FISHERY RESEARCH

LAKE PEND OREILLE FISHERY RECOVERY PROJECT

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LAKE PEND OREILLE FISHERY RECOVERY PROJECT

Project Progress Report

2003 Annual Report

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ABSTRACT

Since October 1996, the winter water level of Lake Pend Oreille has been managed in an effort to recover kokanee *Oncorhynchus nerka*, which are both preferred forage for bull trout *Salvelinus confluentus* and a sport fish. During the winter of 2002-2003, the elevation of Lake Pend Oreille was drawn down to 626.4 m (2055 ft) above mean sea level (MSL), 1.2 m higher than the previous winter's full drawdown. This was an attempt to increase kokanee spawning habitat by keeping more shoreline gravel in the water. We conducted hydroacoustic surveys and trawling in late summer of 2003 to assess the kokanee population and determine if wild fry recruitment had improved. We estimated the total kokanee abundance at 10.7 million based on hydroacoustics (472 kokanee/ha). Of these, the lake was estimated to contain 1.2 million wild fry that came from an estimated 12.6 million wild-spawn eggs deposited the previous fall. This yielded a relatively high egg-to-fry survival rate of 9.7%. High survival was likely due to a low number of mature kokanee in 2002 that spawned in clean gravel made available by raised winter lake levels. Peak counts of spawning kokanee were 960 fish on the shoreline and 3,477 fish in tributary streams. We also core sampled potential spawning areas in 2003 to determine the quality of shoreline substrates. At most sites quality had declined from the previous year, although substrates remained good for kokanee spawning. Density of opossum shrimp *Mysis relicta* increased after nine years of general decline. Total shrimp densities were 524 shrimp/m^2 with densities of adult and juvenile shrimp at 274 shrimp/m^2 (excludes young-of-year shrimp). Shrimp did not appear to be impacting kokanee fry survival.

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INTRODUCTION

The U.S. Army Corps of Engineers began changing the winter pool elevation of Lake Pend Oreille in 1996 to enhance kokanee spawning. In some years the lake was kept above an elevation of 626.4 m (2,055 ft above mean sea level [MSL], 1.2 m higher than typical previous winters) to keep more shoreline gravel in the water and enhance spawning. Other years the lake was lowered to 625.1 (2,051 ft MSL) to allow wave action to clean and resort gravel on the shorelines. The first gravel surveys conducted in 1994 determined that a raised winter lake level would increase the amount of suitable kokanee spawning gravel by 560% (Fredericks et al. 1995). Between 1999 and 2000, the winter lake level was kept 0.6 m higher than the minimum pool elevation of 625.1 m. Kokanee egg-to-fry survival improved 150% (from 3.2% to 8.1%) during the years of higher winter lake levels ($p = 0.06$) (Maiolie et al. 2002). After the fifth year of higher winter lake levels, the quality of the spawning gravel on the shoreline had noticeably declined as the percent of gravel decreased and the percent of cobble increased (Maiolie et al. 2003). During the winter of 2001-02, the lake was drawn down to 625.1 m (the low pool elevation) in an effort to allow wave action to resort gravel and restore spawning areas (Figure 1). In the winter of 2002-03, the lake level was kept at 626.4 m, a reduced drawdown year. This investigation documents the response of the kokanee population and the change in shoreline gravel quality due to this higher winter elevation. We also monitored kokanee biomass, production, yield (to look for evidence of predation), the opossum shrimp population, and lake limnology. These additional factors are monitored to determine if they influence the outcome of the lake level experiment.

OBJECTIVE

1. To rebuild the kokanee population to where it could support a kokanee harvest of 750,000 fish annually with a mean length of 250 mm.

STUDY AREA

Lake Pend Oreille is located in the northern panhandle of Idaho (Figure 2). It is the state's largest lake and has a surface area of 38,300 ha, a mean depth of 164 m, and a maximum depth of 351 m. Pelagic habitat used by kokanee is considered to be 22,646 ha (Figure 2) (Bowler 1978). Summer pool elevation of Lake Pend Oreille is 628.7 m above MSL. The Clark Fork River is the largest tributary to the lake. Outflow from the lake forms the Pend Oreille River.

Lake Pend Oreille is a temperate, oligotrophic lake. Summer temperatures (May to October) averaged approximately 9°C in the upper 45 m (Rieman 1977; Bowles et al. 1987, 1988, 1989). Thermal stratification typically occurs from late June to September. Operation of Albeni Falls Dam on the Pend Oreille River keeps the lake level high and stable at 628.7 m during summer (June-September) followed by reduced lake levels of 625.1 m to 626.4 m during fall and winter.

A diverse assemblage of fish species is present in Lake Pend Oreille. Native game fish include bull trout *Salvelinus confluentus*, westslope cutthroat trout *Oncorhynchus clarkii lewisi*, and mountain whitefish *Prosopium williamsoni*. Native nongame fish include pygmy whitefish

Prosopium coulterii, five cyprinids, two catastomids, and one sculpin. Kokanee entered the lake in the early 1930s as downstream migrants from Flathead Lake, Montana and were well established by the 1940s. At its peak in 1953, the estimated harvest of kokanee was 1.3 million fish. Other introduced game fish include Gerrard rainbow trout *O. mykiss*, lake whitefish *Coregonus clupeaformis*, and lake trout *S. namaycush*, in addition to several other cold, cool, and warmwater species.

METHODS

Hydroacoustics

We conducted hydroacoustic surveys on Lake Pend Oreille to determine population estimates of kokanee. Daytime surveys were conducted between August 7 and August 15, 2003 and night surveys between August 14 and August 19, 2003.

A stratified systematic sampling design was used in our surveys. Thirty-one transects were completed during each of the day and night surveys with 12 transects in section one (southern), 10 in section two (middle), and nine in section three (northern) (Figure 2). The same transects were followed in both day and night surveys. We used a uniformly spaced, zigzag pattern on the lake going from shoreline to shoreline. This hydroacoustic survey design was described by MacLennan and Simmonds (1992). Transect lengths ranged from 3.36 km to 10.3 km and were located using the global positioning system (GPS). Boat speed was approximately 1 m/s (boat speed did not affect our calculations of fish density). Geometric mean (log [x+1]) densities of kokanee were calculated for each section and multiplied by the area of the section to determine kokanee abundance. Ninety percent confidence intervals were calculated by standard expansion formulas for stratified sampling designs using the density estimates and the log transformed data (Scheaffer et al. 1979) (see trawl methods below for equation).

A Simrad EK60 portable scientific echo sounder set to ping at 0.6 s intervals was used for the surveys. The echo sounder was calibrated annually for signal attenuation to the sides of the acoustic axis using Simrad's Lobe program. Fish traces (a single returned echo from a fish) were accepted if they were over –60 dB, the echo length between the points 6 dB below the peak value was 30% to 180% of the transmitted pulse length, the correction value returned from the transducer gain model did not exceed a two-way maximum gain compensation of 6.0 dB (therefore includes 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 in-situ target strengths to split fry from the older age classes of fish using Echoview software version 3.10.135.03. Fish traces were plotted on a bar graph 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 validated this size break with the sizes of kokanee caught in midwater trawl samples conducted in August (see below). Decibels were converted to fish length using Love's equation (1971). Kokanee of ages 1 to 4 were not separated based on their target strengths.

Both day and night density estimates of kokanee in each transect were calculated using Echoview software. A box was drawn around the kokanee layer on each echogram to define the area sampled (usually between the 12 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. Densities were then calculated by the equation:

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

where: NASC is the total backscattering in m^2/nautical mile^2, and
^{TS} is the mean target strength in dB for the area sampled.

This integration accounted for fish that were too close together to be detected as a single target (MacLennan and Simmonds 1992).

The nighttime hydroacoustic surveys were used to calculate a kokanee population estimate. Pelagic targets between –45.9 dB and –33.0 dB were considered kokanee from ages 1 to 4. To split these fish into abundance estimates for each age class, the hydroacoustic estimate of abundance for each lake section was multiplied by the proportion of kokanee ages 1 through 4 in the trawl catches within that section. Targets between -60.0 and –46.0 dB were considered kokanee fry. To estimate abundance of hatchery and wild fry, we took the total estimate of fry in each section of the lake based on hydroacoustics and multiplied it by the proportion of each type of fry collected in the midwater trawl samples for that section. Hatchery fry were identified based on the presence of cold-brand marks in the otoliths. A second method was also used where fry abundance based on hydroacoustics was multiplied by the proportion of each type of fry collected in the fry net samples (described below) in each section of the lake. This was done to examine possible bias in the midwater trawl catch. Section totals were summed to get lakewide abundance estimates of hatchery and wild fry. The first method was used for comparative reasons (similar methods to past reports), whereas the second method probably gives a more accurate estimate of fry abundance.

Egg-to-fry survival from 2002 to 2003 was calculated based on hydroacoustic estimates. First, potential egg deposition (PED) for fall 2002 was calculated by using the acoustic estimate of age-1-4 kokanee in each section of the lake and multiplying it by the percentage of mature kokanee caught in the midwater trawl in those age classes. The number of mature female kokanee collected by hatchery crews was subtracted from the population estimate of mature female kokanee to obtain the number of wild spawners. This estimate was multiplied by kokanee fecundity (as estimated annually at Sullivan Springs Creek) to obtain wild PED. The number of wild fry in 2003 was then divided by wild PED from the previous year to estimate wild egg-to-fry survival.

To compare egg-to-fry survival rates in 2002 to 2003, we recalculated the kokanee population data for 2002 as stated above for 2003. Densities of kokanee in 2002 were recalculated based on Log x+1 transformations to obtain geometric means. In addition, wild PED for 2001 was estimated using hydroacoustic estimates of age-1-5 kokanee times the percentage of mature fish in these age classes in the midwater trawl catch, and then egg-to-fry survival rates were calculated.

Midwater Trawling

We conducted midwater trawling in Lake Pend Oreille from August 24 to August 27, 2003. These dates were during the dark phase of the moon, which optimized the capture efficiency of the trawl (Bowler et al. 1979).

The lake was divided into three sections (Figure 3), and a stratified random sampling scheme was used to estimate kokanee abundance and density. Twelve locations were randomly selected within each section, and one haul was made in a random direction from the selected point (so long as the random direction allowed sufficient length for a trawl before reaching the shore). We located each trawl site using the Global Positioning System (GPS).

Rieman (1992) described in detail the midwater trawl equipment and sampling procedures. A fixed frame net (10.5 m long with a 3.01 m x 2.2 m mouth) was towed through the water at a speed of 1.61 m/s by an 8.8 m boat. We determined the vertical distribution of kokanee using a Furuno Model FCV-582 depth sounder with a 10° hull mounted transducer. A stepwise oblique tow was conducted along each transect to sample the entire vertical distribution of kokanee, with each step lasting for 3 min (a step corresponded to a 3 m depth strata). Four to six steps were conducted during each haul.

Kokanee from each trawl sample were counted and placed on ice until morning (fry were placed on dry ice). Kokanee were then kept frozen until analyzed. 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 fish in each 10 mm size interval for aging. The otoliths from 128 kokanee fry and 204 kokanee between the ages of 1 and 5 were sent to Washington Department of Fisheries for aging and identification of cold brands to identify hatchery fish.

Kokanee catch per trawl haul was divided by the volume of water filtered by the net to obtain density of kokanee caught. The age-specific density estimate for each section was expanded into a total population estimate using standard expansion formulas for stratified sampling designs (Scheaffer et al. 1979). We did not log transform the density estimates. The area of each section was calculated for the 91.5 m contour; however, the northern section was calculated from the 36.6 m contour because of shallower water. The 91.5 m contour was used because it represents the pelagic area of the lake where kokanee are found during late summer (Bowler 1978). For consistency, these same areas have been used each year since 1978, totaling 22,646 ha (Figure 2). Ninety percent confidence intervals were calculated on the kokanee abundance estimates by the following equation from Scheaffer et al. (1979):

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

where:

$\overline{x}$ = the estimated mean number of kokanee in the lake,

t = the Student’s t value,

N_i = the number of possible samples in section I,

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

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

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

Potential egg deposition was also calculated based on trawling results. Percent maturity within each 10 mm length group was multiplied by the population estimate for that length group and then summed across length groups. To obtain the population estimate for mature females, we divided the total mature population by two. The number of mature females in the lake was multiplied by the mean fecundity seen at the Granite Creek spawning station to estimate potential egg deposition. Mean fecundity was determined by dissecting 20 female kokanee from the beginning, middle, and end of the spawning run (n = 60). We subtracted the number of eggs collected by hatchery personnel at the Granite Creek egg-take station to determine the number of eggs spawned by wild fish (wild PED).

Fry Netting

We sampled Lake Pend Oreille with a small mesh net as an additional method to estimate kokanee 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. Ten randomly selected net hauls were made in each of the three lake sections during 2003.

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.

Stepwise oblique tows were made through the layer of kokanee seen on the boat's echo sounder. Fry net depths ranged from 15 m to 36 m. The fry net was towed for three minutes at each "step" (a step corresponded to a 3 m depth strata or a 15 m length of cable) until the entire kokanee layer had been sampled. The average boat speed was 1.5 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. Total length of each fry was rounded down to the nearest whole mm. Otoliths were removed from all kokanee fry (n = 85) caught in the fry net and sent to the Washington Department of Fish and Wildlife Otolith Lab for analysis.

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 lakewide population estimate of fry.

Spawner Counts and Surveys

We walked standard shoreline areas (Appendix A) and tributaries and counted spawning kokanee to continue this time-series data set. All areas surveyed have been documented as historic spawning sites (Jeppson 1960). Nine shoreline areas were surveyed once a week for three consecutive weeks beginning the third week in November 2003. All kokanee, alive or dead, were counted. The highest count at each site was reported.

During the same period as shoreline counts, seven tributary streams were surveyed by walking upstream from their mouth to the highest point utilized by kokanee (determined by visual observation or obstruction to upstream movement). Streams included South Gold Creek, North Gold Creek, Cedar Creek, Johnson Creek, Twin Creek, Spring Creek, and Trestle Creek. Trestle Creek, which supported a run of early-spawning kokanee, was also surveyed on September 23, 2003 to assess this kokanee stock.

Artificial Spawning Areas

Four types of artificial spawning boxes were in Lake Pend Oreille during the 2002-03 spawning season. Two large wooden frames, 2.4 m x 1.2 m x 0.2 m, were placed in the lake during the fall of 2001. Both had screen mesh bottoms to contain any emerging fry and were filled with 6-16 mm diameter gravel. One of these had 4 cm ribs along the bottom in an attempt to provide better water circulation. These ribs held the box above the lake bottom and allowed water to circulate under the box. Both of these boxes were placed on the southern side of Leiberg Point on a sand and gravel spit near Eagle boat ramp in Farragut State Park (47° 57.871 N by 116° 32.553 W).

Four other 1 m x 1 m x 0.2 m wooden frames with screen mesh bottoms were filled with the same size gravel. Two of these had 4 cm ribs along the bottom in an attempt to provide better water circulation. Two others had no ribs and lay directly on the lake bottom. These four frames were placed in the lake in October of 2001 and positioned by scuba divers. One frame with ribs and one frame without ribs were placed in close proximity to each other at each site to determine if the ribs were a benefit. A pair of the boxes was placed on the southern side of Leiberg Point (Farragut State Park) near the large boxes, and a pair was placed near the tip of Leiberg Point (47° 58.156 N by 116° 32.250 W).

In the fall of 2002, six additional 1 m x 1 m x 0.2 m boxes were placed in the lake. The boxes were constructed and paired the same as in 2001. One pair was placed at each end of Bernard Beach (47° 56.947 N by 116° 30.064 W and 47° 56.960 N by 116° 30.550 W) and one pair was placed just south of the Farragut swim area (47° 57.217 N by 116° 34.343 W). All boxes were placed at a minimum depth of five feet below the minimum winter lake level.

Two smaller boxes that were placed on the southern side of Leiberg Point in 2001 were moved in 2002. The boxes were transported approximately 55 meters east from their original location and set on the tip of the sand and gravel spit south of Leiberg Point (47° 57.870 N by 116° 32.506 W).

In the fall of 2002, three gravel patches, approximately 2 m x 2 m, were placed directly on the lake bottom with no supporting frame. Gravel was placed on mostly cobble bottom areas to a depth of about 10 to 15 cm. This was to determine if the frame was causing kokanee to avoid the spawning boxes. These gravel patches were placed on either side of the boxes placed at Bernard Beach and on the shore near the Farragut Park swimming area.

Hatchery Fry Marking

All kokanee released from Cabinet Gorge Fish Hatchery since 1997 have been marked by “thermal mass marking” techniques (cold branding) described by Volk et al. (1990). Therefore, hatchery kokanee of any age should contain thermal marks. The intent of this marking was to be able to separate hatchery and wild kokanee throughout their lifecycle to determine survival rates.

Thermal marking of the otoliths was done at the Cabinet Gorge Fish Hatchery. Thermal treatments were initiated five to ten days after fry entered their respective raceways. Fry released in 2003 (brood year 2002) received a 13 day pattern created by five cool water events. The first and second events and fourth and fifth events were separated by three days. The second and third events and the third and fourth events were separated by one day.

Twenty fry from each raceway were sacrificed to verify the thermal marking. Recognizable otolith marks were verified on all thermally treated individuals. On June 18 and 19, 2003, approximately 2,995,000 late kokanee fry were released into Sullivan Springs. On June 24, 100,000 late kokanee fry were released into Spring Creek and 100,000 late fry were released into Twin Creek.

We sent 332 otoliths from all kokanee age classes collected during the August trawling to the Washington Department of Fish and Wildlife lab to determine origin. Before shipment, we catalogued each fish; recorded total length and weight; and removed, cleaned and numbered the otoliths.

Washington Department of Fish and Wildlife personnel removed one otolith from each of the 332 vials and oriented it on a glass plate labeled to associate the otolith with the specimen vial. Under a fume hood, otoliths were positioned on a glass plate and surrounded with a preformed rubber mold. Rubber molds were then filled with clear fiberglass resin and warmed in an oven for approximately 1 h for curing. The resulting blocks of resin containing the otoliths were cut into groups of four otoliths per block for sectioning and polishing. Blocks of four otoliths were lapped on a rotating disc of 500 grit carborundum paper until the nucleus of each otolith was clearly visible. The otoliths were then polished using a rotating polishing cloth saturated with one micron deagglomerated alpha alumina and water slurry. After lapping and polishing, the otoliths were examined with a compound microscope at 200 power and/or 400 power magnification. Patterns within the otolith were compared to those 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.

Biomass, Production, Yield

We calculated the biomass, production, and yield of the kokanee population in Lake Pend Oreille to look for evidence of high predation. Hydroacoustic population estimates, along with kokanee weights gathered 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. It was 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 for the lake's overall kokanee biomass.

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 use a three-step equation for each age class. First, 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). Second, 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 a linear rate of growth throughout the year.

Yield refers to the total biomass lost from the population due to all forms of mortality (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 times 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. Calculations assumed a linear rate of mortality throughout the year.

We regressed both production and yield against kokanee biomass to determine where these two lines cross. At that point, production and yield were equal and indicated predator and prey were in balance. Data from 1996 to 2001 were used to plot the trend lines, with the exception of 1997, which was a flood year (due to high mortality that was likely not predator related). Data from 2002 and 2003 were added to the graph to see if it indicated a change in the predation level in the lake.

Shrimp Abundance

Opossum shrimp *Mysis relicta* (locally known as Mysis shrimp), were sampled on June 2 and 3, 2003 to estimate their abundance. All sampling occurred at night during the dark phase of the moon. The new moon during June has been the standard sampling date for most of the previous work on shrimp and for all of our sampling since 1997. Ten sampling sites were randomly located in each of three lake sections (Figure 3). We used a GPS unit and coordinates to locate each sample site.

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

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

Limnology

From January through October 2003, we measured water temperature and water clarity (Secchi transparency) monthly. Data were collected at three standardized stations during January, February, and March and then one station at the approximate center of the lake from April through October (Figure 2). Sample dates were approximately the middle of each month. We used a Yellow Springs Instrument Company Model 57 meter to measure temperature and dissolved oxygen from the surface to a depth of 59 m. The meter was calibrated before each survey using the “water saturated air” method suggested by the manufacturer. Water clarity was monitored at each station using a 20 cm diameter Secchi disc during each survey.

Gravel Sampling

Six areas of shoreline were sampled in 2003 to determine if potential spawning gravel was improving or declining in quality for kokanee spawning. Areas surveyed included the shoreline at Garfield Bay, Trestle Creek, Hope, Evans Landing, Bernard Beach, and Ellisport Bay (Figure 4). Garfield Bay, Trestle Creek, Hope, and Ellisport Bay were surveyed in 1992 (Maiolie and Elam 1993) and 1997 through 2002, and were historic locations for kokanee spawning (Jeppson 1960). Evans Landing and Bernard Beach were previously sampled in 2002.

Sampling was conducted during mid July 2003. At this time the lake was at its summer full pool level, and all gravel samples were collected while scuba diving. A rope was secured above the water line at each transect location and stretched out into the lake perpendicular to the shore. Two scuba divers swam parallel to the rope and visually identified bands of similar substrate composition. Flagging was tied to the rope to mark the distance between the top and the bottom of each substrate band. No substrate samples were collected above the upper winter pool level of 626.3 m (2,055 feet). Four substrate samples were collected from random points in each substrate band. 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. Each sample was individually bagged, labeled, and dried. We then screened each substrate sample through soil sieves of the following sizes: 63 mm, 31.5 mm, 15.9 mm, 9.5 mm, 6.3 mm, 2 mm, and 0.85 mm. The substrate retained on each screen and the substrate that fell through the finest screen was 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 6.3 mm, and "fines" as substrate smaller than 6.3 mm.

RESULTS

Hydroacoustics

In 2003, we estimated the lake contained 10.7 million (9.7 million to 11.8 million, 90% CI) kokanee based on our standard nighttime hydroacoustic surveys (472 kokanee/ha). This included 5.3 million age-0 kokanee (4.8 million to 5.9 million, 90% CI) and 5.4 million (4.7 million to 6.1 million, 90% CI) ages 1-4 kokanee (Tables 1 and 2). Mean target strengths of kokanee traces showed a separation between kokanee fry and larger fish at the –46 dB level (Figure 5) or a fish length of 86 mm. This corresponded closely to the gap in the length-frequency distribution of trawl samples at the 90 mm size group (Figure 6). Older age classes (ages 1 to 4) could not be separated based on target strengths alone. We separated the hydroacoustic estimate of age-1 to age-4 kokanee based on the percent frequency of kokanee age classes in trawl samples for each section of the lake. We estimated the lake contained 2.4 million age-1, 1.8 million age-2, 1.1 million age-3, and 90,000 age-4 kokanee (Table 2). No age-5 kokanee were identified in 2003.

We also split the hydroacoustic estimate of age-1 to age-4 kokanee into the number of mature kokanee based on the percentage of mature kokanee in the trawl catch within each section. This was the second year this calculation was made and served as an estimate of mature fish abundance that may avoid the underestimates of kokanee in the trawl catch. In the trawl, 22%, 5%, and 4% of the catch were mature in the southern, middle, and northern sections, respectively. This yielded an estimate of 439,153 mature kokanee or 219,577 mature female kokanee assuming a 50:50, male:female sex ratio (12 out of 27 mature kokanee were female in trawl samples). We estimated the fecundity of female kokanee at 351 eggs/female. This yielded an estimated PED of 77.07 million eggs. Since hatchery personnel collected 43,351 female kokanee (15.21 million eggs in these females), the potential wild PED was 61.86 million eggs (219,577 minus 43,351 females times 351 eggs/female).

Survival rates of kokanee from 2002 to the same year class in 2003 were 35% from age-0 to age-1, 55% from age-1 to age-2 and 65% from age-2 to age-3. We caught too few kokanee caught in the age-3 to age-4 interval to provide a reliable estimate of survival (Table 3).

The hydroacoustic estimate of age-0 kokanee was separated into estimates of wild and hatchery fry. Wild fry made up 40.2%, 27.2%, and 18.2% of the midwater trawl catch from the southern, middle, and northern lake sections respectively. These percentages were multiplied by the hydroacoustic estimate of age-0 fish in each section to obtain a population estimate of wild fry of 1.393 million (Table 1). Hatchery fry totaled 3.9 million. These wild age-0 kokanee came from an estimated 12.64 million wild-spawned eggs that were laid in the lake and in tributaries in 2002 (Maiolie et al. 2003). Survival of naturally deposited eggs to wild fry was therefore 11.0%.

We also made a second estimate of the abundance of wild fry based on the fry net catch (all kokanee fry collected with the fry net had their otoliths examined) and the hydroacoustic estimate for fry using geometric mean densities. The percentage of wild fry caught while fry netting was 42.3%, 20.5%, and 15.0% for the southern, middle, and northern sections of the lake, respectively (Table 1). These were multiplied by the hydroacoustic estimate of fry in each lake section resulting in an estimated 1.23 million wild fry. This equated to a 9.7% survival rate from the estimated 12.64 million wild-spawned eggs that were laid in 2002 (Table 4).

For comparison, the same calculations were applied to the data collected in 2001 and 2002 (using the fry trawl to determine the percentage of wild fry). We estimated 1.41 million wild fry were in the lake in 2002 (Table 4). These fry originated from an estimated lakewide population of 48,500 female kokanee in 2001. Hatchery crews collected 17,759 female kokanee that year. We therefore estimated wild PED to be 14.765 million eggs, yielding a wild egg-to-fry survival rate of 9.5%.

Midwater Trawling

In 2003, total kokanee abundance based on trawling was estimated at 4.15 million fish, with a density of 183 fish/ha (Table 5). Kokanee fry abundance was estimated at 1.44 million (±17%, 90% CI) with wild fry abundance estimated at 383,000. Age-1 kokanee numbered 1.32 million with the wild component consisting of 232,500 individuals. Age-2 kokanee abundance was estimated at 869,000 fish, of which 434,000 were wild. Age-3 kokanee abundance was estimated 487,500 fish with 258,000 being wild. Age-4 kokanee abundance was 34,000 fish with 27,000 being wild. No age-5 fish were sampled in 2003. Total standing stock of kokanee was 5.43 kg/ha (Table 5). Lengths of the various age groups are shown in Figure 6 and Table 5.

Based on trawling, the lake contained 167,500 mature fish. PED was estimated at 29.4 million eggs based on trawling. Hatchery crews collected 12.6 million eggs at Sullivan Springs, which left 16.7 million eggs to be naturally spawned on the lakeshore and in tributary streams during the fall of 2003. (This estimate was considerably less than the 62 million egg estimate for wild PED based on hydroacoustics.)

Fry Netting

Eighty-five kokanee fry were sampled with the small-mesh fry net: 26 in the southern section, 39 in the middle section, and 20 in the northern section. The percentages of wild fry in these same sections were 42.3%, 20.5% and 15.0% respectively (Table 1). Based on this netting, we estimated the lake contained 2.275 million kokanee fry. Of these, 0.513 million were wild and 1.762 million were hatchery produced.

Spawner Counts and Surveys

We counted 960 kokanee spawning on the shoreline in 2003. Of this number, all but 20 were observed in Scenic Bay. The boat basin at Jeb and Margaret's Resort near the mouth of Trestle Creek contained the remaining 20 spawners (Table 6).

Kokanee spawners in tributary streams totaled 3,477 fish (Table 7). Of these, 2,251 were early spawners counted in Trestle Creek on September 23. The remaining spawners were counted in South Gold Creek (591), Spring Creek (626), and Trestle Creek (9) in late November or early December.

Artificial Spawning Areas

In the fall of 2002, it appeared that the gravel in two of the spawning boxes had been disturbed, possibly by spawning kokanee. Scuba divers excavated the gravel in the boxes, but no kokanee eggs were found. No evidence of spawning activity was observed at the remainder of the artificial spawning sites.

Biomass, Production and Yield

This was the second straight year for an increase in kokanee biomass. We estimated kokanee biomass at 258 tonnes (t), an increase of 70 t (37%) over last year although well below the peak estimate of 353 t in 1996. Production dropped from 263 t in 2002 to 236 t this year (Table 8). Yield declined to 172 t, the third straight year of decline. This was the lowest yield since the lake level experiment began in 1996.

We plotted kokanee production and yield against biomass to determine the relationship (Figure 7). Kokanee yield was relatively flat with changes in biomass, whereas kokanee production was positively correlated to biomass. The two trend lines crossed at a point where biomass equals about 270 t.

Shrimp Abundance

Opossum shrimp densities increased in 2003 after a steady decline over the last five years. The estimated total mean density of shrimp during June 2003 was 524 shrimp/m^2 (Table 9). This included 249 young-of-the-year (YOY) shrimp/m^2 (<12 mm in total length) and 274 immature and adult shrimp/m^2. Immature and adult shrimp increased 60 shrimp/m^2 over last year's estimate (Figure 8). In contrast, the number of YOY shrimp decreased by 66% from last year's estimate of 743 shrimp/m^2 to 249 shrimp/m^2 this year. The highest densities of immature and adult shrimp were at the lake's northern end with 337 shrimp/m^2. The middle and southern end of the lake had 249 and 223 shrimp/m^2, respectively.

Limnology

Secchi transparencies averaged 8.8 m this year in Lake Pend Oreille (Table 10). The lowest reading of 4.5 m was taken in May, whereas the maximum reading was recorded in October at 13.0 m. Secchi depths were not collected during August and September.

Water temperatures on the lake surface ranged from a low of 4.3°C during March to a high of 26.2°C in July. A weak stratification of the water column started to form in June at approximately the 11 m depth. The lake stayed stratified until sometime after the last sampling period at the end of August. Water over 14°C (the upper maximum temperature frequented by shrimp) reached a depth of 15 m by August 25.

Gravel Sampling

We collected 112 substrate samples from six separate shoreline locations to determine the quality of the substrate for kokanee spawning. On the shorelines between the elevations of 625.1 m (2051 ft) to 625.8 m (2053 ft), all but one site (Garfield Bay) declined in the percentage of gravel in core samples compared to samples from 2002. During 2003, the change in gravel content at the six locations ranged from a 2% increase to a 17% decrease. At three sites, (Bernard Beach, Trestle Creek, and Hope), gravel decreased and cobble increased in approximately the same proportion (Figures 9-11). At another site, (Evans Landing), a decrease in gravel corresponded to an increase in fines (Figure 9). At the last site (Ellisport Bay), both cobble and fines increased as the gravel decreased (Figure 11).

This is the second year substrate samples have been collected and analyzed at Evans Landing and Bernard Beach. Between the levels of 625.1 and 625.8 m, Bernard Beach substrate consisted of 41.6% gravel, 57.8% cobble, and 0.58% fines (Figure 9). Evans Landing, a site that appeared to have the best substrate overall for kokanee spawning based on composition, consisted of 64.4% gravel, 15.4% cobble, and 20.2% fines (Figure 9). Between 2002 and 2003, gravel at these two locations decreased by an average of 12% but still made up 40-60% of the substrate and visually appeared to be good spawning habitat. Substrate compositions are shown for the sample locations in Figures 12-14.

DISCUSSION

Kokanee Abundance

Historically the kokanee population in Lake Pend Oreille appeared limited by the amount of spawning habitat available to kokanee in the fall (Maiolie and Elam 1993). During the winter of 2001-02 the lake was drawn down to 625.1 m (2051 ft), followed by a winter elevation above 626.4 (2055 ft) in 2002-03. These fluctuations improved the quality of some shoreline spawning areas that were core sampled in 2002 (Maiolie et al. 2002) and likely improved the spawning conditions around the lake. Kokanee spawning in the fall of 2002 should have found good quality and abundant habitat for spawning. We noted an excellent egg-to-fry survival rate of 9.7% in 2003. To put this in perspective, egg-to-fry survival was estimated at 1.4% in 1995, 1.3% in 1978 (Rieman and Bowler 1980), and 1.5% in 1990 (Paragamian and Ellis 1991). The 2003 survival estimate was also better than the 6.1% survival estimate of kokanee that were released into an improved spawning channel in Sullivan Springs Creek (Whitt 1958). Though the method of calculating survival rates was different in these studies, we conclude that kokanee survival in 2003 was very good.

Egg-to-fry survival between 2001 and 2002 was compared to 2002 to 2003. Both years had similar, very low numbers of female kokanee spawning, 30,800 in 2001 and 39,500 in 2002 (Table 4). Even though the lake elevation was at full drawdown during the winter of 2001-02 and was held 1.2 m higher during the winter of 2002-03, survival rates were high in both years: 9.5% in 2002 and 9.7% in 2003. These were two of the highest survival rates documented for Lake Pend Oreille, and we believe it was likely due to the record low numbers of mature kokanee that would have found abundant areas for spawning regardless of lake elevation. Density dependency in spawning success was previously documented (Maiolie et al. 2002). Therefore, it appears the limited spawning habitat available under full drawdown was sufficient for the low number of spawners in 2001. However, as adult kokanee densities increase, survival rates would be expected to decline under consistent full drawdown conditions but remain higher if lake levels are varied between winters (Maiolie et al. 2002).

Good egg-to-fry survival rates in 2001-02 and 2002-03 imply several other points. The finding that nearly 10% of the spawned eggs hatched and survived to fall fry in these years may have indicated that not only was egg incubation good, but also that fry survival during their first summer in the lake was high. A previous hypothesis was that newly emerged kokanee could be having poor survival due to competition with opossum shrimp (Maiolie et al. 2002). This did not appear to be the case in these years with shrimp densities of 215 and 274 shrimp/m^2 (72% and 92% respectively, of the previous nine year average of 297 shrimp/m^2).

Kokanee population estimates in this study (Table 2) along with the survival rate information (Table 3) can be used to predict future kokanee abundance. If the 1.091 million age-3 kokanee have 33% survival (the mean rate in Table 3), then we would expect 360,000 age-4 kokanee next year. Similarly, if the age-2 kokanee have 53% survival, then we would expect 969,000 age-3 kokanee in 2004. We therefore predict stronger spawning numbers over the next two years and recommend that the lake's winter elevation be held higher to increase the spawning area available to these fish.

Spawning boxes of the type used in this study and gravel placed on the lakebed did not show potential as a method to enhance kokanee spawning. Kokanee did spawn near the boxes on the natural shoreline, but did not use the clean gravel provided in the boxes. Boxes will remain in the lake for another year. Possibly the boxes were not used in 2002 because of the low density of spawners and the adequate supply shoreline spawning areas.

Kokanee Biomass, Production and Yield

We have been tracking kokanee biomass, production, and yield as a method to determine predator and prey balances (Figure 7). Ideally, if predation remained relatively constant, then at higher levels of kokanee biomass, kokanee production might exceed yield and the kokanee population might expand until reaching some new limiting factor. At lower levels of kokanee biomass, predation rates (as shown by yield) might exceed production causing a decline in the population. The midpoint between these extremes may be an area where predator and prey are more or less in balance and could indicate a kokanee biomass that could serve as an achievable objective. However, the predator and prey relationship appears dynamic. Compensatory changes in both production and yield occur across the range of kokanee biomass. For example, in 1996 when kokanee biomass was high, kokanee production was 79% of kokanee biomass. When kokanee biomass fell to its low point in 2001, kokanee production increased to 168% of biomass indicating a more than doubling in the growth of new fish flesh on a per unit basis. This helped the kokanee population attain a higher level of biomass. Compensatory responses of predation were more difficult to see on Figure 7. Yield between 1996 and 2003 was fitted with a nearly horizontal trend line, which indicated yield was constant across all levels of kokanee biomass. In actuality yield appears to be changing annually to match kokanee biomass; however, it may lag behind by one or more years. As kokanee declined from 1999 to 2001 (as the result of high mortality during a flood in 1997) yield exceeded production. Then yield remained below production in 2002 and 2003 as the kokanee population expanded as numerically strong year classes worked into the population. The lines on Figure 7 could be changing annually as yield changes to compensate for kokanee biomass. Changes in yield would also change production (i.e. if kokanee do not die they continue to grow) and thus the line for production should not be considered as independent of yield. Gerrard rainbow trout co-evolved with kokanee in Kootenay Lake, British Columbia. Possibly a natural balance may exist between these species. However, lake trout did not co-evolve with kokanee, presenting the possibility that they may destabilize the system if they become a dominant predator in the lake, which in turn may increase competition between lake trout and threatened bull trout.

Shrimp Abundance

Shrimp abundance increased in 2003 (Figure 8). Factors currently controlling the shrimp population are unknown. It was encouraging to note good kokanee egg-to-fry survival in 2003 even with this increase. As stated in previous reports, shrimp abundance did not correlate well to kokanee survival (Maiolie et al. 2002).

Limnology

Mean Secchi depths between April and October in Lake Pend Oreille were deeper in 2003 than in our previous measurements (Maiolie et al. 2002). An increase in Secchi transparency could indicate a reduction in particulate matter suspensoids and in a generalized way indicates a decline in phytoplankton populations (Wetzel 1975). Our data from 1997 to 1999 had mean April to October Secchi depths in the 6.2 to 6.7 m range. From 2000 to 2003 Secchi depths ranged from 8.1 to 8.8 m, which indicated a decline in lake productivity. Secchi readings were variable between months, lake sections, and years; however, this trend should be monitored in the future. Increases in Secchi depth did not correspond to declines in kokanee egg-to-fry survival since survival rates were at their highest levels observed in 2002 and 2003.

Gravel Sampling

A detectable decline in the quality of shoreline substrates occurred in 2003. Five out of six of the areas sampled had declines in gravel and increases in cobble or silt (Figures 9-11). These findings would show the need to draw the lake down periodically to its low pool level in order to enhance shoreline gravel.

RECOMMENDATIONS

1. We recommend holding the lake 1.2 m higher during the next two winters (2004-05 and 2005-06) since stronger adult year classes of kokanee are expected to be spawning.

2. The winter lake level does not need to be held higher to enhance kokanee spawning when the number of mature female kokanee in the lake is below 40,000 fish.

3. We do not recommend using spawning boxes at the current time as a method to attempt to recover kokanee. However, the spawning boxes should be tested in years when spawning habitat becomes more limited.

4. Secchi transparency should be monitored annually to see if the trend in increasing water clarity continues. Changes in water clarity may indicate some change in nutrient levels found within the lake.

5. Lastly, we recommend a close examination of fishery data from Kootenay Lake, British Columbia to see if Gerrard rainbow trout abundance self-regulates with changes in the kokanee population.

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Table 1. Population estimates of kokanee fry (millions) based on hydroacoustic surveys of Lake Pend Oreille, Idaho in 2003. Percentage of wild fry was based on the proportion of wild fry caught using a fry net and by midwater trawling.

	Lake section			Total for lake	90% CI
	Southern	Middle	Northern		
Total kokanee fry abundance by hydroacoustics	1.235	1.709	2.370	5.315	-11 to +12%
Percent wild fry in fry trawl	42.3	20.5	15.0	—	
Wild fry estimate based on acoustics and fry trawling	0.523	0.350	0.356	1.229	
Percent wild fry in midwater trawl	40.2	27.2	18.2	—	
Wild fry estimate based on acoustics and midwater trawling	0.497	0.465	0.431	1.393	

Table 2. Population estimates of kokanee age classes (millions) in Lake Pend Oreille, Idaho, 2003. Estimates were made based on hydroacoustic surveys and partitioned into age classes based on the percent of each age class in the catch of a midwater trawl.

Area	Age-1	Age-2	Age-3	Age-4	Total
Southern Section					
Acoustic estimate of kokanee in section (millions)					1.108
Percent of age class in section by trawling	14.7	41.95	36.63	6.73	
Population estimate in section (millions)	0.163	0.465	0.406	0.074	1.108
Middle Section					
Acoustic estimate of kokanee in section (millions)					1.524
Percent of age class in section by trawling	27.05	45.22	27.01	0.71	
Population estimate in section (millions)	0.412	0.689	0.412	0.011	1.524
Northern Section					
Acoustic estimate of kokanee in section (millions)					2.743
Percent of age class in section by trawling	65.29	24.57	9.99	0.15	
Population estimate in section (millions)	1.791	0.674	0.274	0.004	2.743
Total population estimate for lake (millions)	2.366	1.828	1.092	0.089	5.375

Table 3. Kokanee survival rates (%) estimated by midwater trawling and hydroacoustics, 1990-2003. Hydroacoustic estimates started in 1996. Year refers to the year the older age class in the survival estimate was collected.

	Age							
	0 to 1		1 to 2		2 to 3		3 to 4	
Year	**Trawl**	**Acoustics**	**Trawl**	**Acoustics**	**Trawl**	**Acoustics**	**Trawl**	**Acoustics**
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 and 2003 were based on geometric means transformed by Log(x+1).
[b] Too few kokanee caught in age class to provide a reliable estimate of survival.

Table 4. Comparison of kokanee reproductive success in Lake Pend Oreille, Idaho in 2002 and 2003. In the winter of 2001-02 the lake was held above an elevation of 625.1 m (2051 ft) and in 2002-03 the winter elevation above 626.4 (2055 ft).

	2002	**2003**
Number of mature female kokanee in previous year	48,492	53,737
Number of kokanee collected by hatchery crew in previous year	17,796	14,235
Female kokanee spawning in the wild during the previous year	30,796	39,502
Fecundity (eggs/female) in previous year	481	320
Wild spawn eggs in previous year	14,764,776	12,640,000
Number of wild fry produced	1,409,502	1,228,000
Wild egg-to-fry survival (%)	9.5	9.7

Table 5. Kokanee population statistics based on trawling Lake Pend Oreille, Idaho during August 2003.

Age	0	1	2	3	4	Total
Population estimate (millions)	1.438	1.321	0.869	0.487	0.034	4.15
± 90% CI (%)	17	48	25	20	51	18
Density (fish/ha)	63.48	58.35	38.37	21.53	1.51	183.24
Mean weight (g)	1.94	27.4	53.77	69.41	99.22	
Standing stock (kg/ha)	0.12	1.31	2.49	1.34	0.17	5.43
Mean length (mm)	61.7	151.9	189.3	205.8	228.3	
Length range (mm)	27-87	102-170	156-206	192-237	221-235	

Table 6. Counts of kokanee spawning at several sites along the shoreline of Lake Pend Oreille, Idaho. The numbers shown indicate the highest weekly count.

	Bayview	Farragut Ramp	Idlewilde Bay	Lakeview	Hope	Trestle Cr. Area	Sunnyside	Garfield Bay	Camp Bay	Anderson Point	Total
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.

Year	S. Gold	N. Gold	Cedar	Johnson	Twin	Mosquito	Lightning	Spring	Cascade	Trestle[a]	Trestle	Total
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

Table 8. Biomass, production, and yield (metric tons) of kokanee in Lake Pend Oreille, Idaho 1996-2002.

Year	Biomass	Production	Yield
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		

Table 9. Densities (per m^2) of opossum shrimp in Lake Pend Oreille, Idaho, June 2-4, 2003. Sections are shown in Figure 1.

Section-transect	YOY	Immature & adults	Total shrimp
1-3	208.8	297.4	506.3
1-6	589.1	234.8	824.0
1-9	152.2	139.4	291.5
1-12	277.5	143.8	421.3
1-21	365.1	137.1	502.2
1-27	478.6	260.7	739.3
1-31	383.2	322.5	705.7
1-33	615.0	212.5	827.6
1-40	143.0	271.7	414.7
1-45	201.8	211.2	412.9
Section 1 means	341.4	223.1	564.5
2-1	170.2	317.6	487.8
2-8	478.6	315.1	793.7
2-10	343.8	148.8	492.6
2-16	366.1	343.9	710.0
2-23	179.3	398.5	577.7
2-33	296.1	225.9	522.0
2-40	207.3	217.2	424.5
2-48	347.4	233.9	581.3
2-51	289.3	152.2	441.5
2-62	214.4	133.9	248.3
Section 2 means	289.2	248.7	537.9
3-2	95.9	118.5	214.4
3-16	53.3	314.4	367.7
3-24	173.6	345.7	519.3
3-28	153.3	309.7	463.0
3-34	130.8	210.6	341.4
3-43	149.5	190.5	340.0
3-51	185.5	817.1	1002.6
3-57	176.9	147.9	324.8
3-71	202.0	57.7	259.7
3-74	103.4	861.2	964.6
Section 3 means	142.4	337.3	479.7
Whole lake means (weighted by area)	249.4	274.4	523.8

Table 10. Secchi transparencies (m) at three locations in Lake Pend Oreille, Idaho, 2003. Summer mean transparency is for the period April through October.

Location	Jan 13	Feb 14	Mar 15	Apr 18	May 15	Jun 12	Jul 1	Jul 29	Aug	Sept	Oct 20	Summer mean
Southern station	12.5	17.7	16.2									
Mid-lake station	12.5	16.8	15.3	9.8	4.5	5.0	8.0	12.5	—	—	13.0	8.8
Northern station	11.0	13.5	10.0									

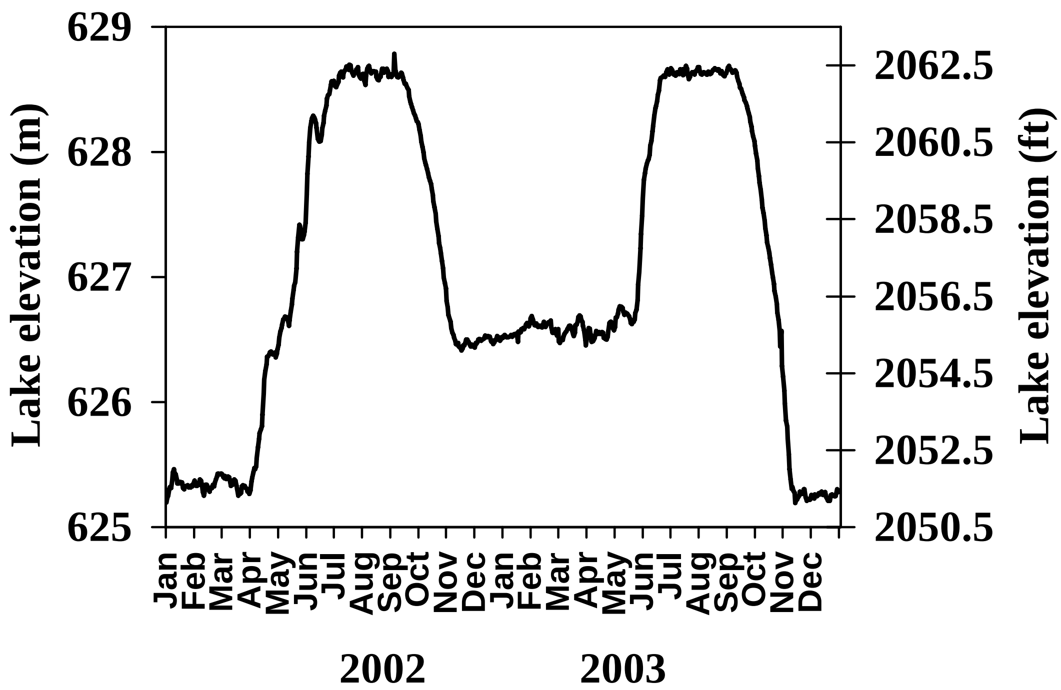
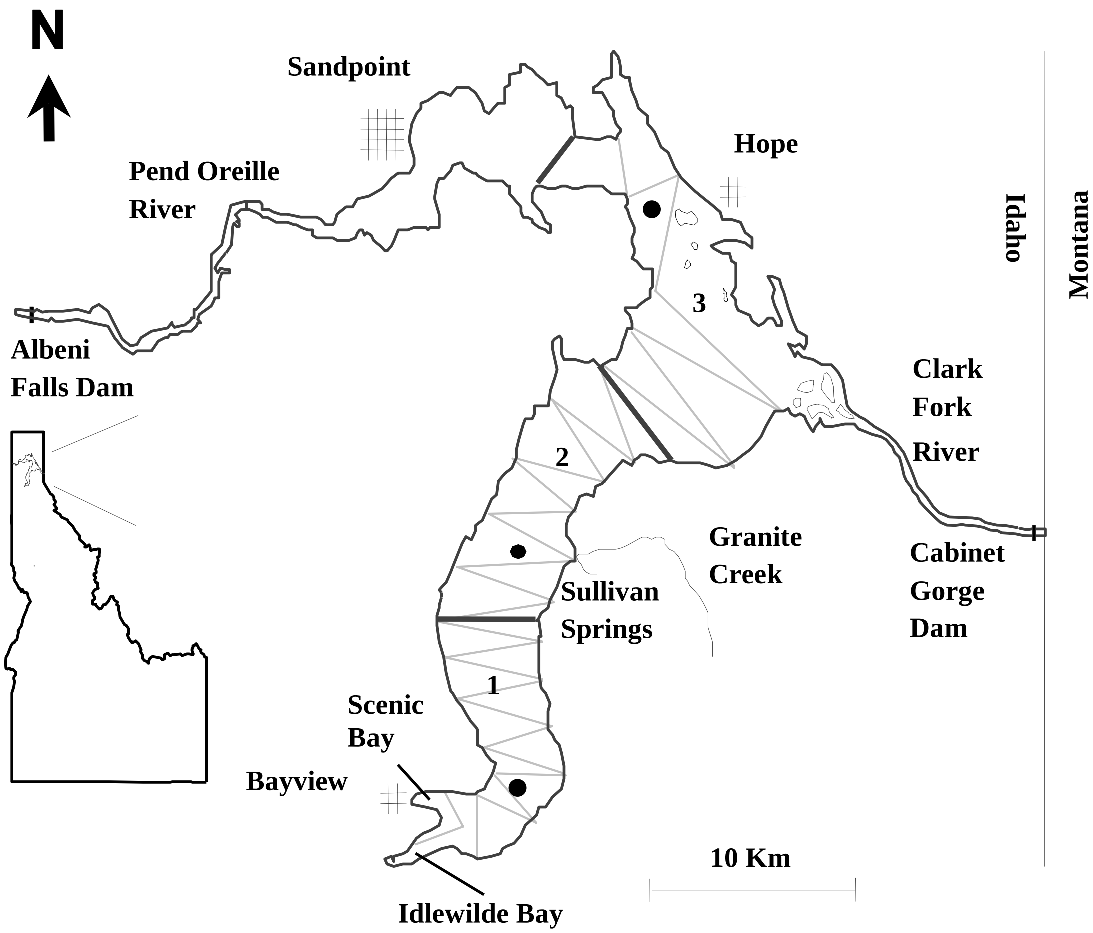


Figure 1. Daily surface elevation of Lake Pend Oreille, Idaho during 2002 and 2003.



Section	Area (hectares)
1	6486
2	7776
3	8384
Lake Total	22,646

● - Limnology stations
- Acoustic transects

Figure 2. Map of Lake Pend Oreille, Idaho showing prominent landmarks, limnology stations and the three lake sections. Grey lines mark the location of hydroacoustic transects in 2003. Inserted table depicts the area of kokanee habitat in each section.

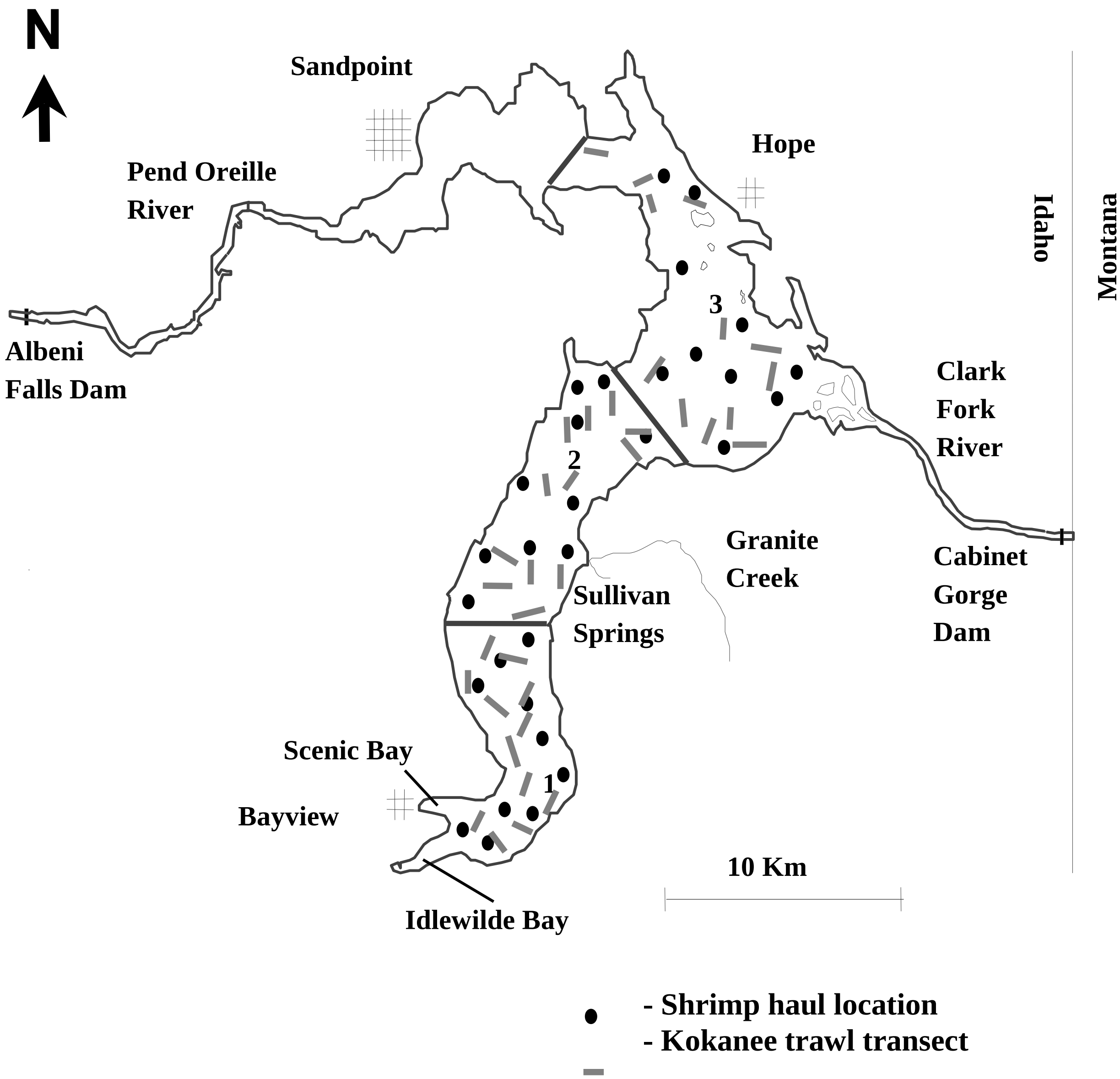


Figure 3. Map of Lake Pend Oreille, Idaho showing the locations of both the kokanee trawling transects and the Mysis shrimp hauls.

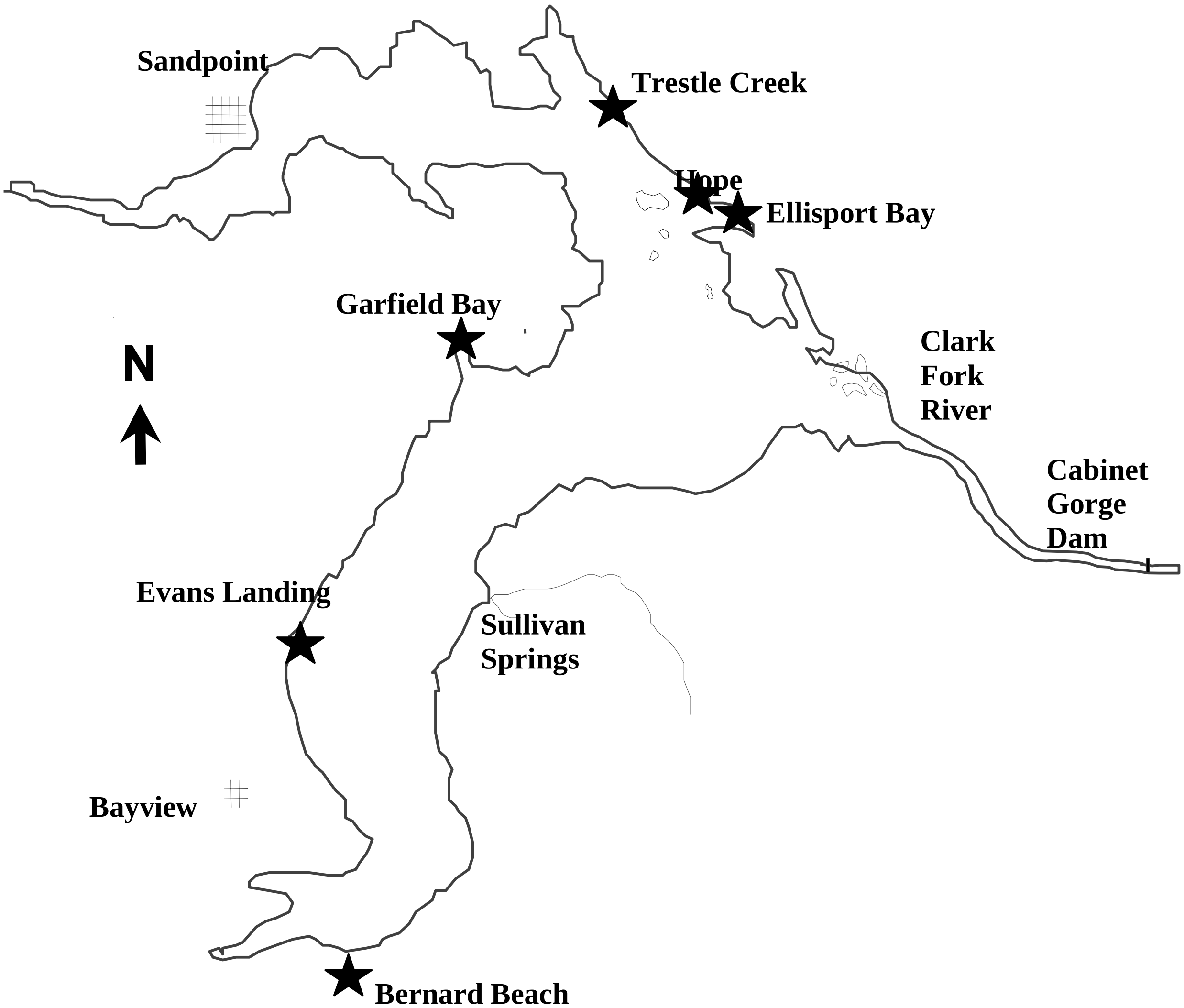


Figure 4. Areas surveyed on Lake Pend Oreille, Idaho to monitor kokanee spawning gravel during 2003.

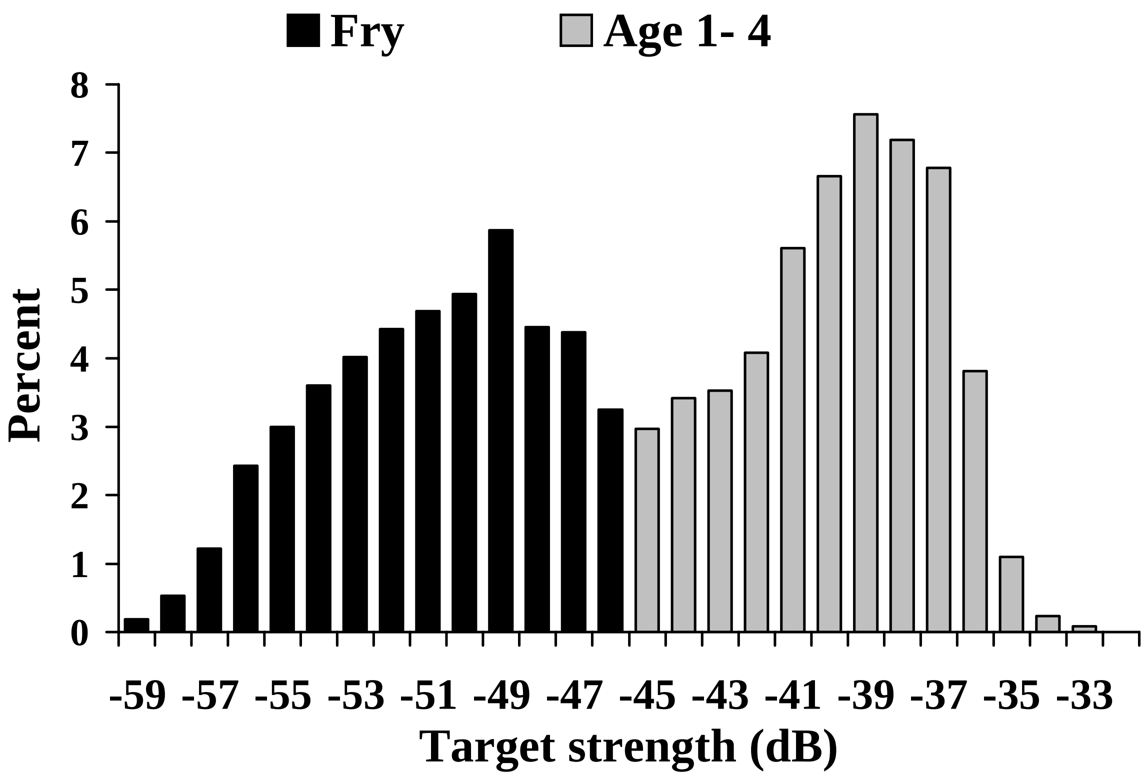


Figure 5. Distribution of target strengths from 8,719 fish recorded during hydroacoustic surveys on Lake Pend Oreille, Idaho, in August 2003.

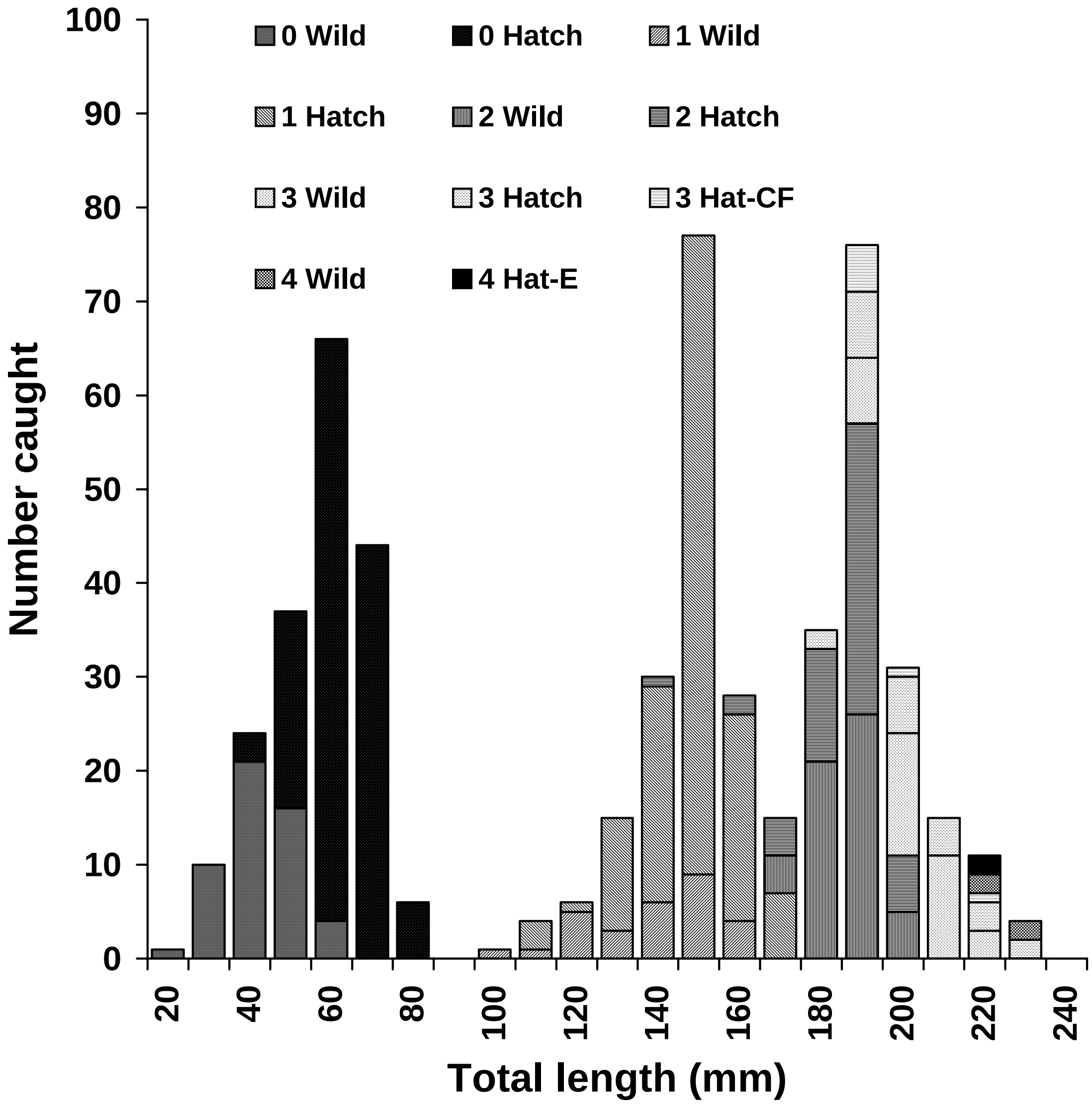


Figure 6. Length-frequency distribution of kokanee caught by midwater trawling in Lake Pend Oreille, Idaho in August 2003. Abbreviations in the legend include Hatch = late spawning kokanee reared at the Cabinet Gorge Hatchery, Hat-CF = late spawning kokanee reared at the Clark Fork Hatchery, Hat-E = early spawning kokanee reared at the Cabinet Gorge Hatchery, Wild = kokanee produced naturally in the lake and its tributaries. Numeral denotes age class.

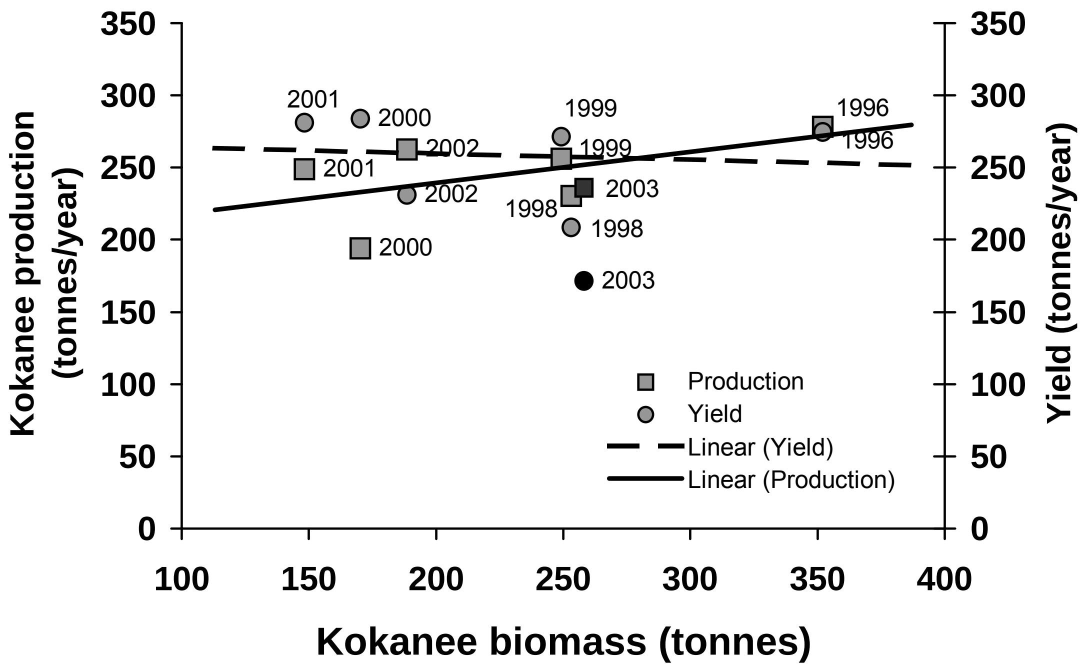


Figure 7. Kokanee biomass, production, and yield (metric tonnes) from Lake Pend Oreille, Idaho 1996-2003, excluding 1997 due to 100 year flood. Lines were fitted to all data points except 2003 to illustrate possible change.

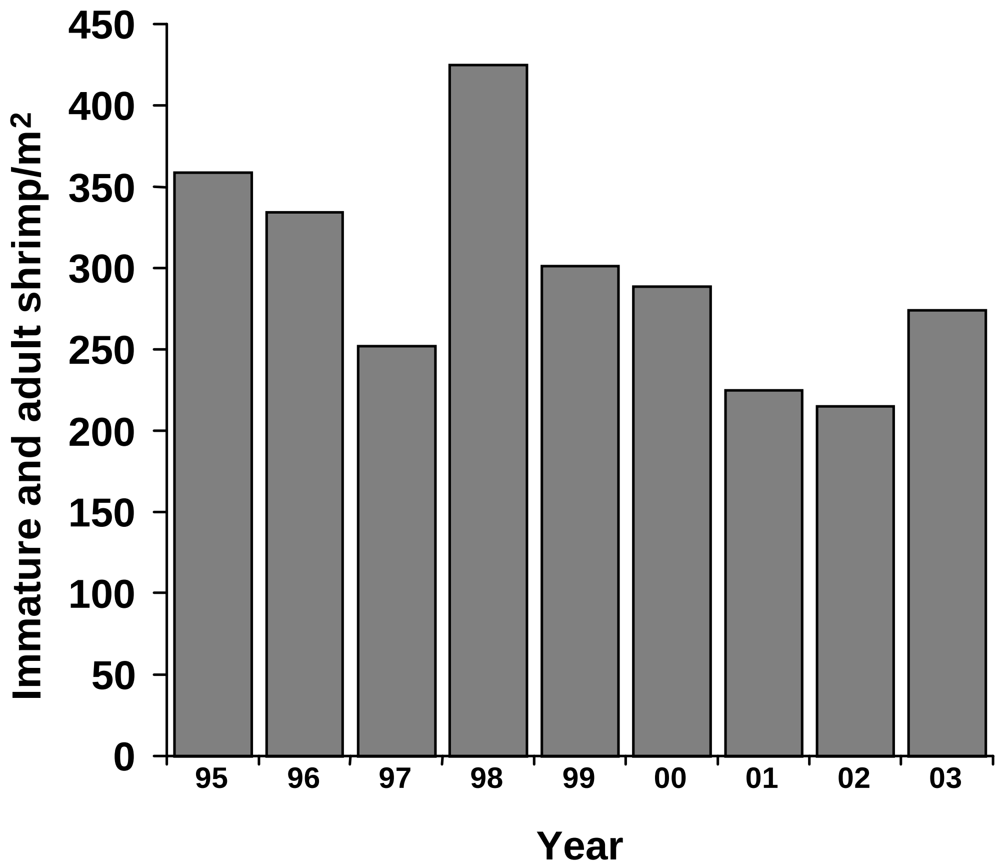
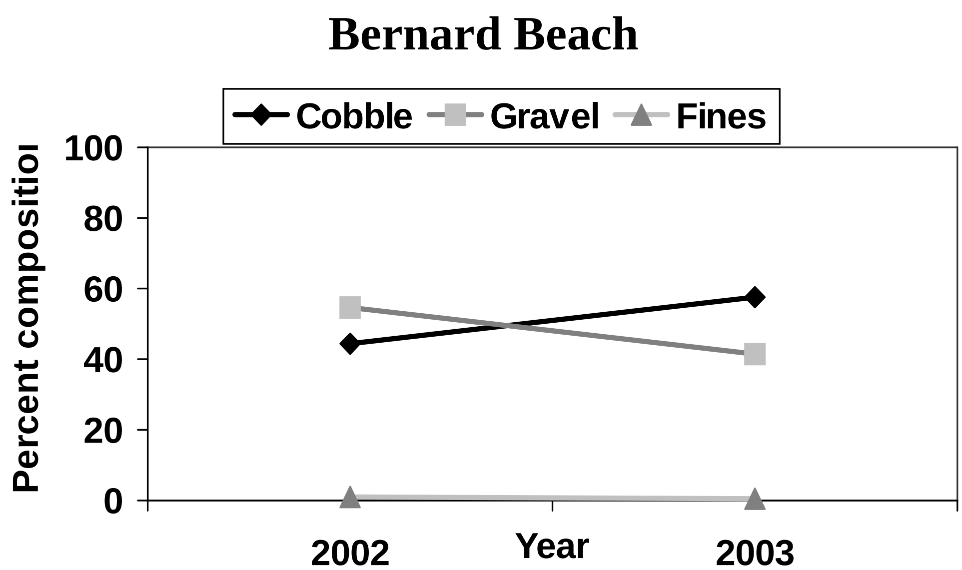


Figure 8. Density of immature and adult opossum shrimp (excluding young-of-the-year shrimp) in Lake Pend Oreille, Idaho. Shrimp densities for 1995 and 1996 were obtained from Chipps (1997).



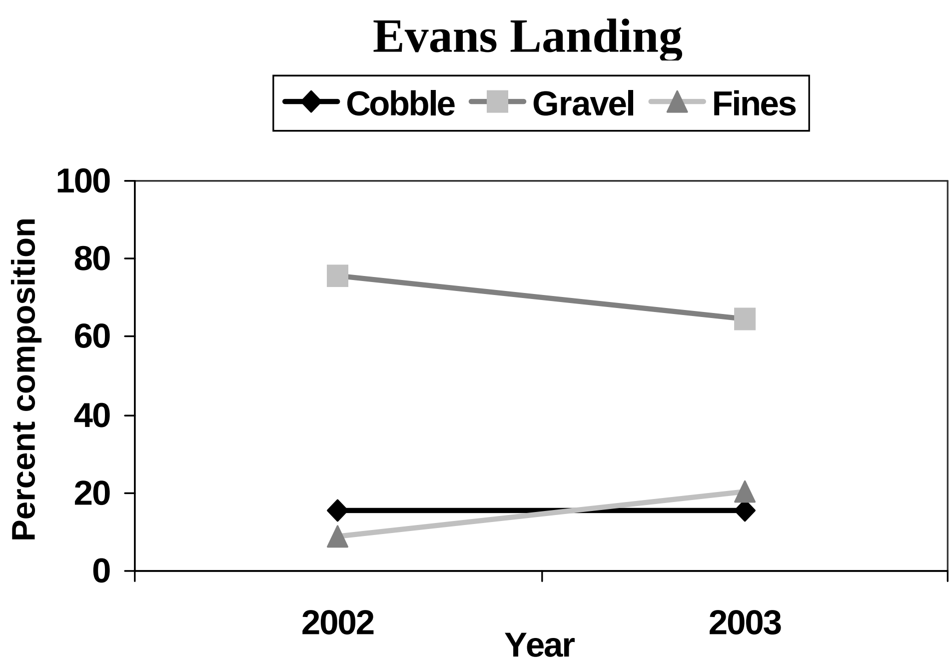
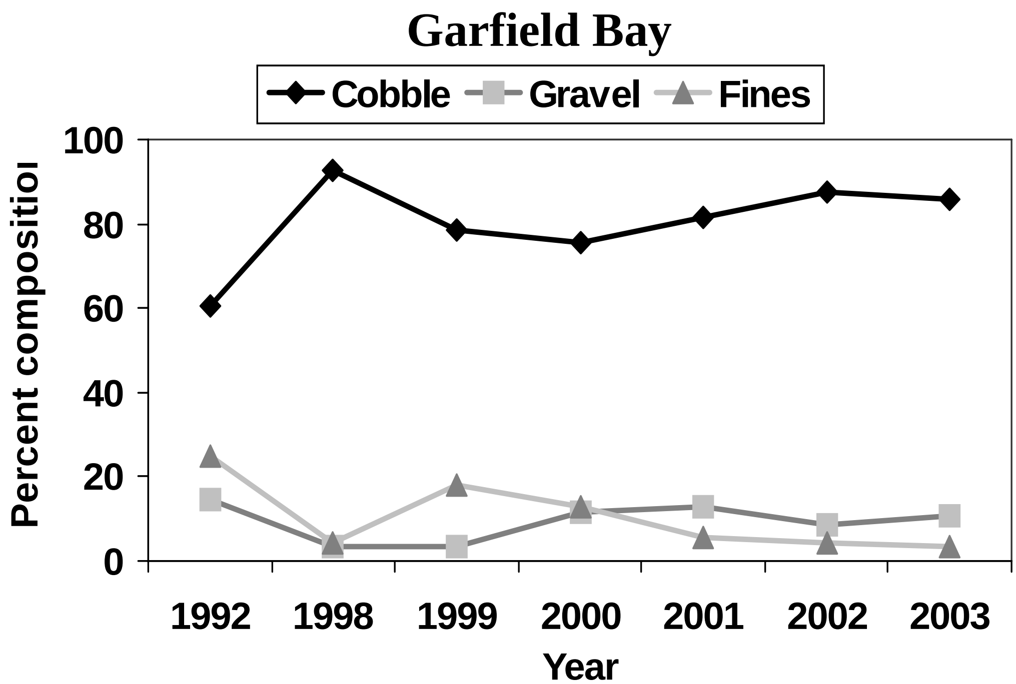


Figure 9. Substrate composition between the elevations of 625.1 m and 625.8 m at Bernard Beach and Evans Landing, Lake Pend Oreille, Idaho.



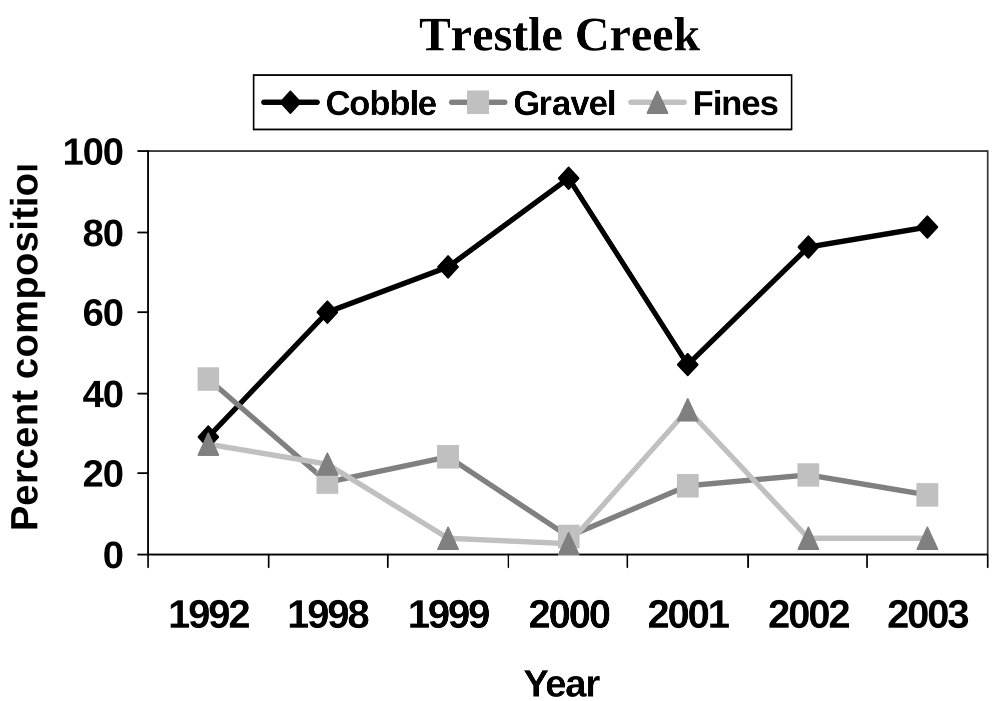


Figure 10. Substrate composition between the elevations of 625.1 m and 625.8 m at Garfield Bay and the lakeshore near Trestle Creek, Lake Pend Oreille, Idaho.

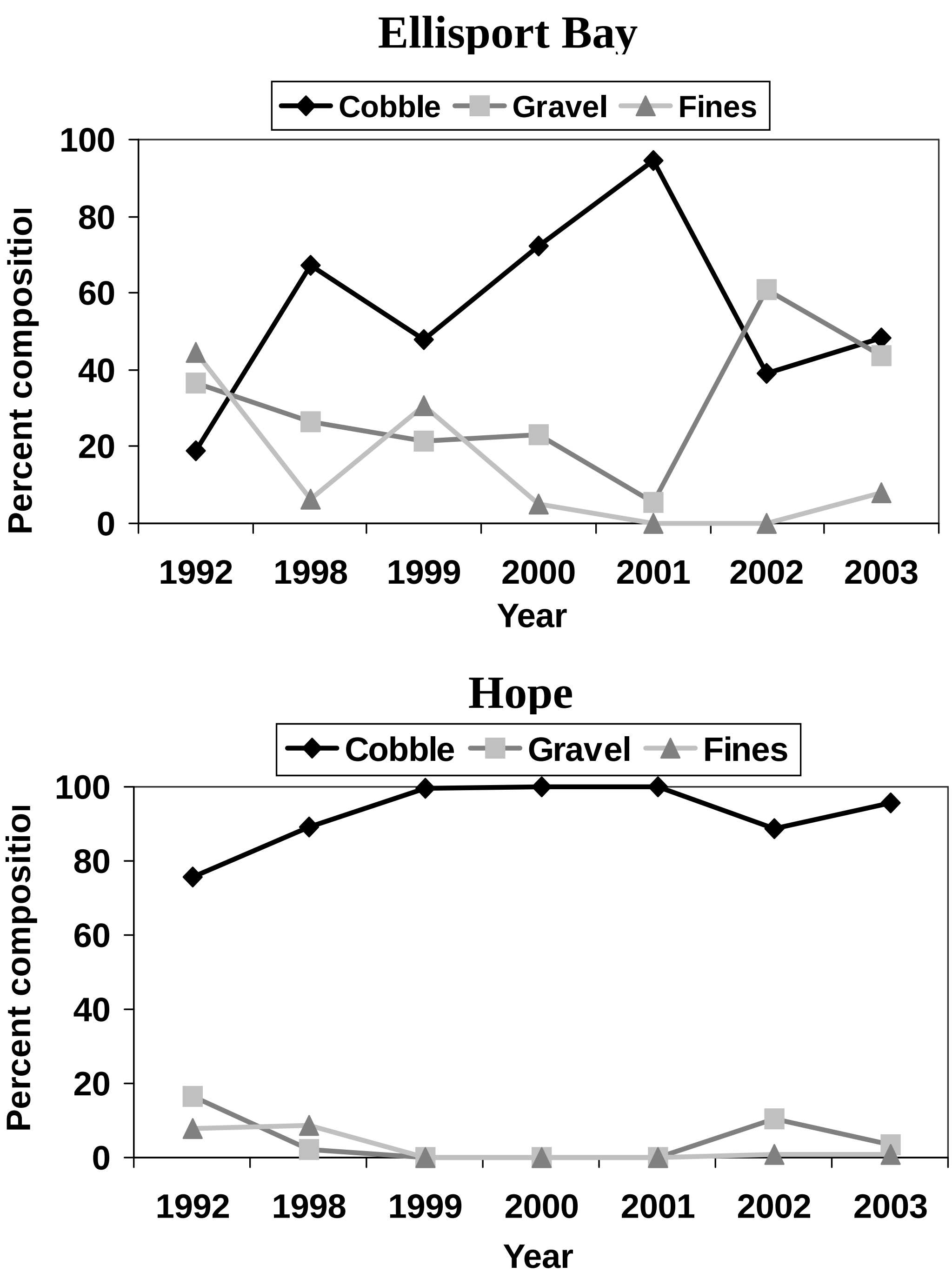
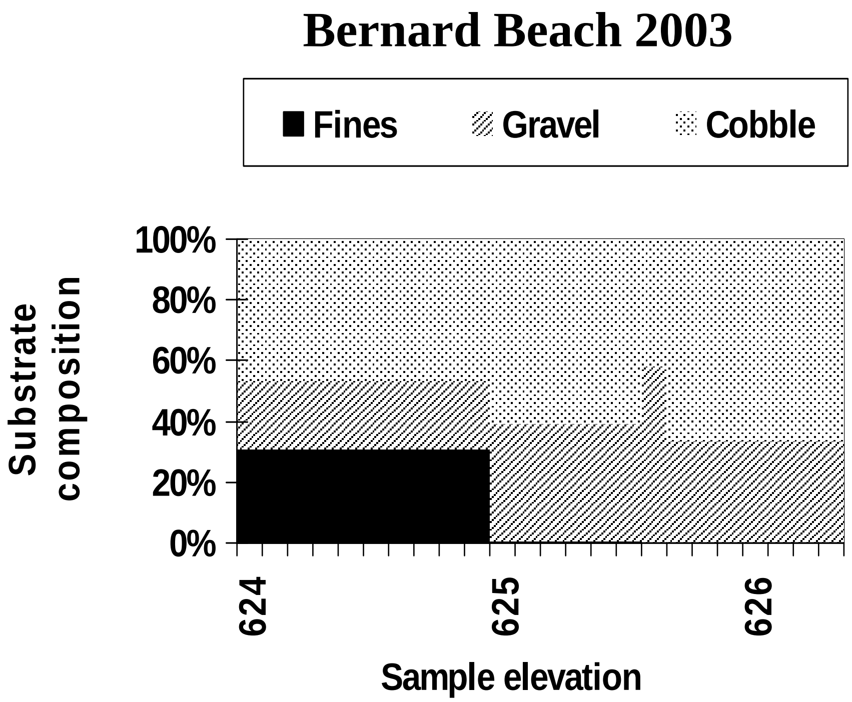


Figure 11. Substrate composition between the elevations of 625.1 m and 625.8 m at Ellisport Bay and Hope, Lake Pend Oreille, Idaho.



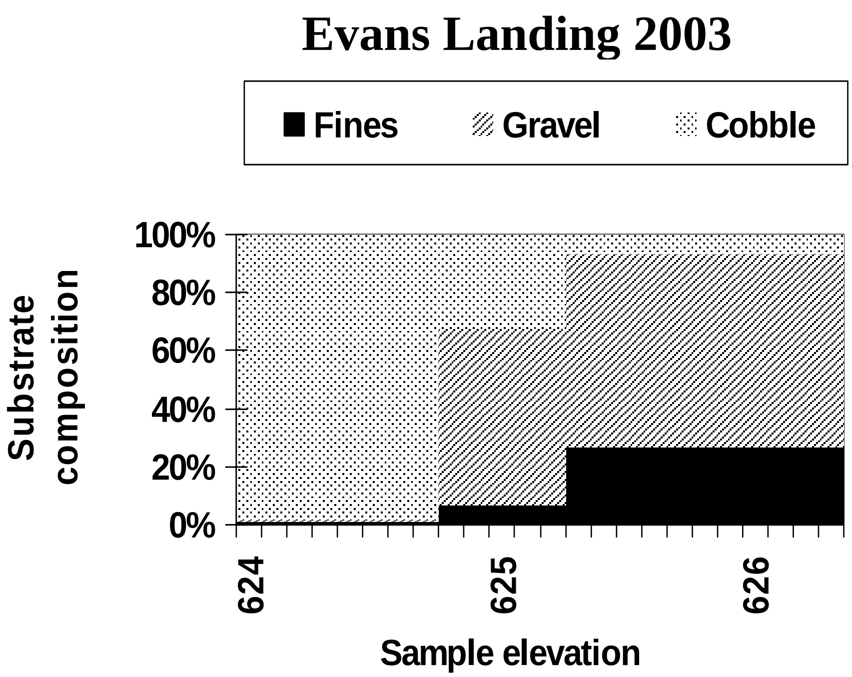


Figure 12. Substrate composition at various elevations on Bernard Beach and Evans Landing, Lake Pend Oreille, Idaho in 2003.

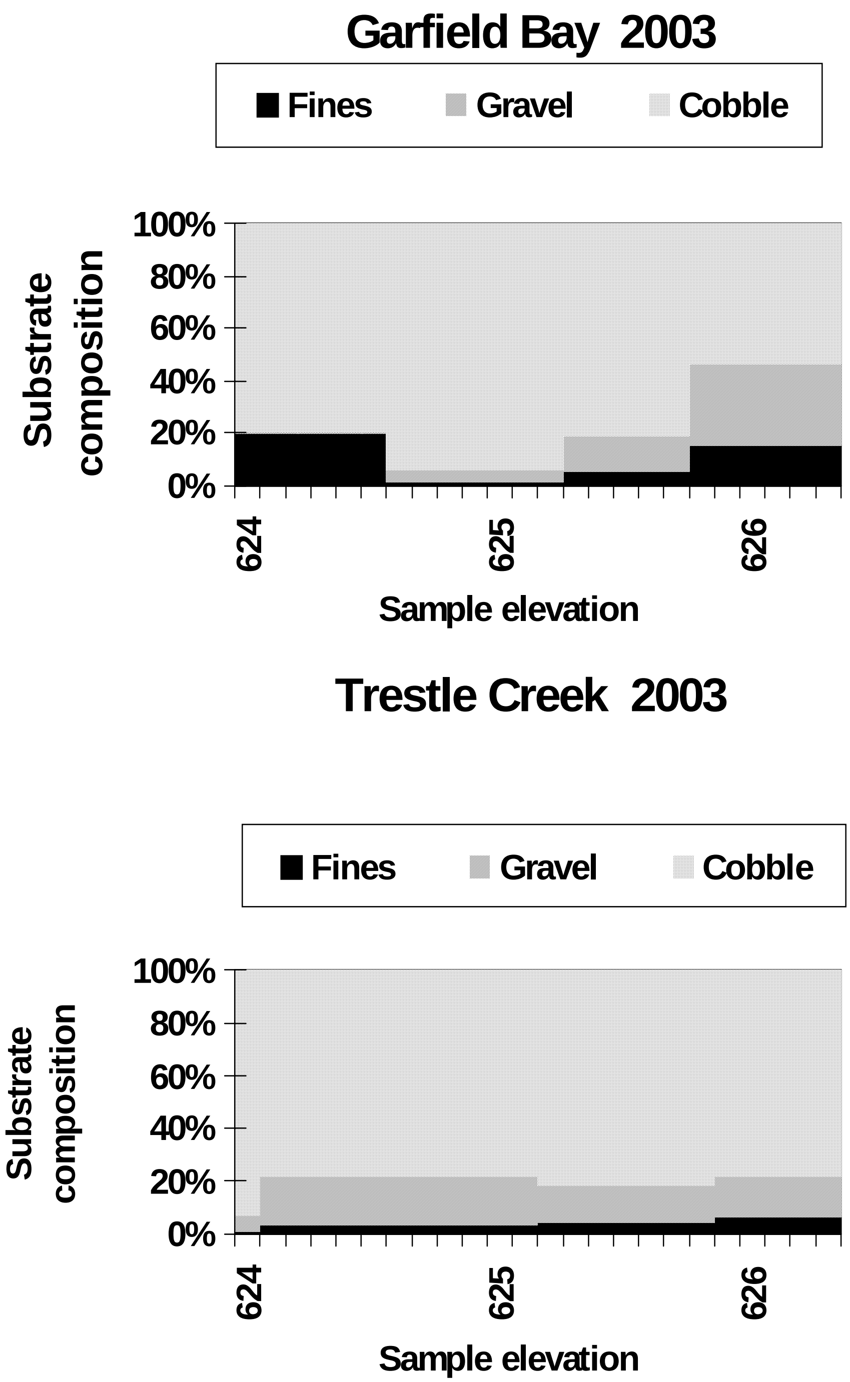
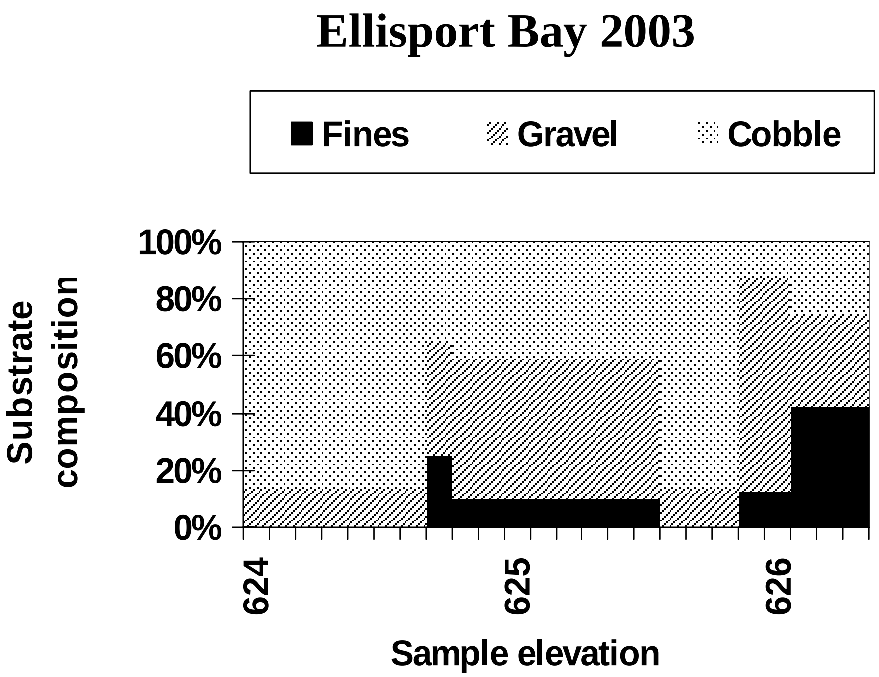


Figure 13. Substrate composition at various elevations in Garfield Bay and near Trestle Creek, Lake Pend Oreille, Idaho in 2003.



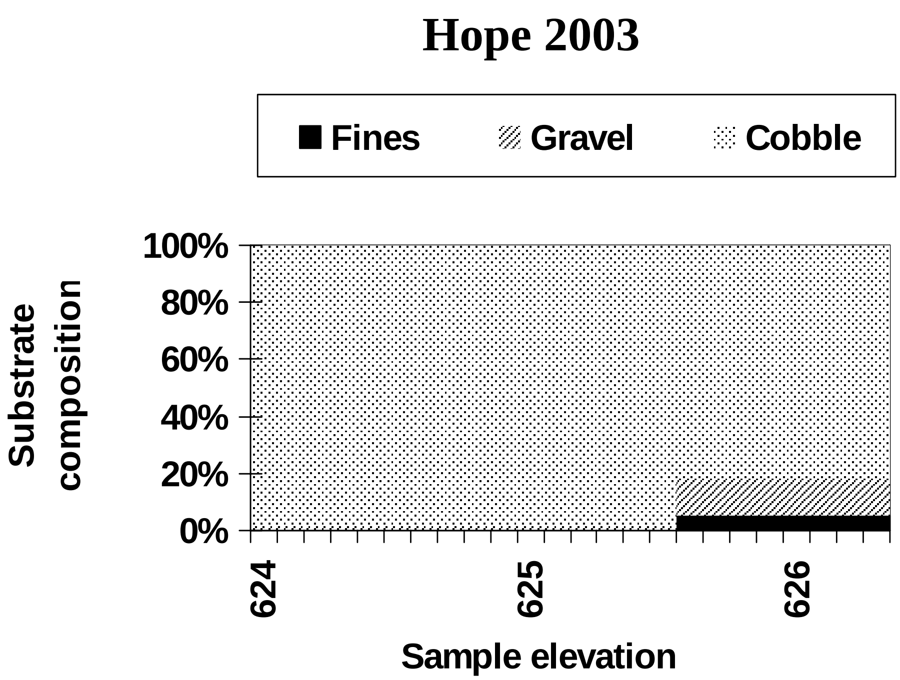


Figure 14. Substrate composition at various elevations in Ellisport Bay and near Hope, Lake Pend Oreille, Idaho in 2003.

LITERATURE CITED

Bowler, B. 1978. Lake Pend Oreille kokanee life history studies. Idaho Department of Fish and Game, Job Performance Report, Federal Aid in Fish Restoration, Project F-53-R-13, Job IV-e, Boise, Idaho.

Bowler, B., B. E. Rieman, and V. L. Ellis. 1979. Pend Oreille Lake fisheries investigations. Idaho Department of Fish and Game, Job Performance Report, Project F-73-R-1, Boise, Idaho.

Bowles, E. C., V. L. Ellis, D. Hatch, and D. Irving. 1987. Kokanee stock status and contribution of Cabinet Gorge Hatchery, Lake Pend Oreille, Idaho. Idaho Department of Fish and Game, Annual Report to Bonneville Power Administration, Contract DE-A179-85BP22493, Project 85-839, Portland Oregon.

Bowles, E. C., V. L. Ellis, and D. Hatch. 1988. Kokanee stock status and contribution of Cabinet Gorge Hatchery, Lake Pend Oreille, Idaho. Idaho Department of Fish and Game, Annual Report to Bonneville Power Administration, Contract DE-A179-85BP22493, Project 85-339, Portland, Oregon.

Bowles, E. C., V. L. Ellis, and B. Hoelscher. 1989. Kokanee stock status and contribution of Cabinet Gorge Hatchery, Lake Pend Oreille, Idaho. Idaho Department of Fish and Game, Annual Report to Bonneville Power Administration, Contract DE-A179-85BP22493, Project 85-339, Portland, Oregon.

Chipps, S. R. 1997. *Mysis relicta* in Lake Pend Oreille: seasonal energy requirements and implications for mysid-cladoceran interactions. Doctoral dissertation, University of Idaho, Moscow, Idaho.

Fredericks, J. P., M. A. Maiolie, and S. Elam. 1995. Kokanee impacts assessment and monitoring on Lake Pend Oreille, Idaho. Idaho Department of Fish and Game, Annual Progress Report to Bonneville Power Administration, Contract 94BI12917, Project 94-035, Portland, Oregon.

Gregg, R. E. 1976. Ecology of *Mysis relicta* in Twin Lakes, Colorado. United States Bureau of Reclamation, REC-ERC-76-14, Denver, Colorado.

Jeppson, P. 1960. Evaluation of kokanee and trout spawning areas in Pend Oreille Lake and tributary streams. Idaho Department of Fish and Game, Job Progress Report, Project F-53-R-10, Boise, Idaho.

Love, R. H. 1971. Dorsal-aspect target strength of an individual fish. Journal of the Acoustic Society of America 49:816-823.

Maiolie, M. A., and S. Elam. 1993. Influence of lake elevation on availability of kokanee spawning gravels in Lake Pend Oreille, Idaho. In Dworshak Dam impacts assessment and fisheries investigations. Idaho Department of Fish and Game, Annual Report to Bonneville Power Administration, Contract DE-AI79-87BP35167, Project 87-99. Portland, Oregon.

Maiolie, M. A., K. Harding, W. Ament, and W. Harryman. 2002. Lake Pend Oreille fishery recovery project. Idaho Department of Fish and Game, Completion Report to Bonneville Power Administration, Contract 1994-047-00, Portland, Oregon.

Maiolie, M. A., W. Harryman and W. Ament. 2003. Lake Pend Oreille fishery recovery project. Idaho Department of Fish and Game, Annual Report to Bonneville Power Administration, Contract 1994-047-00, Portland, Oregon (in press).

MacLennan, D. N., and E. J. Simmonds. 1992. Fisheries Acoustics. Chapman and Hall, New York.

Paragamian, V. L., and V. L. Ellis. 1991. Kokanee stock status and contribution of Cabinet Gorge Fish Hatchery, Lake Pend Oreille, Idaho. Idaho Department of Fish and Game, Progress Report to Bonneville Power Administration, Contract DE-A179 85BP22493, Project 85-339, Portland, Oregon.

Pennak, R. W. 1978. Fresh-water invertebrates of the United States, second edition. John Wiley and Sons, New York, New York.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Fisheries Research Board of Canada, Bulletin 191:382, Ottawa, Ontario.

Rieman, B. E. 1977. Lake Pend Oreille limnological studies. Idaho Department of Fish and Game, Job Performance Report, Project F-53-R-12, Job IV-d, Boise, Idaho.

Rieman, B. E. 1992. Kokanee salmon population dynamics-kokanee salmon monitoring guidelines. Idaho Department of Fish and Game, Job Performance Report, Project F-73-R-14, Subproject II, Study II, Boise, Idaho.

Rieman, B. E., and B. Bowler. 1980. Kokanee trophic ecology and limnology in Pend Oreille Lake. Idaho Department of Fish and Game, Fisheries Bulletin number 1, Boise, Idaho.

Scheaffer, R. L., W. Mendenhall, and L. Ott. 1979. Elementary survey sampling, second edition. Duxbury Press, North Scituate, Massachusetts.

Volk, E. C., S. L. Schroder, and K. L. Fresh. 1990. Inducement of unique otolith banding patterns as a practical means to mass-mark juvenile Pacific salmon. American Fisheries Society Symposium, 7:203-215.

Wetzel, R. G. 1975. Limnology. W. B. Saunders Company, Philadelphia, Pennsylvania.

Whitt, C. 1958. Evaluation of spawning areas in Lake Pend Oreille, Idaho, and tributaries upstream from Albeni Falls Dam, June 1, 1957 to May, 31, 1958. Idaho Department of Fish and Game, Annual Summary Report, Project F3-R-7 and F3-R-8. Boise, Idaho.

APPENDIX

Appendix A. 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 ½ 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 launch area.

Sunnyside

– From Sunnyside Resort go east approximately ½ km.

Garfield Bay

– Along docks at Harbor Marina on east side of bay.
– From the Idaho Department of Fish and Game managed boat ramp go toward Garfield Creek. Cross Garfield Creek and proceed ¼ 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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