FISHERY RESEARCH

LAKE PEND OREILLE FISHERY RECOVERY PROJECT

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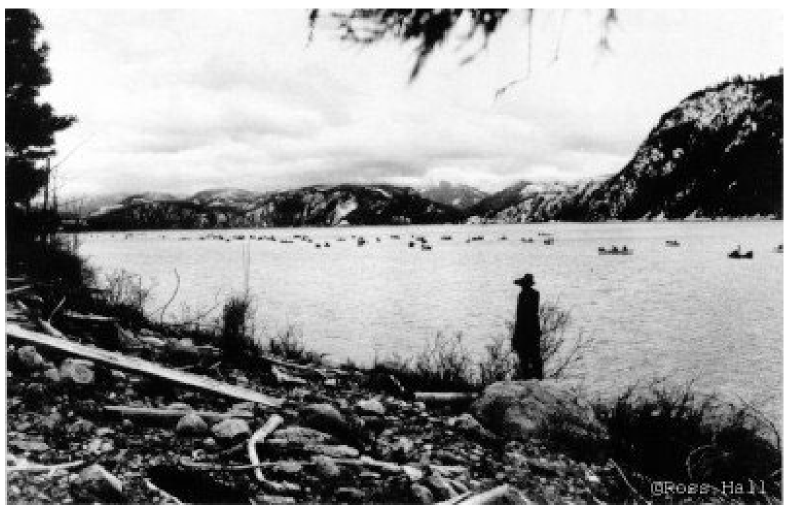

Photo by Ross-Hall of kokanee anglers on Lake Pend Oreille in 1953

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Lake Pend Oreille Fishery Recovery Project

Project Progress Report

2002 Annual Report

By

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ABSTRACT

The winter water level of Lake Pend Oreille has been managed since 1996 in an effort to recover kokanee *Oncorhynchus nerka*, which are both preferred forage for threatened bull trout *Salvelinus confluentus* and potential sport fish. During the winter of 2001-2002, the elevation of Lake Pend Oreille was lowered to 625.1 m (2051 ft) above mean sea level (MSL), 0.6 to 1.2 m lower than the previous five years. This allowed wave action to re-sort and clean gravel on the shorelines of the lake and improve kokanee spawning areas. We conducted hydroacoustic surveys and trawling in late summer of 2002 to assess the kokanee population and determine if the deeper drawdown impacted kokanee spawning success. We estimated the lake contained 1.19 million kokanee fry of wild origin that originated from an estimated 8.46 million wild-spawned eggs during the fall of 2001. Therefore, the survival from wild spawned eggs to wild fry was 14%, which was the highest egg-to-fry survival rate recorded in recent years. These findings indicated that the very low numbers of adult kokanee spawning in 2001 were finding sufficient spawning areas to achieve good egg-to-fry survival even though the lake was drawn down to its low pool elevation.

We also core sampled potential spawning areas to determine whether the gravel was restored. Core samples at Ellisport Bay between the elevations of 625.1 m and 625.8 m showed a marked increase in gravel content from 5% of the total substrate in 2001 to 62% in 2002. Core sampling at Evans Landing and Bernard Beach also documented a buildup of gravel near the low pool elevation because of the lower winter lake elevation. Gravel at these sites comprised 76% and 55% of the core samples, respectively. Shoreline sites at Trestle Creek and Hope showed only minor increases in gravel content. These findings indicate that the low winter pool elevation during the winter of 2001-02 improved the quality of the spawning substrates at some sites.

During August of 2002, we used hydroacoustics to estimate the abundance of kokanee in Lake Pend Oreille and found 6.94 million fry and 5.32 million kokanee ages 1 and older. By trawling, we estimated that total kokanee abundance in the lake was 4.6 million fish and the number of adult kokanee had declined to a new all-time low: 12,400 age-4 kokanee (100% mature) and 53,600 age-3 kokanee (75% mature). These fish laid an estimated 4.04 million eggs in 2002. Hatchery personnel collected 4.0 million eggs, which will be cultured and marked by cold branding the otoliths, and the resulting fry stocked into the lake in 2003. Peak counts of spawning kokanee were 968 fish on the shoreline and 1,491 fish in tributary streams. Counts were higher than expected considering the low population estimate of adults. Density of opossum shrimp *Mysis relicta* declined for the fourth year in a row. Immature and adult shrimp (excluding young-of-the-year shrimp) densities averaged 215 shrimp/m^2. The cause of this downward trend was unknown.

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INTRODUCTION

The U.S. Army Corps of Engineers changed the fall drawdown of Lake Pend Oreille beginning in the winter of 1996-97 to enhance kokanee spawning. The lake was kept above an elevation of 626.4 m (2,055 ft, 1.2 m higher than typical previous winters) for three consecutive winters. Gravel surveys conducted in 1994 determined this would increase the amount of suitable kokanee spawning gravel by 560% (Fredericks et al. 1995). Between 1999 and 2000, the lake was kept 0.6 m higher. 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. 2002). 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 re-sort gravel and restore spawning areas (Figure 1). This investigation documents the response of the kokanee population and the shoreline gravel to the previous winter of full drawdown.

OBJECTIVE

To rebuild the kokanee population to the point 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). 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 during fall and winter (typical dam operation between 1966 and 1996).

A diverse assemblage of fish species is present in Lake Pend Oreille. Native game fish include bull trout, westslope cutthroat trout *Oncorhynchus clarki lewisi*, and mountain whitefish *Prosopium williamsoni.* Native nongame fish include pygmy whitefish *Prosopium coulteri*, 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. Other introduced game fish include Gerrard rainbow trout *Oncorhynchus mykiss,* lake whitefish *Coregonus clupeaformis*, and lake trout *Salvelinus namaycush,* in addition to several other cold-, cool-, and warmwater species.

METHODS

Hydroacoustics

We conducted hydroacoustic surveys on Lake Pend Oreille between August 19 and 23, 2002. Surveys were conducted both day and night in order to determine population estimates, diel kokanee distribution, and to look for kokanee predators as part of the Lake Pend Oreille Predation Research Project.

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). 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 (Figure 2). 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 a global positioning system (GPS) receiver. Boat speed was approximately 1 m/s (boat speed did not affect our calculations of fish density).

A Simrad EY500 portable scientific echo sounder set to ping at 1.0 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. In addition, calibration of the echo sounder was checked using a 23 mm copper calibration sphere before the start of the surveys and gains adjusted to achieve the correct target strengths. Traces (a single returned echo from a fish) were accepted if they were over –60 dB, the echo length between the 6 dB points relative to the peak value divided by the duration of the transmitted pulse was between 0.8 and 1.8, the correction value returned from the transducer gain model did not exceed a one-way maximum gain compensation of 4.0 dB, and the average electrical phase jitter between samples inside an echo pulse was 4.0 phase steps (where 64 phase steps = 180 electrical degrees).

We “trace tracked” 1,109 kokanee to obtain a sample of their target strength frequency distribution. Trace tracking is a process of connecting all of the traces (returned echoes) from a single fish across multiple pings. Trace tracking was conducted only on the nighttime surveys using Simrad’s EP500 software since kokanee tend to school during the day. To be considered a trace tracked fish, targets had to be detected (pinged) at least twice, not move more than 30 cm vertically between detections, and not be missed by more than 1 ping during the tracking. Mean target strengths of trace tracked fish were plotted on a bar graph of target strength versus frequency of occurrence to separate fry from older age classes of kokanee. We used the low point (lowest frequency) on the graph to define the size break between these two groups. Older age classes of kokanee could not be separated on the basis of target strengths.

Density estimates of kokanee in each transect were calculated using the EP500 version 5.2 software. A box was drawn around the kokanee layer on each echogram to define the area sampled. The software then calculated density estimates in fish/ha for each 3 dB size class of targets. Density estimates were computed by echo integration, which accounted for fish that were too close together to be detected as a single target (MacLennan and Simmonds 1992). Arithmetic and 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).

Pelagic targets between –45.9 dB and –33.0 dB were considered kokanee from ages 1 to 5. In order to split these fish into abundance estimates for each kokanee age class, the hydroacoustic estimate of abundance for each lake section was multiplied by the proportion of kokanee that were ages 1 through 5 in the trawl catch 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 trawl samples for that section (fry in the trawl samples had their otoliths sent to Washington Department of Fisheries and Wildlife to see if they had the cold-brand mark of a hatchery fish). 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 in each section of the lake. Section totals were summed to get lakewide abundance estimates of hatchery and wild fry. Survival estimates between year classes were calculated by dividing the hydroacoustic estimate of abundance by the previous year's estimate.

Midwater Trawling

We conducted standardized midwater trawling in Lake Pend Oreille from September 3 to September 6, 2002. 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. We located each trawl site using the GPS.

The midwater trawl equipment and sampling procedures were described in detail by Rieman (1992). The net was 13.7 m long with a 3.05 m x 3.05 m mouth. Mesh sizes (stretch measure) graduated from 32, 25, 19, and 13 mm in the body of the net to 6 mm in the cod end. The trawl net was towed at a speed of 1.33 m/s by an 8.8 m boat. We determined the vertical distribution of kokanee by using a Furuno Model FCV-582 depth sounder with a 10° transom 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.

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. Otoliths were used to determine hatchery or wild origin and to determine the age of hatchery fish. A total of 181 otoliths were sent to Washington Department of Fisheries for analysis.

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 lake section was expanded into a total population estimate using standard expansion formulas for stratified sampling designs (Scheaffer et al. 1979). The area of each section was calculated for the 91.5 m contour; however, the northern section was calculated from the 36.6 m contour because of shallower water. The 91.5 m contour was used because it represents the pelagic area of the lake where kokanee are found during late summer (Bowler 1978). For consistency, these same areas have been used each year since 1978, a total of 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):

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

where:

$\bar{X}$ = the estimated mean number of kokanee in the lake,
t = the student's t value,
N = the number of possible samples in a section,
n = the number of samples collected in a section of the lake,
s_i = the standard deviation of the samples in strata 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 total abundance of wild fish.

Potential egg deposition (PED) 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 then divided the total mature population by two (assuming a 1:1 sex ratio). The number of mature females in the lake was then multiplied by the mean fecundity observed at the Granite Creek spawning station to estimate potential egg deposition. We then 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).

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 straight weeks beginning the third week in November 2002. All kokanee, either 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. 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 20, 2002 to assess this kokanee stock. Data on early spawning kokanee was kept separate from later spawning fish.

Artificial Spawning Areas

We placed artificial spawning boxes in the lake to see if kokanee would use these structures. This would indicate that spawning boxes could help kokanee spawning, particularly in years with a full drawdown. If redds appeared in the boxes, we would then determine if viable fry were being produced by excavating the gravel prior to fry emergence. Our objective was to determine whether artificial spawning areas could be used to help recover kokanee in the lake.

Four types of artificial spawning boxes were in Lake Pend Oreille during the 2001-02 spawning season (Figure 4). Two large wooden frames 2.4 m x 1.2 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 clean 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 wooden frames were built, 1 m x 1 m, with screen mesh bottoms and 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. The wooden frames had steel corners to strengthen the frames. These four frames were placed in the lake during 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 boxes were built and placed in the lake. The boxes were constructed and paired up 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).

Also 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 (Figure 4). This experiment was intended to determine if the frame was causing kokanee to avoid the spawning boxes. These gravel patches were placed on either side of 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 described by Volk et al. (1990). Therefore, hatchery kokanee from age-0 to age-5 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 performed at the Cabinet Gorge Fish Hatchery. Thermal treatments were initiated five to ten days after fry hatched and entered their respective raceways. Fry released in 2002 (brood year 2001) received four coldwater events over an 11-day period, with one day between the first and second events and three days between both the second and third and third and fourth events.

Twenty fry from each raceway were sacrificed to verify the thermal marking. These fry were sent to the Washington Department of Fish and Wildlife Otolith Laboratory in Olympia Washington. Otolith marks were verified on all thermally treated individuals. All 6.526 million fry were stocked in Lake Pend Oreille tributaries with 724,000 going to Twin Creek, 725,000 going to Spring Creek, and 5.077 million fry stocked in Sullivan Springs Creek. All fish were stocked between June 18 and July 2, 2002.

We sent 181 otoliths from all kokanee age classes collected during September trawling to the Washington Department of Fish and Wildlife lab to determine if the kokanee were of hatchery origin. Before shipment, we catalogued each fish, recorded total length and weight, and removed, cleaned, and catalogued the otoliths.

Washington Fish and Wildlife personnel removed one otolith from each of the 181 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 for each year since 1996. For accuracy, two independent readers examined each otolith. Differences between the readers were settled by re-examining the otolith.

Kokanee 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 times the mean weight of kokanee in that year class. The year class weights were then summed to obtain the lake's total 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 obtain 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 age class 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 get 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 through 2001 were used to plot the trend lines, except the flood year of 1997 was not included (due to high mortality that was likely not predator related). Data from 2002 was then 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 10 and 11, 2002 to estimate their abundance. Our intent was to monitor trends in shrimp abundance to determine if they have an effect on kokanee survival. 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 by picking random numbers corresponding to latitude-longitude line intersections on a map of the lake (Figure 3). We used GPS 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 winched 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. Density estimates were made using the volume of water filtered as determined by the flowmeter reading and the number of shrimp collected. This methodology has been used since 1995 to assess the population.

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

Limnology

We monitored basic parameters of physical limnology to determine if they influenced the outcome of the lake level experiment. Unusually cold or warm years, for example, could possibly affect survival of fry and influence the results of the lake level experiment. We measured water temperature, dissolved oxygen, and water clarity (Secchi transparency) monthly from January through December 2002. Data were collected at three standardized stations that represented the southern, middle, and northern sections of the lake (Figure 2). Sampling 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 measured at each station using a 20 cm diameter Secchi disc during each survey.

For the first time during this project, monthly measurements of chlorophyll-a, phosphorus, and nitrogen were collected from April through October 2002. Water quality samples were collected at the same locations and times as the water temperatures. A Wildco Limnology Water Sampler with a messenger was used to collect all samples. Chlorophyll-a samples were collected at each of the three sites by combining samples at three separate depths per site. One third of each sample was collected at a depth of 1 m, another third at the depth of the Secchi depth reading, and the last was collected at twice the Secchi depth. The composite sample was placed in a 946 ml dark brown NALGENE bottle to block light during transport. Phosphorus and nitrogen samples were collected in the same manner but at depths of 1 m, 5 m, and 12 m. Samples were placed in a 1 L "cubitainer" container and immediately placed on ice. All samples were transported to the lab the same day as collected. Samples were analyzed at either the Boise or Coeur d'Alene labs of the Idaho Department of Health and Welfare. Nutrient status will be compared to previous data to determine if Lake Pend Oreille is becoming more oligotrophic.

Substrate Sampling

Six areas of shoreline were sampled in 2002 to determine if the quality of potential spawning gravel was declining for kokanee spawning. Areas surveyed included the shoreline at Garfield Bay, Trestle Creek, Hope, Evans Landing, Bernard Beach, and Ellisport Bay. This year the North Gold Creek site was excluded since stream currents and sediment deposits influenced the results. Evans Landing and Bernard Beach were new sites that had potential as spawning areas. Garfield Bay, Trestle Creek, Hope, and Ellisport Bay sites were surveyed in 1992 (Maiolie and Elam 1993) and from 1997 through 2001 and were historic locations for kokanee spawning (Jeppson 1960).

Substrate sampling was conducted by scuba diving from July 9 to 16, 2002. During this period the lake was at its summer full pool level. 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 (2055 feet). Four random samples of substrate were collected from each substrate band below this depth. 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.

A different approach was used at Garfield Bay to be consistent with previous years. Here we collected two random samples (each about 2 L) every 1.2 m along the transect that extended from the 623.9 m elevation (2,047.2 ft) to the upper winter pool level of 626.3 m (2055 ft). Each sample was individually bagged, labeled, and oven dried. We then screened each substrate sample through soil sieves of the following sizes: 63.5 mm, 31.8 mm, 15.9 mm, 9.5 mm, 6.3 mm, 2 mm, and 0.84 mm. The substrate retained on each screen and the substrate 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 31.8 mm and larger, "gravel" as substrates between 31.8 and 6.3 mm, and "fines" as the substrate smaller than 6.3 mm. This definition of fine material was consistent with Irving and Bjornn (1984).

RESULTS

Hydroacoustics

In 2002, we estimated the lake contained 12.27 million kokanee (±7%, 90% CI) based on our standard nighttime hydroacoustic surveys using the arithmetic means. This included 6.94 million fry (±9%, 90% CI) and 5.32 million (±8%, 90% CI) ages 1 to 4 kokanee (Table 1 and 2). Based on geometric means, the lake contained 11.76 million kokanee (±8%, 90% CI). This included 6.75 million fry (±9%, 90% CI) and 5.01 million kokanee ages 1-4 (-7% to +8%, 90% CI).

Mean target strengths of 1,109 "trace tracked" kokanee showed a clear separation between age-0 kokanee and older kokanee at the –46 dB level (Figure 5). This corresponded to a fish's standard length of 86 mm (Love 1971). This was consistent with the separation of age-0 kokanee from the other age classes at the 90 mm size group in the trawl samples (Figure 6). We therefore separated kokanee fry from older kokanee based on this –46 dB target strength. No separation between older age classes (ages 1 to 4) could be defined based on target strengths alone.

We separated the hydroacoustic estimate of age-1 to age-4 kokanee (45.9 dB to 33.0 dB) based on the percent frequency of kokanee age classes in trawl samples for each section of the lake (Table 2). Therefore, based on hydroacoustics and arithmetic means, we estimated the lake contained 3.42 million age-1, 1.73 million age-2, 132,500 age-3, and 40,018 age-4 kokanee. No age-5 kokanee were identified in 2002.

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 first time this calculation was made and served as a comparison to other approaches. In the trawl, 4.2%, 2.9%, and 0.5% of the catch were mature in the southern, middle, and northern sections, respectively. This yielded an estimate of 101,000 mature kokanee or 50,500 mature female kokanee, assuming a 50% male:female sex ratio. We estimated the fecundity of female kokanee at 320 eggs/female based on a sample of 60 randomly collected female kokanee at the Sullivan Springs egg-take station. This yielded an estimated PED of 16.160 million eggs. Since hatchery personnel collected 4.02 million eggs, wild PED was 12.14 million by these calculations.

Survival rates from 2001 to 2002 were 31% from age-0 to age-1 and 44% from age-1 to age-2. Too few kokanee (n = 6) in the age-3 and age-4 groups were caught to calculate survival rates for these age classes (Table 3).

The hydroacoustic estimate of fry was separated into abundance estimates of wild and hatchery fry. Wild kokanee fry ranged from 20 to 54 mm in total length and were identified by having no temperature mark on their otoliths. In the midwater trawl catch, they made up 28% of the total fry number in the southern end of the lake, 21% of the fry in the middle section of the lake, and 9% of the fry in the northern end of the lake (Table 1). These percentages were multiplied by the hydroacoustic estimate of age-0 fish in each section to obtain an overall population estimate of 1.194 million wild fry (Table 1). These fry came from an estimated 8.5 million wild-spawned eggs that were laid in the lake and in tributaries. Survival of naturally deposited eggs to wild fry was therefore 14% (Table 4).

Age-1 kokanee from wild origin ranged from 91 mm to 159 mm, lacked the temperature mark on their otoliths, and showed one annuli on their scales. Wild age-1 fish made up 38.2% of the total number in the southern end of the lake, 33.7% in the middle section, and 24.6% in the northern section. Multiplying the percent times the number of age-1 kokanee in the hydroacoustic estimate, by section, and summing yielded an estimate of 1.01 million (29.7%) wild, and 2.40 million (70.3%) hatchery age-1 kokanee.

Wild age-2 kokanee ranged from 162 to 191 mm. They comprised 48.9% of the age-2 kokanee in the southern end of the lake and 52% and 46.6% in the middle and northern section of the lake, respectively. We calculated 0.85 million (49.3%) wild and 0.88 million (50.7%) hatchery age-2 kokanee in Lake Pend Oreille.

Wild age-3 kokanee ranged from 202 to 225 mm. All (n = 4) of the age-3 kokanee caught in the trawl were of wild origin; therefore, the population estimate of wild age-3 kokanee was 132,000 based on this low sample size.

Wild age-4 kokanee ranged from 246 to 266 mm. Both (n = 2) age-4 kokanee caught in the trawl were wild; therefore, the population estimate of wild age-4 kokanee was 40,000 based on this low sample size.

Midwater Trawling

In 2002, we estimated total kokanee abundance at 4.6 million fish with a density of 204 fish/ha (Table 5). The density of mature kokanee (ages 3 and 4) was 2.91 fish/ha. Kokanee fry abundance was estimated at 2.17 million (±11%, 90% CI) with a mean length and weight of 63.2 mm and 2.2 g, respectively. We estimated the lake also contained 1.63 million age-1 kokanee (±41%, 90% CI) with a mean length of 137.78 mm and mean weight of 21.3 g. There were 742,000 age-2 kokanee (±21.0%) with a mean length and weight of 182.17 mm and 47.4 g, respectively. Age-3 kokanee numbered 54,000 (±35.7%) with a mean length of 198.45 mm and weight of 60.5 g. There were only an estimated 12,000 age-4 kokanee (±120.3%) in the lake with a mean length of 255 mm and weight of 154 g (Table 5). No age-5 fish were sampled in 2002. Total standing stock of kokanee was 3.53 kg/ha.

Low sample sizes may be a problem with the trawl results. Only eight kokanee >200 mm were caught in 36 trawl hauls in Lake Pend Oreille in 2002. Of these, all of the age-4 kokanee and 75% of the age-3 kokanee in the trawl samples were found to be mature. We estimated the lake contained 25,259 mature fish, of which 50% were estimated to be female. Fecundity averaged 320 eggs per female in 2002, based on our sampling of 60 randomly selected female kokanee at the Sullivan Springs egg-take station. Therefore, PED was estimated at 4.04 million eggs. Hatchery crews collected 4.025 million eggs at Sullivan Springs. This left a very low estimate of only 16,129 eggs to be naturally spawned on the lakeshore and in tributary streams during the fall of 2002, based on this small sample size.

Spawner Counts and Surveys

A total of 968 spawning kokanee were counted along the shoreline in 2002. This count is greater than last year's but is still low compared to other years. All of these fish were observed in Scenic Bay (Table 6). Counts of spawning kokanee in tributary streams totaled 1,492 fish

(Table 7). Of these, 1412 were early spawners counted in Trestle Creek in September. The remaining 79 spawners were counted in South Gold Creek in December.

Artificial Spawning Areas

We did not find redds in any of the artificial spawning areas placed in the lake during the 2001-02 or the 2002-03 spawning seasons. Some redds were located on the sand and gravel spit on the south side of Leiberg Point, but they were not within our spawning beds.

Kokanee Biomass, Production, and Yield

The biomass of kokanee in Lake Pend Oreille increased 45 t (30%) between 2001 and 2002 (Table 8). Kokanee production increased slightly (6%) from 249 t in 2001 to 264 t in 2002. This was the second highest production of kokanee recorded since 1996. Yield dropped by 52.8 t (19%) to 228.5 t when compared to last year's yield of 281.3 t. This estimate of yield was the second lowest since 1996. This was the first time in the last three years that kokanee production was greater than kokanee yield.

We plotted production and yield against biomass to determine the relationship (Figure 7). Kokanee yield was relatively flat with changes in biomass, whereas kokanee production had a positive slope. The two trend lines crossed at a point where biomass equaled about 300 t.

Shrimp Abundance

We estimated the total mean density of shrimp during June 2002 at 960 shrimp/m^2 (Table 9). This included 745 young-of-the-year (YOY) shrimp/m^2 (<12 mm in total length) and 215 immature and adult shrimp/m^2. Density of immature and adult shrimp at the southern end of the lake rose by 82% from 155 in 2001 to 282 shrimp/m^2 in 2002, but stayed more constant in the center of the lake at 221 shrimp/m^2 compared to last year's estimate of 224 shrimp/m^2. Densities decreased in the northern end of the lake by 45% from 282 shrimp/m^2 in 2001 to 154 shrimp/m^2 in 2002. The whole-lake average of immature and adult shrimp (excluding young-of-the-year) decreased from last year's mean of 225 shrimp/m^2 to this year's estimate of 215 shrimp/m^2 (Figure 8).

Limnology

Secchi transparencies averaged 5.5 m at the northern end of Lake Pend Oreille versus 9.3 m and 10.2 m at the middle and southern sections, respectively (Table 10). In early spring (April), transparency dropped to its lowest point of 2.5 m at the northern station. The maximum Secchi depth of 21.0 m was also recorded during April but at the south end of the lake.

Water temperatures on the lake surface ranged from a low of 3.7°C during March to a high of 23°C in July. Stratification began in early July and continued to develop until the end of the month (Figure 9). Cooler weather in August caused the thermocline to weaken, and it remained weak throughout September. Stratification broke down by early October. Water over 14°C (the upper maximum temperature frequented by shrimp) reached a depth of 20 m in the northern section and 15 m in the middle section during the September 17 survey, whereas 14°C water reached its greatest depth of 15 m in the southern section during the August 16 survey. This year's surface temperature was 14°C or greater for only 110 days, the shortest period since 1997 (Table 11). At the 15 m depth, it stayed warmer than 14°C for only 30 days. This was the second shortest period with the average being 53 days.

Dissolved oxygen concentrations were similar among all three stations in 2002. Concentrations ranged from 11.7 mg/l in May to 8.7 mg/l in September on the south end of the lake, from 12.2 mg/l in May to 8.5 in August at the midlake station, and from 11.9 mg/l in April to 8.4 in August at the northern station. As expected, dissolved oxygen declined as temperature increased.

Nitrogen levels varied month to month and by sections. Total nitrogen ranged from a low of 80 μg/L in September to a high of 287 μg/L in May (Table 12). The northern section contained the highest nitrogen concentrations five out of the seven months sampled. The highest concentration of 287 μg/L was collected in the southern section during May with the second highest reading in the middle section during the same month.

Total phosphorus readings ranged from a low of 5 μg/L to a high of 15 μg/L (Table 12). The highest reading was collected at the north end of the lake during the month of April. Phosphorus levels decreased in the month of June, increased slightly in July, then decreased in August and stayed low the remaining two months.

Chlorophyll-a samples were collected five of the seven months. No samples were collected in April or June. The sample collected in May contained the greatest concentration of Chlorophyll-a with the northern portion of the lake reaching 7.2 μg/L (Table 12). The middle and southern portion of the lake was a little more than half that amount with readings of 4.0 and 3.9 μg/L, respectively. The lowest concentration of chlorophyll-a was found in samples collected in September. They averaged 1.9 μg/L for the entire lake.

Substrate Sampling

A total of 144 samples of gravel were collected and analyzed at six separate shoreline locations (Appendix B). At each site, substrates were sorted into bands that were parallel with the shoreline.

Of the four sites with previous substrate data, three had increases in gravel composition over the past year in the 625.1 m (2051 ft) to 625.7 m (2053 ft) range. No site was found to contain substrates with greater than 5% fine material. The gravel component at Ellisport Bay increased from 5.4% to 60.9%, a ten-fold increase (Figure 10). Cobble at Ellisport Bay had a corresponding decrease. Trestle Creek saw gravel increases of only 2.7%, while cobble increased by 62% with a related decrease in fines. The proportion of gravel at Hope increased by 10% with a corresponding drop in cobble substrate, while fines increased a modest 1%. Garfield Bay was the only location that saw a slight decrease in the amount of gravel substrate. Gravel decreased by 4.5% and fines decreased by 1.2%. The cobble substrate at Garfield Bay increased approximately 6%.

The data collected at the two new sites (Bernard Beach and Evans Landing) will be used as baseline data for future comparisons. However, there was a noticeable visual improvement in the spawning potential at these locations compared to the previous year. In 2002, the gravel component made up more than 50% of the substrate composition at each of these new sites. Between the levels of 625.1 and 625.8 m, Bernard Beach substrate consisted of 55% gravel, 45% cobble, and 1% fines (Figure 11). Evans Landing, the site found to have the best substrate overall for kokanee spawning, consisted of 75% gravel, 16% cobble, and 9% fines between the elevations of 625.1 and 625.8 m (Figure 11).

DISCUSSION

Kokanee Abundance

The kokanee population in Lake Pend Oreille continued to show signs of improvement in 2002. Abundance of age-1 to -5 kokanee estimated by hydroacoustics increased to 5.32 million, up from 4.90 million in 2001, 3.84 million in 2000, and 2.82 million in 1999 (Maiolie et al. 2002). This represents an 89% numeric increase in the population since 1999. Kokanee biomass (193.0 metric tonnes) has also increased over the last two years but remains below the level seen during the period from 1995 to 1999 when it averaged 285 metric tonnes annually (Table 8). These increases were concurrent with the increasing trend in egg-to-fry survival rate noted over the last five years (Maiolie et al. 2002).

A general improvement in kokanee survival within the older age classes has also occurred with increases in kokanee abundance (Table 3). Most notably the survival rate from age-1 to age-2 steadily increased from 18% in 1999, to 22% (2000), to 27% (2001) (Maiolie et al. 2002), to 44% this year (2002). This could have been cause-and-effect since as the number of kokanee increased, the survival rate (as a percent) would improve even if predation rates (as a total mass consumed) stayed constant. Fishing regulations were changed in 2000 with the intent of reducing predation from rainbow trout and lake trout. However, no population estimates of predatory fish were made since 1998 (Vidergar 2000) to determine the effect of the regulation changes. Our estimates of kokanee yield in 2002 decreased 19% from the previous two years (Figure 7), but remain above the level estimated in 1998. Future studies will help to clarify if this is the beginning of a declining trend in yield, which may indicate a decline in predation.

Only eight kokanee >200 mm were collected by midwater trawling in 2002, which underrepresented the adult kokanee population. As kokanee populations decline, midwater trawling becomes less efficient and the population is underestimated relative to hydroacoustics. This low sample size hindered our ability to estimate survival rates of the older age groups (Table 3). More importantly, it also affected our ability to measure wild egg-to-fry survival over the winter of 2002-03. Using the previously established methods (Maiolie et al. 2002), the wild PED based on trawling was only 16,000 eggs (50 females). Yet, single spawner counts on the shoreline revealed 968 kokanee, indicating a much higher population. Therefore, we recommend switching trawling gear to a new fixed-frame trawl that is more effective at catching larger-sized kokanee.

Lake Level Changes and the Effect on Kokanee Spawning

The egg-to-fry survival of wild kokanee was estimated at 14% during the period from November 2001 to September 2002. This was the highest survival rate documented in the previous seven years (Maiolie et al. 2002) and occurred during a winter when lake levels were lowered to their low pool elevation (Figure 1). Previous work had demonstrated that egg-to-fry survival rates improved with higher lake levels during winter (Maiolie et al. 2002). This year's finding demonstrated the effect of density-dependency in egg-to-fry survival. With a low adult kokanee population, there appeared to be enough shoreline spawning areas to avoid superimposition of redds and maintain a good survival rate even if the lake was lowered to its low pool elevation. Previous work also showed that under full drawdown most kokanee spawning occurred at deeper depths, primarily 2 to 6 m, and at the south end of the lake (Maiolie et al. 2002). Apparently, there was enough deeper substrate in this area, along with other areas of the lake, to support the very low number of spawning kokanee in 2002.

Artificial Spawning Areas

To date, kokanee have not used any of the five types of spawning areas that were placed in Lake Pend Oreille. The reason for this is unknown, but it may be due to the low densities of adult kokanee finding sufficient spawning gravel in their natal areas. Therefore, there was little incentive for them to use the artificial habitats placed in other areas of the lake. One of our original concerns was that kokanee would avoid our spawning boxes because of the surrounding wooden crib. This may be true; however, they also avoided the more natural looking patches of gravel placed directly on the lake bottom. We recommend continued monitoring of these artificial spawning areas as the kokanee population grows.

Kokanee Biomass, Production, and Yield

The 1996 to 2001 data of kokanee production and yield regressed against biomass indicated the kokanee population would have been in balance if kokanee biomass was 300 t with the same predator abundance (the intersection of the two lines in Figure 7). In 2002, yield had dropped to its second lowest point since 1996 and production increased to its second highest point. This would be consistent with a decline in the amount of predation, possibly resulting from the fishing regulation changes enacted in 2000 (unlimited lake trout harvest and a six fish limit on rainbow trout) or possibly due to a natural cycling of predators to a lower abundance as a result of declines in the prey base. Both production and yield would change simultaneously with a decline in predation, which would cause a substantial shift in the intersection of the two lines. For example, if the slope of the two lines in Figure 7 stayed the same, and they were drawn through the data points for 2002, then the current balance point for the kokanee population would drop to a kokanee biomass of about 90 t. If this shift in the lines remains in future years, it would indicate that predator and prey became balanced in 2002, since kokanee biomass was higher than the intersection of the production and yield lines. It was also interesting to note that it took one generation of kokanee (five years) to record marked improvements in the kokanee population after the perturbation that triggered the imbalance (the flood of 1997). A similar finding was noted at Dworshak Reservoir. Between February 1996 and July 1996, the total kokanee population in the Dworshak Reservoir dropped from 1.4 million to 71,000, a decline of 95%, due to entrainment losses through Dworshak Dam (Maiolie and Elam 1998). It was not until 2000 (one generation plus one year) that the adult kokanee population recovered to more typical densities (Maiolie and Stark 2002).

We advise caution, however, since one year's data should not be considered a trend, and improvements could be due to normal variation or sampling error. It should also be noted that the 2002 kokanee population was disproportionally high in the younger age classes (Figure 6), which would allow the population to have high production even at a relatively low biomass. Therefore, we recommend that regulations intended to reduce rainbow trout predation stay in effect until kokanee abundance approaches the desired level.

Shrimp Abundance

The abundance of immature and adult opossum shrimp declined in 2002 to 215 shrimp/m^2 (Table 9). This was the lowest abundance of shrimp documented in Lake Pend Oreille during the last seven years (Figure 8). These density estimates were even lower than in 1997, a year with the highest spring flows on record that appeared to cause a sharp decline in the shrimp population. Reason for the continued decline in shrimp density was unknown.

We monitored the shrimp population to determine if changes in shrimp abundance could be affecting kokanee survival. If competition between young-of-the-year kokanee and opossum shrimp were occurring, we might see better kokanee survival when the shrimp densities were low. To date, this has not been the case. We found a poor correlation (r^2=0.03) between immature and adult shrimp abundance and the egg-to-fry survival rate of kokanee (Maiolie et al. 2002). Low shrimp abundance in 2002 was coincidental with high egg-to-fry survival of kokanee, but this was not the case in previous years.

Limnology

Surface temperatures in 2002 were unusually cold and stayed above 14°C for only 110 days (Figure 9). Water temperatures also remained colder than average at deeper depths. Cold temperatures would be expected to decrease zooplankton abundance; however, kokanee survival showed marked improvements. It therefore appeared that coldwater temperatures in 2002 did not negatively affect kokanee survival.

Substrate Sampling

The drawdown of the lake during the winter of 2001-2002 was found to rebuild some of the potential spawning sites we monitored. The Ellisport Bay site showed the greatest improvement in spawning potential and had better quality spawning gravel in 2002 than when first surveyed in 1992 (Figure 10). Sites at Bernard Beach and Evans Landing also showed a pronounced bar of gravel just above the low pool elevation that would provide good kokanee spawning habitat. Thus, the drawdown of the lake to its low pool elevation during the winter of 2001-02 appeared to have its desired effect of improving the habitat for kokanee spawning. However, not all areas showed improvements. These surveys recorded the quality of the substrate at discrete, pre-chosen points along the shoreline. Areas of good quality gravel may have formed at many locations; however, they might have been missed in our sampling. We recommend a more comprehensive survey of the entire shoreline the next time the lake is lowered to its minimum elevation.

RECOMMENDATIONS

1. Continue the current fishing regulations that allow for a generous harvest of rainbow trout (six rainbow trout/day, any size, with a year-round season). Reduced predator abundance may help to speed the recovery of kokanee even if it does not determine the

final kokanee abundance. (Carrying capacity of kokanee is more likely determined by available spawning habitat.)

2. Lower the winter lake level of Lake Pend Oreille at least once every three years to improve kokanee spawning habitat along the shorelines.

3. Where possible, time the drawdown of the lake so that it coincides with weak year classes of adult kokanee. This study showed that good survival rates could be maintained during a drawdown year if adult abundance was very low.

4. To date, we cannot recommend the construction of artificial spawning boxes similar to the ones used in this study. These were not selected as spawning sites by the lake's kokanee, though continued monitoring is warranted.

ACKNOWLEDGMENTS

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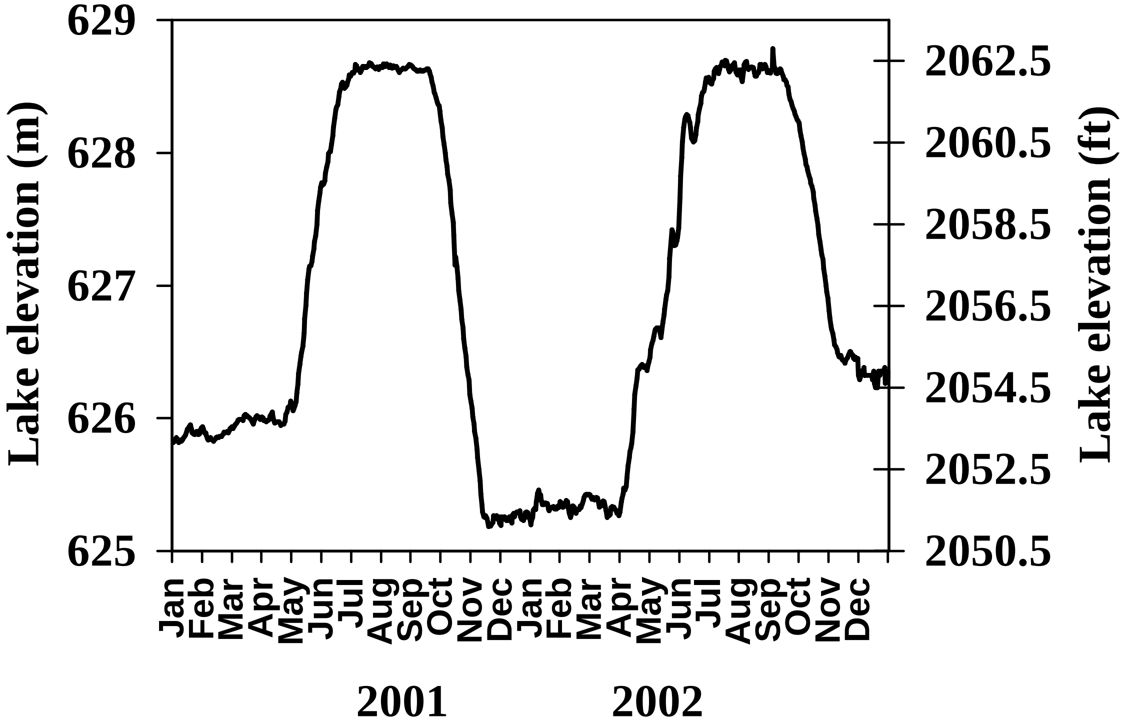
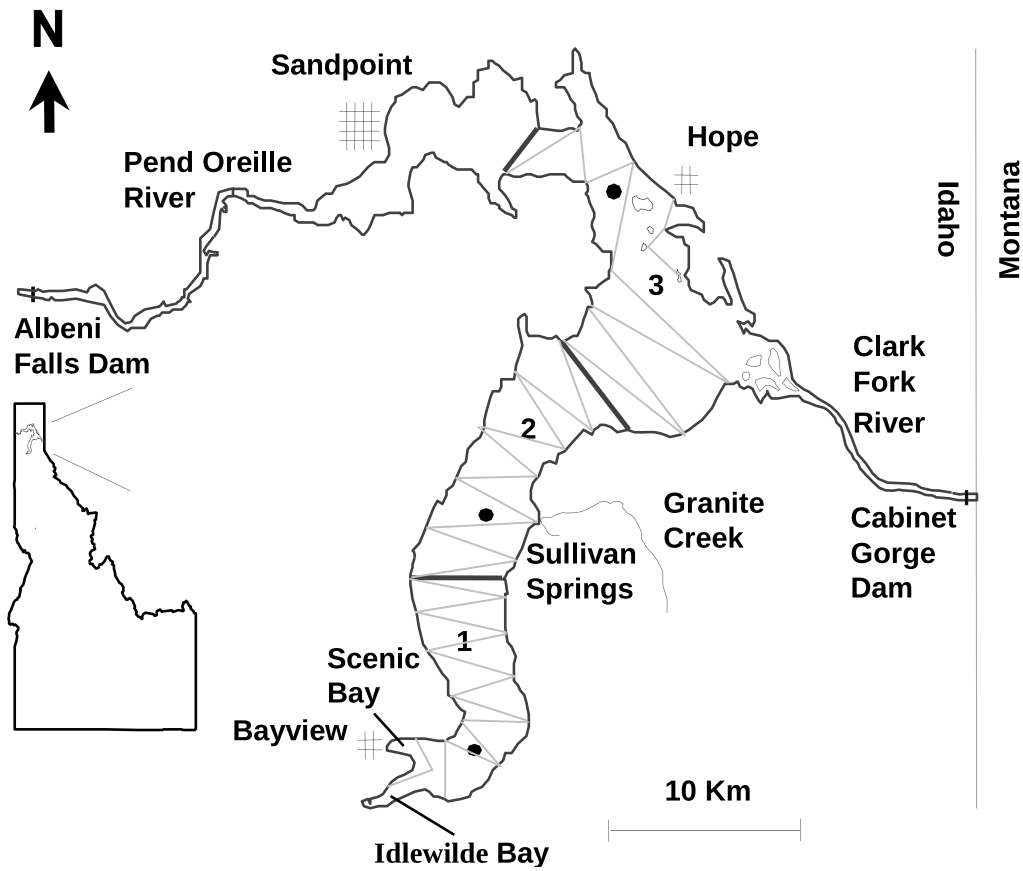


Figure 1. Daily surface elevation of Lake Pend Oreille, Idaho for 2001 and 2002.



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 2002. Inserted table depicts the area of kokanee habitat in each section.

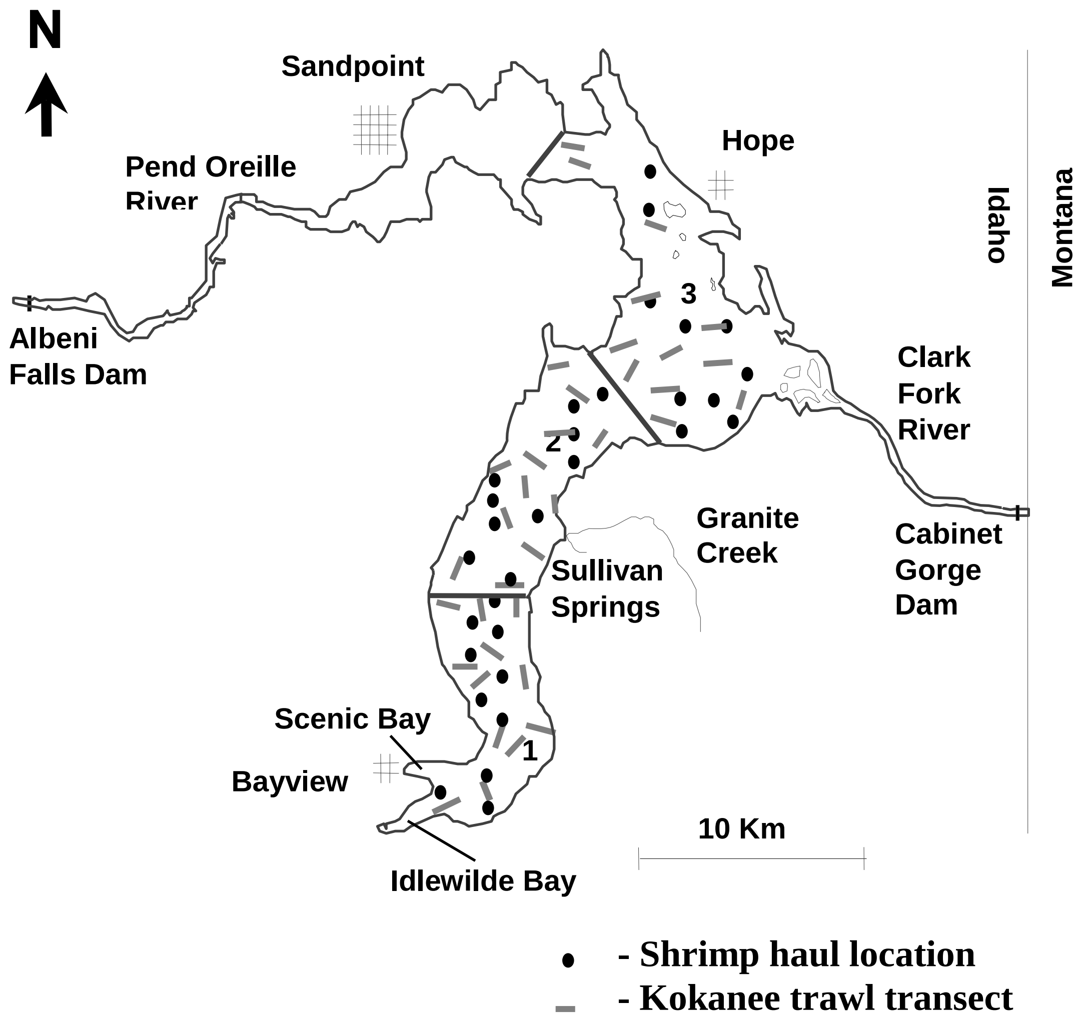


Figure 3. Map of Lake Pend Oreille, Idaho showing the locations of both the kokanee trawling transects and the opossum shrimp hauls.

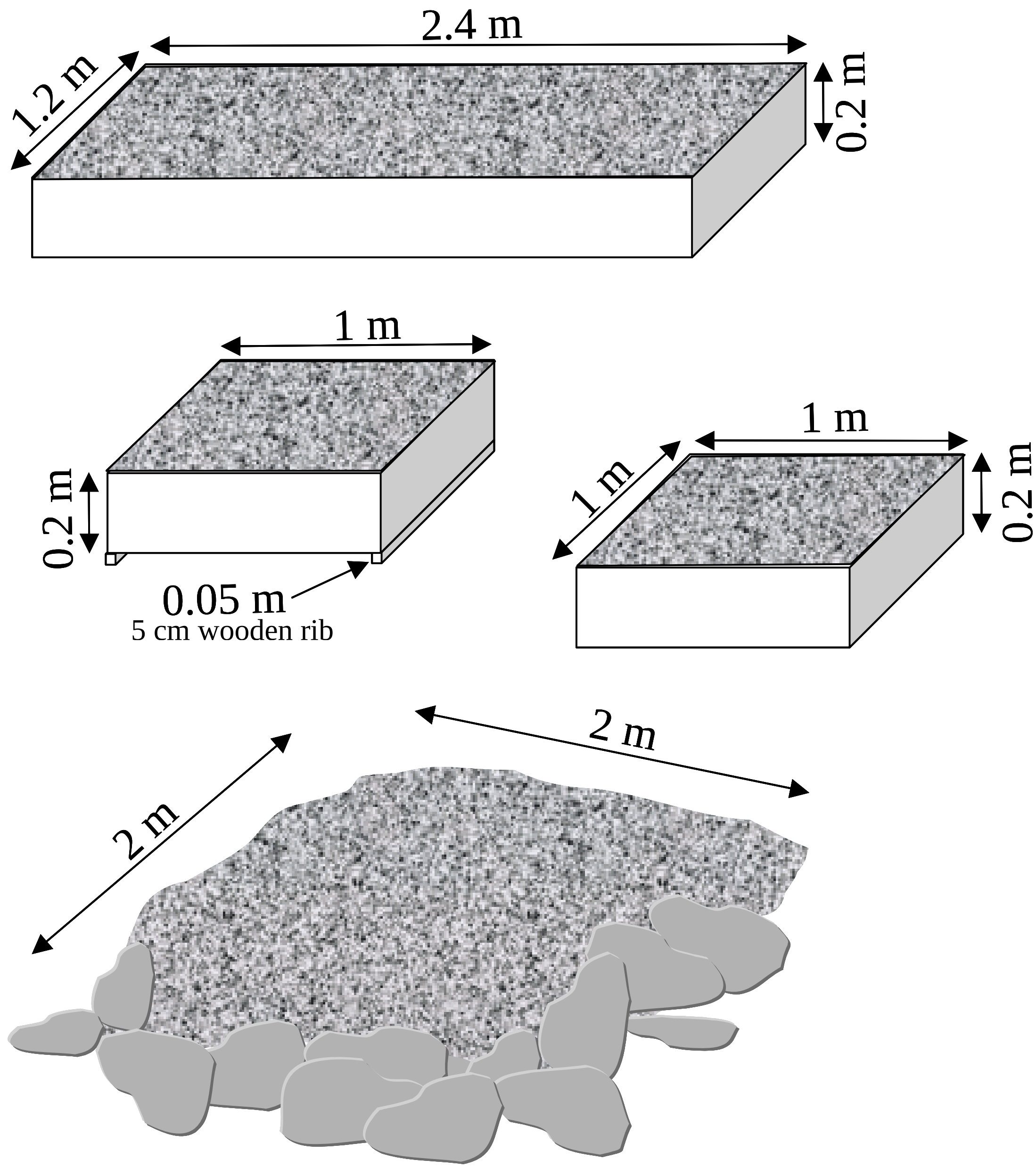


Figure 4. Diagram of three types of artificial spawning areas that were placed in Lake Pend Oreille, Idaho during the 2001 spawning season.

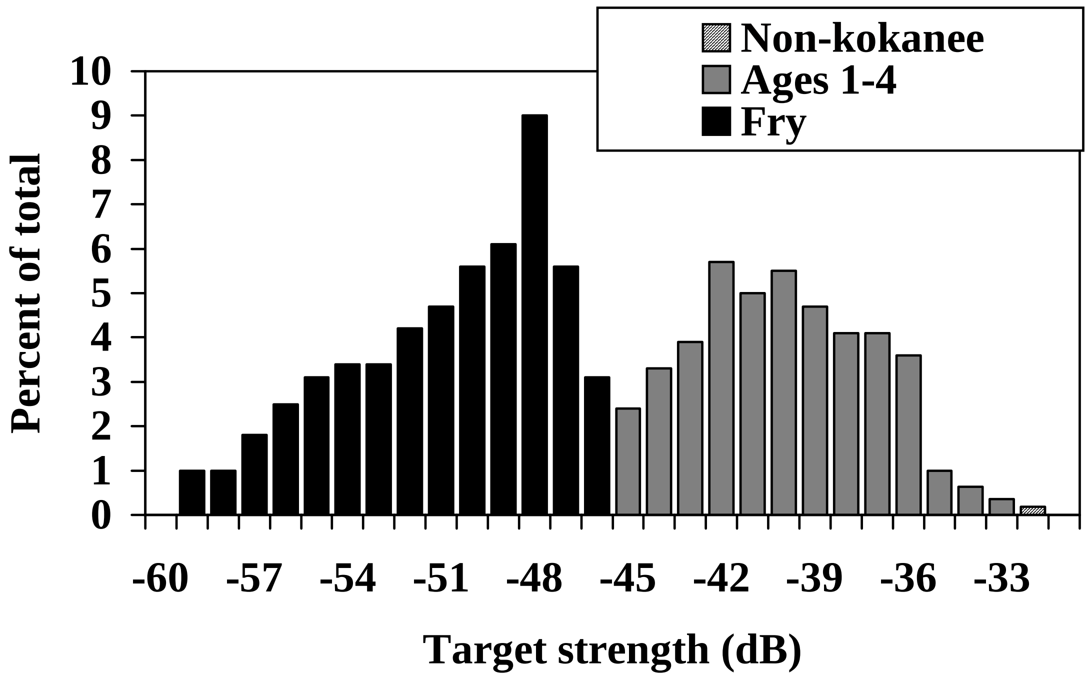


Figure 5. Target strengths of 1,109 fish recorded during a hydroacoustic survey on Lake Pend Oreille, Idaho in August 2002.

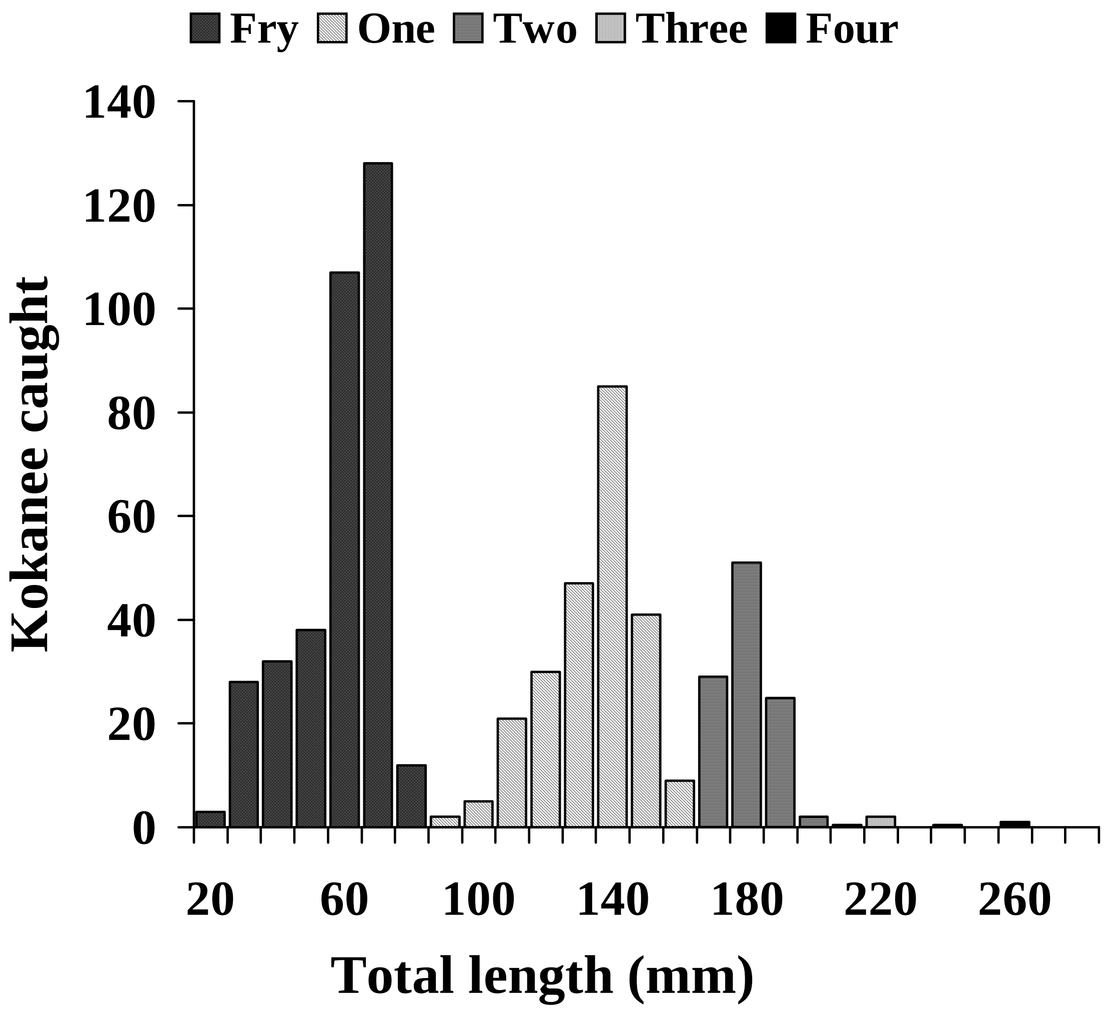


Figure 6. Length-frequency distribution of kokanee caught by midwater trawling in Lake Pend Oreille, Idaho in September 2002. Ages were based on reading scales and thermally marked otoliths.

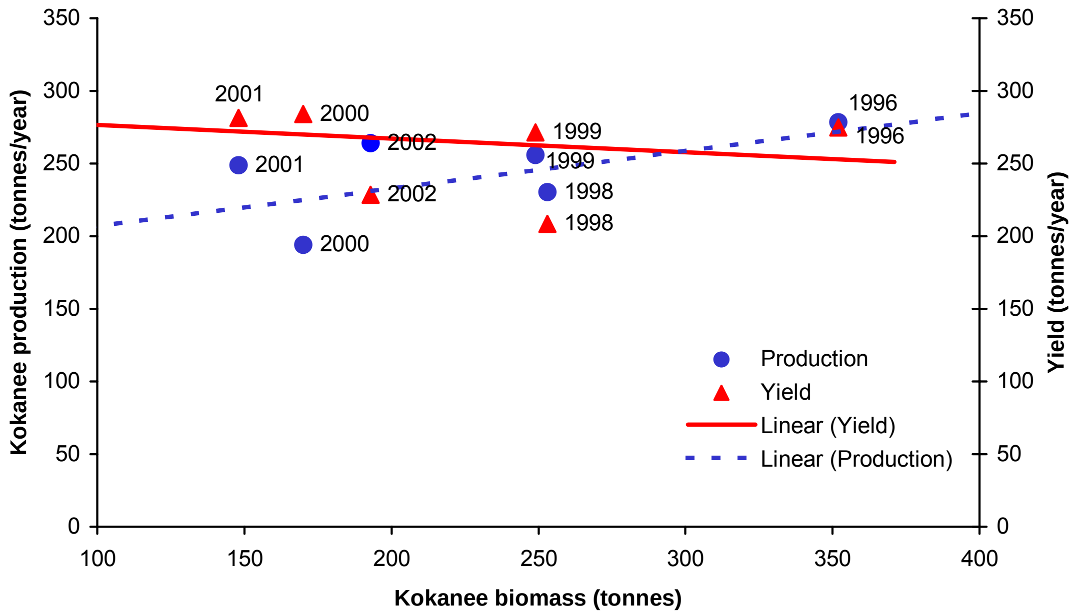


Figure 7. Kokanee biomass, production, and yield (metric tonnes) from Lake Pend Oreille, Idaho 1996-2002, excluding 1997 due to a 100-year flood. Lines were fitted to all data points except 2002 to illustrate possible change.

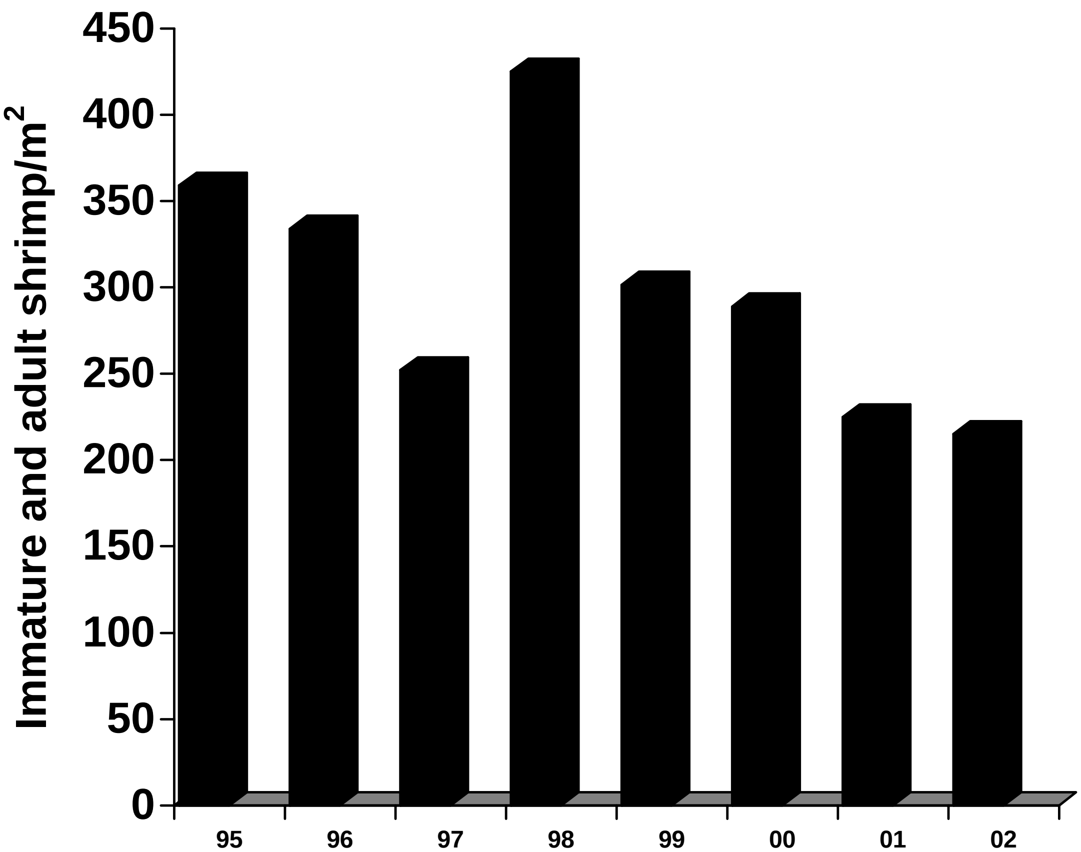


Figure 8. Density of immature and adult opossum shrimp (excluding young-of-the-year shrimp) in Lake Pend Oreille, Idaho. Shrimp densities for 1995 and 1996 were obtained from Chipps (1997).

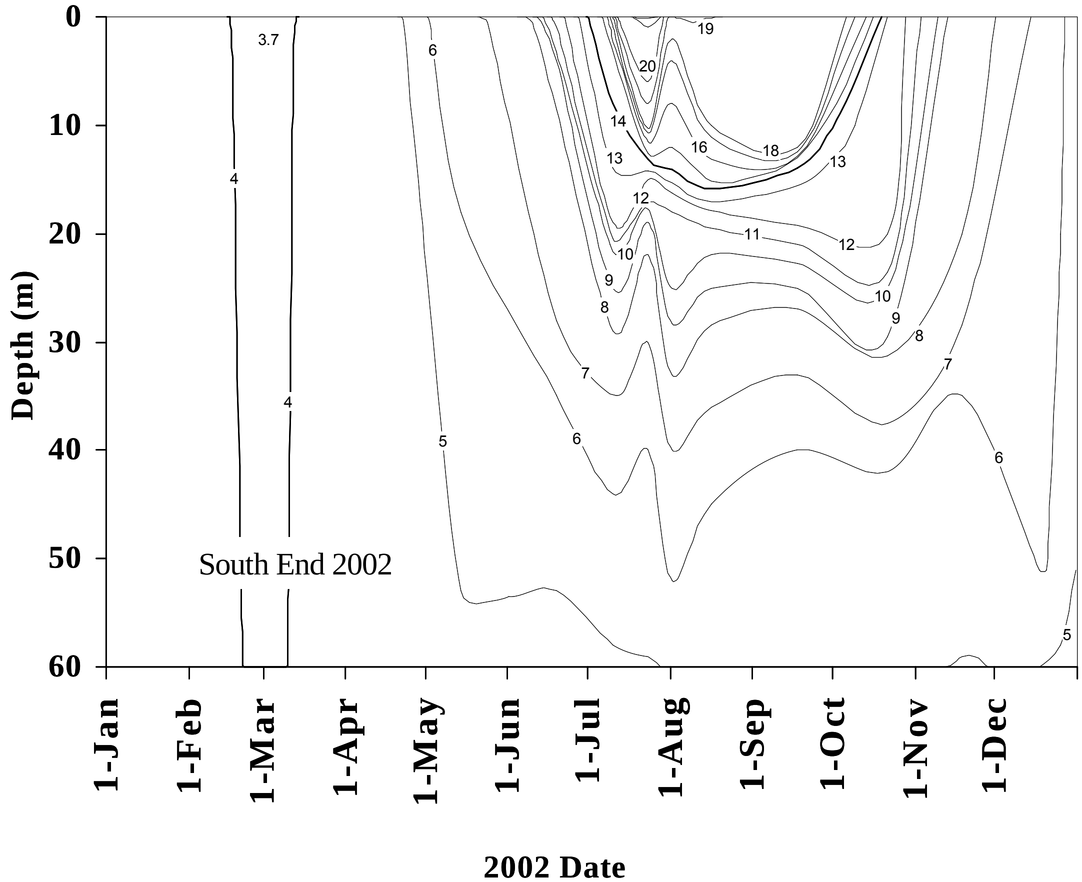
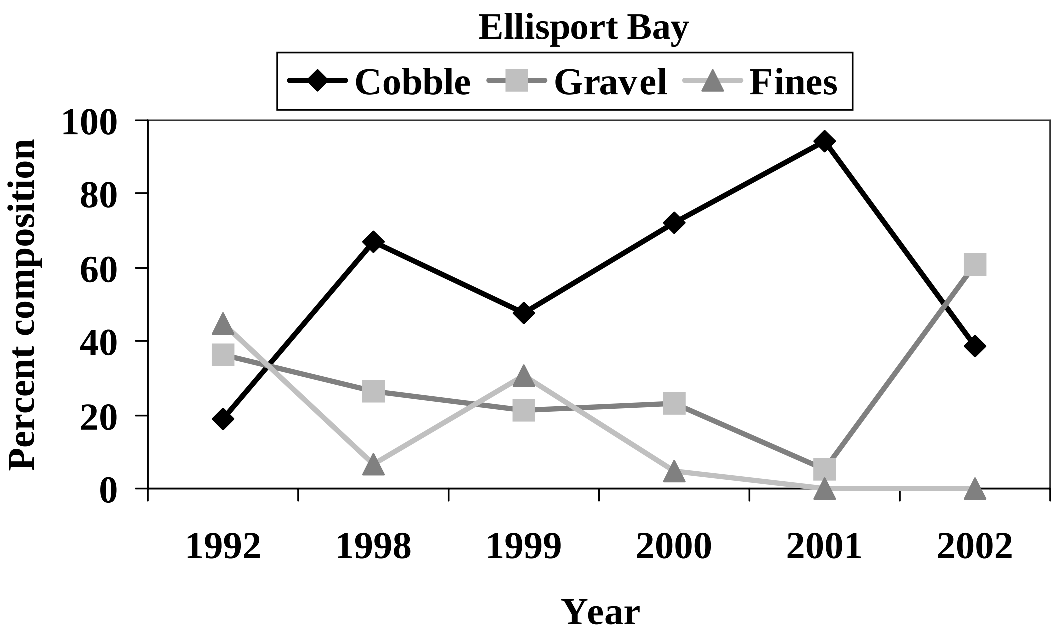


Figure 9. Isopleths of water temperature (°C) at the south end of Lake Pend Oreille, Idaho in 2002. Location in section 1 is shown in Figure 2.



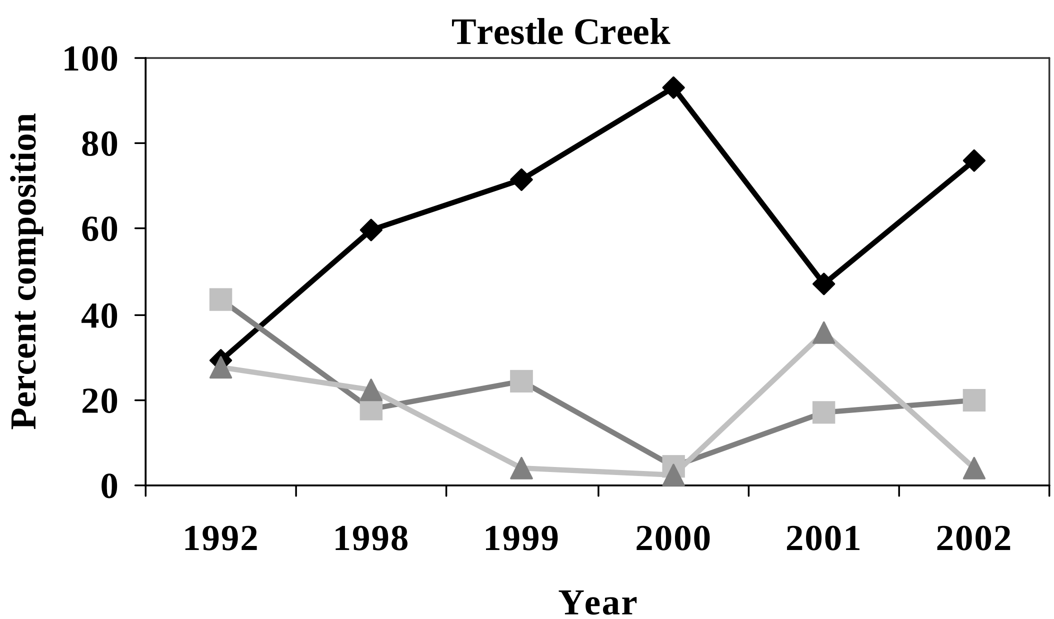
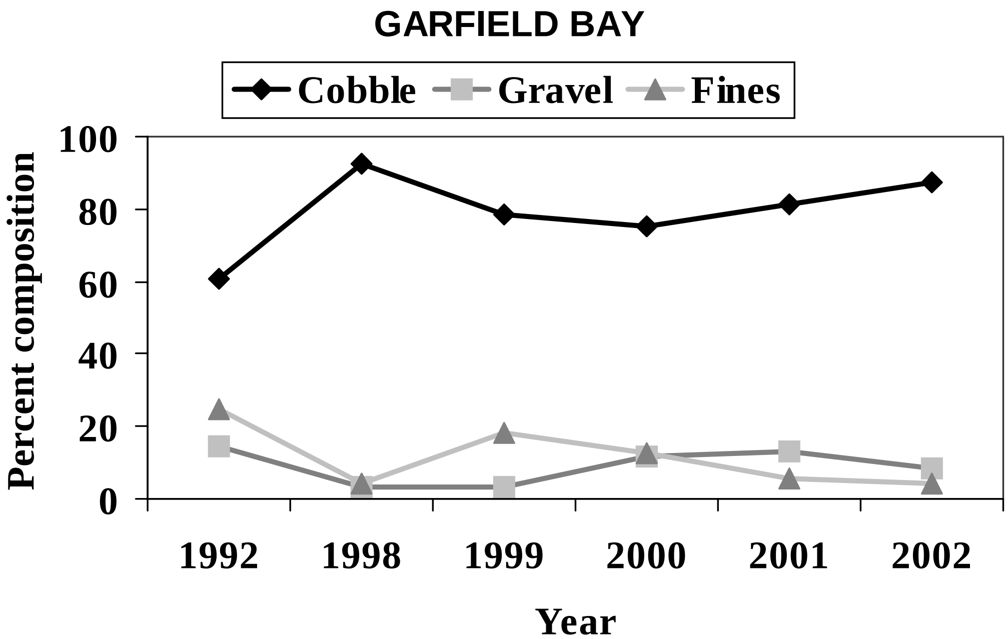
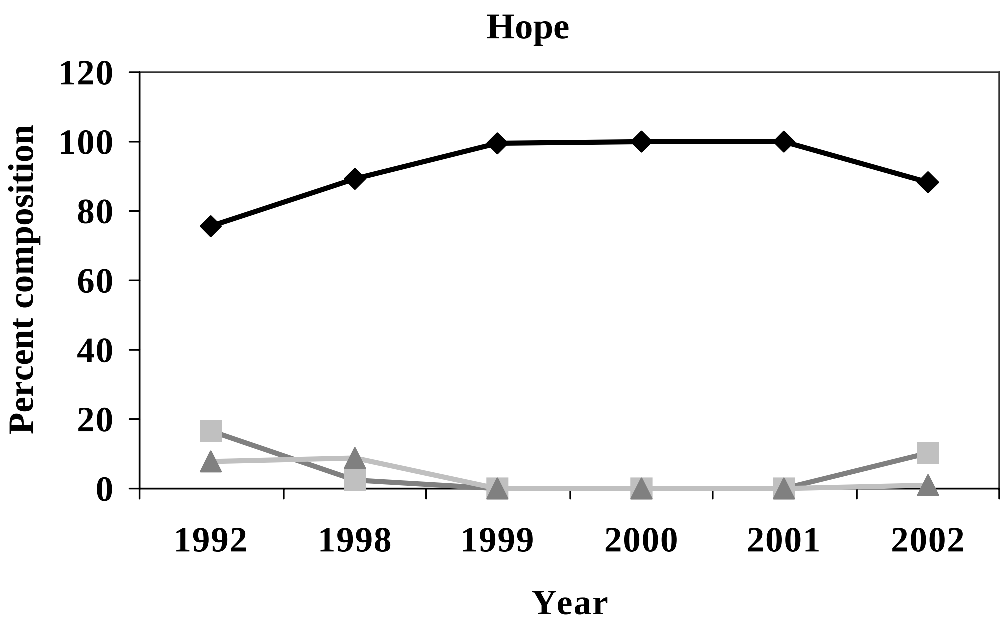
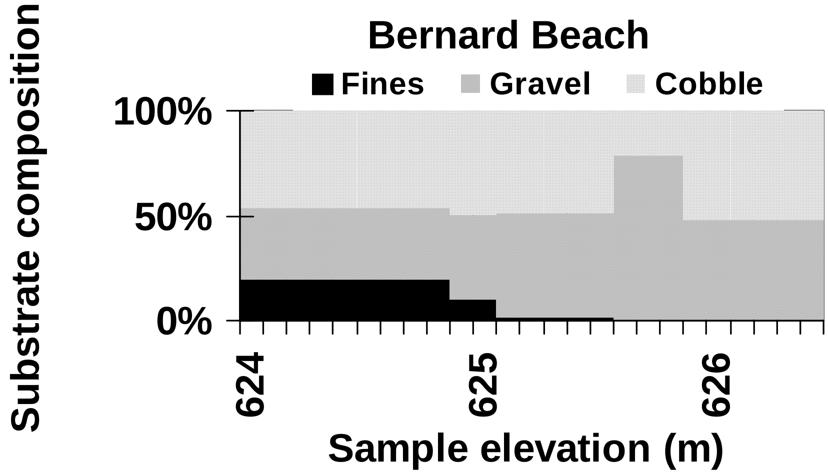


Figure 10. Percent substrate composition at various shore sampling sites on Lake Pend Oreille.

Figure 10. Continued.







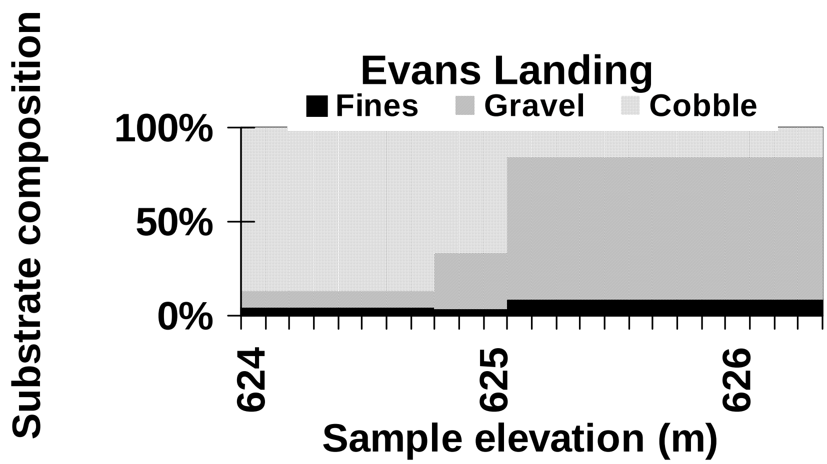


Figure 11. Composition of shoreline substrates at various elevations on Bernard Beach and Evans Landing, Lake Pend Oreille, Idaho during 2002.

Table 1. Population estimates of kokanee fry (millions) based on hydroacoustic surveys of Lake Pend Oreille, Idaho in 2002. Percentage of wild fry was based on the proportion of wild fry caught by midwater trawling and estimates were based on arithmetic means.

Kokanee	Southern section (1)	Middle section (2)	Northern section (3)	Total for lake	90% CI
Total kokanee fry abundance by hydroacoustics	1.395	2.505	3.045	6.944	±9.0%
Percent wild fry in midwater trawl	28%	21%	9%		
Wild fry estimate	0.391	0.529	0.274	1.194	

Table 2. Population estimates of kokanee age classes (millions) in Lake Pend Oreille, Idaho, 2002. 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.

Section	Age-1	Age-2	Age-3	Age-4	Age-5	Total
Southern Section						
Acoustic estimate of age-1-4 in section (millions)						1.071
Percent of age class in section by trawling	54.1	40.3	3.5	2.1	0.0	
Population estimate in section (millions)	0.579	0.432	0.038	0.022	0	
Middle Section						
Acoustic estimate of age-1-4 in section (millions)						1.806
Percent of age class in section by trawling	57.6	38.2	3.3	1.0	0.0	
Population estimate in section (millions)	1.040	0.689	0.060	0.018		
Northern Section						
Acoustic estimate of age-1-4 in section (millions)						2.445
Percent of age class in section by trawling	73.5	25.0	1.4	0.0	0.0	
Population estimate in section (millions)	1.798	0.611	0.034	0	0	
Total population estimate for lake (millions)	3.417	1.732	0.132	0.040	0.00	5.321

Table 3. Survival rates (%) between kokanee year classes estimated by midwater trawling and hydroacoustics, 1990-2002. Hydroacoustic estimates started in 1995. 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**
2002	30	31	20	44	—[a]	—[a]	—[a]	—[a]
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] Too few age-3 and -4 kokanee were caught to provide a reliable estimate of survival (n = 6).

Table 4. Comparison of minimum lake level to number of mature females (as determined by midwater trawling), mean fecundity, hatchery egg take, potential egg deposition (PED), wild fry abundance the following year (by hydroacoustics), and percent survival of kokanee fry in Lake Pend Oreille, Idaho, 1994-2002.

Year Class of Eggs[a]	Minimum Lake Level (ft) (m)	Number of Females	Eggs Per Female	PED (millions)	Hatchery Egg Take (millions)	Wild PED (millions)	Wild Fry Abundance Following Year (millions)	Percent Survival (eggs to fry the next year)
2002	2055.1 626.4	12,629	320	4.041	4.02	0.016[a.]	—	—
2001	2051.1 625.2	33,563	481	16.14	7.68	8.46	1.194	14
2000	2053.1 625.8	167,794	417	69.97	13.30	56.67	3.733	6.6
1999	2053.1 625.8	197,358	379	74.79	22.38	52.41	5.231	10.0
1998	2054.9 626.3	156,580	333	52.14	8.96	43.18	2.573	6.0
1997	2055.1 626.4	33,404	335	11.19	0.54	10.65	1.019	9.6
1996	2055.0 626.4	413,720	353	146.04	4.49	141.55	2.575	1.8
1995	2051.7 625.4	151,650	444	67.33	12.89	54.44	2.661	4.9
1994	2051.1 625.2	599,000	411	246	16.6	229.4	3.140	1.4

[a] Likely an underestimate due to small sample sizes of kokanee collected by the midwater trawl (n = 7 kokanee >200 mm).

Table 5. Kokanee population statistics based on trawling Lake Pend Oreille, Idaho during September 2002.

	Age					
	0	1	2	3	4	Total
Population estimate (millions)	2.175	1.629	0.742	0.054	0.012	4.61
±90% CI	11%	41%	21%	36%	120%	
Density (fish/ha)	96	72	33	2	1	204
Mean weight (g)	2.2	21.3	47.4	60.5	154.3	
Standing stock (kg/ha)	0.22	1.53	1.55	0.14	0.08	3.53
Mean length (mm)	63	138	182	198	255	
Length range (mm)	28-94	91-163	162-220	183-225	246-266	

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

	Bayview	Farragut Ramp	Idlewilde Bay	Lakeview	Hope	Trestle Cr. Area	Sunnyside	Garfield Bay	Camp Bay	Anderson Point	Total
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
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
2002	79	0	0	0	0	—	—	0	—	1412	0	1491
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] September count of early spawning kokanee

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

Year	Biomass	Production	Yield
2002	193.0	264.2	228.5
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 shrimp in Lake Pend Oreille, Idaho, June 10-11, 2002. Sections are shown in Figure 3.

Section — transect	YOY	Immature & Adults	Total Shrimp
1-05	381.4	156.0	537.5
1-06	281.2	292.3	573.5
1-13	484.5	243.0	727.5
1-22	433.5	173.9	607.4
1-25	390.4	226.7	617.2
1-29	610.3	370.3	980.6
1-32	205.6	83.9	289.6
1-41	1,583.5	157.7	1,741.2
1-44	3,284.5	373.9	3,658.3
1-49	4,914.2	740.6	5,654.9
Southern section means	1,256.9	281.8	1,538.8
2-04	549.8	279.7	829.5
2-07	3,994.9	260.0	4,254.9
2-22	101.2	116.2	217.3
2-25	1,822.0	333.6	2,155.7
2-26	116.9	156.4	273.3
2-30	1,561.9	300.7	1,862.6
2-34	141.4	316.1	457.5
2-38	329.7	164.9	494.6
2-49	293.0	153.4	446.4
2-57	312.6	159.8	472.4
Middle section means	922.4	224.1	1,146.4
3-02	52.9	190.7	243.6
3-11	123.2	134.0	257.2
3-14	79.3	107.6	186.9
3-16	117.3	53.8	171.2
3-25	84.7	87.2	171.9
3-43	173.3	115.1	288.4
3-45	15.1	80.8	95.8
3-48	110.5	77.7	188.2
3-63	612.6	245.3	857.9
3-75	484.8	442.6	927.4
Northern section means	185.4	153.5	338.8
Whole lake means (weighted by area)	745.3	214.5	959.8

Table 10. Secchi transparencies (m) at three locations in Lake Pend Oreille, Idaho, 2002. Summer mean transparency was for the period April through October. Location of the limnological stations is shown in Figure 2.

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Summer Mean
Southern station	—	—	13.3	21.0	8.0	5.0	8.9	10.2	8.8	9.6	7.0	11.6	10.2
Mid-lake station	—	18.0	13.5	16.5	7.8	4.3	8.2	9.0	8.7	10.3	8.0	13.5	9.3
Northern station	—	8.8	9.0	2.5	3.8	2.8	8.0	7.2	8.5	7.8	8.1	12.5	5.5
Whole lake mean	—	—	—	13.3	6.5	4.0	8.4	8.8	8.6	9.2	7.7	12.5	8.40

Table 11. Dates and number of days with water temperatures exceeding 14°C at the surface, at the 10 m depth, and at the 15 m depth on the south end of Lake Pend Oreille, Idaho from 1997 to 2002.

	14°C at Surface		14°C at 10 m		14°C at 15 m	
Year	Dates	# Days	Dates	# Days	Dates	# Days
2002	7-1 to 10-18	110	7-14 to 10-1	80	8-7 to 9-6	30
2001	6-24 to 10-15	114	7-28 to 10-6	71	8-7 to 10-2	57
2000	6-14 to 10-9	118	6-25 to 10-3	101	6-28 to 9-25	85
1999	6-11 to 10-11	123	6-21 to 10-5	107	7-4 to 9-30	89
1998	6-25 to 10-25	123	7-21 to 10-16	88	8-22 to 9-25	35
1997	6-1 to 9-29	121	8-1 to 9-20	51	8-27 to 9-15	20

Table 12. Monthly nutrient data (µg/L) collected on Lake Pend Oreille from April to October 2002.

Month	Lake Section	Chlorophyll a	NO^2+NO^3 as N	Kjeldahl N	Total N	Total P	N:P
Apr	southern	—	100	80	180	9	20.0
	middle	—	95	100	195	10	19.5
	northern	—	58	180	238	15	15.9
May	southern	3.9	47	240	287	12	23.9
	middle	4.0	12	260	272	11	24.7
	northern	7.2	23	130	153	11	13.9
Jun	southern	—	<5	120	120	5	24.0
	middle	—	14	130	144	8	18.0
	northern	—	10	170	180	6	30.0
Jul	southern	1.7	<5	130	130	7	18.6
	middle	2.1	<5	240	240	10	24.0
	northern	3.1	<5	170	170	8	21.3
Aug	southern	1.9	<5	160	160	9	17.8
	middle	1.8	<5	140	140	8	17.5
	northern	2.2	<5	170	170	8	21.3
Sep	southern	2.2	<5	80	80	7	11.4
	middle	1.7	<5	90	90	5	18.0
	northern	1.8	<5	160	160	6	26.7
Oct	southern	2.3	<5	160	160	6	26.7
	middle	1.9	<5	150	150	6	25.0
	northern	2.5	<5	200	200	8	25.0

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APPENDICES

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

<u>Scenic Bay</u>

– From Vista Bay Resort to Bitter End Marina (the entire area within the confines of these two marinas and all areas between).

<u>Farragut State Park</u>

– From state park boat ramp go both left and right approximately ⅓ km.
– Idlewilde Bay from Buttonhook Bay north to the north end of the swimming area parking lot.

<u>Lakeview</u>

– From mouth of North Gold Creek go north 100 meters and south ½ km.

<u>Hope/East Hope</u>

– Start at the east end of the boat launch overpass and go west ⅓ 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.

<u>Trestle Creek Area</u>

– 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.

<u>Sunnyside</u>

– From Sunnyside Resort go east approximately ½ km.

<u>Garfield Bay</u>

– 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.

<u>Camp Bay</u>

– Entire area within confines of Camp Bay.

<u>Fisherman's Island</u>

– Entire Island Shoreline—not surveyed since 1978.

<u>Anderson Point</u>

– Not surveyed since 1978.

Appendix B. Weights (g) of substrate samples from potential shoreline spawning areas on Lake Pend Oreille, Idaho, 2002

Band	Elevation to top of band (m) (ft)	Distance from old waterline (2051) to top of band (m) (ft)	Size fractions (mm) >63.5	31.75-63.50	16.00-31.75	9.50-16.00	6.35-9.50	2.00-6.35	0.85-2.00	<0.85
			Bernard Beach 2002							
A	626.3	5.6	0	426.9	2086.7	275.6	0	0	0	0
	2055	18.25	951.0	848.5	912.3	0	0	0	0	0.1
			375.8	471.4	823.8	505.1	18.3	0	0	0.2
			714.6	1786.7	116.6	194.6	8.2	0	0	0
B	625.9	4.1	301.2	592.4	921.8	806.2	271.5	6.4	0	0
	2053.7	13.35	0	881.4	931.2	607.7	105.9	7.7	0	0
			0	472.2	1211.5	486.9	229.8	9.8	0	0
			0	0	715.2	996.9	233.0	3.9	0	0
C	625.6	1.9	306.7	690.9	1319.9	215.4	19.0	0.5	0	0
	2052.6	6.1	0	737.4	778.2	433.5	490.7	127.4	0	0
			601.6	954.9	723.7	0	0	0.2	0	0.1
			0	1092.3	701.9	16.5	2.0	0	0	1.0
D	625.1	-0.5	0	791.7	327.6	606.9	766.1	445.0	0	0
	2050.9	-1.6	405.4	1502.9	388.2	0	0	0	0	0
			0	732.2	334.8	518.8	776.2	502.5	0.1	0.1
			859.1	1272.3	108.7	259.8	581.8	283.8	0	0
Bottom of Band D										
	624.9	-1.4								
	2050.4	4.6								
			Ellisport Bay 2002							
A	626.3	6.0	0	1431.4	641.2	0	0	0	0	0.2
	2054.8	19.7	0	1761.0	643.3	83.6	1.9	0.5	0	0.1
			0	1922.5	357.6	73.2	1.6	0.2	1.1	0.1
			0	2085.0	555.2	80.9	2.7	0.1	0.0	0
B	626.2	5.5	0	906.4	648.6	553.1	159.1	29.0	0	0.2
	2054.6	18.2	0	80.6	870.4	866.6	333.5	42.3	0.0	0.1
			448.0	189.1	676.5	640.7	449.2	53.6	0	0.1
			0	678.8	640.9	1084.7	803.1	499.5	0.2	0.2
C	626.1	5.2	375.8	1804.6	582.7	18.6	1.9	0.2	0	0.1
	2054.3	17.2	1910.6	176.6	12.3	0.4	0	0	0	0.5
			0	1555.5	529.0	18.2	0	0	0	0.1
			0	1592.8	373.0	0	0	0	0	0.2
D	625.7	9.2	0	1058.0	920.7	590.1	17.0	0.4	0	0.5
	2052.8	2.8	859.6	565.8	719.8	710.3	177.6	0.1	0	0.2
			0	837.7	791.6	48.6	0	0	0	0.4
			0	247.6	989.7	122.7	17.0	6.3	0	0.3
E	625.2	0.4	597.2	894.7	834.4	265.8	163.3	181.2	0.1	0.3
	2051.3	1.2	492.1	1436.8	75.8	97.8	169.8	291.3	0.1	0.2
			0	1433.2	139.5	214.3	239.8	419.4	0	0.6
			524.9	677.0	586.0	206.5	247.0	395.9	0.2	1.3
F	625.0	-0.6	0	1535.0	208.5	292.0	438.9	563.7	0.43	0.82
	2050.5	-2.1	0	1521.7	850.6	474.0	483.0	664.7	278.5	1.2
			0	1415.5	455.2	286.8	284.9	380.1	0	0.8
			0	405.4	858.5	173.6	169.9	249.8	0.3	0.6
G	624.9	-1.7	0	0	2224	257.3	10	0.08	0	0.4
	2050.3	-5.7	0	1203.4	69.6	0	0	0	0.02	0
			0	0	1737.0	87.6	0	0	0	0.5
			365.9	1944.6	0	0	0	0	0	0.8

Appendix B. Continued.

Band	Elevation to top of band (m) (ft)	Distance from old waterline (2051) to top of band (m) (ft)	Size fractions (mm) >63.5	31.75-63.50	16.00-31.75	9.50-16.00	6.35-9.50	2.00-6.35	0.85-2.00	<0.85
Bottom of Band G										
	624.0	-5.1								
	2047.3	-16.7								
			Hope 2002							
A	626.4	10.5	0	2082.9	233.7	13.8	8.8	18.9	7.4	13.11
	2055.1	34.4	492.7	592.9	1525	272.9	6	0.01	0	.19
			1214.1	734.1	403.1	51.6	6.3	7.1	1.4	6.1
			1369.6	346	319.6	372.6	122.5	6.3	0.12	1.9
B	625.6	4.9	2265.7	528.7	31.6	17.5	5	7.9	1.7	4.2
	2052.5	16.2	2010	350	171.8	157	80.8	9	0.16	0.85
			1405.2	287.4	18.1	22	14.8	1.1	0	7
			1116	498.2	210.6	125.3	160	197	17.1	20.3
C	625.4	2.4	2607	0	0	0	0	0	0	0
	2052.1	7.9	2156	663.1	224	43.3	0	0	0.6	0.9
			1455	501	0	0	0	0	0	0
			1043	715.7	91.9	17.5	3.4	1.5	0	1.1
D	624.9	-2.3	1165	1061	568.1	164.7	67.2	131.7	113	115
	2050.3	-0.7	1669	772.4	0	0	0	0	0	0
			2230	0	0	0	0	0	0	0
			874	130.7	10.9	76.6	20.1	20.6	4.8	6.1
E	624.8	-2.1	2385	0	0	0	0	0	0	0
	2049.9	-6.9	2502	0	0	0	0	0	0	0
			1820.5	0	0	0	0	0	0	0
			1601.1	0	0	0	0	0	0	0
Bottom of Band E										
	623.9	-4.8								
	2047.1	-15.9								
			Trestle Creek 2002							
A	626.4	18.0	581.5	1420.4	638.3	98.6	20.9	25.1	14.5	41.2
	2055.1	59.2	0	862.6	688.6	157.9	56.4	75.3	26.6	145.6
			0	1518.3	235.4	59.6	22.5	5.2	0.9	7.2
			394.7	1297.2	331.3	196.3	125.0	125.2	44.6	279.0
B	625.8	10.0	347.0	1054.9	214.6	30.5	3.4	2.6	0.35	13.8
	2053.2	32.7	0	906.8	451.3	112.0	50.3	28.4	10.5	63.7
			1743.8	881.2	192.5	0	0	0.3	0.25	5.2
			381.4	632.0	299.7	160.8	52.9	85.7	25.4	50.7
C	625.4	3.4	497.9	1536.3	333.1	68.8	27.5	19.1	3.5	48.6
	2051.8	11.2	0	1608.4	192.7	78.0	36.5	40.0	8.1	72.8
			1573.5	471.7	0	65.3	9.9	0.5	0.3	21.4
			573.1	828.0	571.0	148.7	46.3	31.7	6.9	92.4
D	624.7	-6.6	1468.4	172.6	140.5	6.0	8.7	6.0	1.7	22.0
	2049.7	-21.6	1159.3	266.5	91.5	177.6	182.2	121.2	13.4	69.9
			435.7	1471.5	240.2	1.6	74.8	75.9	93.6	66.5
			323.4	1317.3	317.7	0.8	79.0	81.8	92.2	36.2
Bottom of Band D										
	623.9	-18.8								
	2047.1	-61.6								
			Garfield Bay 2002							
A	626.3	11.6	0	1162	795	100.2	45.1	187.8	244.5	111
	2055	38	1129	1584.3	0	0	0	0	0	0.3
B	626.1	10.4	796	215.6	633.6	193.4	126	374.2	335	207.5
	2054.2	34	530.4	935.3	487.7	101.9	59.2	111.7	132.1	97

Appendix B. Continued.

Band	Elevation to top of band (m) (ft)	Distance from old waterline (2051) to top of band (m) (ft)	Size fractions (mm) >63.5	31.75- 63.50	16.00- 31.75	9.50- 16.00	6.35- 9.50	2.00- 6.35	0.85- 2.00	<0.85
C	625.9	9.1	765	1183	78.8	0	0	0	0	1
	2053.7	30	568.7	1369.5	613.2	125.1	52	57.8	72.6	89
D	625.8	7.9	0	1444.9	133	56	9.2	25.3	25	54.3
	2053.2	26	1909.1	64.2	173.2	74.6	36.8	49.5	56	80.9
E	625.6	6.7	958.6	1427	40	0	0	0.3	2	3.9
	2052.7	22	591	1331	0	0	0	0	0.73	3.4
F	625.6	5.5	2336	456	21.2	0	0	0.03	0.21	3.3
	2052.5	18	1855	537.2	126.6	0.33	0	0	0	5.9
G	625.4	6.3	1748	1162	188.5	9.6	2.5	1.6	3.6	44.5
	2052.0	14	1605.1	920	194.7	32.4	9.1	7	8.5	39
H	625.3	3.0	2114.3	567	22.7	0	0	0.3	0.42	7
	2051.7	10	1824	149	638.7	190	78.1	80.4	266.6	668.1
I	625.2	1.8	4023.3	380.7	15.6	0	0	0.5	0.5	10.4
	2051.3	6	0	1108.9	189.2	268.4	78.5	25.9	22.4	48
J	625.1	0.6	2334	0	0	0	0	0	1.9	20
	2051.1	2	2655	193.7	246	90.4	32.2	35	42.3	223.1
K	625.0	-.06	3222	0	0	0	0	0	0	3.7
	2050.7	-2	3014	0	0	0	0.5	0	0	5.3
L	624.9	-1.8	2705.3	107.9	0	15	5.4	2.6	2.8	66
	2050.5	-6	1190	0	9	0	0.6	1	2.3	17
M	624.8	-3	2718.7	0	11.2	0	2.4	1.4	10.6	140.3
	2050.2	-10	992.9	667	245.8	106.2	58.2	32.3	55	353.1
N	624.7	-1.3	649	143	9.7	21.1	1.2	2	54.4	1300.5
	2049.9	14	1202	113.5	88.5	32	16.4	7.1	39.7	635.8
O	624.7	-5.5	1516	476	54	3.9	0	0.2	5.7	132.2
	2049.7	-18	883.5	405.9	79.7	23.1	7.9	5	12.3	186.1
P	624.6	-6.7	1063	100	86.2	23.8	1	0.73	28	873.9
	2049.4	-22	1048	119.9	321.8	48.2	22	10.3	1.9	282.5
Q	624.5	-7.9	1664.5	162	17	2.8	4.2	1.2	7.6	72
	2049.2	-26	2658.2	0	50.9	30.3	4.1	1.6	4.1	136.5
R	624.5	-9.1	1220	0	7.6	7.8	1	0.71	0.5	76.1
	2049.0	-30	2795	0	0	0	1	2.5	8.6	383.7
S	624.4	-10.4	1769.6	0	0	0	0	0.29	4.4	422.9
	2048.7	-34	767.4	551.2	0	0	0.96	4.2	16.7	897
T	624.3	-11.6	1417	329	0	0	0	0.86	4.6	514.3
	2048.4	-38	2287	0	55.1	3.9	1.6	1.9	5.1	334.6
U	624.3	-12.8	346.1	0	0	0	0	0.31	3.9	1190.3
	2048.3	-42	3570	0	0	0	0	0.3	0.5	10.34
V	624.2	-14	1869	0	0	0.48	0	0.32	2	586
	2048.2	-46	802.6	0	89.6	4.4	0.4	2.4	7.9	884.3
W	624.2	-15.2	2625.7	0	0	7.6	2.6	5	2.7	374.5
	2047.9	-50	2405	361	65.5	28.1	10	5	3.2	461.3
X	624.1	-16.5	3362	624.1	14.7	16.2	6.8	6.1	2	107
	2047.7	-54	1406	285	56.8	5.6	1.8	3.4	2	161.3

Appendix B. Continued.

Band	Elevation to top of band (m) (ft)	Distance from old waterline (2051) to top of band (m) (ft)	Size fractions (mm) >63.5	31.75-63.50	16.00-31.75	9.50-16.00	6.35-9.50	2.00-6.35	0.85-2.00	<0.85
Y	624.0	-17.7	2090.3	0	6.3	20.4	13	18.1	5.7	601.6
	2047.5	-58	1185	333.1	0	0	1.1	1.3	2	358.2
Z	623.98	-18.9	0	0	0	0	0	1.3	4.2	1453.5
	2047.3	-62	0	0	0	0	0	1.6	6.2	865.4
Bottom of Band C										
	623.95	-19.5								
	2047.2	-64								

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