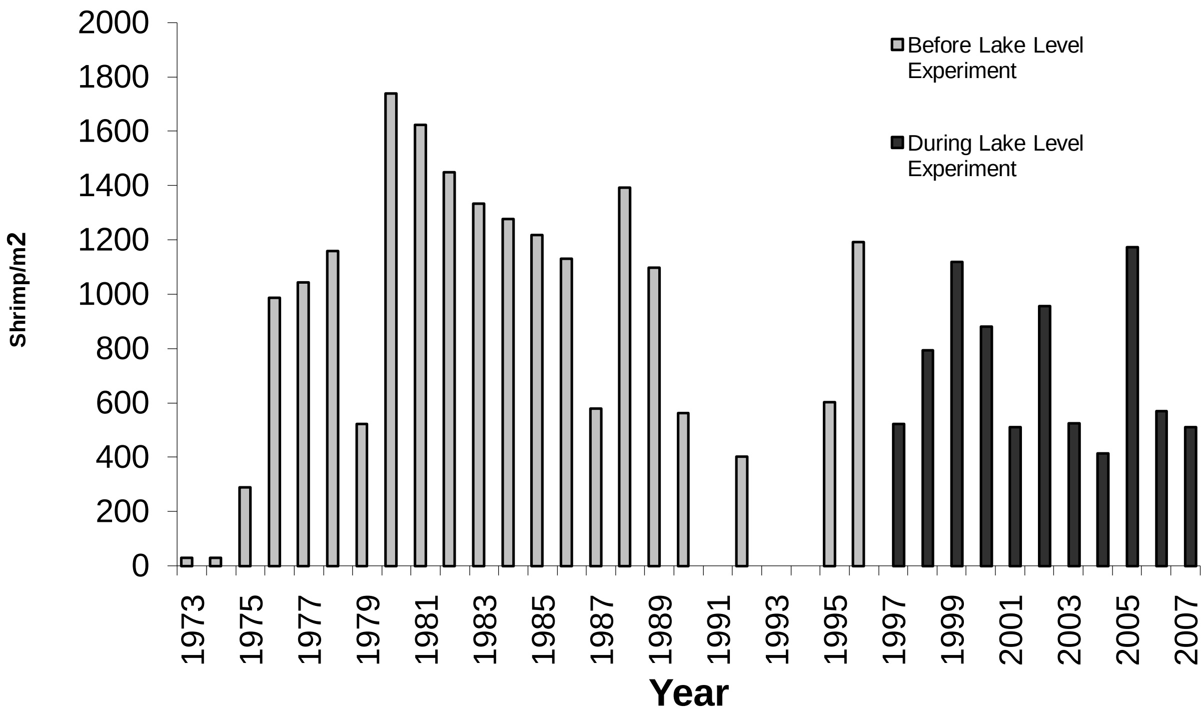



Figure 13. Annual mean density of *Mysis* shrimp in Lake Pend Oreille, Idaho from 1973-2007. Data collected before 1989 were obtained from Bowles et al. (1991), and data from 1995 and 1996 were from Chipps (1997). Densities from 1992 and earlier were converted from Miller sampler estimates to vertical tow estimates by using the equation y = 0.5814x (Maiolie et al. 2002). Gaps in the histogram indicate no data were collected that year.

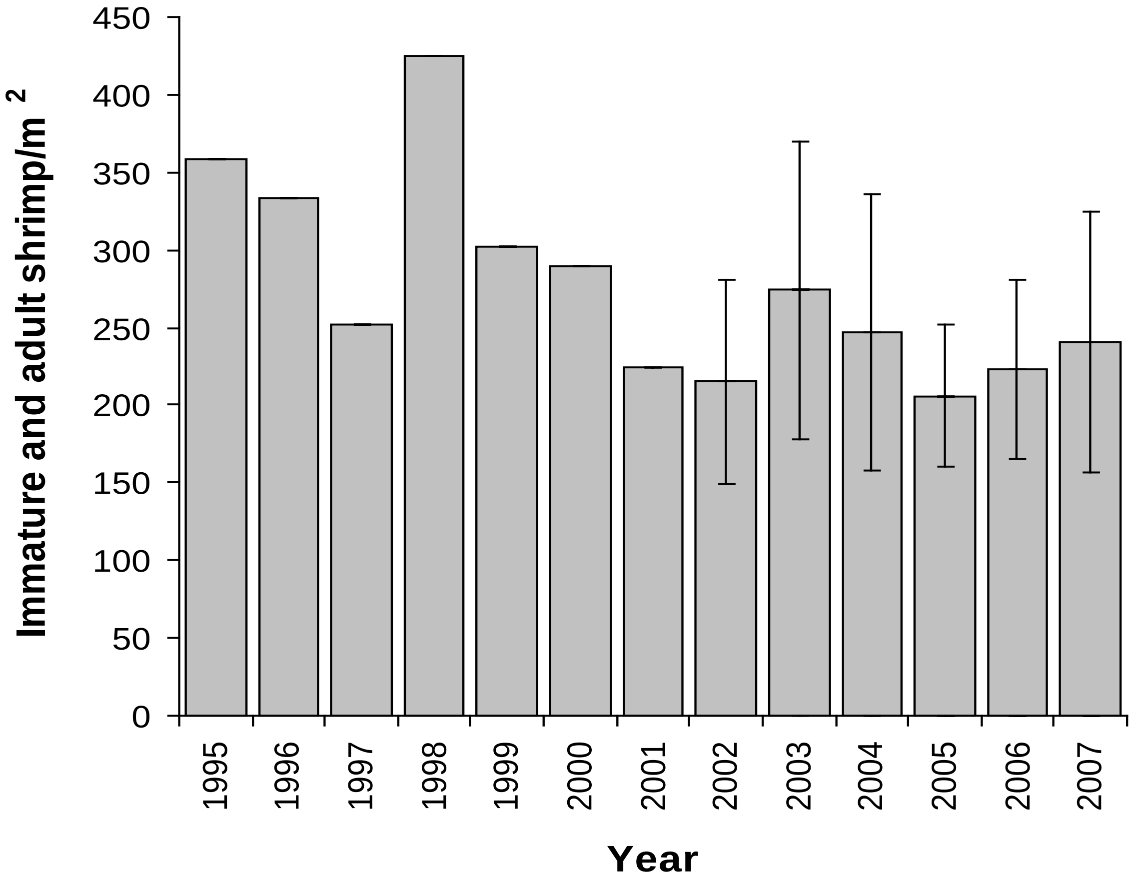



Figure 14. Density estimates of immature and adult *Mysis* shrimp in Lake Pend Oreille, Idaho for the past 13 years (1995-2007). Error bounds were added to the recent population estimates to identify 90% confidence intervals around the estimate.

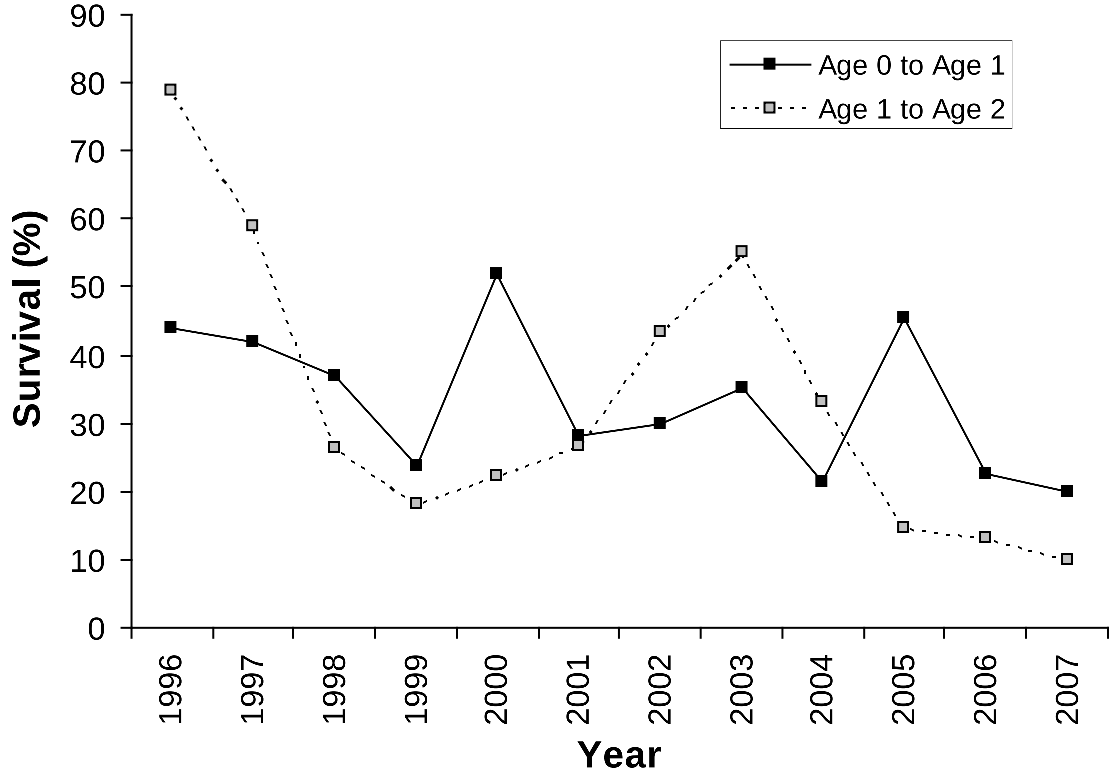



Figure 15. Survival rates of kokanee from ages 0-1 and ages 1-2 in Lake Pend Oreille, Idaho. Estimates were generated from hydroacoustic surveys conducted between 1996 and 2007.

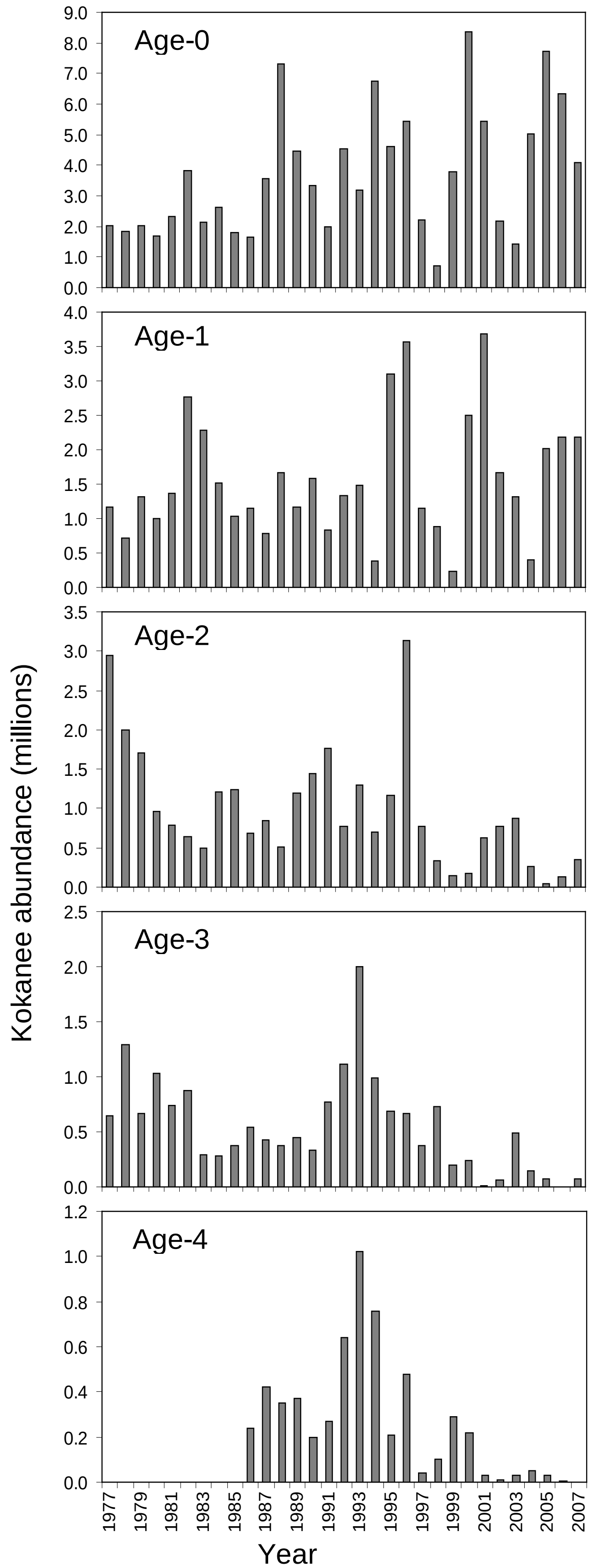



Figure 16. Kokanee age-specific population estimates based on midwater trawling between 1978 and 2007. Age-3 and -4 kokanee were not separated prior to 1986.

# 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 2007.

| **Calibration date:** | **June 25, 2007** | **May 25, 2007** |
|---|---|---|
| **Setting** | **Short Cord** | **Long Cord** |
| Transducer: Simrad | Split Beam 120-7C | Split Beam 120-7C |
| Absorption Coefficient (dB/m) | .004265 | .004433 |
| Sound Speed (m/s) | 1451 | 1447 |
| Transmitted Power (w) | 500 | 500 |
| Two-way Beam Angle (dB re: 1 steradian) | -21.00 | -21.00 |
| Transducer Gain (dB) | 26.82 | 24.44 |
| SA Correction (dB) | -0.56 | -0.52 |
| Transmitted Pulse Length(ms) | 0.256 | 0.256 |
| Frequency (kHz) | 120 kHz | 120 kHz |
| Minor-Axis Angle Offset (degrees along) | -0.01 | 0.00 |
| Major- axis Angle Offset (degrees Athwart) | 0.00 | -0.04 |
| Major Axis 3 dB Angle (degrees) | 6.65 | 6.59 |
| Minor Axis 3 dB Angle (degrees) | 6.74 | 6.55 |
| Athwart Angle Sensitivity | 23.00 | 23.00 |
| Along Angle Sensitivity | 23.00 | 23.00 |
| Depth of Calibration Sphere (m) | ~25 m | ~25 m |
| Depth of Transducer (m) | 0.75 | 0.75 |
| Receiver Band (kHz) | 8.71 | 8.71 |
| Water Temp at Mid-depth (°C) | 11° | 10° |

Appendix B. Location of areas surveyed for shoreline spawning kokanee in Lake Pend Oreille, Idaho since 1972.

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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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