FISHERY RESEARCH

KOKANEE AND RAINBOW TROUT RESEARCH EFFORTS, LAKE PEND OREILLE, 2006

LAKE PEND OREILLE FISHERY RECOVERY PROJECT

ANNUAL PROGRESS REPORT
March 1, 2006—February 28, 2007

Prepared by:

Melo A. Maiolie, Principal Fishery Research Biologist
Gregory P. Schoby, Senior Fishery Research Biologist
William J. Ament, Senior Fishery Technician
and
William Harryman, Senior Fishery Technician

IDFG Report Number 08-06
April 2008

KOKANEE AND RAINBOW TROUT RESEARCH EFFORTS, LAKE PEND OREILLE, 2006

LAKE PEND OREILLE FISHERY RECOVERY PROJECT

Annual Progress Report

March 1, 2006—February 28, 2007

By

Melo A. Maiolie
Gregory P. Schoby
William J. Ament
and
William Harryman

Idaho Department of Fish and Game
600 South Walnut Street
P.O. Box 25
Boise, ID 83707

To

U.S. Department of Energy
Bonneville Power Administration
Division of Fish and Wildlife
P.O. Box 3621
Portland, OR 97283-3621

Project Number 1994-047-00
Contract Number 25744

IDFG Report Number 08-06
April 2008

TABLE OF CONTENTS

Page

ABSTRACT 1
INTRODUCTION 2
STUDY AREA 2
PROJECT GOAL 3
PROJECT OBJECTIVES 3
METHODS 3
- Down-looking Hydroacoustic Survey 3
- Up-looking Hydroacoustic Survey 6
- Midwater Kokanee Trawling 6
- Kokanee Fry Netting 7
- Hatchery Kokanee Marking 8
- Kokanee Biomass, Production, and Yield 9
- Kokanee Spawner Counts 9
- Kokanee Spawning Habitat Sampling 10
- Mysis Shrimp Abundance 10
- Rainbow Trout Population Estimate 10

RESULTS 13
- Down-looking Hydroacoustic Survey 13
- Up-looking Hydroacoustic Survey 13
- Midwater Trawling for Kokanee 14
- Kokanee Fry Netting 14
- Kokanee Biomass, Production, and Yield 14
- Kokanee Spawner Counts 15
- Kokanee Spawning Habitat Sampling 15
- Mysis Shrimp Abundance 15
- Rainbow Trout Population Estimate 15

DISCUSSION 16
- Kokanee Population Dynamics 16
- Predator Abundance 17
- Gravel Sampling 17
- Mysis Shrimp Abundance 18
- Rainbow Trout Population Estimate 18

RECOMMENDATIONS 19
ACKNOWLEDGEMENTS 20
LITERATURE CITED 21
APPENDICES 50

LIST OF TABLES

Page

Table 1. Population estimates of kokanee fry (millions) based on hydroacoustic surveys of Lake Pend Oreille, Idaho in 2006. Percentage of wild fry was based on the proportion of wild fry caught using a fry net and by midwater trawling. 24

Table 2. Population estimates of kokanee age classes (millions) in Lake Pend Oreille, Idaho, 2006. Estimates were made based on hydroacoustic surveys and partitioned into age classes based on the percent of each age class in the catch of midwater trawls. 24

Table 3. Survival rates (%) between kokanee year-classes estimated by midwater trawling and hydroacoustics, 1990-2005. Hydroacoustic estimates started in 1996. Year refers to the year the older age class in the survival estimate was collected. 25

Table 4. Comparison of kokanee reproductive success in Lake Pend Oreille, Idaho from 2004-2006. 25

Table 5. Kokanee population statistics based on $\log_{10}$ transformed means ($\log_{10}(x+1)$) of midwater trawl catches on Lake Pend Oreille, Idaho during August 2006. 25

Table 6. Biomass, production, and yield (metric tons) of kokanee in Lake Pend Oreille, Idaho 1996-2006. 26

Table 7. Counts of kokanee spawning along the shorelines of Lake Pend Oreille, Idaho. The numbers shown indicate the highest weekly count. 26

Table 8. Counts of kokanee spawning in tributaries of Lake Pend Oreille, Idaho. The numbers shown indicate the highest weekly counts at each site. 27

Table 9. Densities of shrimp (number per m^2), by life stage (young of year [YOY], and immature and adult), in Lake Pend Oreille, Idaho, June 20-23, 2006. Lake sections are shown in Figure 2. 27

Table 10. Summary of rainbow trout heads collected from Lake Pend Oreille, Idaho, through the Idaho Department of Fish and Game Angler Incentive Program and the number of recaptures (passive integrated transponder [PIT] and spaghetti tags) used in the 2006 population estimate. 28

Table 11. Monthly population estimates of rainbow trout over 305 mm in Lake Pend Oreille, Idaho, including 95% confidence intervals (CI) and coefficient of variation (CV). 28

Table 12. Monthly population estimates of rainbow trout >406 mm for Lake Pend Oreille, Idaho, including 95% confidence intervals (CI) and coefficient of variation (CV). 28

Table 13. Kokanee egg-to-fry survival rates compared with previous winter's lake level in Lake Pend Oreille, Idaho, 1998-2006. 28

LIST OF FIGURES

Page

Figure 1. Daily surface elevation of Lake Pend Oreille, Idaho, during 2005 and 2006. The dashed line at September 15 of each year marks the typical beginning of winter drawdown. Drawdown in the fall of 2006 was delayed until October. 29

Figure 2. Map of Lake Pend Oreille, Idaho, showing prominent landmarks, with the three lake sections marked with dashed lines. The dark lines mark the location of hydroacoustic transects in 2006. The inserted table depicts the area of kokanee habitat in each section. 30

Figure 3. Pictorial representation of towed body, hydroacoustic transducer arrangement, and towing vessel used during up-looking hydroacoustic surveys for predatory salmonids on Lake Pend Oreille, Idaho in August of 2006. 31

Figure 4. Map of Lake Pend Oreille, Idaho, showing the locations of kokanee trawling transects used in 2006. The inserted table depicts the area of kokanee habitat in each section. 32

Figure 5. Map of Lake Pend Oreille, Idaho, showing the locations of kokanee fry trawling transects used in 2006. The inserted table depicts the area of kokanee habitat in each section. 33

Figure 6. Map of Lake Pend Oreille, Idaho, showing the opossum shrimp sampling locations used during June 2006. 34

Figure 7. Target strengths of 1,987 fish recorded in Lake Pend Oreille, Idaho, during hydroacoustic surveys in August 2006, used to define the target strength break between kokanee fry and age 1 and older kokanee (>-46 dB). 35

Figure 8. Survival rates of kokanee from age-1 to age-2 in Lake Pend Oreille, Idaho, based on hydroacoustic surveys conducted between 1997 and 2006. 36

Figure 9. Length-frequency distribution of fish over -33 dB (410 mm) insonified in a down-looking hydroacoustic survey in Lake Pend Oreille, Idaho, in 2006. Decibel levels were converted to total length (mm) using Love's equation (1971). 37

Figure 10. Target strengths of fish in Lake Pend Oreille, Idaho, as measured during up-looking (A) and down-looking (B) hydroacoustic surveys in 2006. Fish were insonified from below (A) and from above (B). 38

Figure 11. Kokanee year-class population estimates based on midwater trawling between 1978 and 2006. Age 3 and 4 kokanee were not separated by age prior to 1986. 39

Figure 12. Length-frequency distribution of individual age classes of wild (A) and hatchery (B) kokanee caught by midwater trawling in Lake Pend Oreille, Idaho, in August 2006. 40

Figure 13. Mean weight (g) of age classes of kokanee from Lake Pend Oreille, Idaho, since midwater trawling began in 1977. 41

Figure 14. Annual kokanee standing stock (kg/ha) in Lake Pend Oreille, Idaho, from 1995 to 2006. 41

List of Figures, continued.

Page

Figure 15. Kokanee biomass, production, and yield (metric tonnes) from Lake Pend Oreille, Idaho, 1996-2006, excluding 1997 due to 100 year flood. Kokanee biomass was measured at the start of the year. Gray squares indicate production and black circles indicate yield. The solid black line represents the production curve, while the dashed line is the yield trend line. Numeral by each point represents the year of the estimate. 42

Figure 16. Substrate composition on potential kokanee spawning beaches in Lake Pend Oreille, Idaho. Sampling during spring 2004 was conducted above the water line at an elevation of 625.1 to 625.8 m while lake was at its low pool level. Other samples were collected at the same elevation by scuba diving during summer. 43

Figure 17. Annual mean density of opossum shrimp in Lake Pend Oreille, Idaho, 1973-2006. Data collected before 1989 were obtained from Bowles et al. (1991), and data from 1995 and 1996 were from Chipps (1997). Shrimp densities from 1992 and earlier were converted from Miller sampler estimates to vertical tow estimates by using the equation y = 0.5814x (Maiolie et al. 2002). Gaps in the bar chart indicate no data were collected that year. 44

Figure 18. Density estimates of immature and adult opossum shrimp in Lake Pend Oreille, Idaho, for the past 12 years (1995-2006). A linear trend line was fit to the data points to show the apparent decline. Error bounds were also added the recent population estimates to identify 90% confidence intervals around the estimate. 45

Figure 19. Mysis shrimp length frequency distribution during June 2006 on Lake Pend Oreille, Idaho. 46

Figure 20. Length-frequency of rainbow trout tagged with spaghetti and PIT tags in Lake Pend Oreille, Idaho, during the spring of 2006 by tag type. 46

Figure 21. Length-frequency of rainbow trout tagged through gillnetting, electrofishing, and angling, in Lake Pend Oreille, Idaho, during the spring of 2006. 47

Figure 22. The relationship between head length (mm) and total length (mm) of rainbow trout captured from Lake Pend Oreille, Idaho. The equation of the line is total length (mm) = 4.278 head length (mm) + 103.72 (r^2 = 0.90, n = 209). 47

Figure 23. Length-frequency of 5,907 rainbow trout harvested by anglers between May and December 2006 in Lake Pend Oreille, Idaho. Total lengths were derived from the head length-total length regression for rainbow trout in Lake Pend Oreille obtained during the spring of 2006. 48

Figure 24. Monthly population estimates of rainbow trout >300 mm and >406mm in Lake Pend Oreille, Idaho, during 2006. 48

Figure 25. Length-frequency of rainbow trout captured during the spring and fall of 2006 in Lake Pend Oreille, Idaho. Total lengths were derived from the head length-total length regression for rainbow trout in Lake Pend Oreille obtained during the spring of 2006. 49

List of Figures, continued.

Page

Figure 26. Rainbow trout population estimates (± 95% confidence intervals) for Lake Pend Oreille, Idaho, from 1998 to 2006. Population estimate data for 1998, 2003, and 2004 are from Vidergar (2000), Bassista et al. (2005), and Maiolie et al. (2006), respectively. The population was estimated by mark-recapture in 1998 and 2006, while estimates in 2003 and 2004 used hydroacoustics. 49

LIST OF APPENDICES

Appendix A. Transceiver settings for the Simrad EK 60 echo sounder used for down-looking (short cord) and up-looking (long cord) surveys on Lake Pend Oreille, Idaho during August 2006. 51

Appendix B. Location of areas surveyed for shoreline spawning kokanee in Lake Pend Oreille since 1972. 52

ABSTRACT

Lake Pend Oreille, Idaho was held 1.2 m above the low pool elevation during the winter of 2005-2006 in an attempt to improve kokanee *Oncorhynchus nerka* spawning habitat. We estimated that 134,000 female kokanee laid 50.5 million eggs on the shores and in tributary streams around the lake in the fall of 2005. From these eggs, an estimated 6.4 million wild fry were produced in 2006 for a survival rate of 12.7%. This was the highest egg-to-fry survival rate recorded during this project and was a substantial improvement from the 2.0% survival rate estimated in 2004 when the lake was drawn down to its minimum pool elevation. These results were consistent with past findings and showed the benefit of using lake level changes to enhance spawning habitat. However, low total biomass of kokanee and poor survival rates for ages 1 through 4 continued to indicate that this population was in danger of being lost from the lake due to high levels of predation.

Using mark-recapture, we estimated Lake Pend Oreille contained 36,209 (95% CI: 28,976–45,878) rainbow trout >300 mm during the spring of 2006. The estimated abundance of rainbow trout >406 mm was 19,157 (95% CI: 15,303–24,322). The annual exploitation rate was 27% based on the return of spaghetti tags with a $100 reward, or 25% based on harvest divided by the population estimate. Exploitation at this level was not believed to be sufficient to reduce rainbow trout abundance and reduce kokanee predation.

We tested split-beam hydroacoustics as a second method to estimate predator abundance. Using down-looking techniques during mid-August, we estimated the abundance of large pelagic fish over 590 mm (-30 dB) at 14,400 fish ± 83% (90% CI). Up-looking hydroacoustic surveys did not reveal any large fish in the upper 10 m of water, indicating we were not missing many shallow fish.

Authors:

Melo A. Maiolie
Principal Fishery Research Biologist

Gregory P. Schoby
Senior Fishery Research Biologist

William J. Ament
Senior Fishery Technician

William Harryman
Senior Fishery Technician

INTRODUCTION

Lake Pend Oreille once provided the largest kokanee *Oncorhynchus nerka* fishery in the state of Idaho. Between 1952 and 1966, harvests of kokanee averaged 1 million kokanee/yr and provided up to 522,692 angler hours of fishing pressure (Jeppson 1953; Maiolie and Elam 1993). From 1966 to 1985 kokanee harvest dramatically declined, reaching a low of 71,208 kokanee harvested and only 179,229 angler hours in 1985 (Bowles et al. 1987; Maiolie and Elam 1993). Much of the kokanee decline was related to fall draw downs of the lake for flood control and power production (Maiolie and Elam 1993). During 2000, the kokanee fishery was closed because of low numbers of adult kokanee. Continued declines in kokanee occurred after 2000 and were attributed to high predation levels on the reduced kokanee stocks (Maiolie et al. 2002; Maiolie et al. 2006).

During the winter of 2005-06, the winter water level of Lake Pend Oreille was held higher as part of a continuing experiment to enhance kokanee spawning and incubation success (Figure 1). We monitored the kokanee population to evaluate if changes in winter water levels affected recruitment and survival and compared the results to previous years. We also estimated abundance of opossum shrimp *Mysis relicta* to determine if they were affecting the outcome of the lake level experiment. The quality of potential spawning areas was monitored by core sampling to see how lake level changes were impacting spawning habitat.

It appeared that changing lake levels have increased spawning and incubation success and the abundance of kokanee fry (Maiolie et al. 2006). In 2005, fry abundance was two to three times higher than during the 1970s. However, abundance of harvestable-sized kokanee has decreased, likely due to high predation rates by lake trout and rainbow trout (Maiolie et al. 2002; Maiolie et al. 2006). To better understand these interactions, we increased our efforts to determine predator abundance, while fishery management personnel attempted to remove lake trout and rainbow trout from the lake. This year we completed a mark-recapture population estimate on rainbow trout. We also conducted down-looking and up-looking hydroacoustic surveys to enumerate large fish in the pelagic area of the lake. If successful, hydroacoustic surveys would be a much easier and cost effective way to monitor predator abundance than mark-recapture estimates. All work on this project was funded by the Bonneville Power Administration to mitigate for the construction of Albeni Falls Dam.

STUDY AREA

Lake Pend Oreille is located in the northern panhandle of Idaho (Figure 2). It is the state's largest lake and has a surface area of 32,900 ha, a mean depth of 164 m, and a maximum depth of 357 m. The Clark Fork River is the largest tributary to the lake and the outflow from the lake forms the Pend Oreille River. Lake Pend Oreille is a temperate, oligotrophic lake with summer temperatures (May to October) averaging 9°C in the upper 45 m (Rieman 1977). Thermal stratification typically occurs from late June to September (Maiolie et al. 2002). Operation of Albeni Falls Dam on the Pend Oreille maintains a lake level of 628.7 m above mean sea level during summer (June-September) and winter lake levels between 626.4 m and 625.1 m.

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

sculpin *Cottus cognatus*, five cyprinids, and two catostomids. Kokanee entered the lake in the early 1930s as downstream migrants from Flathead Lake, Montana and were well established by the 1940s. Since this time, kokanee have been the primary pelagic forage species in Lake Pend Oreille. Pelagic habitat used by kokanee is approximately 22,646 ha (Figure 2) (Bowler 1978). Pelagic habitat inside the 70 m contour line was measured at 21,332 ha; 6390.6 ha in the southern section, 7,719.3 ha in the middle section, and 7,222.2 in the northern section. 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.

Historically, bull trout and northern pikeminnow *Ptychocheilus oregonensis* were the top two native predatory fish in Lake Pend Oreille (Hoelscher 1992). The historic native prey population included mountain whitefish, pygmy whitefish, slimy sculpin, suckers, peamouth *Mylocheilus caurinus*, and redside shiner *Richardsonius balteatus*, as well as juvenile bull trout and westslope cutthroat trout. Presently, the top four predatory fish are lake trout, rainbow trout, bull trout, and northern pikeminnow. Other less abundant predators include northern pike *Esox lucius*, brown trout *Salmo trutta*, smallmouth bass *Micropterus dolomieu*, largemouth bass *M. salmoides*, and walleye *Sander vitreus* (Hoelscher 1992).

PROJECT GOAL

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

PROJECT OBJECTIVES

1. Recover kokanee abundance so that the population could support an annual harvest of 750,000 fish.

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

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

METHODS

Down-looking Hydroacoustic Survey

We conducted lakewide hydroacoustic surveys on Lake Pend Oreille to monitor the kokanee population and provide an estimate of large pelagic fish likely to be kokanee predators. Surveys were performed at night between August 14 and August 16, 2006. A Simrad EK60 portable scientific echo sounder equipped with a 120 kHz split beam transducer set to ping at 0.6 s intervals was used to perform mobile hydroacoustic surveys. The pole-mounted transducer was located 0.5 m below the surface, off the port side of the boat, and with the

transducer pointing downward. The echo sounder was calibrated annually for signal attenuation to the sides of the acoustic axis using Simrad's ER60 software. Calibration settings for the echo sounder are listed in Appendix A.

A stratified systematic sampling design was used in our survey. We followed a uniformly spaced, zigzag pattern of transects traveling from shoreline to shoreline, as described by MacLennan and Simmonds (1992). The starting point of the first transect in each section was chosen randomly. Transect lengths ranged from 3.6 km to 7.7 km and a global positioning system (GPS) was used to navigate each transect. Twenty-one transects were completed with eight in the southern section, six in the middle section, and seven in the northern section (Figure 2). For all transects we utilized a 7.3 m boat and maintained a speed of approximately 1.3 m/s. Boat speed did not affect our calculations of fish density.

We determined kokanee abundance using echo integration techniques. Echoview software version 3.10.135.03 was used to view and analyze the data. Hydroacoustic traces (a single returned echo from a fish) were accepted if they were between -60 and -33 dB and the echo length was between 30% and 180% of the original pulse length at a point 6 dB below the peak echo value. Additionally, the correction value returned from the transducer gain model could not exceed a two-way maximum gain compensation of 6.0 dB (therefore, it included all targets within the 3 dB beam width) and the maximum standard deviation of the minor and major axis angles was less than 0.6 degrees.

Once kokanee targets met the above criteria, we calculated density estimates of kokanee in each transect using the Echoview software. A box was drawn around the kokanee layer on each echogram to define the area sampled (usually between the 10 m and 50 m depths). The area in the box was integrated to obtain the nautical area scattering coefficient (NASC) and analyzed to obtain the mean target strength of all returned echoes. This integration accounted for fish that were too close together to be detected as a single target (MacLennan and Simmonds 1992). Densities were then calculated by the equation:

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

where:

NASC = the total backscattering in m^2/nautical $mile^2$, and
TS = the mean target strength in dB for the area sampled.

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

We used *in-situ* target strengths to separate fry from the older age classes of kokanee using Echoview software. Fish traces (a single returned echo off a single fish) 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 by comparing them to the kokanee caught in our midwater trawl samples. Kokanee of ages 1 to 4 were not separated based on their target strengths, but were separated based on the percentages of each age class collected by trawling in that section.

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

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

where:

$\bar{x}$ = the estimated mean density of kokanee in the lake (fish/ha),
t = the Student's t value,
N_i = the number of possible samples in a section i,
n_i = the number of samples collected in a section i, and
s_i = the standard deviation of the samples in strata i.

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

We also used the hydroacoustic data to estimate the potential egg deposition (PED) by kokanee. The acoustic estimate of age 1-4 kokanee (-45.9 dB to –33 dB) in each lake section was multiplied by the percentage of mature kokanee caught in the midwater trawl in that section. We then divided this number by two to obtain the number of females. The number of mature female kokanee collected by hatchery crews at the Sullivan Springs egg collection facility was subtracted from the population estimate of mature female kokanee to obtain the number of wild spawners. The wild spawner estimate was then multiplied by kokanee fecundity to obtain wild PED. The number of wild kokanee fry was divided by the previous year's wild PED to estimate wild egg-to-fry survival.

The same down-looking survey was used to estimate the abundance of large pelagic fish in the open waters of Lake Pend Oreille. Density estimates of large fish were determined using echo-counting techniques. Echoview software version 3.10.135.03 was used to view and analyze the data. Hydroacoustic traces (a single returned echo from a fish) were included if they were over -40 dB and met the previously described criteria used for kokanee traces. Fish tracks (a series of traces returned from the same fish) were defined as a large pelagic fish based on several criteria: 1) the average target strength of all traces was > -30 dB, 2) the track was more than 10 m off of the lake bottom, 3) it was not aggregated with other similar sized fish, 4) it was between the surface and a depth of 35 m, and 5) it was in water >75 m deep (bottom depth). The number of traces on each larger fish within the 3 dB beam width was binned into 1 m depth intervals and divided by the area sampled at that depth to calculate fish density. Sampled area

for each bin was calculated by multiplying the number of pings on the transect by the 3 dB beam width at the center of the bin.

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

Up-looking Hydroacoustic Survey

An up-looking hydroacoustic survey was conducted to estimate large (>590 mm) pelagic fish abundance near the surface. The survey was conducted at night from July 31 to August 3, 2006. The same echo sounder was used as described in our down-scanning survey. We used our 8.8 m trawler to tow a 1.9 m torpedo-shaped towed body. The transducer was mounted near the center of the towed body and pointed upward (Figure 3). The transducer cable was lengthened with an additional 100 m length of cable equipped with SeaCon® waterproof connectors at each end. The towed body was deployed and retrieved using the trawler's winch cable that was rigged to pass through a pulley at the end of a 3 m long outrigger pole. The outrigger was attached to the boat across the trawler's A-frames and held the towed body to the starboard side of the boat away from the boat's propeller wash. The weighted towed body was deployed approximately 30 m below the surface when pulled on a 100 m length of cable. This placed the towed body about 95 m behind the boat and provided a clear view of the surface. A separate calibration for the hydroacoustic gear was used to correct for using the additional 100 m length of transducer cable. Specific echo sounder settings used for these surveys are listed in Appendix A.

We followed the same transect paths that were used for the down-looking hydroacoustic survey shown in Figure 2, but water less than 75 m deep was avoided. Transects were viewed and analyzed using Echoview software. Density estimates were calculated using echo counting techniques, where the number of individual traces in 1 m depth bins was divided by total area sampled by the acoustic beam at each depth. Target depths were calculated with reference to the distance from the lake surface. Targets larger than -30 dB were assumed to be pelagic predators. The intent was to use the up-looking surveys to calculate densities of large pelagic fish in the top 10 m of water and use the down-looking survey to calculate densities between the 10 and 35 m depths.

Midwater Kokanee Trawling

We conducted midwater trawling in Lake Pend Oreille from August 18 to 21, 2006. These dates were during the dark phase of the moon, which optimized the capture efficiency of the trawl (Bowler et al. 1979). A stratified random sampling scheme was used to estimate kokanee abundance and density within the three lake sections. We randomly selected 12 locations within each section and made hauls in a predetermined, random direction from the selected point (Figure 4). Sites were located and transects were navigated using a GPS.

We followed the methods of Rieman (1992) for our sampling procedures for midwater trawling. However, we used a fixed frame net (10.5 m long with a 3.0 m tall x 2.2 m wide mouth). This net had a rigid steel frame that kept the mouth of the net open and, therefore, did not have otter boards preceding the net mouth. Mesh sizes (stretch measure) graduated from

32 to 25 to 19 to 13 mm in the body of the net to 6 mm in the cod end. We towed the net through the water at a speed of 1.58 m/s 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° hull-mounted transducer. A stepwise oblique tow was conducted along each transect, consisting of 3 to 6 steps, which sampled the entire vertical distribution of kokanee. Each step lasted for 3 minutes, and represented a 3 m thick portion of the kokanee layer.

Kokanee from each trawl sample were counted and placed on ice until they were processed the following day. Fry were placed on dry ice to quickly freeze them and remained frozen until they were processed. Length and weight were recorded for individual fish, and all kokanee over 180 mm were checked for maturity. Scales and otoliths were taken from a sample of 10 to 15 fish in each 10 mm size interval for ageing. The otoliths from 95 kokanee fry and 122 kokanee between ages 1 and 4 were sent to the WDFW Otolith Laboratory for aging and to determine if they were of hatchery or wild origin.

Kokanee catch per trawl haul was divided by the volume of water filtered by the net (while in the kokanee layer) to obtain density of kokanee at each trawl site. The age-specific density estimates for each section were expanded to a whole lake population estimate, and 90% confidence intervals calculated using standard formulas for stratified sampling designs (Scheaffer et al. 1979) (see equation under Hydroacoustic Population Sampling). Kokanee abundance was estimated using geometric (log [x+1)) and arithmetic means (the geometric means provided a more accurate estimate of kokanee abundance; however, arithmetic means were calculated for comparisons to past data). 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 were found during late summer (Bowler 1978). For consistency, these same areas (totaling 22,646 ha) have been used each year since 1978 (Figure 4).

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

Potential egg deposition was also calculated based on midwater trawl catch. Percent maturity within each 10 mm length group was multiplied by the population estimate for that length group and then summed across length groups. We assumed 50% of the mature population was female based on past sampling. The estimated number of mature females in the lake was multiplied by the mean fecundity seen at Sullivan Springs to estimate PED. Mean fecundity was determined by dissecting 20 female kokanee from the beginning, middle, and end of the spawning run. We subtracted the number of female kokanee spawned by hatchery personnel at Sullivan Springs including trap mortalities to determine the number of eggs deposited by wild and/or naturally spawning fish (wild PED).

Kokanee 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 moon phase as the midwater trawling to maintain consistency. Eight net hauls were made in each lake section during August 22-24, 2006 (Figure 5).

The fry net was 1.27 m high by 1.57 m wide across the mouth (2 m^2) and 5.5 m in length. Bar mesh size for the net was 0.8 mm by 1.6 mm. The sampling bucket, on the cod end of the net, contained panels of 1 mm mesh.

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

All kokanee caught in the fry net were immediately frozen on dry ice. Upon return to the dock, the fry were stored in a freezer for later analysis. Lengths and weights were measured and otoliths were removed from 33 kokanee fry from sections 1 and 3, and 34 otolith pairs were removed from fry in section 2. Otoliths were sent to the WDFW Otolith Lab to determine if the fry were wild or of hatchery origin.

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. This value was multiplied by the thickness of the kokanee layer (m), and by 10,000 to convert the 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.

Hatchery Kokanee Marking

All kokanee produced at the Cabinet Gorge Fish Hatchery since 1997 have been marked by "thermal mass marking" techniques (or cold branding) described by Volk et al. (1990). Therefore, hatchery kokanee of all ages should contain distinct thermal marks. Thermal treatments were initiated five to ten days after fry entered their respective raceways. Fry released in 2006 (brood year 2005) received a 13 day pattern created by five single-day coldwater events. The first and second events were each followed by one day of warm water, while the third and fourth events were followed by three-day warmwater events. The last warmwater event was followed by a final coldwater mark. Ten fry from each raceway were sacrificed to verify the thermal marking. Recognizable otolith marks were verified on all thermally treated individuals.

During the spring of 2006, Cabinet Gorge Fish Hatchery released 15.04 million thermally marked kokanee fry into Lake Pend Oreille. Out of this total, 1.11 million were the early spawning strain and the remainder the late spawning strain. We sent 317 otoliths from all kokanee age classes collected during the 2006 trawling to the WDFW lab to determine origin. Before shipment, we catalogued each fish; recorded total length and weight; and removed, cleaned and numbered the otoliths. WDFW personnel removed one otolith from each of the 317 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 reference samples taken from the hatchery. For accuracy, two independent readers examined each otolith. Differences between the readers were settled by re-examination.

Kokanee Biomass, Production, and Yield

We calculated the biomass, production, and yield of the kokanee population in Lake Pend Oreille to determine the effects of predation. Hydroacoustic population estimates, 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 used 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. Then we averaged the population estimates between the two years and multiplied the increase in mean weight by the average population estimate for each age class. We then summed the results for all of the year-classes to determine the production for the entire population. These calculations assume linear rates of growth and mortality throughout the year. Hayes et al. (2007) provides additional details on this summation method for estimating production.

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

We plotted both production and yield against kokanee biomass to examine the rate of decline within this population. Data from 1996 to 2006 were used to plot the trend lines. However, we excluded the flood year of 1997 since significant kokanee mortality occurred that was likely not due to predation.

Kokanee Spawner Counts

We counted spawning kokanee in standard shoreline areas (Appendix B) and tributaries to continue the time-series data set that was initiated in 1972. All areas surveyed were documented as historic spawning sites (Jeppson 1960). Nine shoreline areas and seven tributary streams were surveyed the third week of November. We counted all kokanee, either alive or dead.

The seven tributary streams were surveyed by walking upstream, from their mouth to the highest point utilized by kokanee. Streams included South Gold Creek, North Gold Creek,

Cedar Creek, Johnson Creek, Twin Creek, Spring Creek, and Trestle Creek (both the early and late run of kokanee were counted).

Kokanee Spawning Habitat Sampling

We investigated the quality of shoreline substrates around Lake Pend Oreille to determine their suitability for kokanee spawning. Six sites were sampled during mid-July 2006 to monitor changes in substrate composition after the second year of higher winter pool levels (626.3 m msl). Scuba divers collected 4-5 randomly located substrate samples between the elevations of 625.1 and 625.7 msl at each of the six sites. Divers removed approximately two liters of substrate, placed it into a container, and sealed it underwater to eliminate the loss of fine material during transport to the surface. Samples were dried and screened using soil sieves (sizes 31.5 mm, 6.3 mm, 4.0 mm, and 2.0 mm). The substrate retained on each screen and the substrate that fell through the finest screen were weighed and calculated as a percent of the total sample weight. We defined cobble as substrates that were 31.5 mm and larger, gravel as substrates between 31.5 and 4.0 mm, and fines as the substrate smaller than 4.0 mm.

Mysis Shrimp Abundance

We sampled opossum shrimp *Mysis relicta*, from June 20-23, 2006 to estimate their density within Lake Pend Oreille. All sampling occurred at night during the dark phase of the moon. The new moon during June has been the standard sampling date for most of the previous work on shrimp and for all of our sampling since 1997. Fifteen random sites were sampled in each of the three lake sections (Figure 6). Previously (from 1997-2003), ten sites were sampled from each lake section. Beginning in 2004, the number of sample sites was increased to 15 to improve population estimates and tighten confidence intervals. We used GPS coordinates to locate each sampling location.

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

During laboratory analysis, mysids from all samples were enumerated and classified as either young-of-the-year (YOY) (<11 mm total length) or adult (≥11 mm total length). Mysids from seven samples were examined under a dissecting scope to determine sex and total length. Total length was measured from the tip of the rostrum to the end of the telson, excluding setae. Shrimp were then classified into five categories according to sexual characteristics: YOY, immature male, immature female, mature male, and mature female (Pennak 1978). Density estimates were based on the number of shrimp collected in each sample and the volume of water filtered as determined by the flow meter reading. We calculated the arithmetic and the geometric means, and 90% confidence intervals (CI) for the immature and adult portion of the opossum shrimp sample but did not use the geometric means for the YOY sample.

Rainbow Trout Population Estimate

To estimate rainbow trout abundance and angler exploitation in Lake Pend Oreille, a mark-recapture program was implemented during the spring of 2006. Rainbow trout were

tagged with passive integrated transponder (PIT) tags and green $100 reward spaghetti tags. Tagging occurred between March 27 and June 7, 2006. Rainbow trout were captured and tagged from Lake Pend Oreille using hook-and-line and gill nets. Rainbow trout were also captured and tagged by electrofishing in the Clark Fork River, the upper Pack River, and Spring Creek. Electrofishing in the Clark Fork River utilized a 6m jet boat with a Coffelt VVP-15 electroshocker powered by a 5000-watt Honda generator, while a 5 m drift boat with a Coffelt VVP-15 electroshocker powered by a 5000-watt Honda generator was used in the upper Pack River. A Smith-Root SR-15 backpack electrofishing unit was used in Spring Creek. PIT tags were implanted into the left opercle muscle, while spaghetti tags were implanted through the muscle under the dorsal fin.

To encourage angler harvest of lake trout and rainbow trout from Lake Pend Oreille, the Idaho Department of Fish and Game (IDFG) implemented an Angler Incentive Program (AIP) during the spring of 2006. To receive awards through the AIP, anglers were required to turn in the heads from harvested lake trout and rainbow trout into one of five freezers located around Lake Pend Oreille. Freezers were placed at Holiday Shores Marina and Hope Marine Services at Ellisport Bay, the public boat ramp in Garfield Bay, Hudson's Bay Marina in Bayview, and at the IDFG Research Office in Bayview. Freezers were emptied on a weekly basis and heads were scanned to determine the presence of PIT tags. Heads returned through the AIP were used as the recapture portion of the rainbow trout population estimate. Rainbow trout heads were also measured to estimate the total length of harvested fish. Total length was derived from a head length to total length regression from rainbow trout captured from Lake Pend Oreille during the annual K & K angling derby between April 29 and May 7, 2006. The head length-total length regression was established by measuring the head length (from the tip of the snout to the edge of the opercle) (mm) and total length (mm) of 209 rainbow trout. Linear regression was used to describe the relationship between the two variables.

The AIP was implemented at the beginning of the Lake Pend Oreille Idaho Club (LPOIC) annual K & K spring derby on April 29, 2006. The rainbow trout tagging effort continued until June 7, 2006; therefore, any heads turned in prior to this time were excluded from the population estimate. Rainbow trout population estimates were calculated for each month after all head returns were summarized and included all catchable sized rainbow trout (>300 mm). Population estimates were also calculated for rainbow trout >406 mm to compare to past estimates and determine the abundance of rainbow trout large enough to consume kokanee (Vidergar 2000).

We used the Chapman mark-recapture estimate to determine rainbow trout abundance. The Chapman method was chosen over other mark-recapture techniques because individuals sampled after the initial tagging period were removed from the population (both marked and unmarked). The formula for this estimator is:

$$\mathrm{N} = \frac{(M+1)(C+1)}{R+1} - 1$$

where N is the population estimate of rainbow trout, *M* is the total number of marked fish, *C* is the total number of fish sampled, and *R* is the number of marked fish that were recaptured.

Binomial confidence limits for *R/C* were estimated using equations 24.28 and 24.29 from Zar (1999). The lower confidence limit for N is:

$$L_1 = \frac{X}{X + (n - X + 1)\, F_{\alpha(2),\, v_1,\, v_2}},$$

where

$$v_1 = 2(n - X + 1)$$

and

$$v_2 = 2X.$$

The upper confidence limit for N is:

$$L_2 = \frac{(X+1)\, F_{\alpha(2),\, v_1',\, v_2'}}{n - X + (X+1)\, F_{\alpha(2),\, v_1',\, v_2'}},$$

where

$$v_1' = 2(X+1) = v_2 + 2$$

and

$$v_2' = 2(n - X) = v_1 - 2.$$

We replaced *X* and *n* in Zar's equations with *R* and *C*, respectively. Upper and lower limits (L_1 and L_2) were then multiplied by C to estimate limits for R to obtain upper and lower 95% confidence intervals of N.

Exploitation was based on the return of tagged rainbow trout from anglers between June 8, 2006 and June 8, 2007. To encourage tag returns, rewards were associated with both tag types. Spaghetti tags were labeled "$100 reward – return to IDFG," while PIT tagged rainbow trout heads were awarded cash prizes ranging from $100 to $2000. In an attempt to increase harvest of rainbow trout, the AIP switched from only paying for tagged heads to a $15 per head award system. Instructions for spaghetti tag returns were distributed with information about the AIP. Exploitation was calculated as the total number of tags returned divided by the total number of tagged fish released into the population. Exploitation was calculated by each tag type, as well as by dividing the total number of rainbow trout harvested thru the AIP by the population estimate.

RESULTS

Down-looking Hydroacoustic Survey

For 2006, we estimated the lake contained 15.2 million (13.4 million to 17.2 million, 90% CI) kokanee, or 670 fish/ha, based on our standard nighttime hydroacoustic surveys. This included 11.9 million age 0 kokanee (10.4 million to 13.6 million, 90% CI) (Table 1) and 3.3 million (2.8 million to 3.8 million, 90% CI) kokanee of ages 1-4 (Table 2). Mean target strengths of kokanee traces showed a separation between kokanee fry and larger fish at –46 dB (Figure 7), or a fish length of about 85 mm. This corresponded closely to the gap in the length-frequency distribution of trawl samples between fry and age 1 kokanee. As can be seen in Figure 7, the larger kokanee did not show separate age class peaks in target strengths. We, therefore, separated kokanee into ages 1 to 4 based on their percent frequency in trawl samples for each section of the lake (Table 2). The lake contained an estimated 2.8 million age 1; 410,000 age 2; 20,000 age 3; and 27,000 age 4 kokanee.

In past years, we also split the hydroacoustic estimate of age 1 to 4 kokanee into the number of mature kokanee based on the percentage of mature fish in the trawl catch within each section. This year only three mature kokanee were caught in 36 trawl hauls, one in each lake section. This would translate into 2.0%, 1.2%, and 0.5% of the trawl catch were mature in the southern, middle, and northern sections, respectively. If these percentages of mature kokanee were used, it would only yield an estimate of 34,248 mature kokanee or 17,124 mature female kokanee assuming a 50:50 ratio of males to females. This number was less than the number of female kokanee collected at Sullivan Springs (21,802 female kokanee) and therefore was an underestimate.

Based on hydroacoustics with kokanee age classes estimated by trawl percentages, we calculated the survival rate of each year-class of kokanee between 2005 and 2006. Survival was 23% from age 0 to age 1, 13% from age 1 to age 2, 12% from age 2 to age 3, and 14% from age 3 to age 4 (Table 3). Survival of kokanee from age 1 to age 2 continued on a downward trend since 2003 (Figure 8).

The abundance of wild fry was estimated based on the percentage of wild fry caught in our fry net in each section multiplied by the hydroacoustic estimate of all fry. Wild fry made up 75.8%, 76.5%, and 15.2% of the fry net catch in the southern, middle, and northern sections, respectively (Table 1). Based on these numbers we estimated the wild fry population at 6.41 million. The survival of naturally deposited eggs (50.5 million deposited in 2005) to wild fry was 12.7% (Table 4).

We also estimated large pelagic fish during down-looking hydroacoustic surveys. A total of 17 fish over -30 dB (590 mm) were recorded in all sections (Figure 9). Abundance estimates in the southern, middle, and northern sections were 8,767, 2,543, and 3,292 fish, respectively. A total population estimate of large pelagic fish by down-looking hydroacoustics was 14,602 fish ± 83% (0.6845 fish/ha). This estimate was combined with the up-looking estimate of large fish in the top 10 m of water to obtain a total estimate for the entire water column above 35 m.

Up-looking Hydroacoustic Survey

No large (>-30 dB [>590 mm]) pelagic fish were seen in our up-looking hydroacoustic survey in the top 10 m of water. Only two fish over -33 dB (410 mm) were recorded; one at -32.9

dB (415 mm) at a depth of 9.5 m, and one at -32.2 dB (450 mm) at a depth of 6 m. These fish were too small to meet our criteria of fish over -30 dB. Therefore, no fish were added to the population estimate from down-looking hydroacoustic surveys.

A total of 9,166 traces were returned from fish over -56 dB (25 mm) at all depths. The peaks in the target strength frequency distribution for the up-looking survey were similar to the peaks in target strengths seen during the down-looking survey (Figure 10). This indicated that insonifying the fish from either the dorsal or the ventral direction provided similar estimates of fish sizes.

Midwater Trawling for Kokanee

Population estimates of kokanee were also calculated based on midwater trawling. In August 2006, total kokanee abundance based on geometric means was 8.651 million fish (7.440 million [-14%] to 10.060 million [+16%], 90% CI) with a density of 382 fish/ha (Table 5). This included 6.323 million kokanee fry, 2.189 million age 1 kokanee, 0.131 million age 2 kokanee, 3,996 age 3 kokanee, and 3,851 age 4 kokanee (Figure 11). Kokanee ranged in length from 25 mm to 302 mm (Table 5; Figure 12). Mean weight of age 0 kokanee was 1.63 g; age 1 18.5 g; age 2s 42.4 g; age 3s 230.8 g; and age 4s 264.9 g (Figure 13). The total standing stock of kokanee was 2.58 kg/ha (Table 5; Figure 14).

We caught only three mature kokanee in the trawl. Based on this catch, the lake contained 26,188 mature fish. Using a 50:50 ratio, we estimated 13,094 females spawning in 2006. Hatchery crews collected 21,802 female kokanee in Sullivan Springs showing that the estimates based on trawling had underestimated the abundance of mature kokanee. Therefore, we could not estimate the potential egg deposition of wild kokanee since this would result in a negative number. Fecundity averaged 565 eggs/ female at Sullivan Springs.

Kokanee Fry Netting

A total of 226 fry were collected using the small-mesh fry net during September 2006. We collected 80 in the southern section, 80 in the middle section, and 66 in the northern section of the lake. Based on this method and using arithmetic means, we estimated 9.24 million kokanee fry, of which 5.24 million were wild. Based on the examination of fry otoliths by the WDFW Otolith lab, the percentages of wild fry in the southern, middle, and northern sections were 76%, 76% and 15%, respectively.

Kokanee Biomass, Production, and Yield

We calculated estimates of kokanee biomass, production, and yield based on the hydroacoustic estimates of kokanee abundance. Kokanee biomass was estimated at 100 metric tonnes (t). Kokanee production decreased from 231 t in 2005 to 206 t in 2006. Total yield of kokanee was 274 t (Table 6).

We plotted kokanee production and yield against kokanee biomass to examine trends and correlations (Figure 15). Yield in 2006 was 68 t higher than production, and biomass declined considerably from 2005. Production in 2006 was again near the trend line fitted to the production data from 1996 through 2005. A biomass to production curve was fitted to the available production data and forced through the origin.

Kokanee Spawner Counts

In 2006, we observed 1,781 kokanee spawning on the lake's shorelines. We counted 1,752 on the shoreline around Bayview, 17 in Ellisport Bay (Hope), and 12 in Garfield Bay (Table 7). We observed 897 kokanee spawning in tributaries around Lake Pend Oreille (Table 8). Counts included 414 in South Gold Creek, 61 in North Gold Creek, 60 in Spring Creek, 21 in Cedar Creek, and 14 in Trestle Creek. An additional 327 kokanee were counted in September as part of the early spawning run that occurs in Trestle Creek. In addition to the Trestle Creek early fish, early spawning fish were documented in a number of tributaries on the eastern shore of the lake for the first time. These fish were likely two-year-old strays from fry released in Sullivan Springs in 2004 in an attempt to establish a run of early spawners. Early spawning kokanee were observed in Sullivan Springs and Granite Creek, Cedar Creek, North Gold Creek, and Gold Creek for the first time this year.

Kokanee Spawning Habitat Sampling

We collected substrate samples in July from the same six sites where samples were collected in 2004 and 2005. Percent gravel composition increased at three sites and decreased at three sites. Ellisport Bay had the largest decrease in gravel substrate with a decline of 20 percent. Twin Creek and Kilroy Bay gravel declines were 14 and 4.7 percent, respectively (Figure 16). At all three sites, cobble replaced the gravel in approximately the same proportion. There was a mean increase in gravel of 15.2 percent at the other three sites, mainly resulting from the decline in cobble. The largest gain was at Green Bay with an increase of 25 percent. The Evans Landing site was the only location with an increase in fines and a corresponding decrease in cobble.

Mysis Shrimp Abundance

We estimated the total mean density of shrimp during June 2006 at 569 shrimp/m^2 (Table 9). This included 346 YOY shrimp/m^2 and 223 immature and adult shrimp/m^2. Overall, total density of Mysis shrimp in Lake Pend Oreille decreased by 52% from 1,173 shrimp/m^2 in 2005 to 569 shrimp/m^2 during 2006 (Figure 17). From 2005 to 2006, the density of YOY shrimp decreased by 64%, while the density of immature and adult shrimp increased by 9% (Figure 18). The length-frequency distribution of shrimp cohorts is presented in Figure 19.

The arithmetic mean for the immature and adult shrimp was 223 shrimp/m^2 with 90% CI of $\pm$ 57 (26%). The geometric mean estimate was 187 immature and adult shrimp/m^2 with 90% CI of 158 (-15%) and 222 (+19%).

Rainbow Trout Population Estimate

A total of 555 rainbow trout were tagged between March 27 and June 7, 2006. Average size of tagged rainbow trout was 504 mm total length (range: 334 – 935). Four hundred and seventy-seven rainbow trout were implanted with PIT tags (mean TL: 495 mm; range: 334-935) and 78 were tagged with green $100 reward spaghetti tags (mean TL: 563 mm; range: 435-792) (Figure 20). Rainbow trout were captured by angling (n = 461), electrofishing (n = 81), and gillnetting (n = 13) (Figure 21). Of the 81 rainbow trout captured by electrofishing, 77 were tagged in the Clark Fork River, three were tagged in the upper Pack River, and one was tagged in Spring Creek.

Through December 31, 2006, 6,307 rainbow trout were harvested by anglers as determined by heads entered into the AIP. A total of 58 PIT and 19 spaghetti tagged fish were recaptured. Of the 6,307 rainbow trout heads returned, 1,397 were harvested before all tagged fish were released into the population (June 7, 2006) and therefore were not included in the recapture effort of the population estimate. Two PIT tagged rainbow trout were removed by anglers before June 7 and therefore were excluded from the marked population of fish used in the population estimate. One spaghetti-tagged rainbow trout was also excluded from the marked population as this fish was tagged in the Clark Fork River and harvested from Lightning Creek on June 11. It was unknown if this fish ever inhabited Lake Pend Oreille and was therefore eliminated from the marked population. The final number of marked individuals used in the population estimate was 552. The recapture effort after June 7, 2006 yielded 4,910 rainbow trout, of which 74 were tagged (PIT = 56; spaghetti = 18). The total number of heads as well as the total number of recaptures returned are summarized by month throughout the summer and fall of 2006 (Table 10).

The total length (mm) of rainbow trout caught by anglers was estimated by using the head length-total length regression. The equation of the line was total length (mm) = 4.278 head length (mm) + 103.72 (n = 209; r^2 = 0.90) (Figure 22). From May thru December, total length was estimated for 5,907 (94%) rainbow trout heads turned in through the AIP. The total length of rainbow trout captured by anglers during the AIP ranged from 219 mm to 938 mm (average: 458 mm) (Figure 23).

Based on the calculations at the end of the recapture period (December 31, 2006), the estimated abundance of rainbow trout >300 mm on June 7, 2006 was 36,209 (95% CI: 28,976–45,878). Between July and December 2006, monthly rainbow trout population estimates ranged from 29,523 to 36,629 (Table 11; Figure 24). The estimated abundance of rainbow trout >406 mm was 19,157 (95% CI: 15,303–24,322). Monthly population estimates of rainbow trout >406 mm ranged from 18,252 to 19,654 between July and December 2006 (Table 12; Figure 24).

Overall, the annual exploitation rate of rainbow trout in Lake Pend Oreille was 18.6% (103/554). Exploitation of spaghetti tagged fish (27.3%) (21/77) was greater than exploitation of PIT tagged fish (17.2%) (82/477).

DISCUSSION

Kokanee Population Dynamics

Changes in the winter water level of Lake Pend Oreille continued to improve the wild egg-to-fry survival of kokanee. We documented the highest kokanee egg-to-fry survival rate recorded during this study at 13% for eggs laid in 2005. This survival rate was considerably higher than in some full drawdown years (Table 13). Wild fry abundance was 6.4 million, which was noteworthy considering the rather low number of adults documented in 2005 (Table 4).

In addition to the wild production, hatchery stocking boosted the number of kokanee fry in the lake to 525 fry/ha. Rieman and Meyers (1990) recommended kokanee stocking rates between 100 and 500 fry/ha; therefore, we believe Lake Pend Oreille was well seeded with kokanee fry.

Unfortunately, kokanee declines continued during 2006. Standing stock, as measured by trawling, dropped to 2.58 kg/ha in 2006 (Table 5; Figure 14). This was well below the 13-17

kg/ha in the late 1970s (Rieman and Bowler 1980) and the 16.22 kg/ha estimated in 1996 (Maiolie et al. 2002) (Figure 14). Similarly, kokanee biomass estimates based on hydroacoustics (which give a higher estimate than trawling) have also shown a considerable decline. We estimated the lake contained about 350 t of kokanee in 1995 and 1996, but biomass dropped to 100 t by 2006 (Table 6).

Kokanee spawner counts have been conducted each year since 1972 (Tables 7 and 8). Counts of kokanee along the shoreline did not show a large decline in abundance during 2006. Although spawner abundance remained relatively high, we believe that the population estimates made by trawling and hydroacoustics are a better indication of the number of adults present.

Since 1999, we have been concerned that predation will cause the complete loss of kokanee from Lake Pend Oreille (Maiolie et al. 2002). Continuing declines in survival rates indicated that this situation is worsening (Table 3). It is unlikely that this population will persist if the current survival rates do not improve. One factor that has kept this population from complete extirpation from the lake has been the pronounced increases in the production: biomass ratio. In 2006, the kokanee population produced 206 t of fish flesh from a population with a biomass of 100 t for a ratio of 2.06:1. This ratio was closer to 1:1 or less in 1996 through 1999. Increases in the production to biomass ratio helped to slow the decline, but with yield exceeding production, a decline in biomass was observed. Any future declines in kokanee biomass are likely to cause a decrease in kokanee production (Figure 15). Declines in production would be expected to cause an increase in the rate of decline in biomass, thus causing a negative feedback loop.

Predator Abundance

In 2006, we estimated Lake Pend Oreille contained 14,600 ± 83% large (>590 mm) pelagic fish using hydroacoustics. This was an increase from the 9,200 ± 98% estimate in 2005, although the difference was not significant. Based on mark-and–recapture estimates of rainbow trout in 2006, the lake contained approximately 5,900 rainbow trout above 590 mm. Thus, it appears that many of the large pelagic targets are lake trout and bull trout.

Side-scanning in 2005 (Maiolie et al. 2007) and up-looking acoustics in 2006 both failed to find any large pelagic fish in the top 10 m of water during the peak of summer stratification. Water temperatures taken in the upper 10 m were not prohibitively high (range: 13.5–19.1°C) and should not have prevented rainbow trout from venturing to the surface. Sonic tracking of rainbow trout in 2004 showed that one rainbow trout did stay on the surface throughout the summer (Maiolie et al. 2006). We conclude that the occurrence of rainbow trout in the top 10 m was fairly rare in 2006 and may not alter population estimates made by down-scanning surveys.

Gravel Sampling

The quality of the kokanee spawning sites remains good. The last drawdown of the lake to its low pool elevation was during the winter of 2003-04, which allowed wave action to clean and re-sort shoreline gravel. During our sampling in the summer of 2006, these areas remained clean even after being inundated the previous two winters. Previously we had recommended that the lake be drawn down after three years of higher winter levels to allow wave action to improve spawning habitat (Maiolie et al. 2002). This recommendation still seemed valid.

Mysis Shrimp Abundance

Opossum shrimp in Lake Pend Oreille have gone through a cycle of expansion and then decline. Shrimp expanded from their introduction in 1966 until 1980, but have declined slightly over the last 24 years (Figure 17). Immature and adult shrimp densities (the segment of the population most likely to compete with kokanee) have also shown a downward trend during the current study (Figure 18). Although immature and adult shrimp densities increased by 9% in 2006, it was the third lowest density measured in the past 12 years. A similar pattern of expansion followed by decline has been seen in other western lakes after opossum shrimp introductions (Richards et al. 1991; Beattie and Clancey 1991).

It is unclear what limits the opossum shrimp population within Lake Pend Oreille. Data collected from the trap net evaluation project in 2003-2004 indicated a substantial lake whitefish population in Lake Pend Oreille (Peterson and Maiolie 2005). Preliminary examination of lake whitefish stomachs suggests they fed heavily on opossum shrimp. However, much of the area of Lake Pend Oreille contains water depths over 300 m and does not contain many whitefish (based on hydroacoustic surveys over deep water). Shrimp in these areas would be isolated from predation.

Lake Pend Oreille appeared to have higher shrimp densities than other lakes in the region. Rumsey (1988) saw densities of opossum shrimp ranging from 5.1 shrimp/m^2 to 223 shrimp/m^2 in six lakes in western Montana using similar sampling methods, although he only sampled down to 30 m instead of the 45.7 m in this study. Though these numbers may not be directly comparable, it still appeared that densities of opossum shrimp in Lake Pend Oreille (569 shrimp/m^2) are higher.

One possible reason for higher densities of shrimp may be due to the depth of the lake. Beattie and Clancey (1991) showed that mysid populations in Flathead Lake have high spatial variability, similar to what we see in Lake Pend Oreille. They suggested that densities of shrimp were higher at sampling stations that were >40 m in depth (>100 shrimp/m^2 at some stations) and considerably lower at shallower sampling stations (<15 shrimp/m^2 in all stations <25 m). Much of Lake Pend Oreille has depths exceeding 40 m.

It appears that opossum shrimp are not limiting kokanee recovery in Lake Pend Oreille. Shrimp densities have continued to decline and kokanee survival has continued to fluctuate over the past several years. Maiolie et al. (2002) did not find a correlation between shrimp densities and survival rates of kokanee between the egg and fry stages. This weak correlation remains in 2006. Continued monitoring of shrimp is recommended.

Rainbow Trout Population Estimate

The rainbow trout population estimate of harvestable-sized fish (>300 mm) varied by month, but remained relatively consistent from July through September (between 29,523 and 29,975). The population estimate increased by about 6,500 fish between September and October, and remained around 36,000 fish from October through December (Figure 24). The fall increase in the rainbow trout population estimate was likely due to the increase in smaller fish (ranging from 300–380 mm) being captured during this time. It was likely that the majority of this age class was less vulnerable to capture by angling during the spring tagging efforts and therefore were underrepresented in the marked group of fish. As summer progressed and fish in this age class grew, they became more vulnerable to angling in the fall. Of the 1,383 rainbow

trout <380 mm caught between May and December, 79.1% (1,094) were caught in the fall (September through December) (Figure 25). The recruitment of this age class of rainbow trout into the fall fishery may have inflated our population estimates in October, November, and December.

The rainbow trout population estimate for fish greater than 406 mm was higher in 2006 (19,157) than in previous estimates (Figure 26). Vidergar (2000) used mark-recapture to estimate the population of rainbow trout in Lake Pend Oreille to be 14,607 in 1998. Bassista et al. (2005) and Maiolie et al. (2006) used hydroacoustics in 2003 and 2004 to estimate the rainbow trout population at 11,700 and 15,800, respectively.

Overall, the annual exploitation rate of rainbow trout in Lake Pend Oreille was low (18.6%) and differed by tag type (spaghetti tags: 27.3% vs. PIT tags: 17.2%). The relatively low exploitation rate of PIT-tagged rainbow trout may be related to angler releases, mortality due to the tagging procedure, and/or tag loss. Even with the monetary incentives associated with the AIP, many trophy rainbow trout anglers on Lake Pend Oreille resisted the idea of harvesting rainbow trout. Anglers may have released rainbow trout (including PIT-tagged fish), contributing to the lower exploitation rate. Another possible reason for lower exploitation of PIT-tagged rainbow trout is tag loss. We are unaware of any studies on cheek PIT tagging retention rates for rainbow trout, but Baxter et al. (2001) observed an 89.4% annual retention rate of cheek PIT tags by bull trout. It is unknown if rainbow trout would exhibit a lower retention rate than bull trout, but morphological differences in the head and jaw structure between the two species may account for a lower retention rate by rainbow trout.

When looking at the number of rainbow trout harvested through the angler incentive program (8,961 from spring derby 2006 to spring derby 2007) and the resulting population estimate (36,209), exploitation of the rainbow trout population is approximately 25%. This is similar to exploitation rates based on tag returns, but still is likely too low to reduce the rainbow trout population enough to increase kokanee survival.

Little research has been conducted to determine the amount of exploitation necessary to collapse rainbow trout populations. Donald and Alger (1989) found that by exploiting brook trout at an annual rate of 20%, population density and biomass did not change significantly, while growth rates increased as the density of the older cohort of fish was reduced. In Sagehen Creek, California, exploitation of stream-dwelling brook trout, rainbow trout, and brown trout greater than 99 mm ranged between 23 and 47% (average 33%) annually over a nine-year study, but recruitment replaced the loss (Gard and Seegrist 1972). Conversely, Moore and Schill (1984) found that 62% exploitation of cutthroat trout age 4 to 7 led to overharvest and declines in the fishery. In order to reduce predation pressure on kokanee in Lake Pend Oreille, we believe rainbow trout exploitation needs to increase to 60-70%.

RECOMMENDATIONS

1. Continue to work with the U.S. Army Corps of Engineers to manage water levels for the benefit of kokanee spawning habitat while maintaining flood control and not unnecessarily impacting power production.

2. Reduce predation on kokanee so that the population has a chance to increase in biomass and recover.

ACKNOWLEDGEMENTS

Many people contributed to making this study possible. Fisheries technician Mark Duclos and biological aide Jacob Miller assisted with many of the field and laboratory activities and the maintenance of equipment. The U.S. Army Corps of Engineers made the necessary lake level changes, and the Bonneville Power Administration provided funding for this study. We wish to thank Jay Marcotte for his help in administering our BPA contract and Pete Rust and Joe DuPont who edited drafts of this report. The help from these people and agencies was greatly appreciated.

LITERATURE CITED

Bassista, T. P., M. A. Maiolie, and M. A. Duclos. 2005. Lake Pend Oreille predation research. Idaho Department of Fish and Game, Annual Report to Bonneville Power Administration, Contract 2002-009-00, Report number 05-04, Portland, Oregon.

Baxter, J. S., B. Westover, T. Down, and S. Snelson. 2001. Retention of floy tags and passive integrated transponder tags in a wild bull trout (*Salvelinus confluentus*) population one and two years after tagging. Pages 177-180 *in* Brewin, M.K., A.J. Paul, and M. Monita, editors. Bull trout II conference proceedings. Trout Unlimited Canada, Calgary, Alberta.

Beattie, W. D., and P. T. Clancey. 1991. Effects of *Mysis relicta* on the zooplankton community and kokanee population of Flathead Lake, Montana. American Fisheries Society Symposium 9:39-48.

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., B. E. Rieman, G. R. Mauser, and D. H. Bennett. 1991. Effects of introductions of *Mysis relicta* on fisheries in northern Idaho. American Fisheries Society Symposium 9:65-74.

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

Donald, D. B., and D. J. Alger. 1989. Evaluation of exploitation as a means of improving growth in a stunted population of brook trout. North American Journal of Fisheries Management 9:177-183.

Gard, R., and D. W. Seegrist. 1972. Abundance and harvest of trout in Sagehen Creek, California. Transactions of the American Fisheries Society 101:463-477.

Hayes, D. B., J. R. Bence, T. J. Kwak, and B. E. Thompson. 2007. Abundance, biomass, and production. Pages 327-374 in C. S. Guy and M. L. Brown, editors. Analysis and interpretation of freshwater fisheries data. American Fisheries Society, Bethesda, Maryland.

Hoelscher, B. 1992. Pend Oreille Lake fishery assessment 1951 to 1989. Idaho Department of Health and Welfare, Division of Environmental Quality Community Programs. Boise, Idaho.

Jeppson, P. 1953. Biological and economic survey of fishery resources in Lake Pend Oreille. Idaho Department of Fish and Game, Job Completion Report, Project F 3-R-3. Boise, Idaho.

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.

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

Maiolie, M. A., W. J. Ament, and W. Harryman. 2007. Hydroacoustic estimates of large pelagic fish in Lake Pend Oreille. Idaho Department of Fish and Game, Annual Report to Bonneville Power Administration, Contract number 00016828, Report number 07-35. Portland, Oregon.

Maiolie, M. A., T. P. Bassista, M. P. Peterson, W. Harryman, W. J. Ament, and M. A. Duclos. 2006. Lake Pend Oreille fishery recovery project. Idaho Department of Fish and Game, Completion Report to Bonneville Power Administration, Contract number 1994-047-00, Report number 06-25. Portland, Oregon.

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. J. Ament, and B. Harryman. 2002. Lake Pend Oreille fishery recovery project. Idaho Department of Fish and Game, Completion Report to Bonneville Power Administration, Contract number 1994-047-00, Report number 02-56. Portland, Oregon.

Maiolie, M. A., M. P. Peterson, W. J. Ament, and W. Harryman. 2006. Kokanee response to higher winter lake levels in Lake Pend Oreille during 2005. Idaho Department of Fish and Game, Annual Report to Bonneville Power Administration, Contract number 00016828, Report number 06-31. Portland, Oregon.

Moore, V., and D. Schill. 1984. South Fork Snake River fisheries investigations. Idaho Department of Fish and Game, Job Completion Report, Project F-73-R-5, Boise, Idaho.

Pennak, R. W. 1978. Freshwater invertebrates of the United States. Second edition. John Wiley and Sons. New York, New York.

Peterson, M. P., and M. A. Maiolie. 2005. Evaluation of large trap nets for lake trout removal in Lake Pend Oreille, Idaho. Idaho Department of Fish and Game, Project Progress Report, Report Number 04-35. Boise, Idaho.

Richards, R., C. Goldman, E. Byron, and C. Levitan. 1991. The mysids and lake trout of Lake Tahoe: A 25-year history of changes in the fertility, plankton, and fishery of an alpine lake. American Fisheries Society Symposium 9:30-38.

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., and B. Bowler. 1980. Kokanee trophic ecology and limnology in Pend Oreille Lake. Idaho Department of Fish and Game, Fisheries Bulletin 1. Published by the Forest, Wildlife and Range Experiment Station, University of Idaho. Moscow, Idaho.

Rieman, B. E., and D. Meyers. 1990. Status and analysis of salmonids fisheries, kokanee population dynamics. Idaho Department of Fish and Game. Job Performance Report, Project F-73-R-12, 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.

Rumsey, S. 1985. Mysis monitoring in western Montana lakes 1983-1984. Montana Department of Fish, Wildlife, and Parks. Progress Report, Project F-7-R-34, Job 1-a. Kalispell, Montana.

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

Vidergar, D. T. 2000. Population estimates, food habits and estimates of consumption of selected predatory fishes in Lake Pend Oreille, Idaho. Master's thesis. University of Idaho, Moscow, Idaho.

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.

Zar, J. H. 1999. Biostatistical Analysis, 4th edition. Prentice Hall, Inc. Englewood Cliffs, New Jersey.

Table 1. Population estimates of kokanee fry (millions) based on hydroacoustic surveys of Lake Pend Oreille, Idaho in 2006. Percentage of wild fry was based on the proportion of wild fry caught using a fry net and by midwater trawling.

	Southern	Middle	Northern	Total for lake	90% CI
Total kokanee fry abundance by hydroacoustics	2.104	5.443	4.339	11.887	10.4 to 13.6
Percent wild fry in fry trawl	75.76	76.47	15.15	—	
Wild fry estimate based on acoustics and fry trawling	1.594	4.163	0.657	6.414	
Percent wild fry in midwater trawl	43.86	30.92	16.86	—	
Wild fry estimate based on acoustics and midwater trawling	0.923	1.683	0.732	3.338	

Table 2. Population estimates of kokanee age classes (millions) in Lake Pend Oreille, Idaho, 2006. Estimates were made based on hydroacoustic surveys and partitioned into age classes based on the percent of each age class in the catch of midwater trawls.

Area	Age 1	Age 2	Age 3	Age 4	Total
Southern Section					
Acoustic estimate of kokanee in section (millions)					0.717
Percent of age class in section by trawling	76.02	20.16	1.91	1.91	
Population estimate in section (millions)	0.545	0.144	0.014	0.014	0.717
Middle Section					
Acoustic estimate of kokanee in section (millions)					1.175
Percent of age class in section by trawling	85.15	13.73	0.0	1.12	
Population estimate in section (millions)	1.001	0.161	0.000	0.013	1.175
Northern Section					
Acoustic estimate of kokanee in section (millions)					1.392
Percent of age class in section by trawling	92.06	7.45	0.49	0.0	
Population estimate in section (millions)	1.281	0.104	0.007	0.000	1.392
Total population estimate for lake (millions)	2.827	0.410	0.020	0.027	3.284

Table 3. Survival rates (%) between kokanee year-classes estimated by midwater trawling and hydroacoustics, 1990-2005. Hydroacoustic estimates started in 1996. Year refers to the year the older age class in the survival estimate was collected.

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

[a] Data from 2002 to 2006 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 from 2004-2006.

	2004	2005	2006
Number of mature female kokanee in previous year	219,584	198,364	134,288
Number of kokanee collected by hatchery crew in previous year	43,351	50,023	35,453
Female kokanee spawning in the wild during the previous year	176,233	148,341	98,835
Fecundity (eggs/female) in previous year	351	406	511
Wild spawn eggs in previous year	61.8 m	60.2 m	50.5
Number of wild fry produced	1.25 m	5.67 m	6.41
Wild egg-to-fry survival (%)	2.0	9.4	12.7
Previous winter lake elevation (m)	625.1	626.4	626.4

Table 5. Kokanee population statistics based on $\log_{10}$ transformed means ($\log_{10}(x+1)$) of midwater trawl catches on Lake Pend Oreille, Idaho during August 2006.

	Age 0	Age 1	Age 2	Age 3	Age 4	Total
Population estimate (millions)	6.323	2.189	0.131	0.004	0.0004	8,650,892
90% CI (lower & upper limits)	—	—	—	—	—	7.44 to 10.06 m
Density (fish/ha)	279.21	96.68	5.77	0.18	0.17	382.01
Mean weight (g)	1.63	18.51	42.35	230.78	264.93	—
Standing stock (kg/ha)	0.46	1.79	0.24	0.04	0.05	2.58
Mean length (mm)	58.6	136.9	181.4	281.5	293.3	—
Length range (mm)	25-96	102-160	162-201	267-293	286-302	—

Table 6. Biomass, production, and yield (metric tons) of kokanee in Lake Pend Oreille, Idaho 1996-2006.

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

Table 7. Counts of kokanee spawning along the shorelines 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
2006	1,752	0	0	0	17	0	0	12	0	—	1,781
2005	1,565	0	5	1	0	1	0	66	0	—	1,638
2004	2,342	0	100	1	0	0	0	34	0	—	2,477
2003	940	0	0	0	0	20	0	0	0	—	960
2002	968	0	0	0	0	0	0	0	0	—	968
2001	22	0	0	0	0	0	0	0	1	—	23
2000	382	0	0	2	0	0	0	0	0	—	384
1999	2,736	4	7	24	285	209	0	275	0	—	3,540
1998	5,040	2	0	0	22	6	0	34	0	—	5,104
1997	2,509	0	0	0	0	7	2	0	0	—	2,518
1996	42	0	0	4	0	0	0	3	0	—	49
1995	51	0	0	0	0	10	0	13	0	—	74
1994	911	2	0	1	0	114	0	0	0	—	1,028
1993	—	—	—	—	—	—	—	—	—	—	—
1992	1,825	0	0	0	0	0	0	34	0	—	1,859
1991	1,530	0	—	0	100	90	0	12	0	—	1,732
1990	2,036	0	—	75	0	80	0	0	0	—	2,191
1989	875	0	—	0	0	0	0	0	0	—	875
1988	2,100	4	—	0	0	2	0	35	0	—	2,141
1987	1,377	0	—	59	0	2	0	0	0	—	1,438
1986	1,720	10	—	127	0	350	0	6	0	—	2,213
1985	2,915	0	—	4	0	2	0	0	0	—	2,921
1978	798	0	0	0	0	138	0	0	0	0	936
1977	3,390	0	0	25	0	75	0	0	0	0	3,490
1976	1,525	0	0	0	0	115	0	0	0	0	1,640
1975	9,231	0	0	0	0	0	0	0	0	0	9,231
1974	3,588	0	25	18	975	2,250	0	20	0	50	6,926
1973	17,156	0	0	200	436	1,000	25	400	617	0	19,834
1972	2,626	25	13	4	1	0	0	0	0	0	2,669

Table 8. 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
2006	414	61	21	0	0	—	—	60	—	327	14	897
2005	5,463	615	1	0	1,244	—	—	—[b]	—	427	76	7,826
2004	721	2,334	600	16	6,012	—	—	3,331[b]	—	682	0	13,696
2003	591	0	0	0	—	—	—	626	—	2,251	9	3,477
2002	79	0	0	0	0	—	—	0	—	1412	0	1,491
2001	72	275	50	0	0	—	—	17	—	301	0	715
2000	17	37	38	0	2	0	0	0	0	1,230	0	1,324
1999	1,884	434	435	26	2,378	—	—	9,701	5	1,160	423	16,446
1998	4,123	623	86	0	268	—	—	3,688	—	348	578	9,714
1997	0	20	6	0	0	—	—	3	—	615	0	644
1996	0	42	7	0	0	—	—	17	—	753	0	819
1995	166	154	350	66	61	—	0	4,720	108	615	21	6,261
1994	569	471	12	2	0	—	0	4,124	72	170	0	5,420
1992	479	559	—	0	20	—	200	4,343	600	660	17	6,878
1991	120	550	—	0	0	—	0	2,710	0	995	62	4,437
1990	834	458	—	0	0	—	0	4,400	45	525	0	6,262
1989	830	448	—	0	0	—	0	2,400	48	466	0	4,192
1988	2,390	880	—	0	0	—	6	9,000	119	422	0	12,817
1987	2,761	2,750	—	0	0	—	75	1,500	0	410	0	7,496
1986	1,550	1,200	—	182	0	—	165	14,000	0	1,034	0	18,131
1985	235	696	—	0	5	—	127	5,284	0	208	0	6,555
1978	0	0	0	0	0	0	44	4,020	0	1,589	0	5,653
1977	30	426	0	0	0	0	1,300	3,390	0	865	40	6,051
1976	0	130	11	0	0	0	2,240	910	0	1,486	0	4,777
1975	440	668	16	0	1	0	995	3,055	0	14,555	15	19,740
1974	1,050	1,068	44	1	135	0	2,350	9,450	0	217	1,210	15,525
1973	1,875	1,383	267	0	0	503	500	4,025	0	1,100	18	9,671
1972	1,030	744	0	0	0	0	350	2,610	0	0	1,293	6,027

[a] Trestle Creek early-spawners

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

Table 9. Densities of shrimp (number per m^2), by life stage (young of year [YOY], and immature and adult), in Lake Pend Oreille, Idaho, June 20-23, 2006. Lake sections are shown in Figure 2.

Section	YOY/m^2	Immature & Adults/m^2	Total Shrimp/m^2
Section 1	407.1	216.6	623.7
Section 2	537.3	331.0	868.3
Section 3	121.1	128.2	249.3
Whole lake means	**345.6**	**223.1**	**568.8**

Table 10. Summary of rainbow trout heads collected from Lake Pend Oreille, Idaho, through the Idaho Department of Fish and Game Angler Incentive Program and the number of recaptures (passive integrated transponder [PIT] and spaghetti tags) used in the 2006 population estimate.

	May	June	July	Aug	Sept	Oct	Nov	Dec	Total	Recapture period (after 6/7/06)
Number of Heads	1,248	523	218	373	607	1,676	1,455	207	6,307	**4,910**
Recaptures										
PIT	0	6[a]	4	6	8	19	11	4	58	**56**
Spaghetti	0	1[b]	3	0	3	3	9	0	19	**18**
Total	0	7	7	6	11	22	20	4	77	**74**

[a] Includes two PIT tagged fish recaptured before end of tagging period (6/7/06)
[b] Spaghetti tagged fish recaptured in Lightning Creek (excluded from population and exploitation estimate)

Table 11. Monthly population estimates of rainbow trout over 305 mm in Lake Pend Oreille, Idaho, including 95% confidence intervals (CI) and coefficient of variation (CV).

	July	Aug	Sept	Oct	Nov	Dec
Population Estimate	29,660	29,523	29,975	35,218	36,629	36,209
Lower 95%CI	16,940	18,929	21,044	26,905	29,134	28,976
Upper 95%CI	56,130	48,599	44,226	47,044	46,731	45,878
CV	28.6%	22.7%	18.1%	13.8%	11.7%	11.4%

Table 12. Monthly population estimates of rainbow trout >406 mm for Lake Pend Oreille, Idaho, including 95% confidence intervals (CI) and coefficient of variation (CV).

	July	Aug	Sept	Oct	Nov	Dec
Population Estimate	19,654	19,176	18,824	18,252	19,595	19,157
Lower 95%CI	11,247	12,314	13,233	13,929	15,553	15,303
Upper 95%CI	37,164	31,538	27,748	24,428	25,068	24,332
CV	28.5%	22.7%	18.0%	13.8%	11.8%	11.5%

Table 13. Kokanee egg-to-fry survival rates compared with previous winter's lake level in Lake Pend Oreille, Idaho, 1998-2006.

Year	Lake elevation (m) during previous winter	Egg-to-fry survival (%)
2006	626.8	12.7
2005	626.8	9.4
2004	625.6	2.0
2003	626.8	9.7
2002	625.6	9.5
2001	626.0	6.6
2000	626.0	10.0
1999	626.8	6.0
1998	626.8	9.7

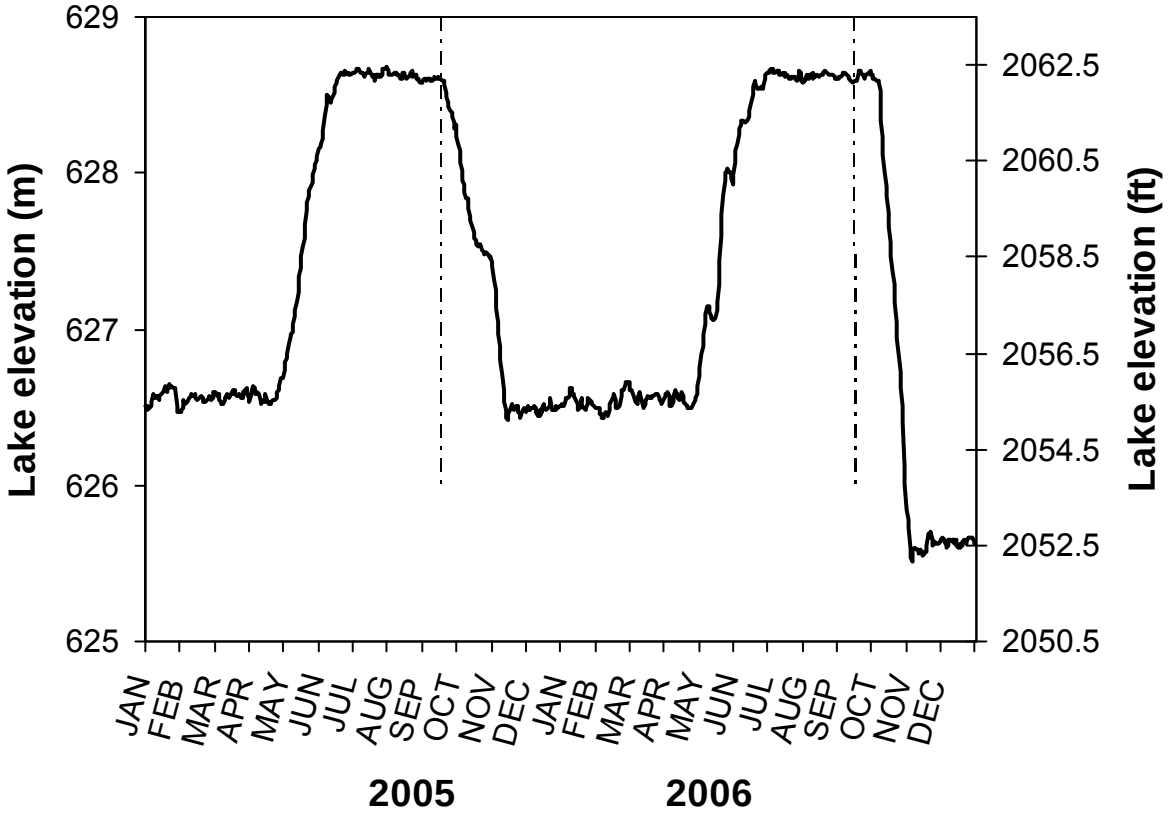
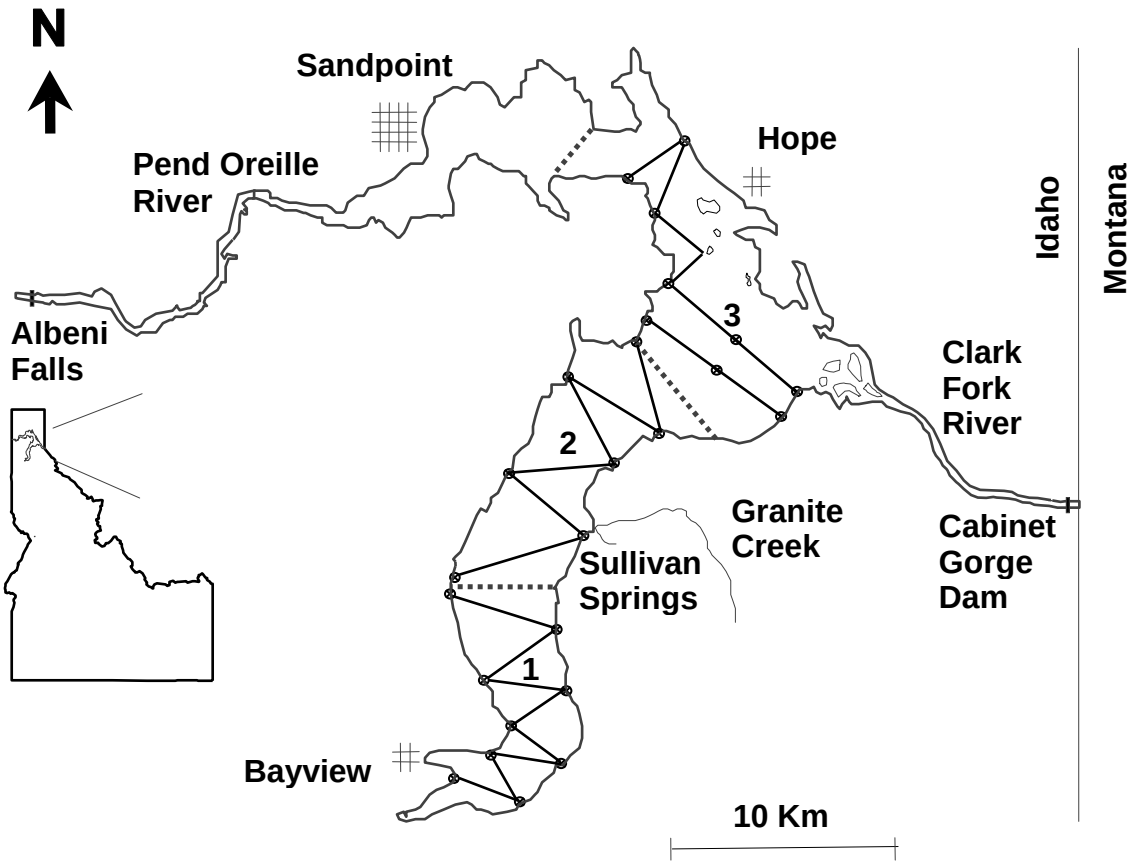


Figure 1. Daily surface elevation of Lake Pend Oreille, Idaho, during 2005 and 2006. The dashed line at September 15 of each year marks the typical beginning of winter drawdown. Drawdown in the fall of 2006 was delayed until October.



Area Section	(hectares)
1	6486
2	7776
3	8384

⊗ - Start and stop of transects

Figure 2. Map of Lake Pend Oreille, Idaho, showing prominent landmarks, with the three lake sections marked with dashed lines. The dark lines mark the location of hydroacoustic transects in 2006. The inserted table depicts the area of kokanee habitat in each section.

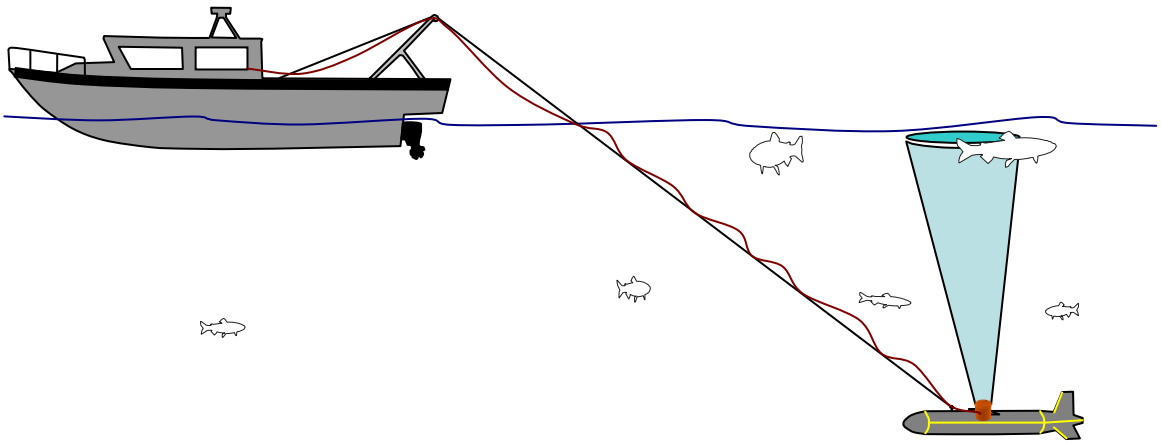
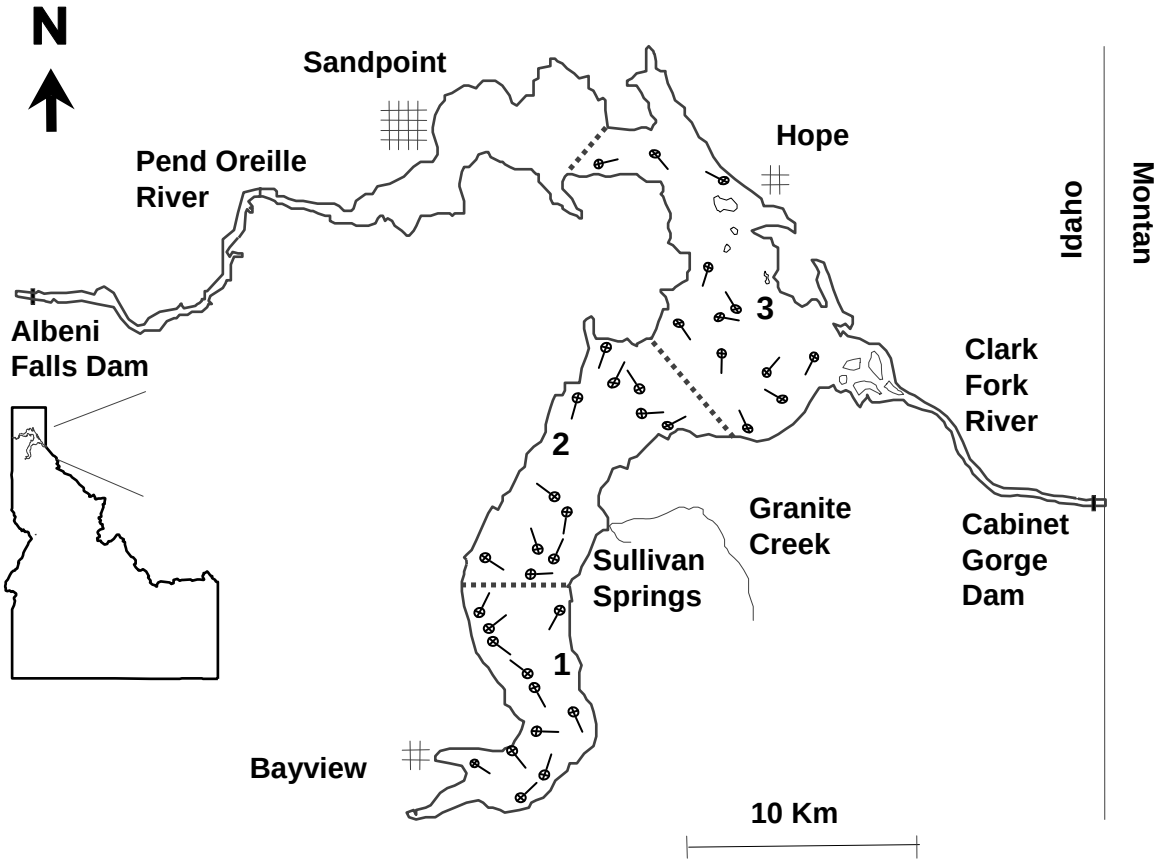


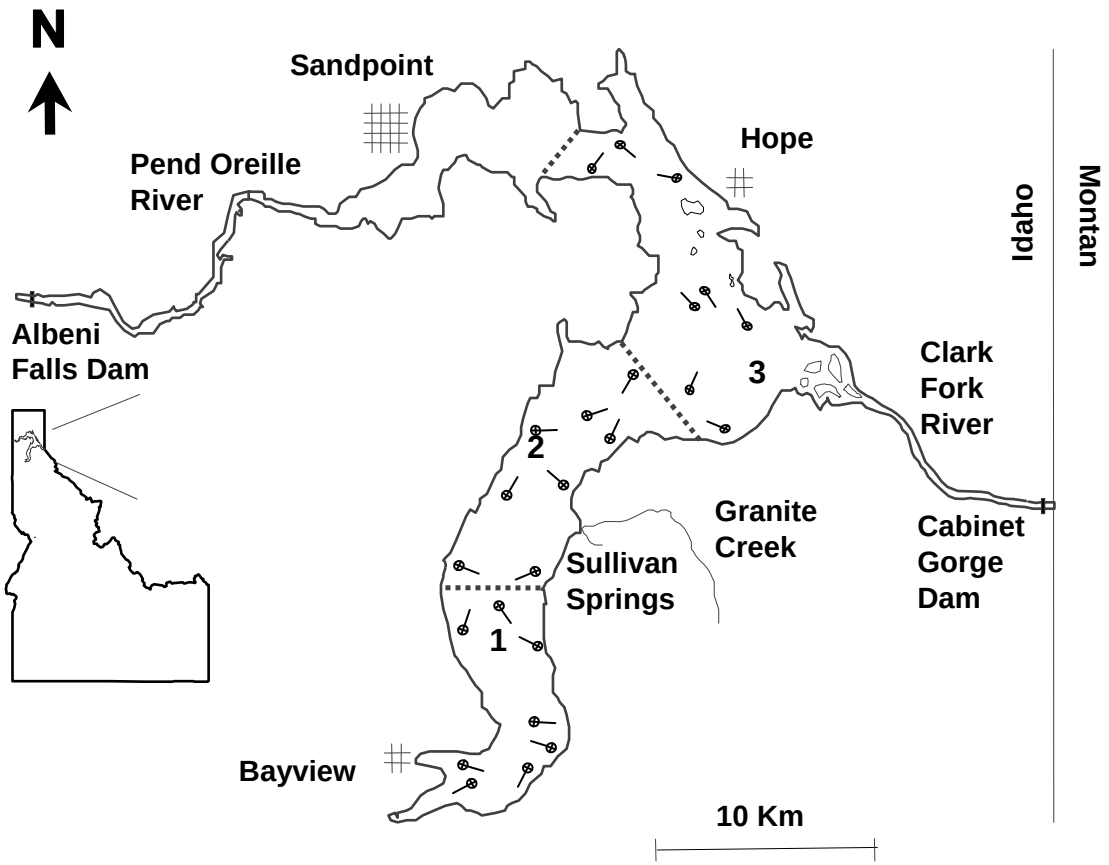
Figure 3. Pictorial representation of towed body, hydroacoustic transducer arrangement, and towing vessel used during up-looking hydroacoustic surveys for predatory salmonids on Lake Pend Oreille, Idaho in August of 2006.



Area Section	(hectares)
1	6486
2	7776
3	8384

- Transect location and direction

Figure 4. Map of Lake Pend Oreille, Idaho, showing the locations of kokanee trawling transects used in 2006. The inserted table depicts the area of kokanee habitat in each section.



Area Section	(hectares)
1	6486
2	7776
3	8384

- Transect location and direction

Figure 5. Map of Lake Pend Oreille, Idaho, showing the locations of kokanee fry trawling transects used in 2006. The inserted table depicts the area of kokanee habitat in each section.

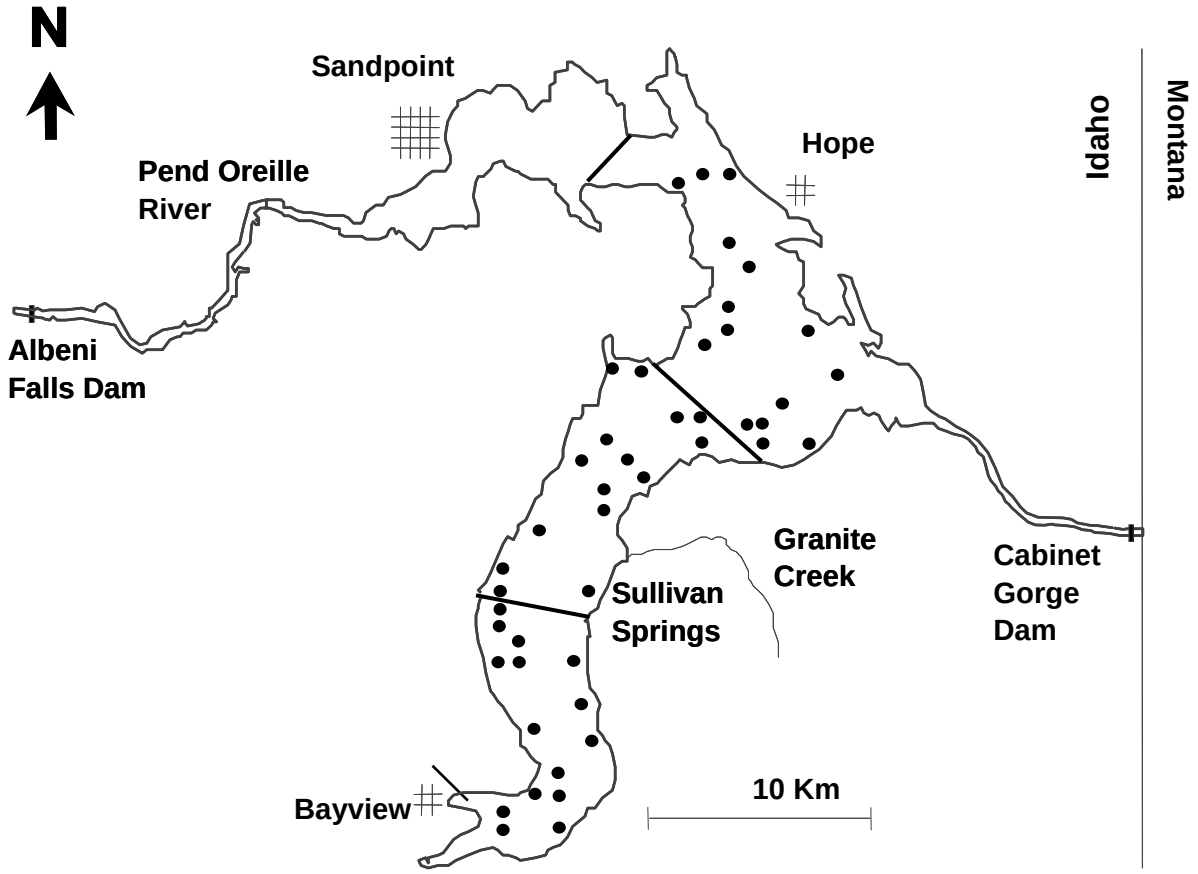


Figure 6. Map of Lake Pend Oreille, Idaho, showing the opossum shrimp sampling locations used during June 2006.

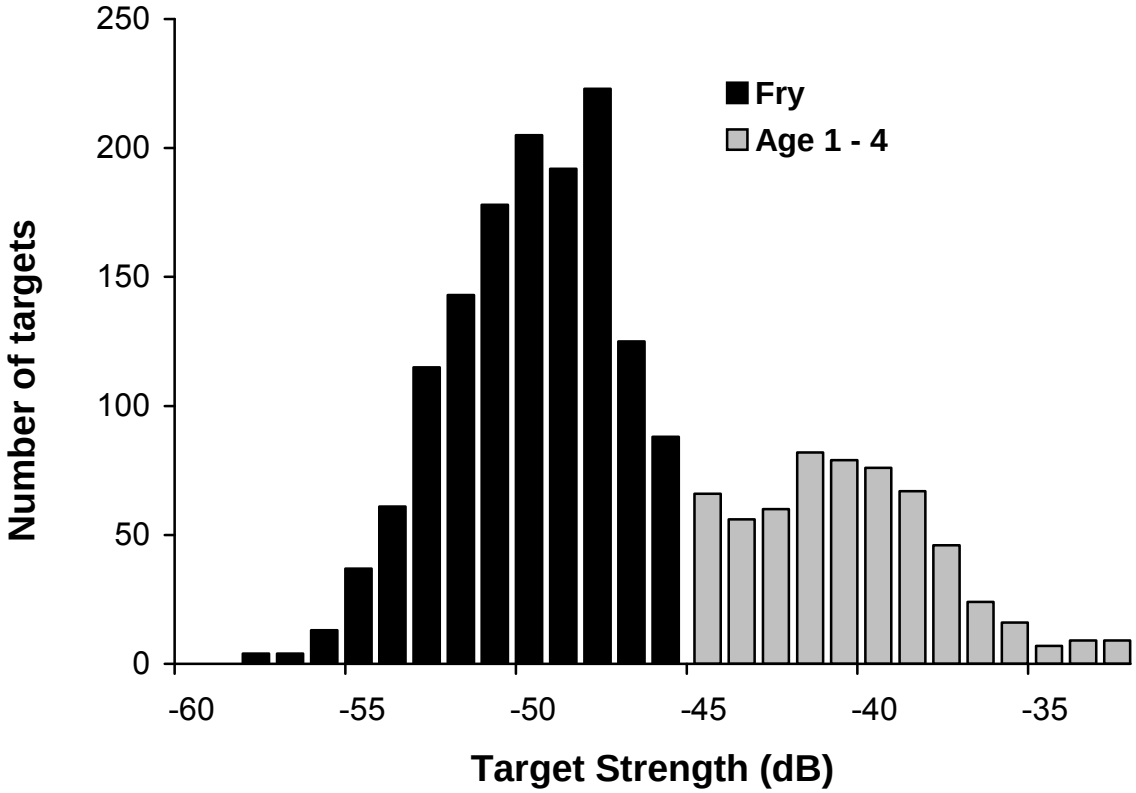


Figure 7. Target strengths of 1,987 fish recorded in Lake Pend Oreille, Idaho, during hydroacoustic surveys in August 2006, used to define the target strength break between kokanee fry and age 1 and older kokanee (>-46 dB).

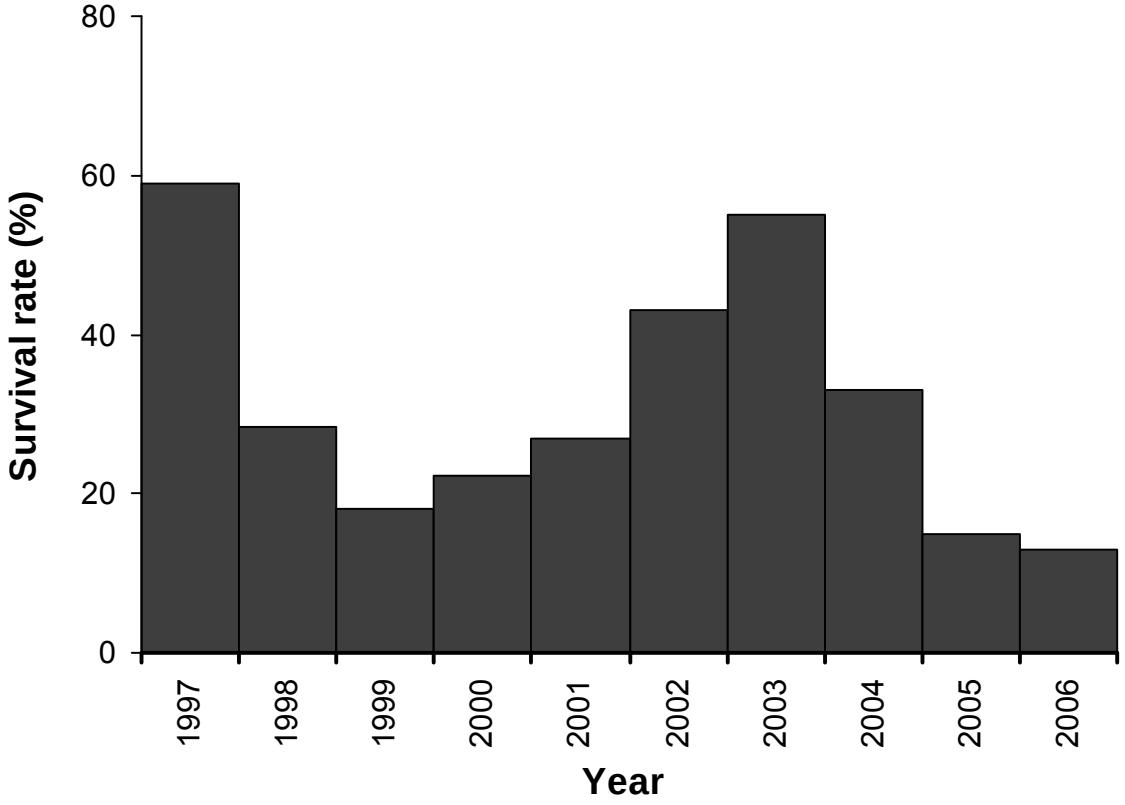


Figure 8. Survival rates of kokanee from age-1 to age-2 in Lake Pend Oreille, Idaho, based on hydroacoustic surveys conducted between 1997 and 2006.

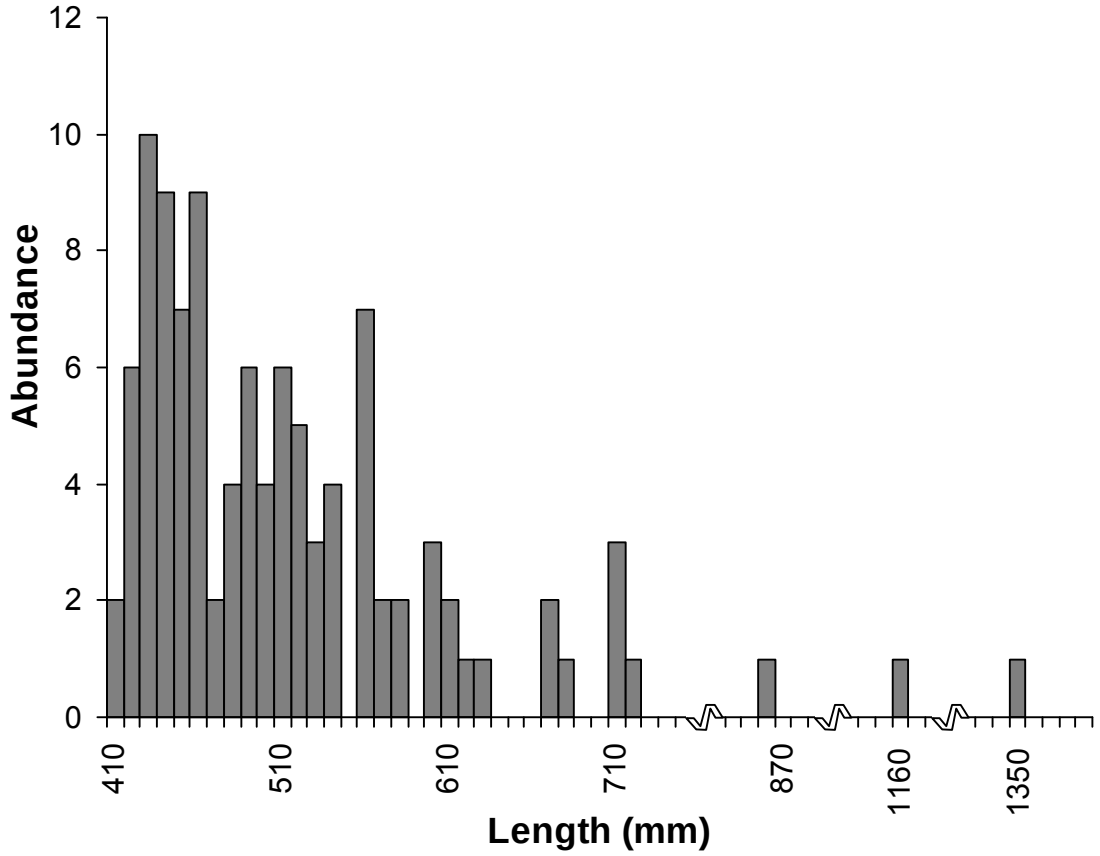


Figure 9. Length-frequency distribution of fish over -33 dB (410 mm) insonified in a down-looking hydroacoustic survey in Lake Pend Oreille, Idaho, in 2006. Decibel levels were converted to total length (mm) using Love's equation (1971).

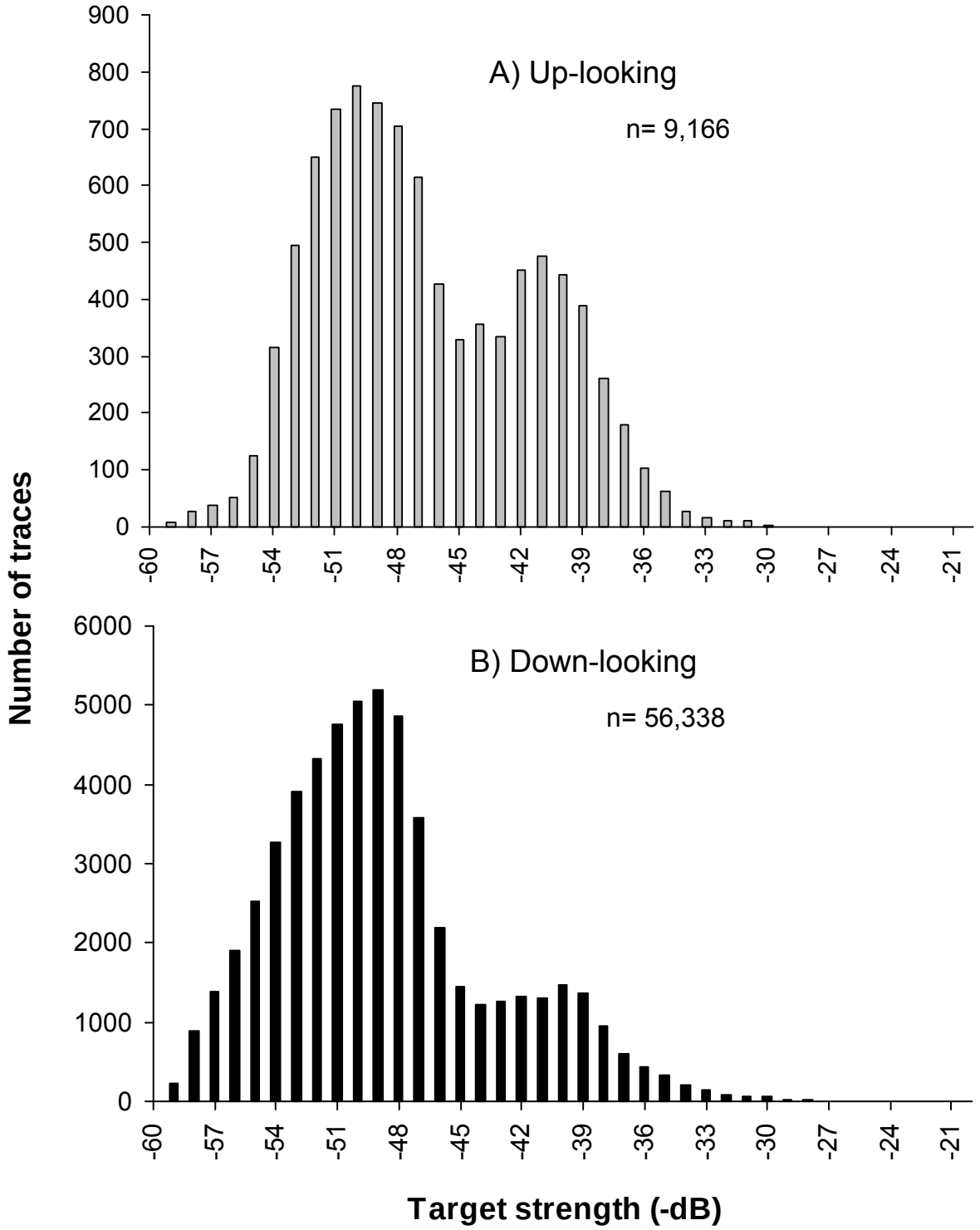


Figure 10. Target strengths of fish in Lake Pend Oreille, Idaho, as measured during up-looking (A) and down-looking (B) hydroacoustic surveys in 2006. Fish were insonified from below (A) and from above (B).

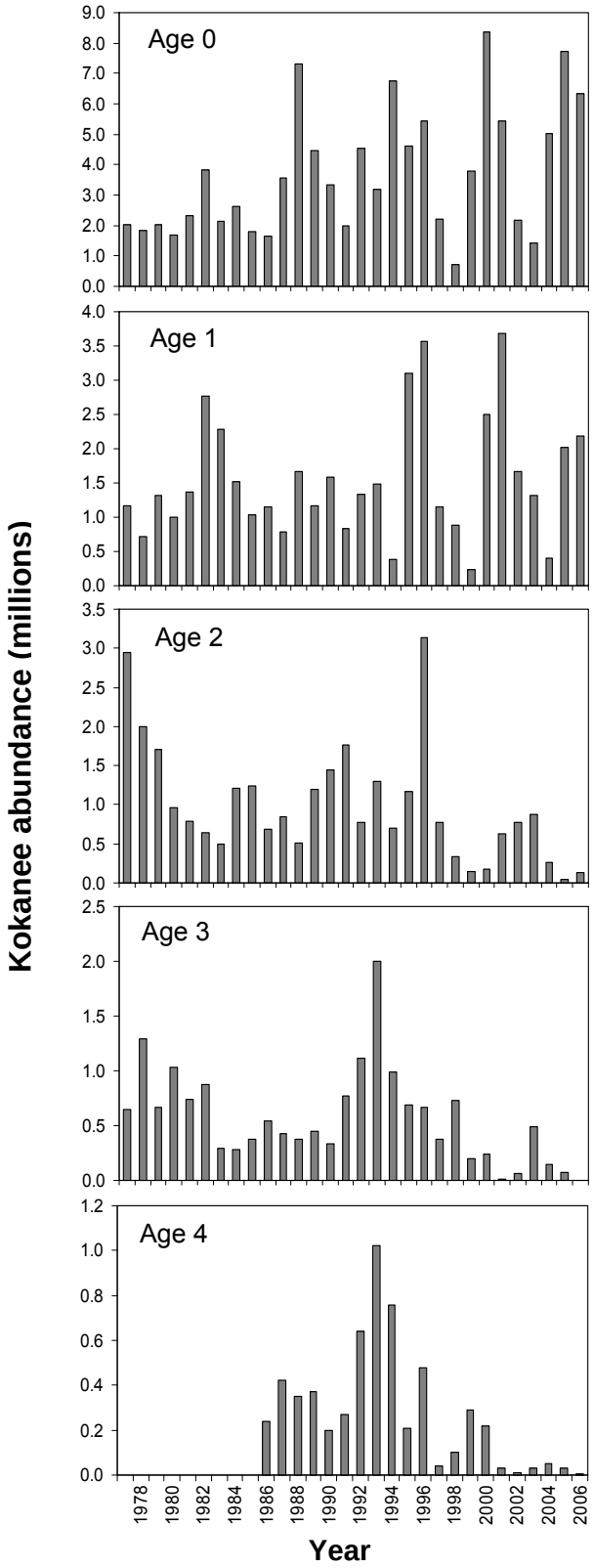


Figure 11. Kokanee year-class population estimates based on midwater trawling between 1978 and 2006. Age 3 and 4 kokanee were not separated by age prior to 1986.

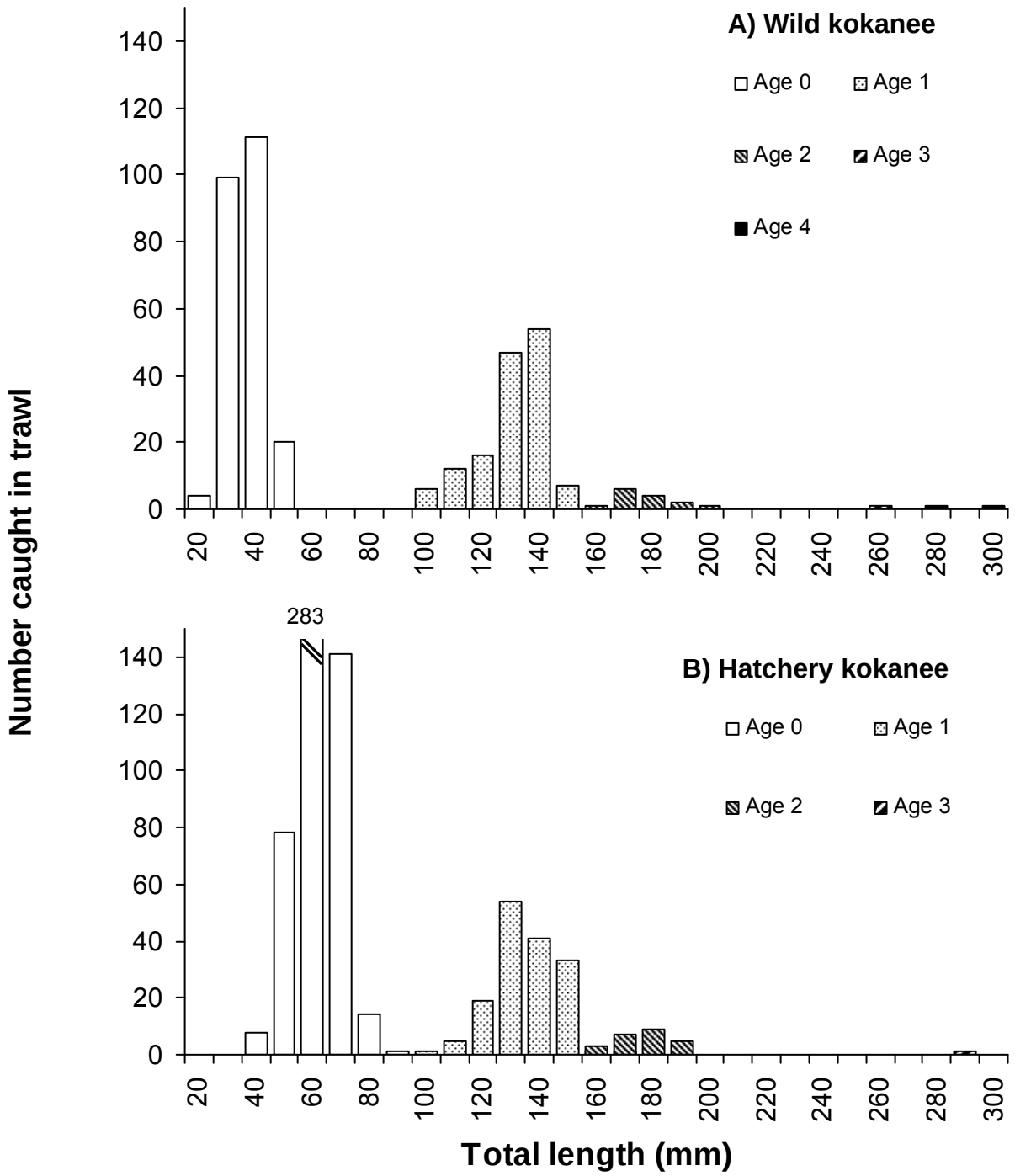


Figure 12. Length-frequency distribution of individual age classes of wild (A) and hatchery (B) kokanee caught by midwater trawling in Lake Pend Oreille, Idaho, in August 2006.

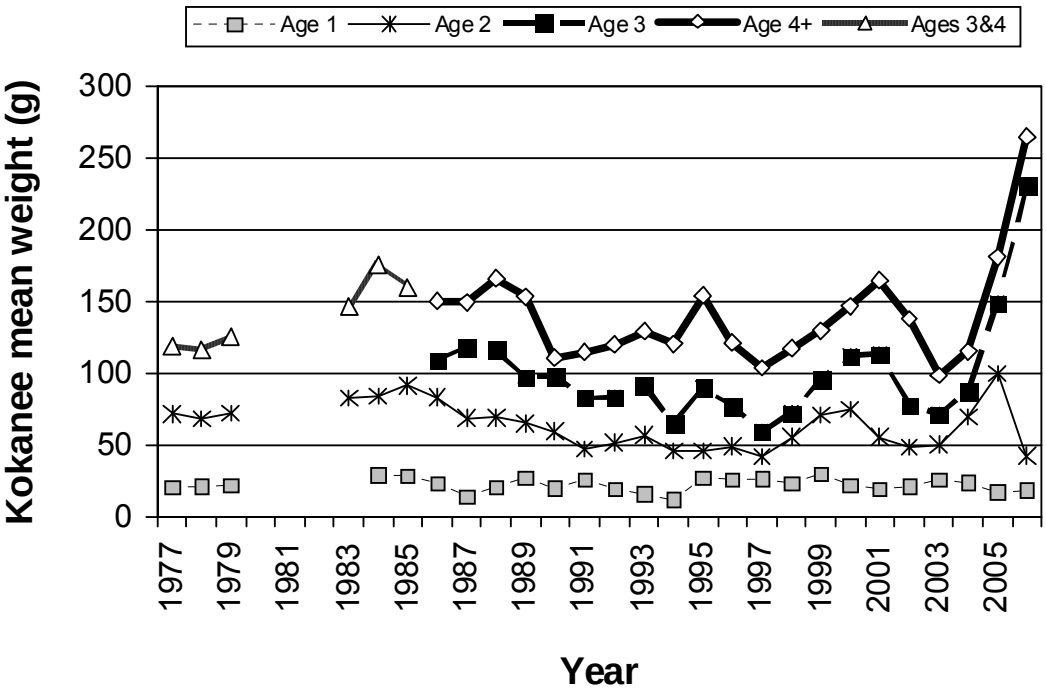


Figure 13. Mean weight (g) of age classes of kokanee from Lake Pend Oreille, Idaho, since midwater trawling began in 1977.

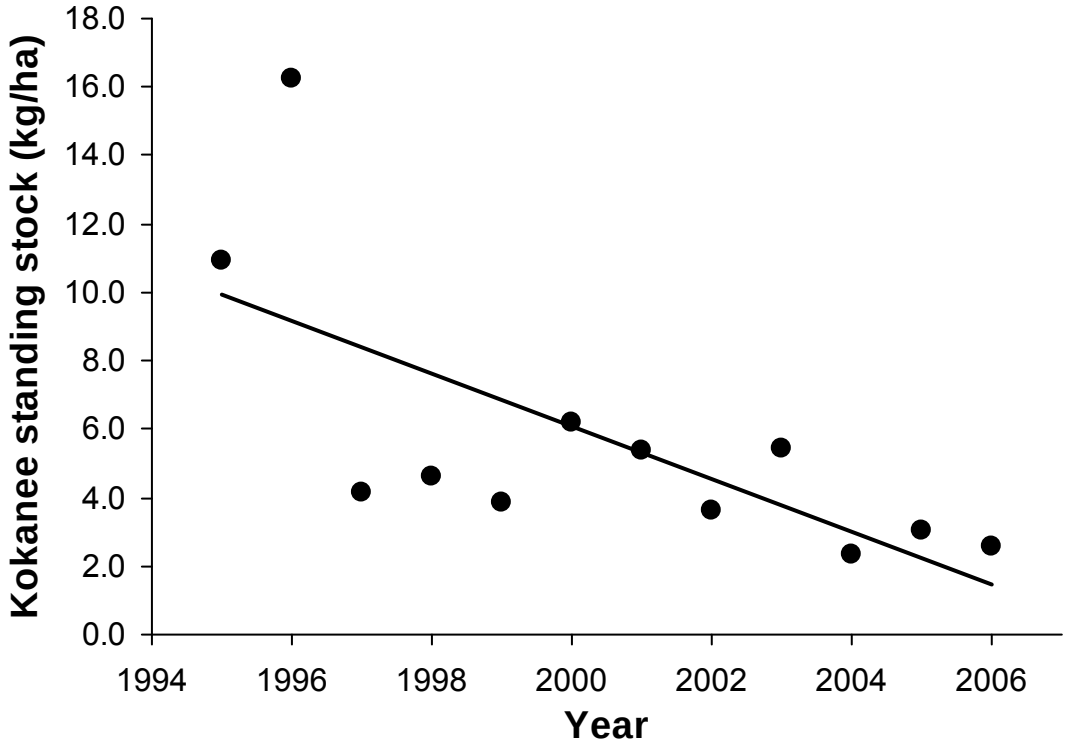


Figure 14. Annual kokanee standing stock (kg/ha) in Lake Pend Oreille, Idaho, from 1995 to 2006.

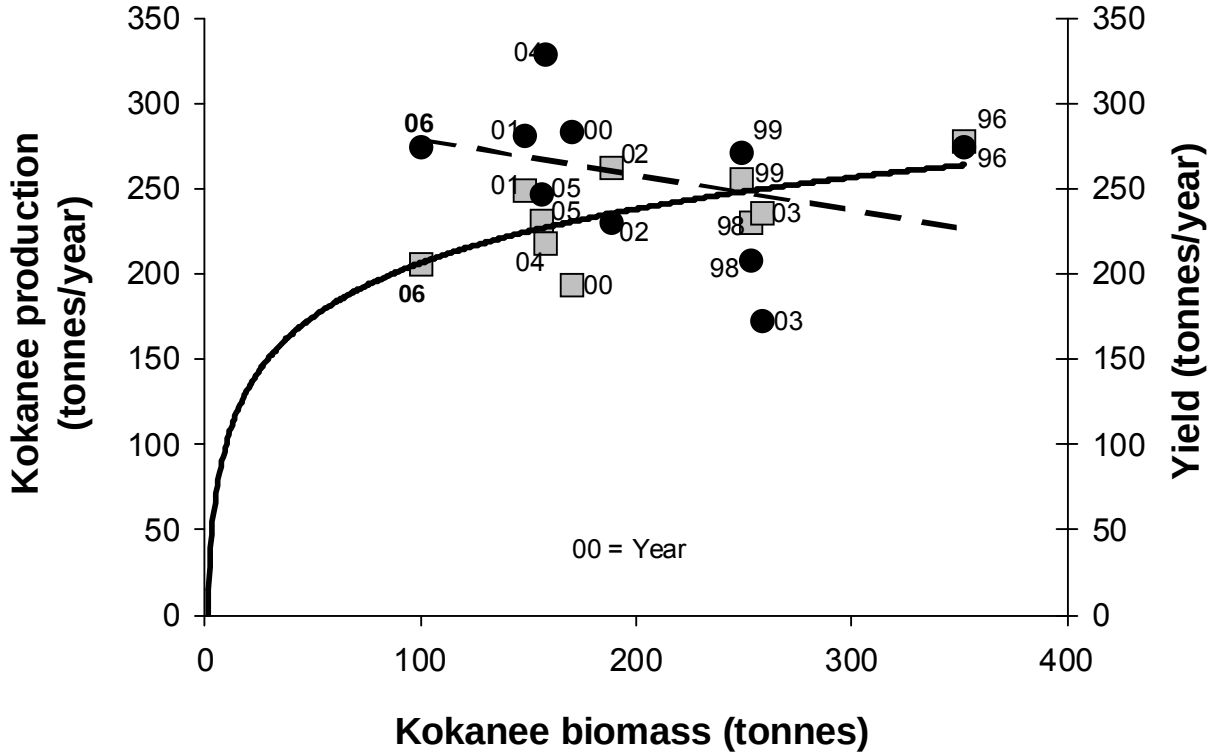


Figure 15. Kokanee biomass, production, and yield (metric tonnes) from Lake Pend Oreille, Idaho, 1996-2006, excluding 1997 due to 100 year flood. Kokanee biomass was measured at the start of the year. Gray squares indicate production and black circles indicate yield. The solid black line represents the production curve, while the dashed line is the yield trend line. Numeral by each point represents the year of the estimate.

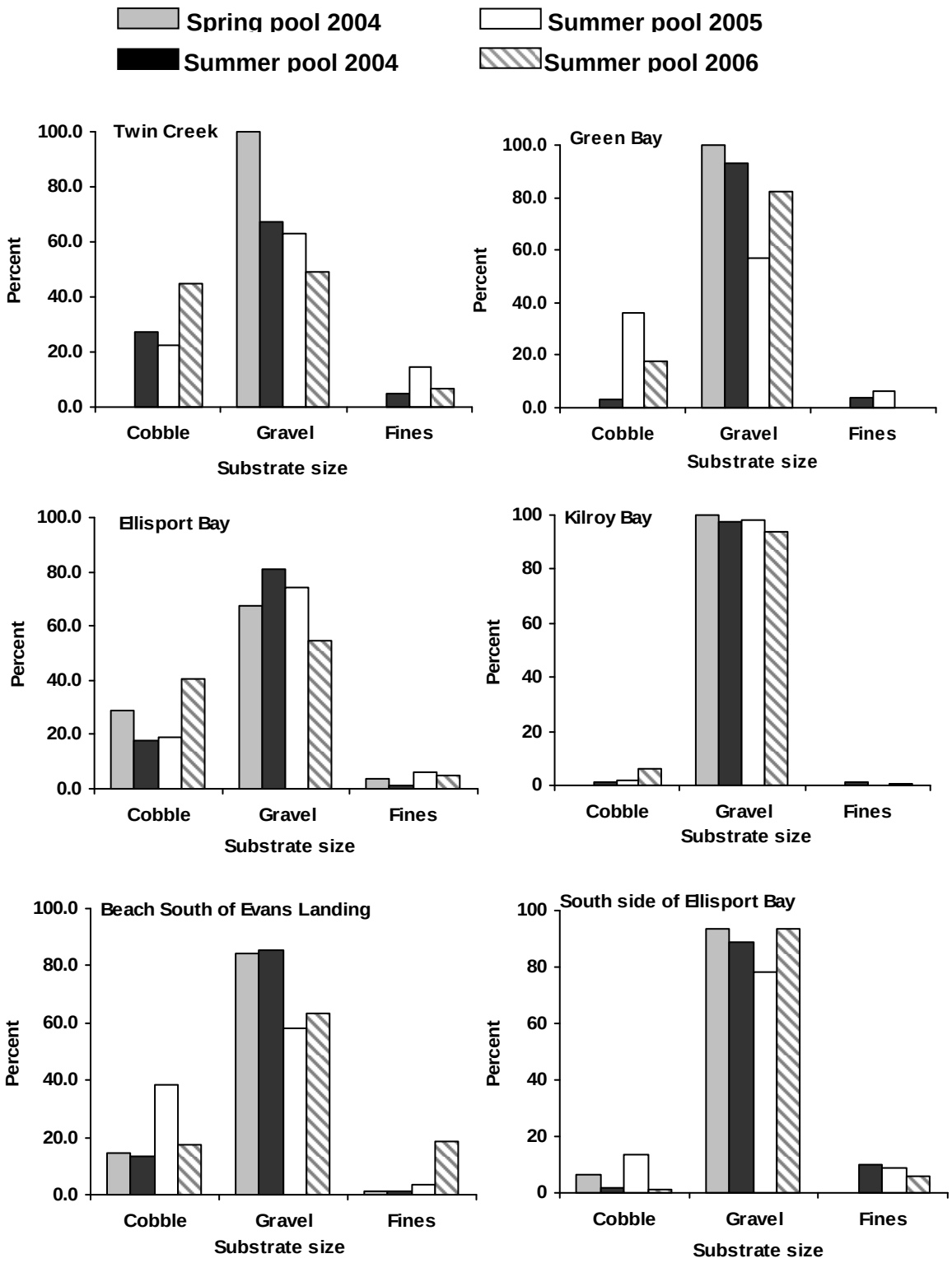


Figure 16. Substrate composition on potential kokanee spawning beaches in Lake Pend Oreille, Idaho. Sampling during spring 2004 was conducted above the water line at an elevation of 625.1 to 625.8 m while lake was at its low pool level. Other samples were collected at the same elevation by scuba diving during summer.

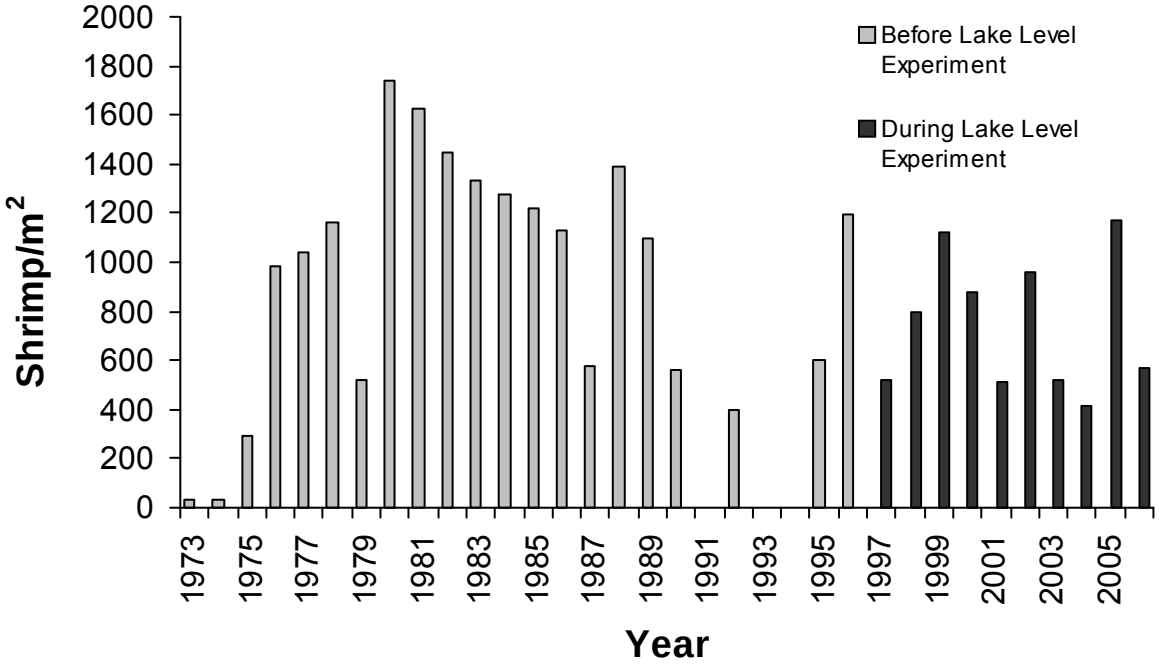


Figure 17. Annual mean density of opossum shrimp in Lake Pend Oreille, Idaho, 1973-2006. Data collected before 1989 were obtained from Bowles et al. (1991), and data from 1995 and 1996 were from Chipps (1997). Shrimp densities from 1992 and earlier were converted from Miller sampler estimates to vertical tow estimates by using the equation y = 0.5814x (Maiolie et al. 2002). Gaps in the bar chart indicate no data were collected that year.

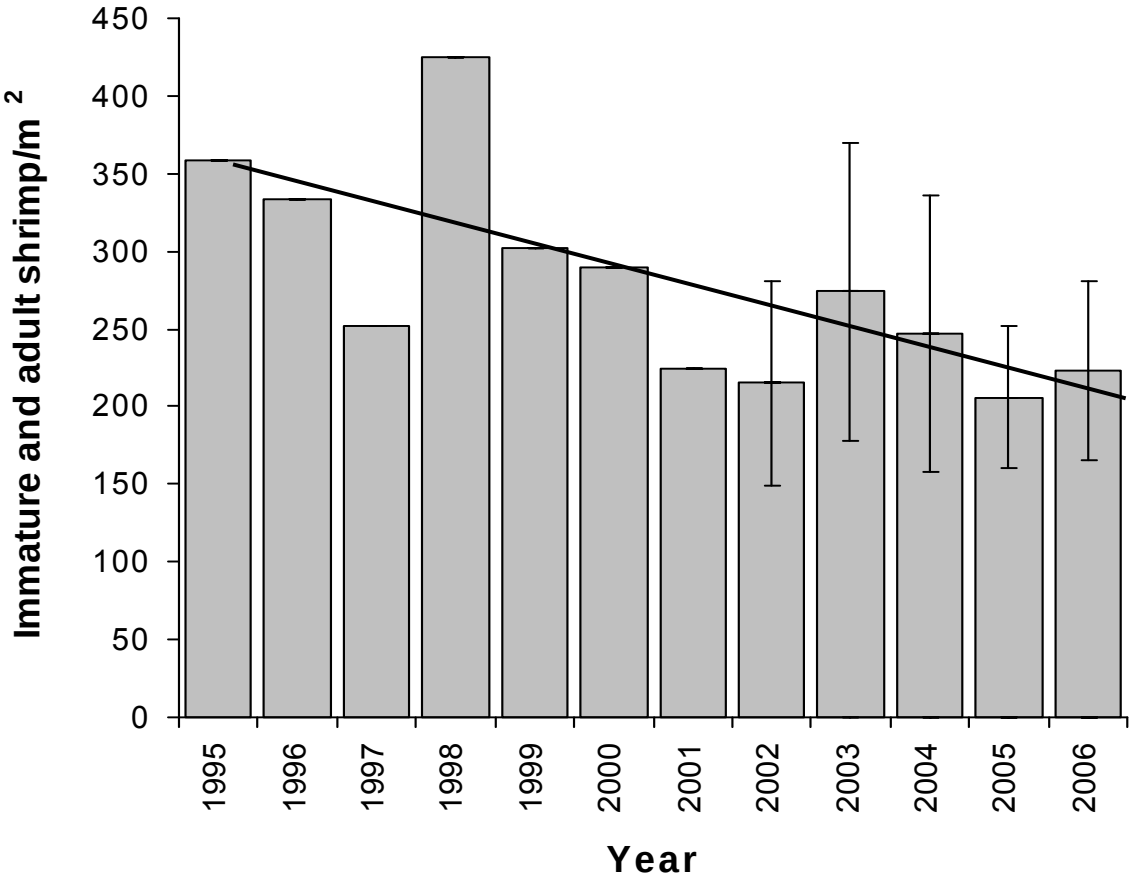


Figure 18. Density estimates of immature and adult opossum shrimp in Lake Pend Oreille, Idaho, for the past 12 years (1995-2006). A linear trend line was fit to the data points to show the apparent decline. Error bounds were also added the recent population estimates to identify 90% confidence intervals around the estimate.

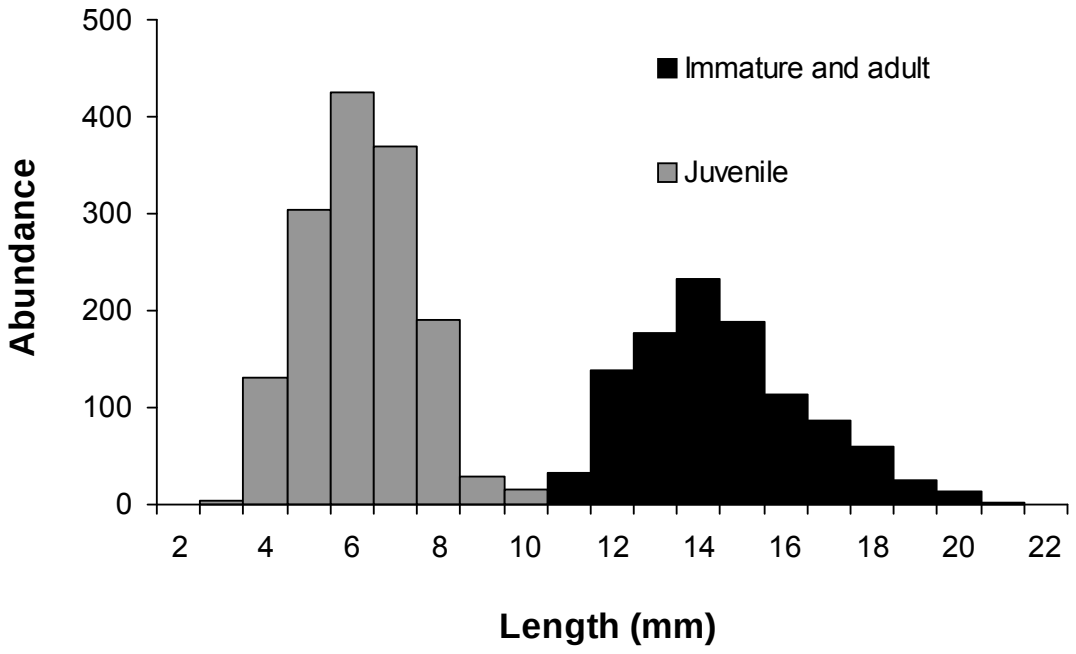


Figure 19. Mysis shrimp length frequency distribution during June 2006 on Lake Pend Oreille, Idaho.

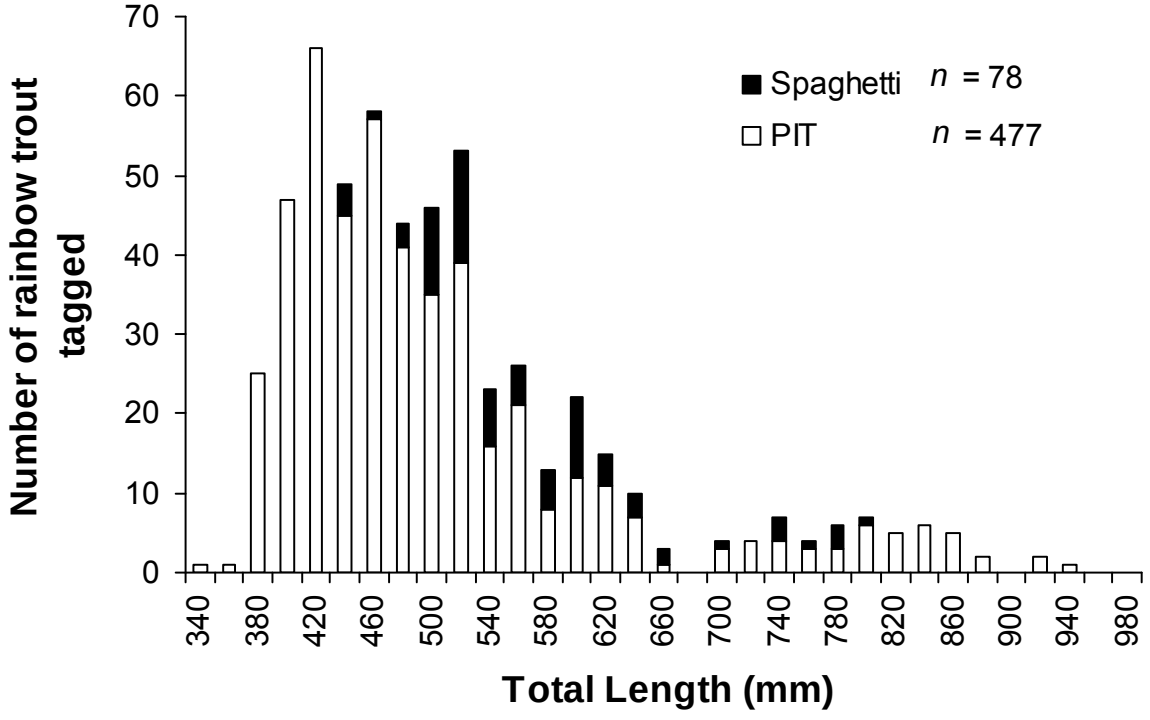


Figure 20. Length-frequency of rainbow trout tagged with spaghetti and PIT tags in Lake Pend Oreille, Idaho, during the spring of 2006 by tag type.

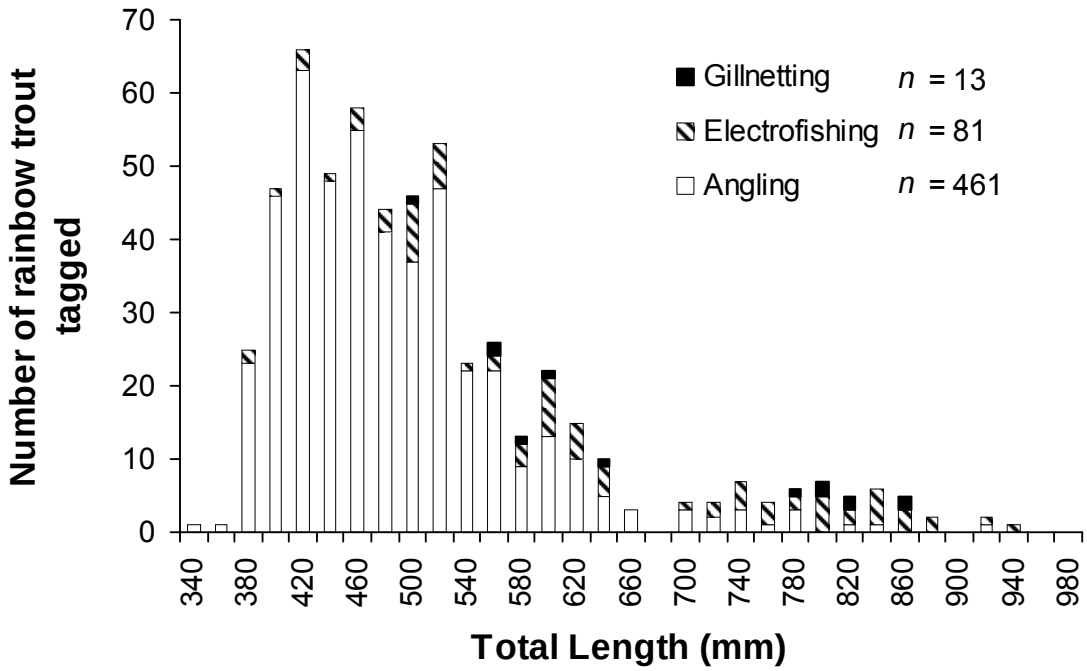


Figure 21. Length-frequency of rainbow trout tagged through gillnetting, electrofishing, and angling, in Lake Pend Oreille, Idaho, during the spring of 2006.

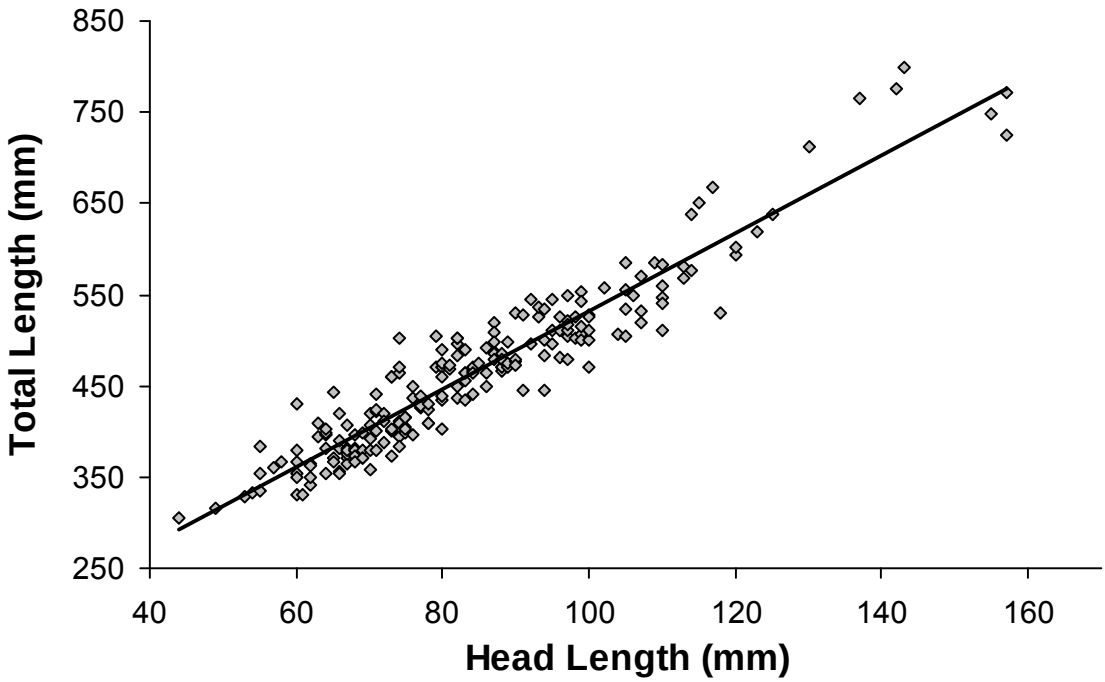


Figure 22. The relationship between head length (mm) and total length (mm) of rainbow trout captured from Lake Pend Oreille, Idaho. The equation of the line is total length (mm) = 4.278 head length (mm) + 103.72 (r^2 = 0.90, n = 209).

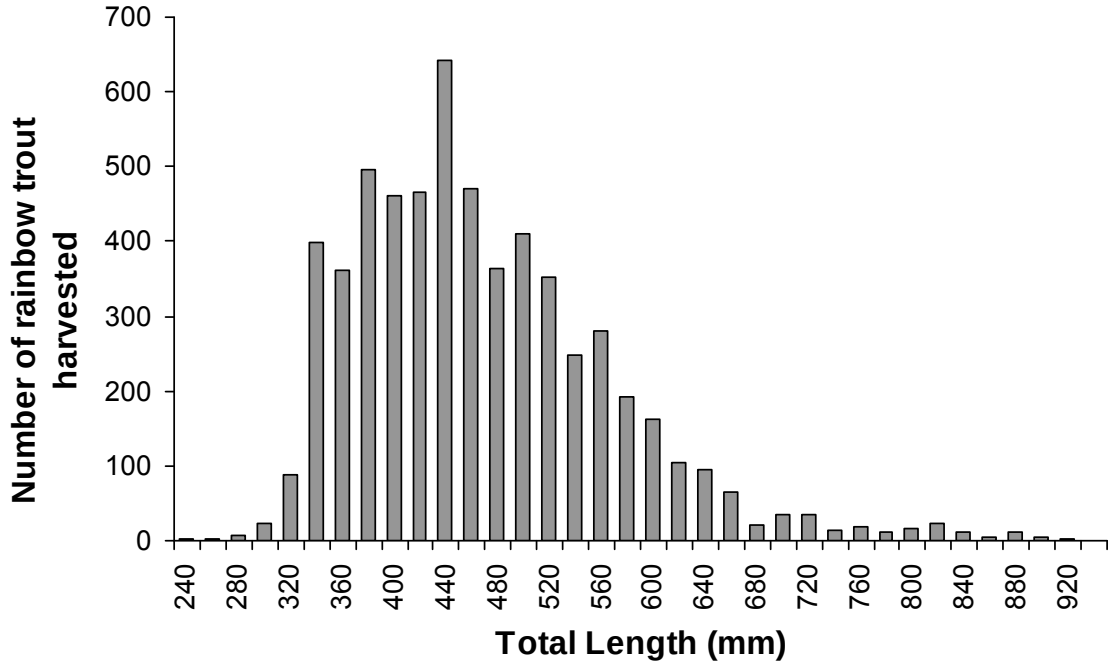


Figure 23. Length-frequency of 5,907 rainbow trout harvested by anglers between May and December 2006 in Lake Pend Oreille, Idaho. Total lengths were derived from the head length-total length regression for rainbow trout in Lake Pend Oreille obtained during the spring of 2006.

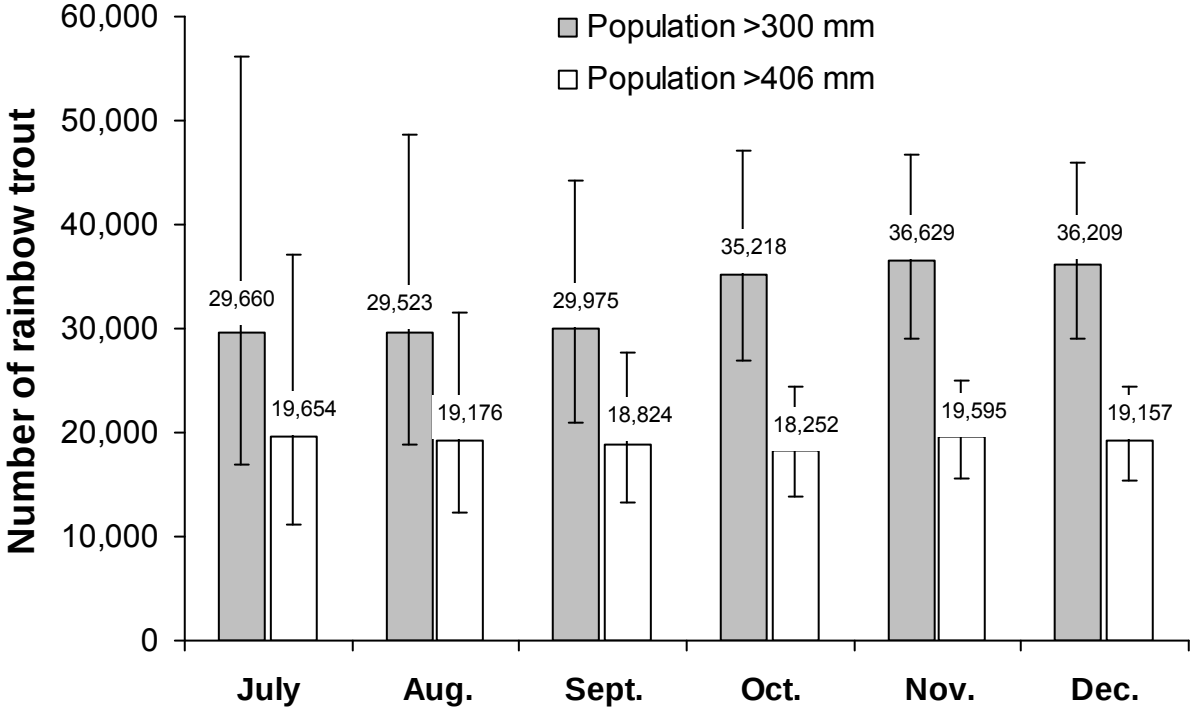


Figure 24. Monthly population estimates of rainbow trout >300 mm and >406mm in Lake Pend Oreille, Idaho, during 2006.

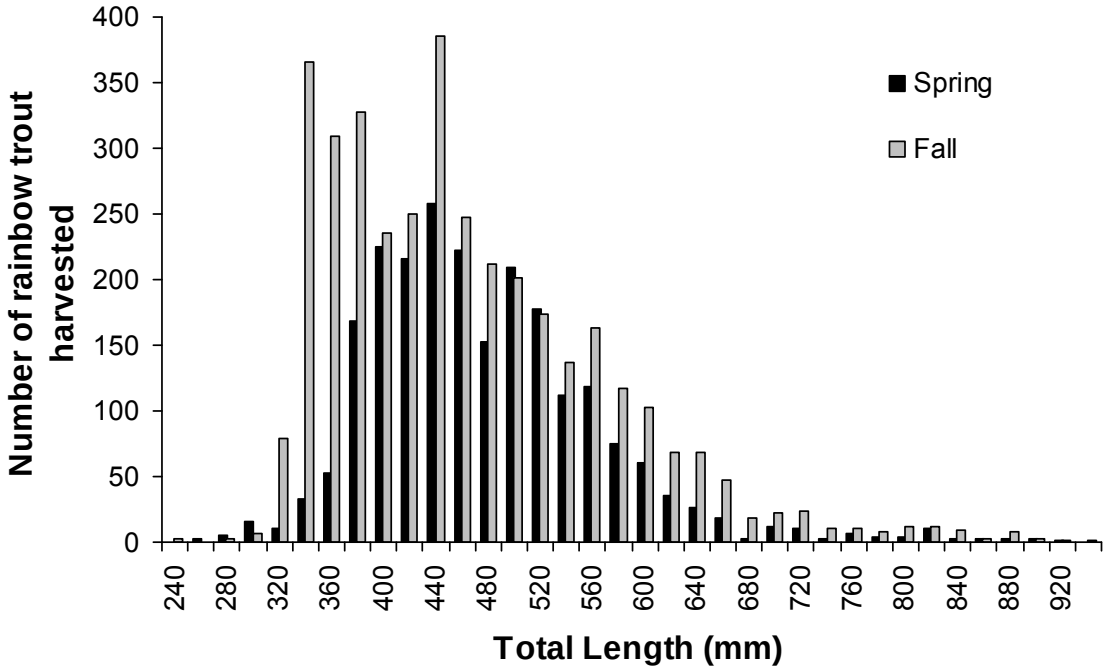


Figure 25. Length-frequency of rainbow trout captured during the spring and fall of 2006 in Lake Pend Oreille, Idaho. Total lengths were derived from the head length-total length regression for rainbow trout in Lake Pend Oreille obtained during the spring of 2006.

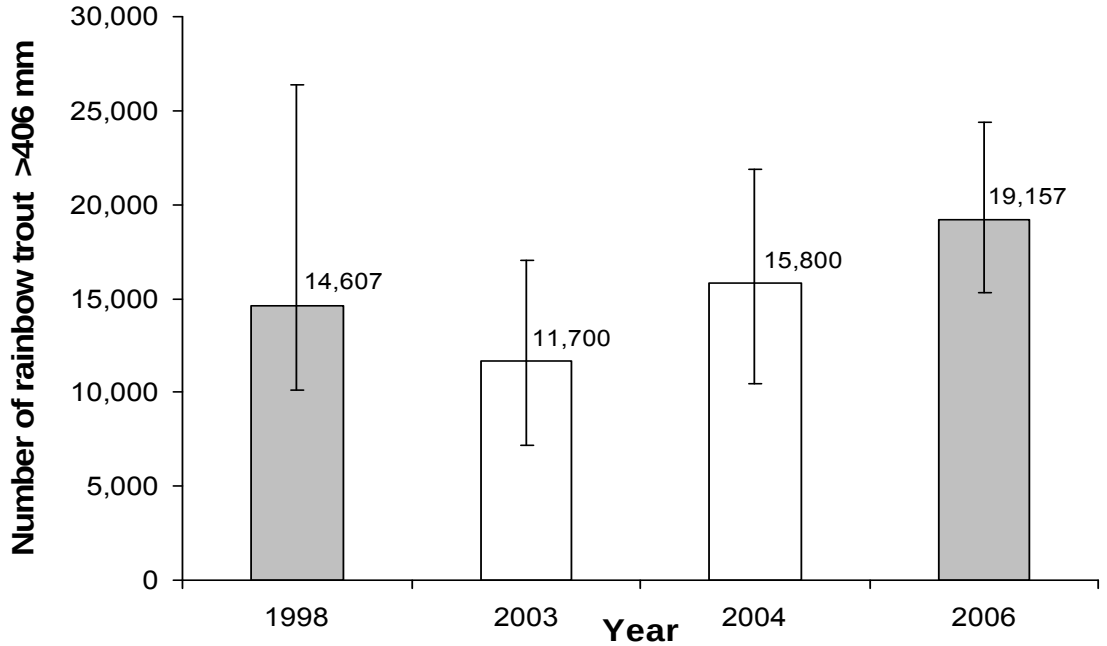


Figure 26. Rainbow trout population estimates (± 95% confidence intervals) for Lake Pend Oreille, Idaho, from 1998 to 2006. Population estimate data for 1998, 2003, and 2004 are from Vidergar (2000), Bassista et al. (2005), and Maiolie et al. (2006), respectively. The population was estimated by mark-recapture in 1998 and 2006, while estimates in 2003 and 2004 used hydroacoustics.

APPENDICES

Appendix A. Transceiver settings for the Simrad EK 60 echo sounder used for down-looking (short cord) and up-looking (long cord) surveys on Lake Pend Oreille, Idaho during August 2006.

Calibration date:	July 18, 2006	July 18, 2006
Setting	Short Cord	Long Cord
Transducer: Simrad	Split Beam 120-7C	Split Beam 120-7C
Absorption Coefficient (dB/m)	.004249	.004249
Sound Speed (m/s)	1452	1452
Transmitted Power (w)	500	500
Two-way Beam Angle (dB re: 1 steradian)	-21.00	-21.00
Transducer Gain (dB)	26.44	24.34
SA Correction (dB)	-0.53	-0.47
Transmitted Pulse Length(ms)	0.256	0.256
Frequency (kHz)	120 kHz	120 kHz
Minor-Axis Angle Offset (degrees along)	0.01	-0.02
Major- axis Angle Offset (degrees Athwart)	0.02	-0.02
Major Axis 3 dB Angle (degrees)	6.59	6.46
Minor Axis 3 dB Angle (degrees)	6.59	6.45
Athwart Angle Sensitivity	23.00	23.00
Along Angle Sensitivity	23.00	23.00
Depth of Calibration Sphere (m)	~25 m	~25 m
Depth of Transducer (m)	0.32	0.32
Receiver Band (kHz)	8.71	8.71
Water Temp at Mid Depth (^{o}C)	11°	11°

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

Scenic Bay

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

Farragut State Park

- From state park boat ramp go both left and right approximately 1/3 km.
- Idlewild Bay, From Buttonhook Bay north to the north end of the swimming area parking lot.

Lakeview

- From mouth of North Gold Creek go north 100 meters and south 1/2 km.

Hope/East Hope

- Start at the east end of the boat launch overpass and go west 1/3 km.
- From Strong Creek go west and stop at Highway 200. Go east to Lighthouse Restaurant.
- Start at East Hope Marina and go west stopping at Highway 200.

Trestle Creek Area

- From the Army Corps of Engineers recreational area boat ramp go west to mouth of Trestle Creek, including Jeb and Margaret's RV boat basin area.

Sunnyside

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

Garfield Bay

- Along docks at Harbor Marina on east side of bay.
- From the public boat ramp go southwest toward Garfield Creek. Cross Garfield Creek and proceed 1/4 km.
    - Survey Garfield Creek up to road culvert.

Camp Bay

- Entire area within confines of Camp Bay.

Fisherman's Island

- Entire Island Shoreline - not surveyed since 1978.

Anderson Point

- Not surveyed since 1978.

Prepared by:

Melo A. Maiolie
Principal Fishery Research Biologist

Gregory P. Schoby
Senior Fishery Research Biologist

William J. Ament
Senior Fishery Technician

William Harryman
Senior Fishery Technician

Approved by:

IDAHO DEPARTMENT OF FISH AND GAME

_____
Edward B. Schriever, Chief
Bureau of Fisheries

_____
Daniel J. Schill
Fisheries Research Manager