FISHERY RESEARCH

LAKE PEND OREILLE FISHERY RECOVERY PROJECT

COMPLETION REPORT
October 1, 1996 – December 31, 2001

Prepared by:

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IDFG Report Number 02-56
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CHAPTER 1: LAKE LEVEL CHANGES AND THEIR EFFECT ON KOKANEE SURVIVAL

ABSTRACT

The winter elevation of Lake Pend Oreille, Idaho was changed in an attempt to enhance shoreline spawning areas for kokanee. Winter lake elevations were kept 1.2 m higher than full drawdown for three years (winters of 1996-97, 1997-98, and 1998-99) and 0.6 m higher than full drawdown for the next two years (1999-00 and 2000-01). Kokanee egg-to-fry survival increased more than 150% (from a mean of 3.2% to 8.1%) during the years of elevated lake levels (excluding 1997) ($p = 0.06$). The only year not showing a substantial improvement was 1997, a year with the highest spring flows on record. Egg-to-fry survival was positively correlated to the amount of change in elevation of the lake ($r^2 = 0.85$). During years of elevated water levels, kokanee utilized the shallow, newly inundated gravel and had a modal spawning depth of 1.2 m. During a full drawdown year, kokanee spawned at deeper depths with a modal spawning depth of 4.0 m. Egg-to-fry survival rates did not correlate well to warmer water conditions, the number of hatchery kokanee stocked, or the abundance of opossum shrimp in the lake. These findings lead to the conclusion that lake level manipulations can be used to recover the kokanee population in Lake Pend Oreille.

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INTRODUCTION

Lake Pend Oreille historically provided the largest sport fishery in Idaho. From 1952 until 1966, it produced an angler harvest that averaged one million kokanee annually. Kokanee attracted most of the fishing effort and was an extremely popular fishery. At its peak in 1953, total fishing effort was 522,700 hours and harvest was 1.3 million kokanee (Jeppson 1954). To put this into perspective, on a single day in 1953, 863 fishermen were fishing the Bayview section of the lake (approximately the southern third of the lake). This sport fishery was extremely important to local communities based on the amount of angler participation.

Harvest of kokanee began a prolonged, steady decline in the mid-1960s. By this time, Cabinet Gorge Dam had been built (1952), which blocked kokanee from spawning in the Clark Fork River and caused the population to be largely dependent on shoreline spawning. Kokanee need areas of gravel that are relatively free from silt and sand (<30%) to have good survival as the eggs incubate. Shoreline spawning success was also influenced by the operation of Albeni Falls Dam (Maiolie and Elam 1993). In 1966, the dam began a pattern of operation that lowered lake levels 3.5 m (11.5 feet) each fall. Drawdowns were finished immediately before kokanee began spawning on the shorelines. These consistently deep drawdowns reduced the amount of gravel available for kokanee spawning along the lake's shorelines (Fredericks et al. 1995).

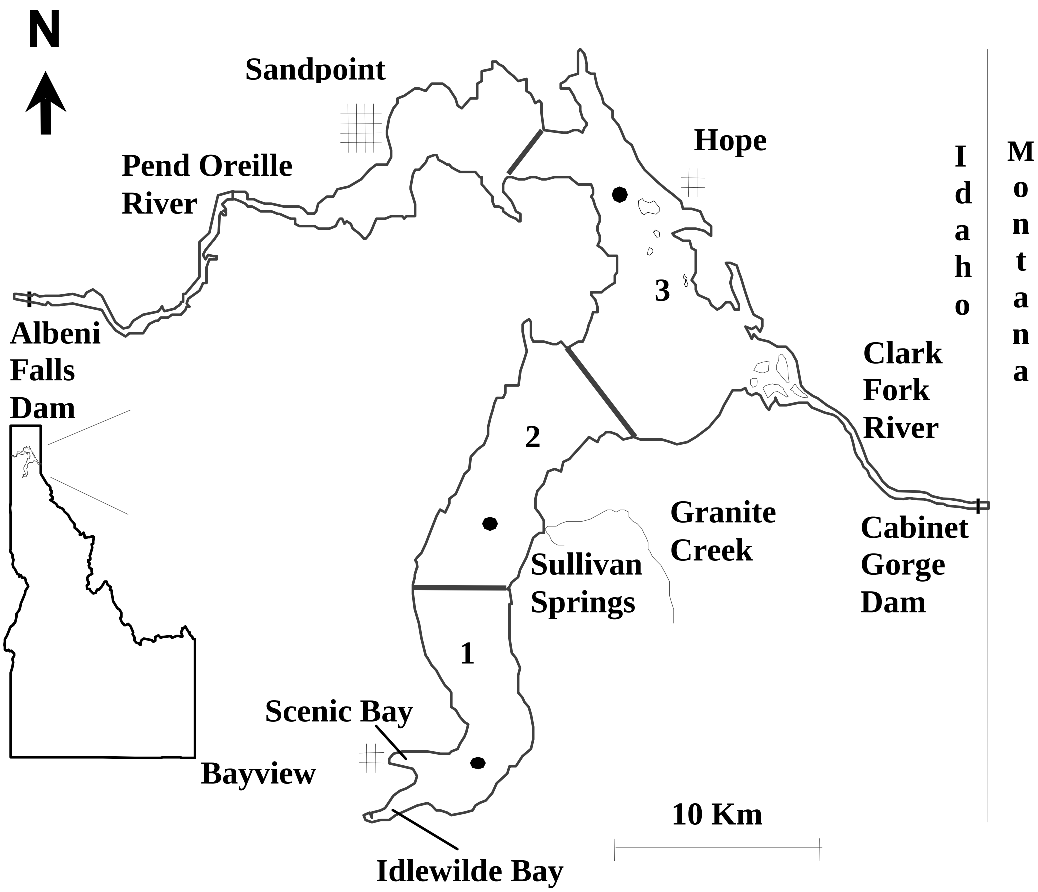
Idaho Department of Fish and Game recognized the need to change lake levels to enhance kokanee spawning in 1991. In 1996, the U.S. Army Corps of Engineers changed the drawdown of the lake as recommended by the Northwest Power Planning Council. These changes were made on a temporary basis to determine whether an altered drawdown of the lake could be used to recover the impacted kokanee population. In this chapter, we examined the effects on kokanee recruitment of a higher winter pool level that provided enhanced spawning areas on the shoreline.

STUDY AREA

Lake Pend Oreille is located in the northern panhandle of Idaho (Figure 1.1). It is the state’s largest lake and has a surface area of 38,300 ha, a mean depth of 164 m, and a maximum depth of 351 m. Summer pool elevation of Lake Pend Oreille is 628.7 m. Pelagic habitat used by kokanee is considered to be 22,546 ha (Bowler 1978). The Clark Fork River is the largest tributary to the lake. Outflow from the lake forms the Pend Oreille River.

Lake Pend Oreille is a temperate, oligotrophic lake. The average summer water temperature (May to October) is approximately 9°C in the upper 45 m of water (Rieman 1977; Bowles et al. 1987, 1988, 1989). Thermal stratification typically occurs from late June to September. Operation of Albeni Falls Dam on the Pend Oreille River keeps the lake level high and stable at about 628.7 m from July through September, followed by lower lake levels of 625.1 m during fall and winter. This was typical dam operation between 1966 and 1996, although the minimum elevation varied between years (Figure 1.2).

A wide diversity of fish species is present in Lake Pend Oreille. Kokanee migrated downstream from Flathead Lake in the early 1930s and were well established by the 1940s. Other game fish include: Gerrard rainbow trout *Oncorhynchus mykiss*, bull trout *Salvelinus confluentus,* westslope cutthroat trout *Oncorhynchus clarki lewisi*, lake whitefish *Coregonus clupeaformis,* mountain whitefish *Prosopium williamsoni*, and lake trout *Salvelinus namaycush*, in addition to several other cool and warm water species.



● - Limnology stations

Section	Area (hectares)
1	6,386
2	7,776
3	8,384

Figure 1.1. Map of Lake Pend Oreille, Idaho, showing prominent landmarks and the three lake sections used in sampling. Inserted table shows the amount of kokanee habitat in each lake section.

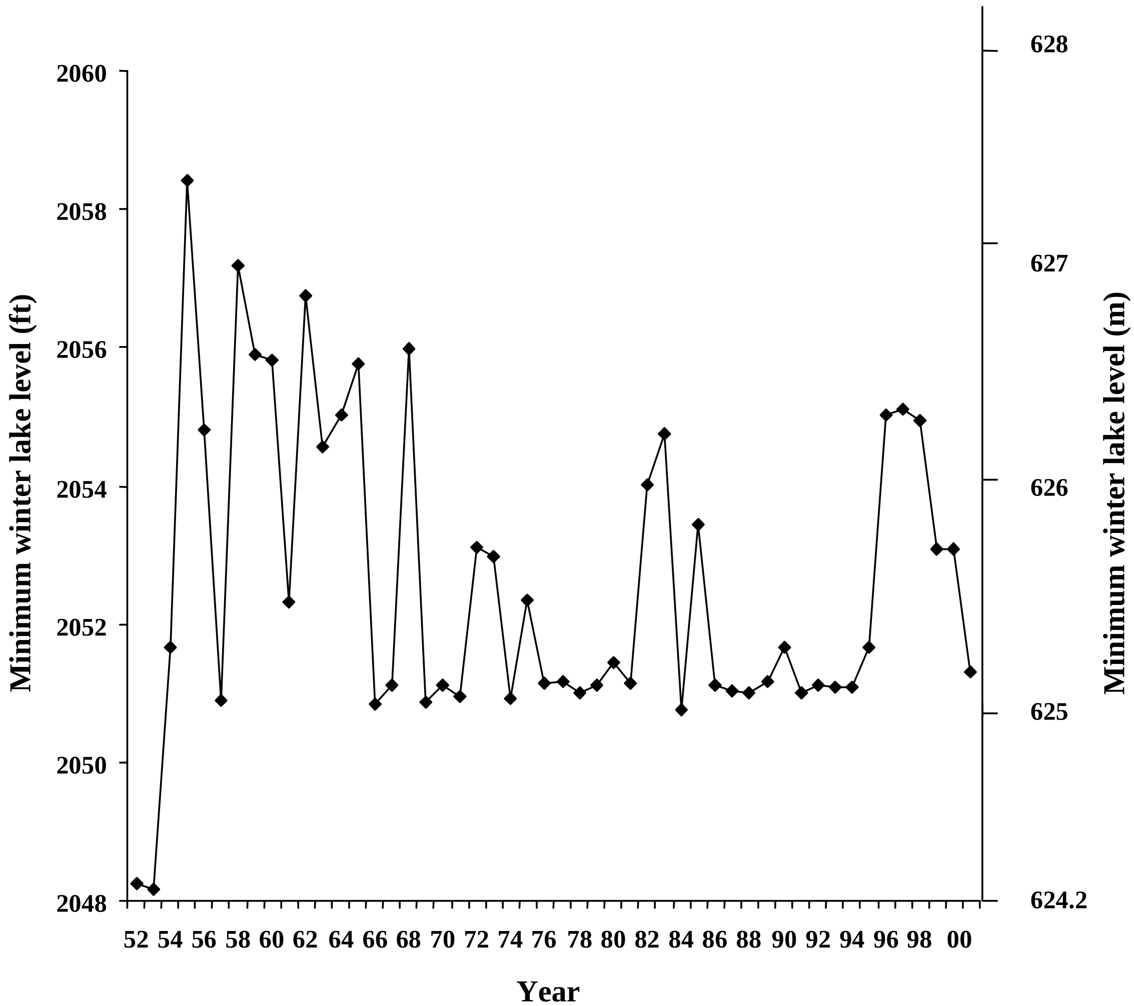


Figure 1.2. Minimum lake levels of Lake Pend Oreille, Idaho, 1952-2001. Data provided by the U.S. Army Corps of Engineers at Albeni Falls Dam. Note the pattern of lower lake levels after 1966.

METHODS

The overall approach of this study was to change the winter elevation of Lake Pend Oreille and then monitor the resulting changes in the kokanee population. The most sensitive variable was the survival rate between naturally spawned eggs and wild (non-hatchery) fry. This wild egg-to-fry survival was estimated three ways: 1) taking the hydroacoustic estimate of fry for each section of the lake and multiplying it times the percent of wild fry in each section based on the midwater trawl catch, and then dividing by the potential wild egg deposition (wild PED) as estimated by midwater trawling; 2) estimating the abundance of fry, and the percentage that were wild, in each section of the lake by a separate collection using a smaller, fine mesh, fry net, and then dividing by the potential wild PED as estimated by midwater trawling; and 3) taking the hydroacoustic estimate of fry for each section of the lake and multiplying it times the percent of wild fry in each section based on the percent of wild kokanee fry collected with the fry net, and then dividing by the potential wild PED as estimated by midwater trawling. The former method was calculated for each year of the study and the latter two methods were calculated from 1999 to 2001.

Lake Level Changes

Since consistent drawdowns to 625.1 m (2051 ft above mean sea level) were implicated in the declines of kokanee (Maiolie and Elam 1993), the lake level experiment was designed to determine if higher minimum lake levels would benefit the population. Thus, the test was to compare kokanee survival during years of full drawdown to their survival when the lake level was held higher. This test, therefore, took an adaptive management approach. The identified limiting factors of the system were examined and changed to see if the survival rate of kokanee fry would improve.

Lake Pend Oreille was drawn down to nearly its full extent in 1994 and 1995: 625.4 m and 625.3 m, respectively. Kokanee survival during these years served as baseline data for this experiment. However, the drawdown in fall of 1995 was somewhat unusual in that the lake was lowered to 625.3 m on November 24, then raised to 626.5 m on December 5. Kokanee, therefore, could spawn at a higher lake elevation in the second half of the spawning season. Lake levels remained above 626.4 m for the remainder of the winter.

During the first three winters of elevated lake levels (1996-97, 1997-98, and 1998-99), the winter lake elevation was held above 626.4 m (2055 ft), which was 1.2 m higher than most previous years in the last three decades (Figure 1.3). During the next two winters (1999-00 and 2000-01), the winter lake level was held above 625.8 m (2053 feet) or 0.6 m higher than most previous years. The original study design was for the lake to be at its low pool level (625.1 m) in 1999 and 2000, but it was held higher due to legal action over lake levels.

During this study, as in most years since 1966, the lake was lowered to its winter pool level prior to the peak of the kokanee-spawning season. This was to minimize the damage to redds caused by dropping the lake level after eggs were laid. We compared our estimates of kokanee fry survival and abundance under each of these drawdown regimes. At the onset of the experiment, we defined a >26% increase in egg-to-fry survival as one of the criteria for a successful test (Maiolie 1996).

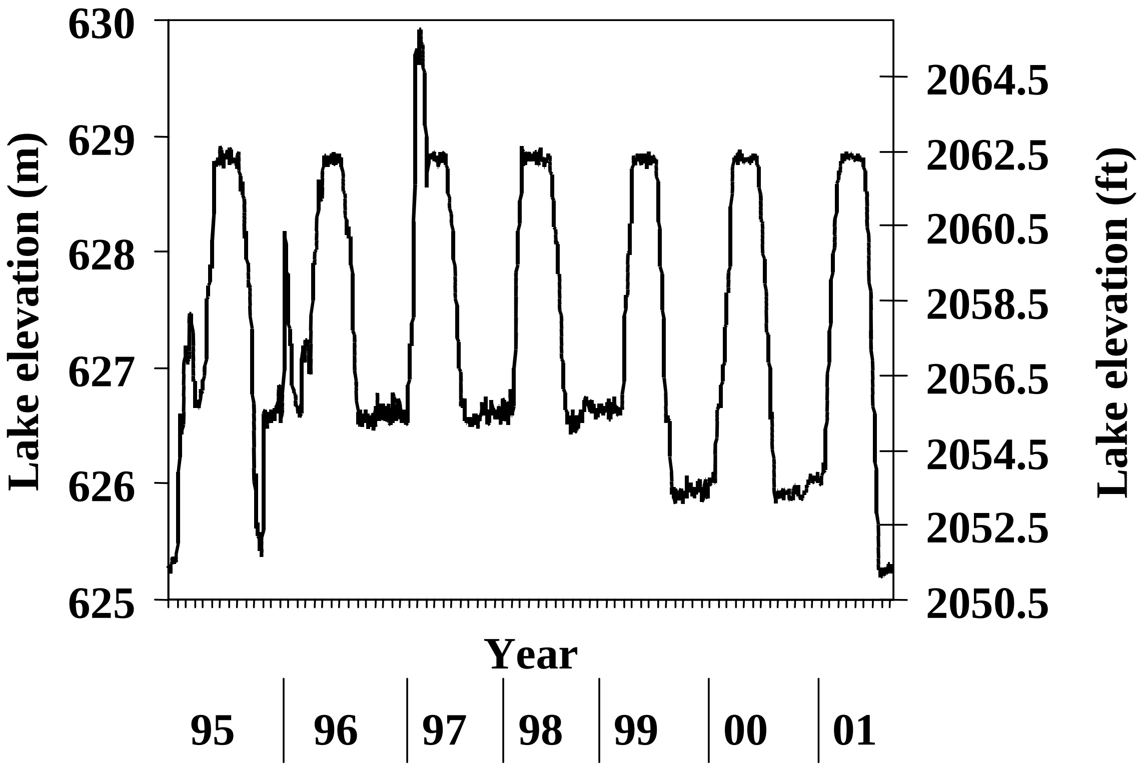


Figure 1.3. Monthly average water level of Lake Pend Oreille, Idaho, 1995-2001.

Hydroacoustics

We conducted hydroacoustic surveys on Lake Pend Oreille between mid-August and mid-September in 1995-2001. Transect selection was determined by a stratified-random or a stratified uniform approach (Figure 1.4). All hydroacoustic surveys were conducted at night and took approximately four consecutive nights to complete. A Simrad EY500 portable scientific echo sounder set to ping at 1.0 s intervals was used for the surveys. The echo sounder was calibrated annually for signal attenuation to the sides of the acoustic axis using Simrad's Lobe program. In addition, calibration of the echo sounder was checked using a 23 mm copper calibration sphere before the start of the surveys and gains adjusted to achieve the correct target strengths. Data collected during the surveys were analyzed using Simrad EP500 software version 5.2 (Figure 1.5).

The mean target strengths of at least 300 kokanee were "trace tracked" annually to separate age classes of kokanee. To be considered a fish in the trace track, the fish had to be detected (pinged) at least twice, not move more than 30 cm vertically between detections, and not missed by more than one ping during the tracking. A bar graph of target strengths versus frequency was drawn each year (Figure 1.6). We used the low points on the graph to define the breaks between fry and all other age classes of fish (older age classes could not be separated on the basis of target strengths). Density estimates of kokanee fry and older age classes were averaged within lake sections and multiplied by the area of each section (Figure 1.1) to obtain population estimates. Abundance of each older age class of kokanee was estimated based on its percent frequency within trawl samples for each section of the lake.

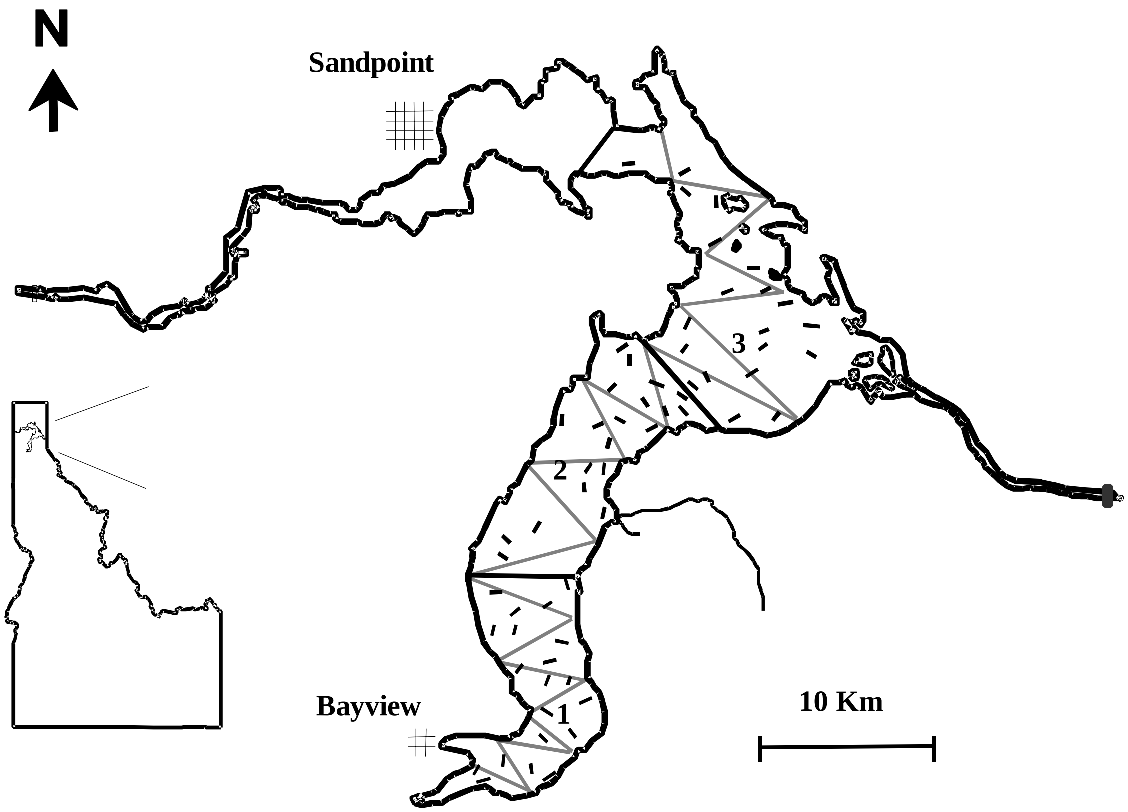
To estimate the abundance of hatchery and wild fry, we took the total estimate of fry in each section of the lake based on hydroacoustics and multiplied it by the proportion of each type of fry collected in the midwater trawl samples for that section. Section totals were summed to get lake-wide abundance estimates of hatchery and wild fry. Fry in the trawl samples had their otoliths sent to Washington Department of Fisheries and Wildlife to determine how many fry had the cold-brand mark of a hatchery fish (see Hatchery Fry Marking for more details on otolith analysis).

Wild egg-to-fry survival rates were determined by subtracting the annual hatchery egg takes from the annual potential egg deposition, as determined by the trawl data (see Midwater Trawling in Methods section). The wild PED was then divided into the estimates of wild fry based on hydroacoustic data from the following year to determine egg-to-fry survival rates for wild kokanee.

In 1995 and 1996, 12 transects were randomly chosen in each of three lake sections, totaling 36 transects per year. Each transect took approximately 15 minutes, with an average boat speed of 1.5 m/s. In both years, sampling sites were located using Global Positioning System (GPS), and a compass bearing for the direction of each transect was randomly chosen. A total of 785 fish were trace tracked in 1995 and 1,765 fish in 1996 to delineate the size distribution of kokanee fry and older age classes of fish.

In 1997, 1998 and 1999, 20 transect locations were randomly chosen in each of three lake sections, totaling 60 transects per year (Figure 1.4). Sampling sites were located using GPS, and a compass bearing for the direction of each transect was randomly chosen at each site. The boat speed was approximately 1.4 m/s (boat speed does not affect the calculations of fish density). Each transect was 10 minutes in length. A total of 1,231 fish were trace tracked in 1997, 308 in 1998, and 496 in 1999.

In 2000 and 2001, 21 transects were completed throughout the lake with eight transects in section one, six in section two, and seven in section three. We used a uniformly spaced, zigzag pattern on the lake going from shoreline to shoreline (Figure 1.4). Transect length ranged from 3.36 km to 9.46 km. Sampling sites were located using GPS. Approximately 1245 fish were trace tracked in 2000 and 880 fish in 2001. The boat speed was approximately 1.4 m/s.



Section	Area (hectares)
1	6,386
2	7,776
3	8,384

▬ 1999 Hydroacoustic transects
> 2000 Hydroacoustic transects

Figure 1.4. The location of the hydroacoustic transects used to assess the kokanee population in Lake Pend Oreille, Idaho during 1999 and 2000.

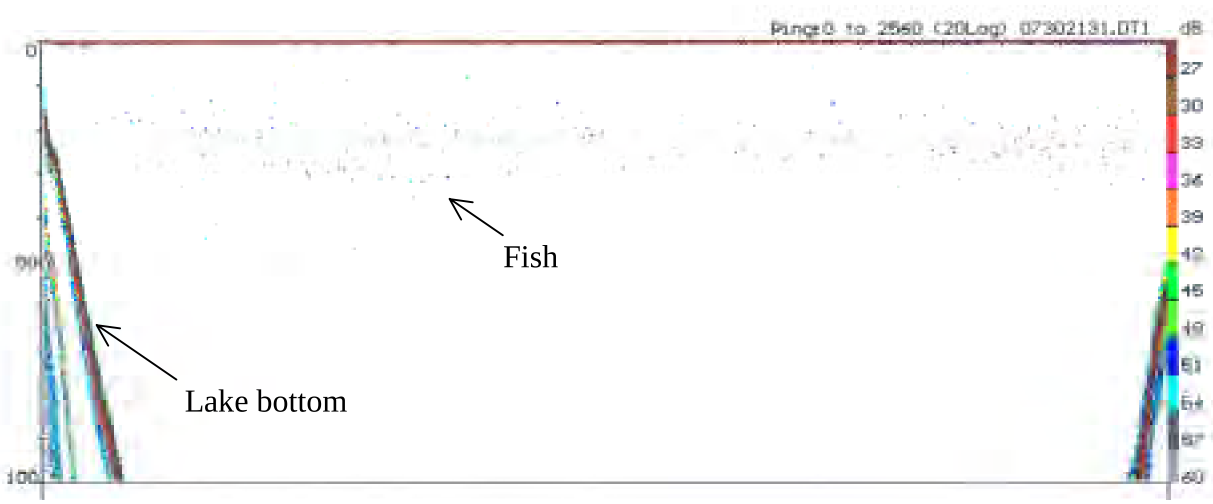


Figure 1.5. Example of an echogram collected during hydroacoustic surveys on Lake Pend Oreille, Idaho, July 2001. Scale of depth is in meters. Horizontal distance across the echogram was approximately 3.9 km.

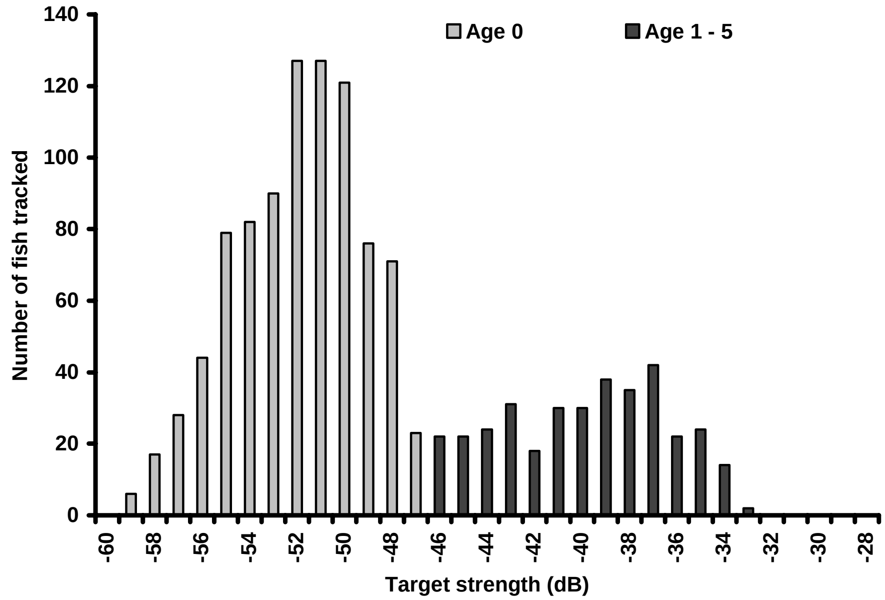


Figure 1.6. Example of target strengths of pelagic fish used to determine population estimates of kokanee in Lake Pend Oreille, Idaho. Data was collected in 2000.

Fry Netting

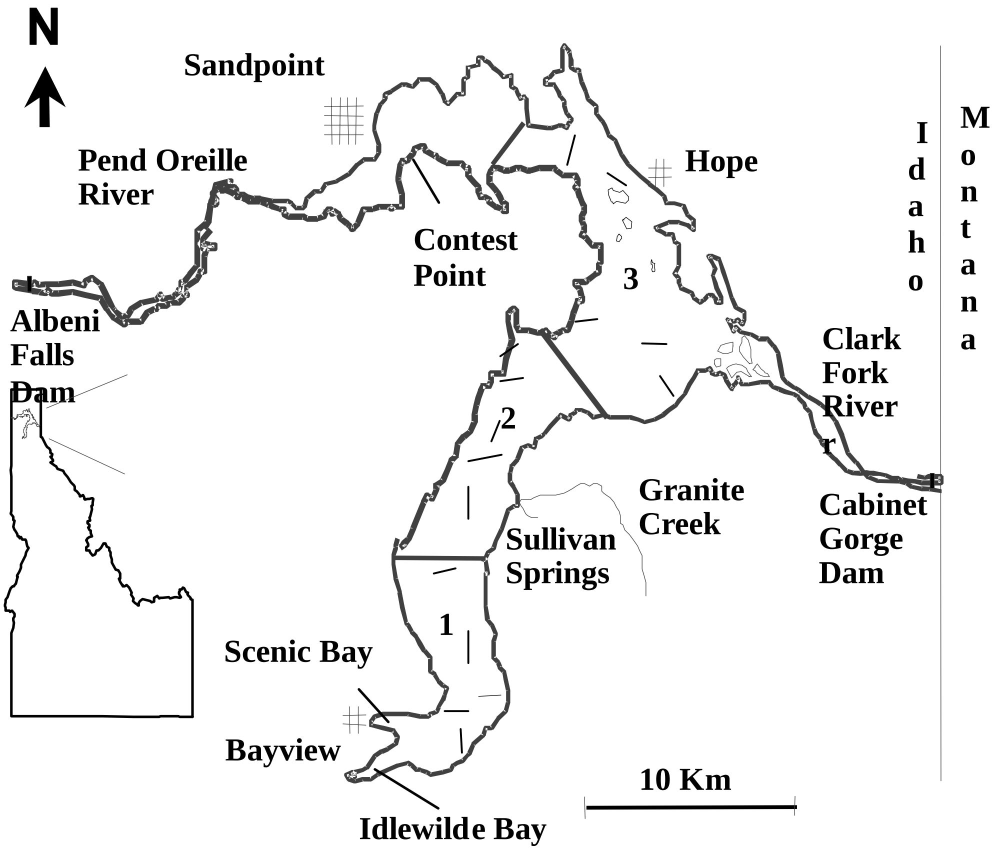
We designed and constructed a small mesh net as a second method to estimate kokanee fry abundance. Sampling with the fry net began on Lake Pend Oreille in 1999 and has continued annually thereafter. Net hauls were made during the same new moon period as that year's midwater trawling. Five transects in each lake section were chosen randomly by a stratified random sampling technique, totaling 15 transects during 1999 (Figure 1.7). The number of net hauls was increased to 10 in each lake section during 2000 and 2001.

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

Stepwise oblique tows were made through the layer of kokanee seen on the boat's echo sounder. Fry net depths ranged from 13 m to 41 m. The fry net was towed for three minutes at each "step" (a step corresponded to a 15 m length of cable) until the entire kokanee layer had been sampled. The average boat speed was 1.5 m/s. A Kahlsico digital flowmeter model 005WE138 was secured to the fry net's mouth approximately one third of the way between the net frame and the center of the mouth.

All kokanee caught in the fry net were immediately frozen on dry ice. Upon return to the dock, the fry were stored in a freezer for later analysis. The fish were later thawed and measured for length and weight. Total length of each fry was rounded down to the nearest whole mm. In 1999 only, wild and hatchery fry in the fry net were determined based on the percent of hatchery and wild fry in each centimeter length group as determined by otolith analysis of kokanee fry caught in the mid-water trawling. Beginning in 2000, otoliths were removed from the fry caught in the fry net and sent to Washington Department of Fish and Wildlife for analysis. We randomly selected 30 fry from each section to have their otoliths analyzed. In 2001, we randomly selected 33 fry from both sections 1 and 2 and 34 fry from section 3 for otolith analysis.

Density of fry (fish/ha) in the kokanee layer was calculated for each net tow based on the volume of water sampled by the net [boat speed (m/s) x time (s) x the area of the net mouth (m^2)] as it passed through the kokanee layer, multiplied by the thickness of the kokanee layer (m), and multiplied by 10,000 to convert estimates to fish/ha. Flowmeter readings were not used since they recorded the distance obtained while raising and lowering the fry net. Density estimates were averaged per section and expanded by the area of the section. Estimates of fry within each section were summed to determine the lake-wide population estimate of fry.



Section	Area (hectares)
1	6386
2	7776
3	8384

Fry trawl transects

Figure 1.7. Map of Lake Pend Oreille, Idaho, showing fry trawl transects. Five transects were randomly chosen in each lake section in 1999.

Hatchery Fry Marking

All kokanee fry released from the Cabinet Gorge Fish Hatchery since 1997 were marked by "cold branding" their otoliths (Volk et al. 1990). Cold branding provided researchers with a method to separate hatchery and wild kokanee throughout their lifecycles by noting the dark banding pattern on the otoliths of the hatchery fry (Figure 1.8). A total of 8.25, 17.71, and 12.21 million kokanee fry were stocked in 1999, 2000, and 2001 respectively. This included a 1999 total of 1.12 million early spawning variety and 7.13 million late spawning kokanee, as well as a 2000 total of 16.00 million late spawning variety and an additional 1.71 million late spawning kokanee released late in May. During 2001, all 12.21 million were late spawners.

Personnel from the Cabinet Gorge Fish Hatchery and the Clark Fork Hatchery reared and marked all of the kokanee fry. Fry within an individual raceway were from eggs collected within ten days of each other. Thermal treatments were initiated five to ten days after the fry entered their respective raceways. Each year the fry are treated to create a unique banding pattern on their otoliths. In 1999 (brood year 1998), fry of Lake Pend Oreille origin received four 24 h cool water events scheduled over nine days with one day between the first two and last two events, and three days between the second and third events. In 2000 (brood year 1999), fry of Lake Pend Oreille origin received four dark (coldwater) brands as the rearing water was systematically raised and lowered 6-9°F, alternated in 24 to 48 hour time periods. In 2001 (brood year 2000), fry received a banding pattern of four dark rings in an 11-day period. There were three days between the first two and last two events and only one day between the second and third events.

Each year, fry from each raceway were sacrificed to verify the thermal marking. These fry were sent to the Washington Department of Fish and Wildlife Otolith Laboratory in Olympia, Washington. Recognizable otolith marks were verified on all thermally treated individuals. There were no examples of thermally treated individuals not exhibiting their respective mark patterns.

To determine the banding pattern, the Washington Department of Fish and Wildlife personnel removed one sagitta from each specimen vial and oriented it on a glass plate. The otoliths were then surrounded with a preformed rubber mold. Rubber molds were then filled with clear fiberglass resin and were cured in an oven for one hour. 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 200x and/or 400x magnification. Patterns within the otolith were compared to those on reference samples taken from the hatchery fry during rearing. For accuracy, two independent readers examined each otolith. Differences between the readers were settled by reexamining the otolith.

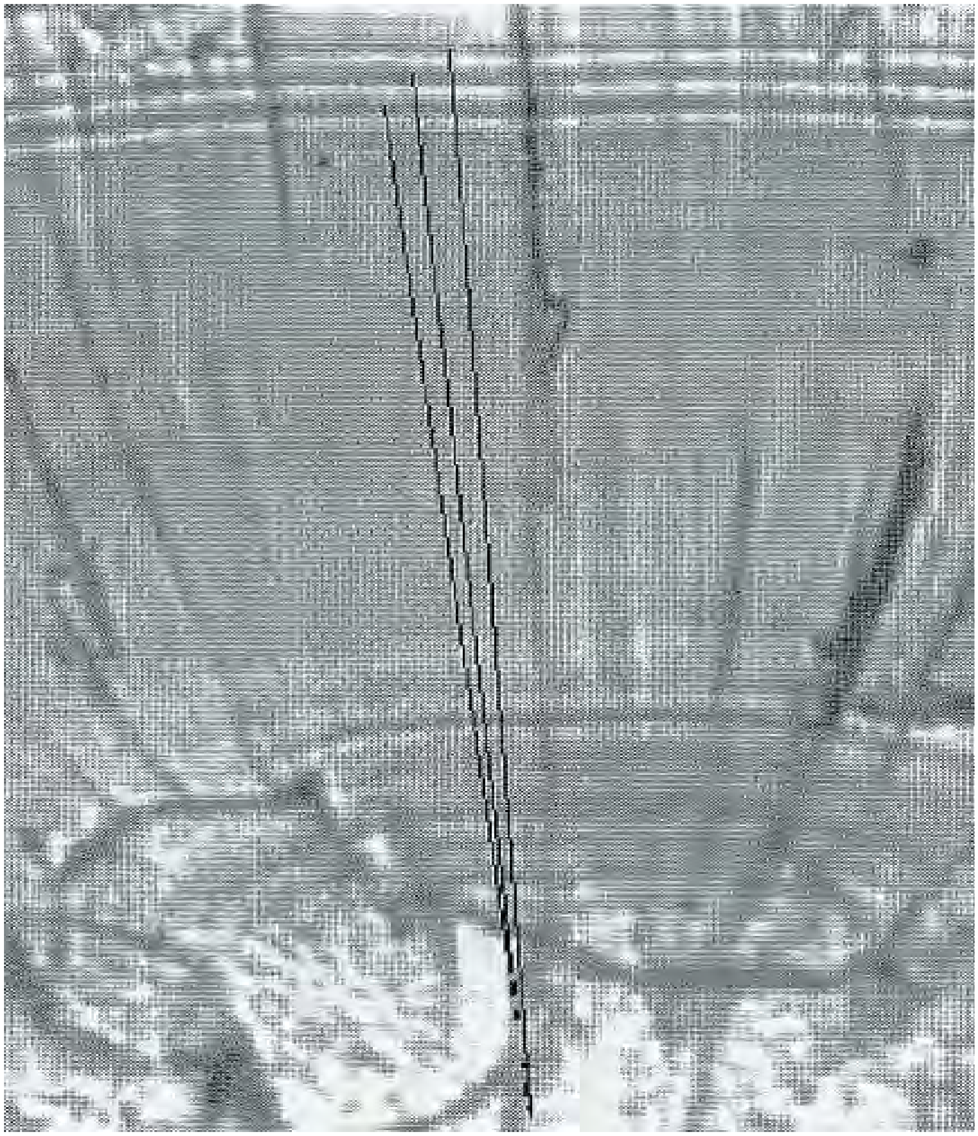


Figure 1.8. Example of cold-water branding on otolith. There were three 48-hour warm water events. The first two events were followed by 48 hours of ambient (cold) water and the final event by a return to ambient water. Overlay lines originate in the otolith core and terminate at the cold-water events. Notice the three white spaces created by the warm water events. Shown at 400X.

Midwater Trawling

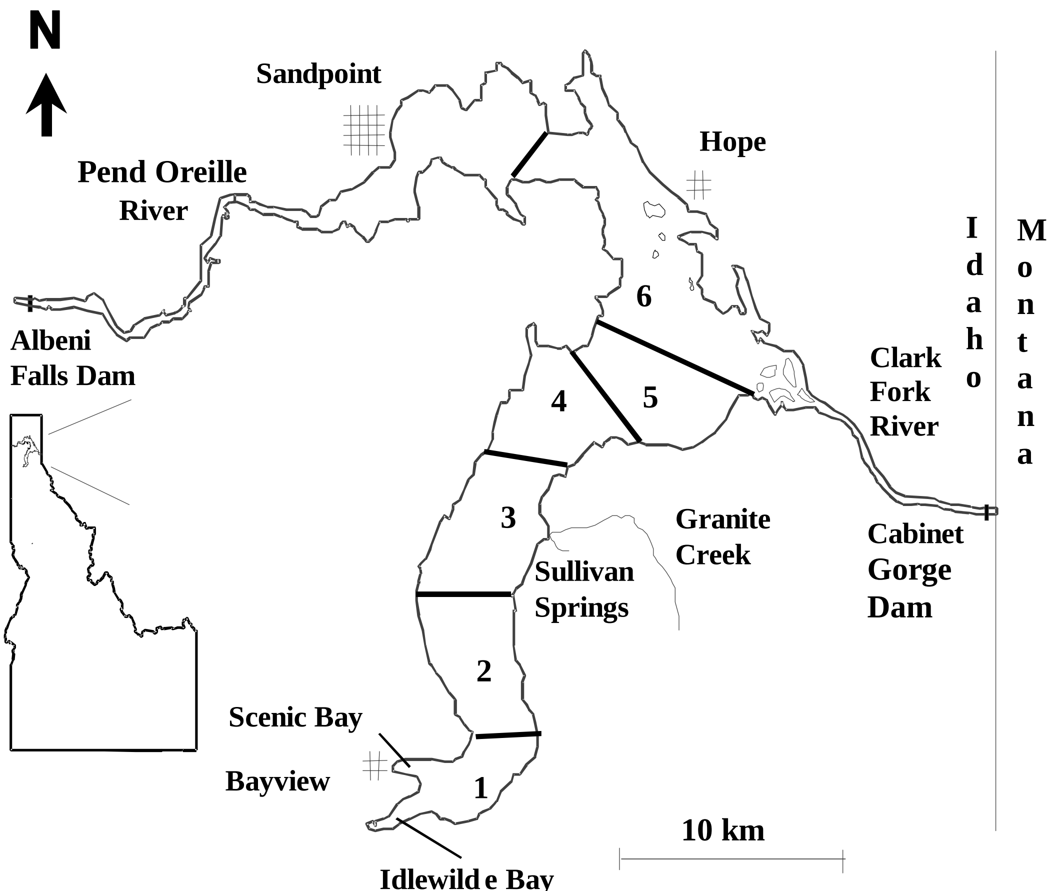
We conducted standardized midwater trawling in Lake Pend Oreille on August 22-29, 1995; September 8-12, 1996; September 29 to October 4, 1997; August 17-24, 1998; September 7-10, 1999; August 28 to September 1, 2000; and August 13-16, 2001. In addition, trawling was conducted by similar methodology during 1994 under a different project proposal (Maiolie et al. 1994). Trawling dates were during the dark phase of the moon, which optimized the capture efficiency of the trawl (Bowler et al. 1979).

The locations of the individual sampling transects changed in some years. In 1994 and 1995, the lake was divided into six sections (Figure 1.9), and a stratified systematic sampling scheme was used to estimate kokanee abundance and density. Six transects were systematically selected within each section, and one haul was made along each transect. The same transect locations were used in kokanee population monitoring on Lake Pend Oreille since 1977 (Bowler et al. 1979; Bowles et al. 1988, 1989; Paragamian and Ellis 1994). During 1996 and all later years, sections 1 and 2, 3 and 4, 5 and 6 were combined to stratify the lake into three sections to improve the precision of our estimates based on the advice of a statistician. Twelve randomly selected locations were chosen within each section for a total of 36 trawls (Figure 1.10).

Rieman (1992) described the midwater trawl and sampling procedure in detail. The net was 13.7 m long with a 3 m x 3 m mouth. Mesh sizes (stretch measure) graduated from 32, 25, 19, and 13 mm in the body of the net to 6 mm in the cod end. The trawl net was towed at a speed of 1.5 m/s by an 8.5 m boat. We determined the vertical distribution of kokanee by using a Raytheon Model V850 depth sounder with a 20° hull-mounted transducer. In 1998, we switched to using a Furuno Model FCV-582 depth sounder with a 10° transom mounted transducer. A step-wise oblique tow was conducted along each transect which sampled the entire vertical distribution of kokanee.

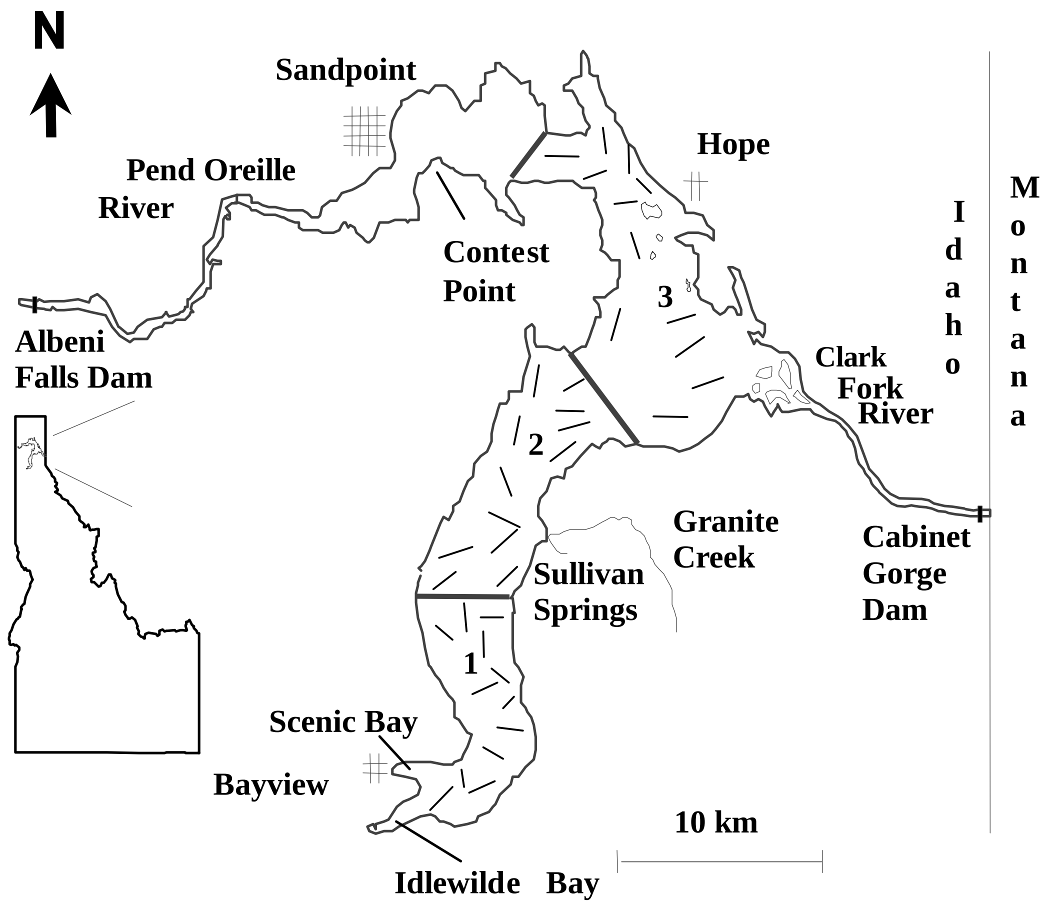
Fish from each trawl sample were counted and placed on ice until morning when they were transferred to a freezer. Lengths and weights of individual kokanee were recorded, and all fish over 170 mm were checked for maturity. Scales were taken from 10 fish in each 10 mm size interval for aging (Figure 1.11). Beginning in 1997, otoliths (317 pairs) were removed from kokanee fry and sent to the Washington Department of Fish and Wildlife Otolith Analysis Laboratory to determine if the fry were of hatchery or wild origin. In 1998, 200 pairs of otoliths were removed from age-0 and age-1 kokanee; in 1999, 205 pairs of otoliths were removed from age-0, age-1, and age-2 kokanee; in 2000, 291 pairs of otoliths were removed from age-0, age-1, age-2, and age-3 kokanee, and in 2001, 242 pairs of otoliths were sent for analysis from all age classes of kokanee.

Potential egg deposition was calculated by using percent maturity within each 1 cm length group. Percent maturity was multiplied by the population estimate within each length group and then summed. To obtain the population estimate for mature females, we then divided the total mature population by two. The number of mature females in the lake was then multiplied by the mean fecundity seen at the Granite Creek spawning station to estimate PED. We then subtracted the number of eggs collected by hatchery personnel at the Cabinet Gorge Hatchery and Granite Creek egg-take stations to determine the number of eggs spawned by wild fish (wild PED).



Section	Area (hectares)
1	3166
2	3220
3	3739
4	4037
5	3373
6	5011

Figure 1.9. Map of Lake Pend Oreille, Idaho, showing prominent landmarks and the six lake sections used in 1995.



Lake Sections (hectares)

1	6386
2	7776
3	8384

Trawl Transect

Figure 1.10. Map of Lake Pend Oreille, Idaho, showing the location of transects used for midwater trawling in 1999 on Lake Pend Oreille.

Figure 1.11. Example of a kokanee scale (age-4). Arrows indicate the location of annuli.

Limnology

We measured water temperature, dissolved oxygen, and water clarity (Secchi transparency) monthly from January through December 1997 to 2001. Data were collected at three standardized locations, representing the southern, middle, and northern sections of the lake (Figure 1.1). Sample dates were approximately the middle of each month. We used a Yellow Springs Instrument Company model 57 meter to measure temperature and dissolved oxygen from the surface to a depth of 59 m. The meter was calibrated before each survey using the "water saturated air" method suggested by the manufacturer. Water clarity was monitored at each station using a 20 cm diameter Secchi disk during each survey.

RESULTS

Hydroacoustics

Population estimates of kokanee fry made by hydroacoustics ranged from 3.708 million (1998) to 14.141 million (2000) (Table 1.1). The highest densities of fry were generally found in the northern third of the lake (Section 3), closer to where the hatchery fry are stocked. Ninety percent confidence limits on these estimates ranged from 8.6 to 15.7%

The hydroacoustic estimates of wild fry derived using the percent composition of wild fry in the midwater trawl net ranged from 1.019 million fry (1998) to 5.231 million fry (2000) (Table 1.2 and Figure 1.12). Wild fry were distributed differently across the lake sections in different years. During 2000, wild fry abundance was highest in the middle of the lake; however, in 1996 they were higher in the north end, and in 1995 they were highest in the south end.

Abundance estimates of kokanee ages 1 to 5 ranged from 2.218 to 7.327 million (Table 1.3). The northern section of the lake (section 3) generally had the highest population estimate of kokanee.

Table 1.1. Hydroacoustic population estimates (millions) of kokanee fry in three sections of Lake Pend Oreille, Idaho, from 1995 through 2001.

Year	Southern Section (1)	Middle Section (2)	Northern Section (3)	Total for Lake	90% C.I.
2001	2.384	4.857	3.806	11.047	±10.2%
2000	2.489	5.951	5.701	14.141	±11.5%
1999	1.234	2.128	2.661	6.023	±8.6%
1998	0.755	0.926	2.027	3.708	±11.8%
1997	1.126	1.700	3.264	6.090	±9.9%
1996	1.412	2.592	2.936	6.940	±15.7%
1995	1.691	2.268	3.251	7.210	±9.0%

Table 1.2 Hydroacoustic population estimates of wild kokanee fry (millions) in Lake Pend Oreille, Idaho, 1995 to 2001 by lake section. Fry estimates (Table 1.1) were partitioned into wild fry based on otolith analysis of fry caught by midwater trawling (Table 1.6).

Year	Section 1	Section 2	Section 3	Total Wild Fry Abundance
2001	1.355	1.541	0.837	3.733
2000	1.326	2.342	1.563	5.231
1999	0.805	0.940	0.828	2.573
1998	0.318	0.218	0.483	1.019
1997	0.714	0.538	1.323	2.575
1996	0.841	0.886	0.934	2.661
1995	1.305	1.235	0.600	3.140

Table 1.3. Hydroacoustic population estimates (millions) of kokanee ages 1-5 in three sections of Lake Pend Oreille, Idaho, from 1995 through 2001.

Year	Section 1	Section 2	Section 3	Total for Lake	90% C.I.
2001	0.980	1.479	2.443	4.902	±9.5%
2000	0.871	1.032	1.935	3.838	±14.2%
1999	0.762	0.240	1.817	2.819	±17.8%
1998	0.933	0.823	3.272	5.028	±16.7%
1997	1.234	1.316	3.211	5.761	±15.8%
1996	2.208	2.384	2.736	7.328	±18.6%
1995	2.951	1.171	2.746	6.868	±11.8%

Fry Netting

Density estimates of kokanee fry made with the fry net were closely correlated to fry density estimates based on hydroacoustics (r^2 = 0.88) (Figure 1.13 and Table 1.4). Fry densities in the hydroacoustic estimates were 1.33 times the estimates in the fry net. Lower estimates with the fry net were likely due to net avoidance by the fry. Whole lake population estimates using the two sampling methods showed a slightly better correlation than did the lake section estimates (r^2 = 0.90), probably due to the larger sample size in the whole lake estimates. Close correlation between the two sampling methods helps to corroborate the accuracy of either method.

Kokanee fry collected with the fry net ranged from 12% wild (northern section in 2001) to 88% wild (southern section in 2001) (Figure 1.14). Highest percentages of wild fry were found in the southern section of the lake where most of the shoreline spawning occurs. These percentages of wild fry provide a second method to partition the hydroacoustic estimates. This yielded population estimates of wild fry of 3.937 million in 1999, 7.822 million in 2000, and 3.537 in 2001 (Table 1.5). Wild fry survival rates were therefore 9.1% in 1999, 14.9% in 2000, and 6.2% in 2001 based on this methodology.

Sizes of the fry showed a bimodal distribution with the wild fry being smaller than the hatchery fry (Figure 1.15). Wild fry generally ranged in size from 24 to 80 mm, with a mean of about 40 mm and the majority of them smaller than 60 mm.

Table 1.4. Population estimates (millions) of all kokanee fry in Lake Pend Oreille, Idaho 1999 to 2001 based on fry netting.

Lake Section	1999	2000	2001
Southern	1.220	2.271	1.962
Middle	1.529	4.548	3.409
Northern	2.085	3.693	3.432
Total	4.834	10.513	8.804

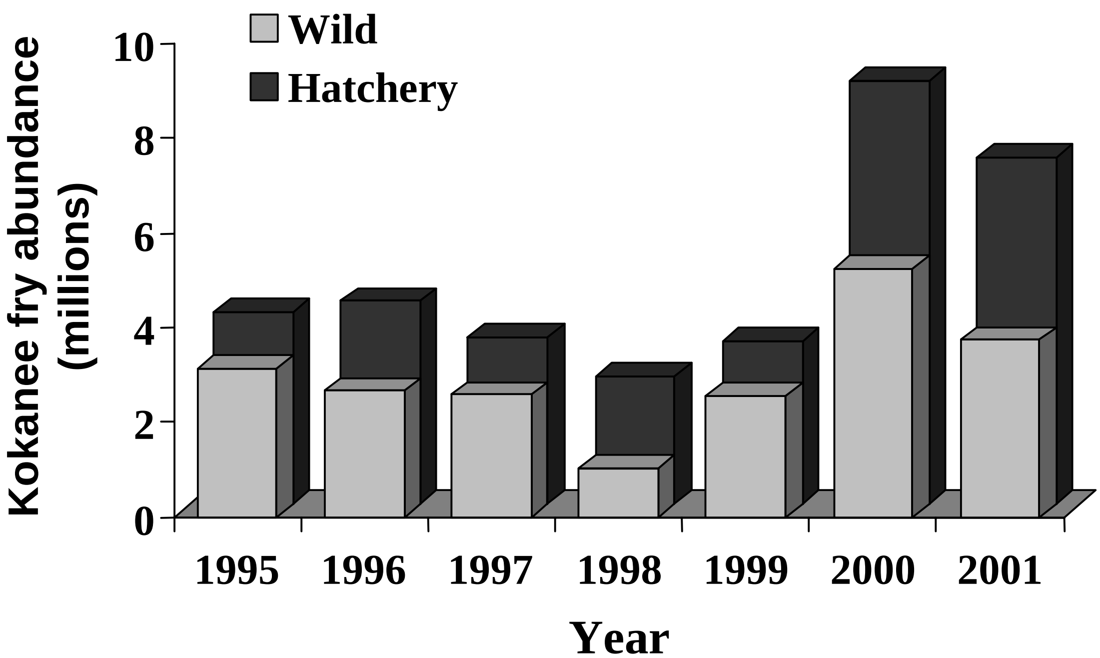


Figure 1.12. Population estimates of kokanee fry based on hydroacoustic surveys in Lake Pend Oreille, Idaho, 1995 to 2001. Estimates were partitioned into hatchery and wild components based on the composition of the mid-water trawl catch.

Table 1. 5. Hydroacoustic/fry net estimates of wild kokanee fry (millions) in Lake Pend Oreille, Idaho 1999 to 2001. Population estimate was based on hydroacoustic fry abundance (Table 1.0) and partitioned into the percent of wild fry based on the otolith analysis of the catch in a fry net. Wild potential egg deposition (PED) (millions) was estimated by midwater trawling.

Lake Section	**1999**		**2000**		**2001**	
	Percent Wild	**Estimate**	**Percent Wild**	**Estimate**	**Percent Wild**	**Estimate**
Southern	81%	1.000	73%	1.817	88%	1.727
Middle	78%	1.660	53%	3.154	41%	1.398
Northern	48%	1.277	50%	2.851	12%	0.412
Total of wild fry		3.937		7.822		3.537
Wild PED previous year		43.185		52.41		56.67
Wild egg-to-fry survival		9.1%		14.9%		6.2%

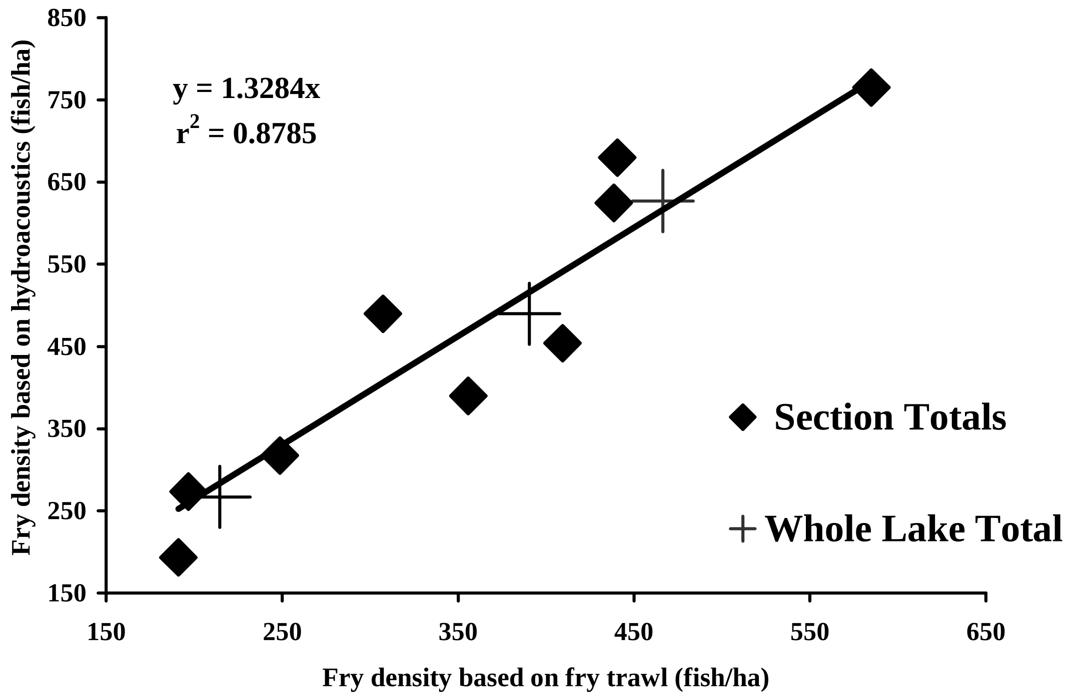


Figure 1.13. Comparison of kokanee fry density estimates made by hydroacoustics and fry netting in Lake Pend Oreille 1999, 2000, and 2001. Correlation and equation were based on section totals. Density estimates for each lake section (diamonds) used five to ten fry trawls and six to eight hydroacoustic transects. Whole lake density estimates (+) were based on 15 to 30 fry trawls and 20 to 60 hydroacoustic transects.

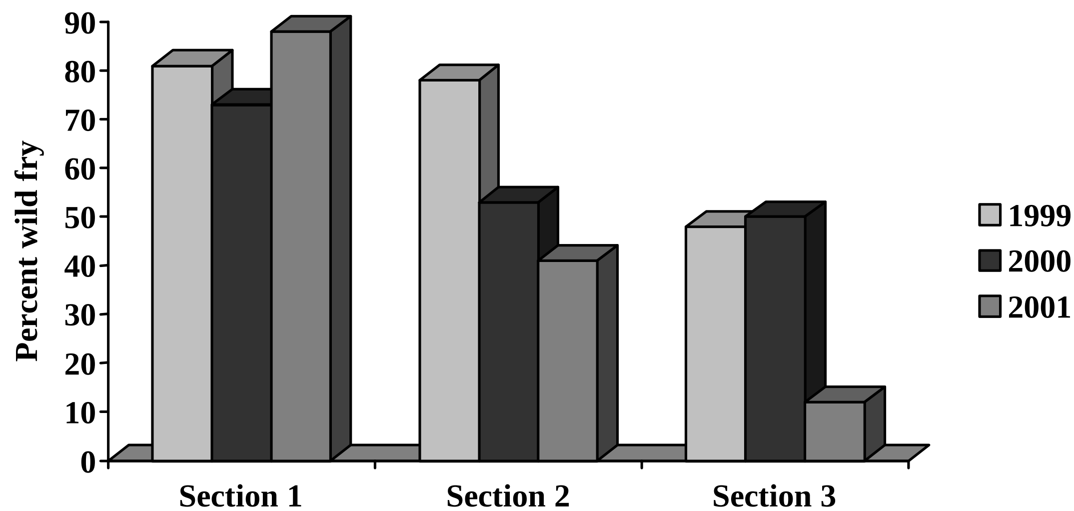


Figure 1.14. Percentage of wild fry collected in a fry net in each section of Lake Pend Oreille, Idaho, 1999, 2000, and 2001.

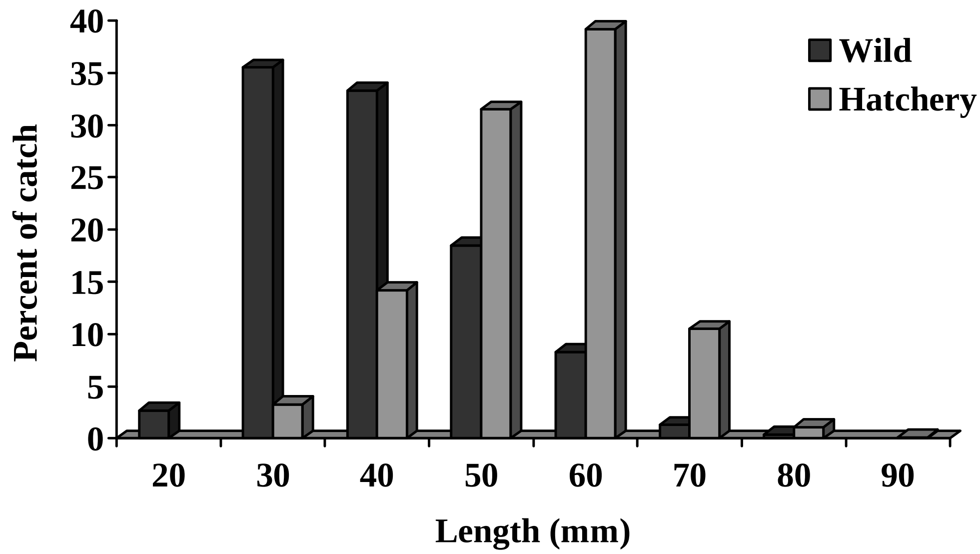


Figure 1.15. Length frequency of wild and hatchery kokanee fry collected in Lake Pend Oreille, Idaho, August 2000 with a fry net.

Midwater Trawling

Wild kokanee fry comprised 18% to 77% of the fry caught in individual sections of Lake Pend Oreille (Table 1.6) with the midwater trawl. Section 1 (southern section) consistently had the highest percentage of wild fry. These percentages were used to partition the hydroacoustic estimate into an abundance estimate of wild fry (Table 1.2).

The population estimate of mature female kokanee ranged from 33,404 females in 1997 to 599,000 females in 1994 (Fredericks et al. 1995) (Table 1.7). Wild PED was estimated to range from 10.65 million eggs in 1997 to 229.4 million eggs in 1994 (Idaho Department of Fish and Game files).

Table 1.6. The percent of wild kokanee fry in three sections of Lake Pend Oreille, Idaho based on their collection in a midwater trawl and examination of their otoliths for hatchery banding patterns.

Year	Section 1	Section 2	Section 3
2001	56.83	31.73	21.99
2000	53.29	39.35	27.42
1999	65.22	44.16	31.13
1998	42.11	23.53	23.81
1997	63.41	31.65	40.52
1996	59.52	34.20	31.82
1995	77.19	54.45	18.46

Wild Fry Survival

Based on hydroacoustic estimates of fry abundance partitioned by the percent that were wild in the midwater trawl, survival rates from wild kokanee eggs to wild fry varied from a low of 1.4% to a high of 10.0% (Table 1.7 and Figure 1.16). Survival rates showed dramatic improvement during four out of five years when lake levels were raised (Figure 1.16). Mean survival was 3.15% before lake levels changed in 1995 and 1996 (n = 2). After lake levels changed in 1998 to 2001, wild fry survival averaged 8.05% (n = 4). The increase in survival rate was statistically significant at the probability level of p = 0.059 (5.9% probability that the observed changes were due to random chance). Data from 1997 was not used in this comparison since it was a flood year with the highest spring flow on record for the Pend Oreille River (McGrane 1999). Survival remained low during 1997 (eggs laid in 1996) (1.8%).

Wild egg-to-fry survival was positively correlated to the increase in winter lake elevation during this study (r^2 = 0.85, 1997 data excluded) (Figure 1.17). For example, wild fry survival was estimated at 9.6% in 1998 (eggs that were laid in 1997) when the lake was held at an elevation of 626.4 m or 1.3 m above the lake's minimum pool level. Survival was also high (10%) in 2000, a year that lake levels were held 0.6 m higher than normal. Wild fry survival was also inversely correlated to the number of mature female kokanee in the lake (Figure 1.18). When the lake was drawn down to its low pool elevation, fry survival was 1.4 % and 4.9% as the abundance of mature female kokanee went from 599,000 to 152,000, respectively. Better survival rates were estimated in years when the lake was held higher during the winter. Survival rates in these years varied from 6.0% to 10.0%.

An additional calculation of wild egg-to-fry survival was based on the number of wild kokanee fry in the hydroacoustic estimates, partitioned into wild fry based on the proportion of wild fry in the fry net, and dividing by the wild PED estimates made by trawling. Egg-to-fry survival rates were 9.1% in 1999, 14.9% in 2000, and 6.2% in 2001.

Table 1.7. Comparison of minimum lake level to number of mature females (as determined by midwater trawling), mean fecundity, hatchery egg take, potential egg deposition (PED), wild fry abundance the following year (by hydroacoustics), and percent survival of kokanee fry in Lake Pend Oreille, Idaho, 1995-2001.

Year Class of Eggs[a]	Minimum Lake Level (ft) (m)	Number of Females	Eggs Per Female	PED (millions)	Hatchery Egg Take (millions)	Wild PED (millions)	Wild Fry Abundance Following Year (millions)	Percent Survival (eggs to fry the next year)
2001	2051.3 625.2	33,563	481	16.14	7.68	8.46	—	—
2000	2053.1 625.8	167,794	417	69.97	13.30	56.67	3.733	6.6
1999	2053.1 625.8	197,358	379	74.79	22.38	52.41	5.231	10.0
1998	2054.9 626.3	156,580	333	52.14	8.96	43.18	2.573	6.0
1997	2055.1 626.4	33,404	335	11.19	0.54	10.65	1.019	9.6
1996	2055.0 626.4	413,720	353	146.04	4.49	141.55	2.575	1.8
1995	2051.7 625.4	151,650	444	67.33	12.89	54.44	2.661	4.9
1994	2051.1 625.2	599,000	411	246	16.6	229.4	3.140	1.4

[a] Year class of eggs is defined as the year the eggs were laid.

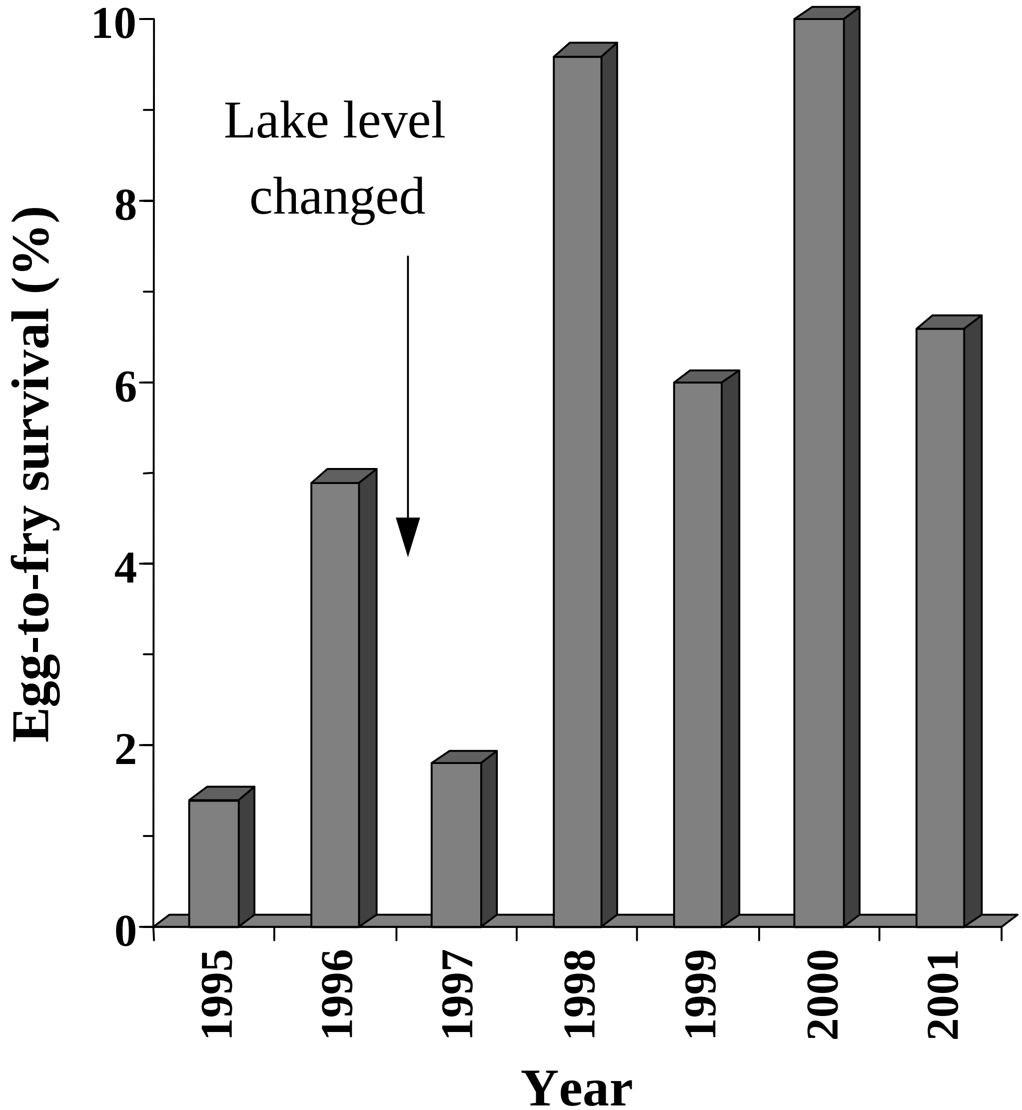


Figure 1.16. Survival of wild kokanee eggs to fry in the fall of their first year of life in Lake Pend Oreille, Idaho. Survival was based on potential wild egg deposition estimates made by trawling and wild fry abundance estimated by hydroacoustics. Winter lake levels were changed in each year after 1996. Year on the x axis is the year the fry were sampled.

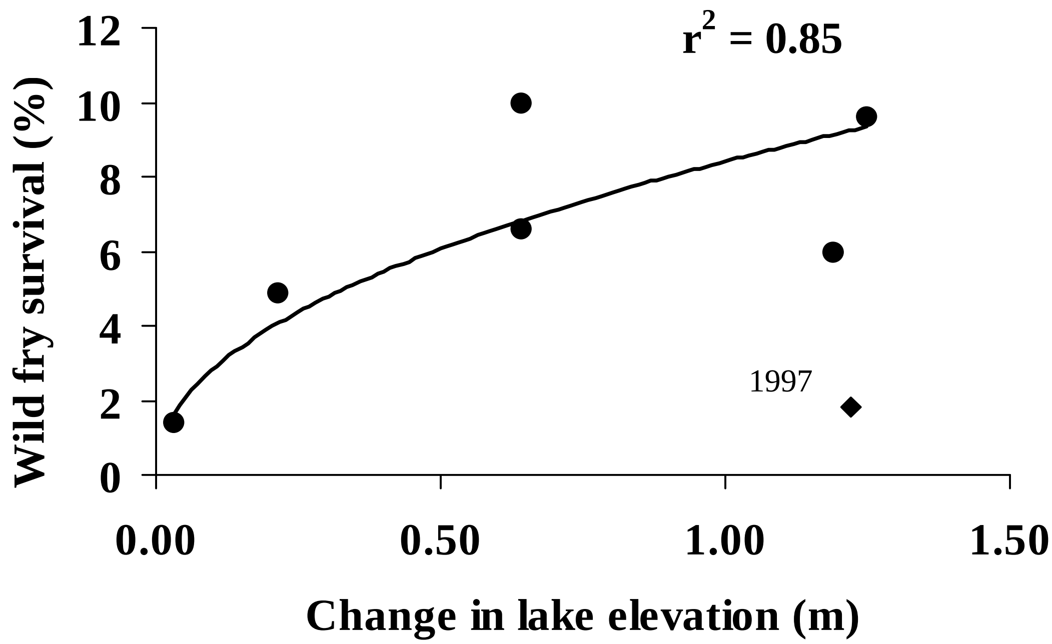


Figure 1.17. Correlation between wild fry survival (Table 1.7) and the change in lake elevation above low pool level (elevation 625.1 m, 2051 ft). Data from the flood year of 1997 was omitted from the correlation.

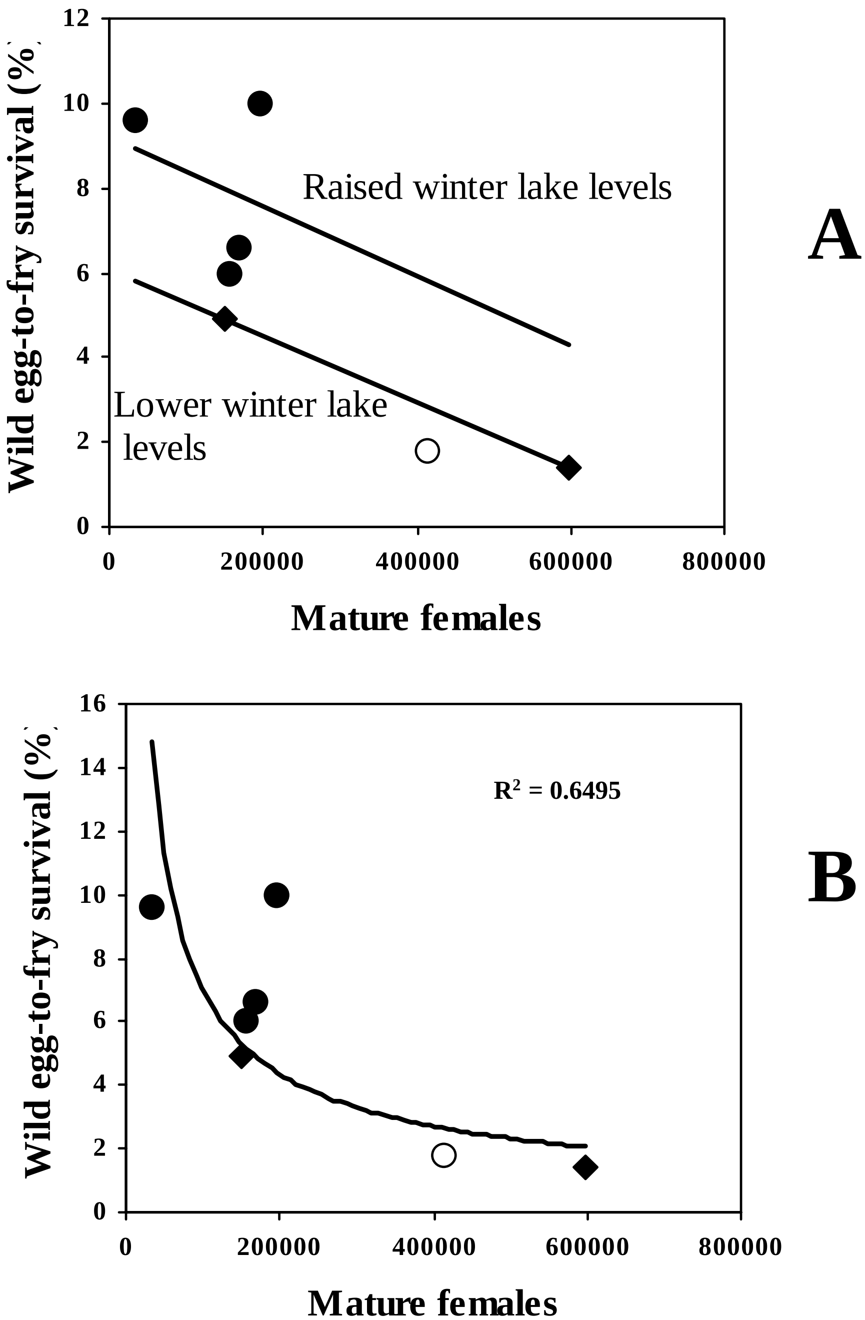


Figure 1.18. Survival of kokanee from wild spawned eggs to fry in Lake Pend Oreille, Idaho. A.) Lower line (diamonds) is the survival trend when lake is lowered to its minimum pool level during the fall drawdown (n = 2). Upper line (dots) is the survival trend when lake elevation is raised during winter (n = 4). Lines were extended beyond the range of points for clarity. Flood year of 1997 (open circle) was omitted from correlations. B.) Relationship between the number of female kokanee and wild egg-to-fry survival data. Line was fitted by power regression.

Depth of Kokanee Spawning

We found that the modal depth of kokanee spawning was at 1.2 m during the spawning season of 1997 during a year in which the lake level was 1.2 m above minimum pool (Figure 1.19). Thus, the most frequently used area for spawning was the old water line at elevation 625.1 (2051 ft). Scenic Bay contained 37% of the redds based on area during that year (Figure 1.20).

During 1999, the peak depth of kokanee spawning was again 1.2 m (Figure 1.19). The lake's minimum elevation that winter was 625.8, making the peak depth utilized by kokanee at elevation 624.6 (0.5 m below the old water line at minimum pool). Thirty-eight percent of all redds by area were located in Scenic Bay (Figure 1.20).

We noted much deeper spawning in 2001 with a modal spawning depth of 4.0 m (Figure 1.19). The lake was drawn down to an elevation of 625.1 m (2051 ft); thus, the peak of spawning occurred at an elevation of 621.1. Most of the spawning activity occurred in Scenic Bay (70% of the total area of all redds) (Figure 1.20).

Limnology

The lowest and highest Secchi depths obtained during the four-year analysis occurred in 1997 and 2000 respectively (Table 1.8). In May of 1997, we measured a Secchi depth of 0.7 m at the north end and a depth of 19.5 m in the southern section during March of 2000. Overall, the northern section of the lake had considerably lower water transparencies than the middle and southern sections between 1997 and 2000. The mean Secchi depth from April to October was not well correlated to the survival rates of wild kokanee fry ($r^2 = 0.50$).

Surface water temperature ranged from 2.9°C to 25.2°C between 1997 and 2000. The maximum water temperature for *Mysis* shrimp feeding is thought to be 14°C (Martinez and Bergersen 1991). Throughout the study, the maximum depth reached by 14°C water was generally between depths of 15 and 23 m, but timing and duration of this warm water at these depths varied considerably from year to year (Figure 1.21 and 1.22). Lake Pend Oreille maintained 14°C temperatures at the surface, 10 m depth, and 15 m depth for more days in 1999 than any other year (Table 1.9). Mid-June water temperatures between 1997 and 2000 rose above an eight-year range of temperatures (from 1985 to 1992) in 1999 between 5 m and 10 m depths and in 2000 between 20 m and 50 m depth (Figure 1.23). Days of water temperature over 14°C at the 10 m depth and 15 m depth were weakly correlated to the survival rates of wild kokanee fry ($r^2 = 0.50$ and 0.22, respectively) (Figure 1.24).

Each year of analysis, the dissolved oxygen concentrations were similar among all three stations. At each station in 1997, we measured oxygen concentrations between 13.5 mg/l and 14.0 mg/l in May and 8.2 mg/l to 8.3 mg/l in September. The values in May 1997 represent oxygen saturation levels over 130% when adjusted for water temperature and elevation. At each station in 1998, we obtained oxygen concentrations between 12.0 mg/l to 12.6 mg/l in May and 7.8 mg/l to 8.0 mg/l in September. At each station in 1999, we obtained oxygen concentrations between 11.2 mg/l and 11.6 mg/l in May and 8.3 mg/l to 8.6 mg/l in September. In 2000, we measured oxygen concentrations of 11.9 mg/l to 12.0 mg/l in April and 8.3 mg/l to 8.6 mg/l in September. As expected, dissolved oxygen readings declined as water temperature increased. All measurements of dissolved oxygen were sufficient for good kokanee growth and survival, with the exception that gas supersaturation in May of 1997 could potentially be lethal.

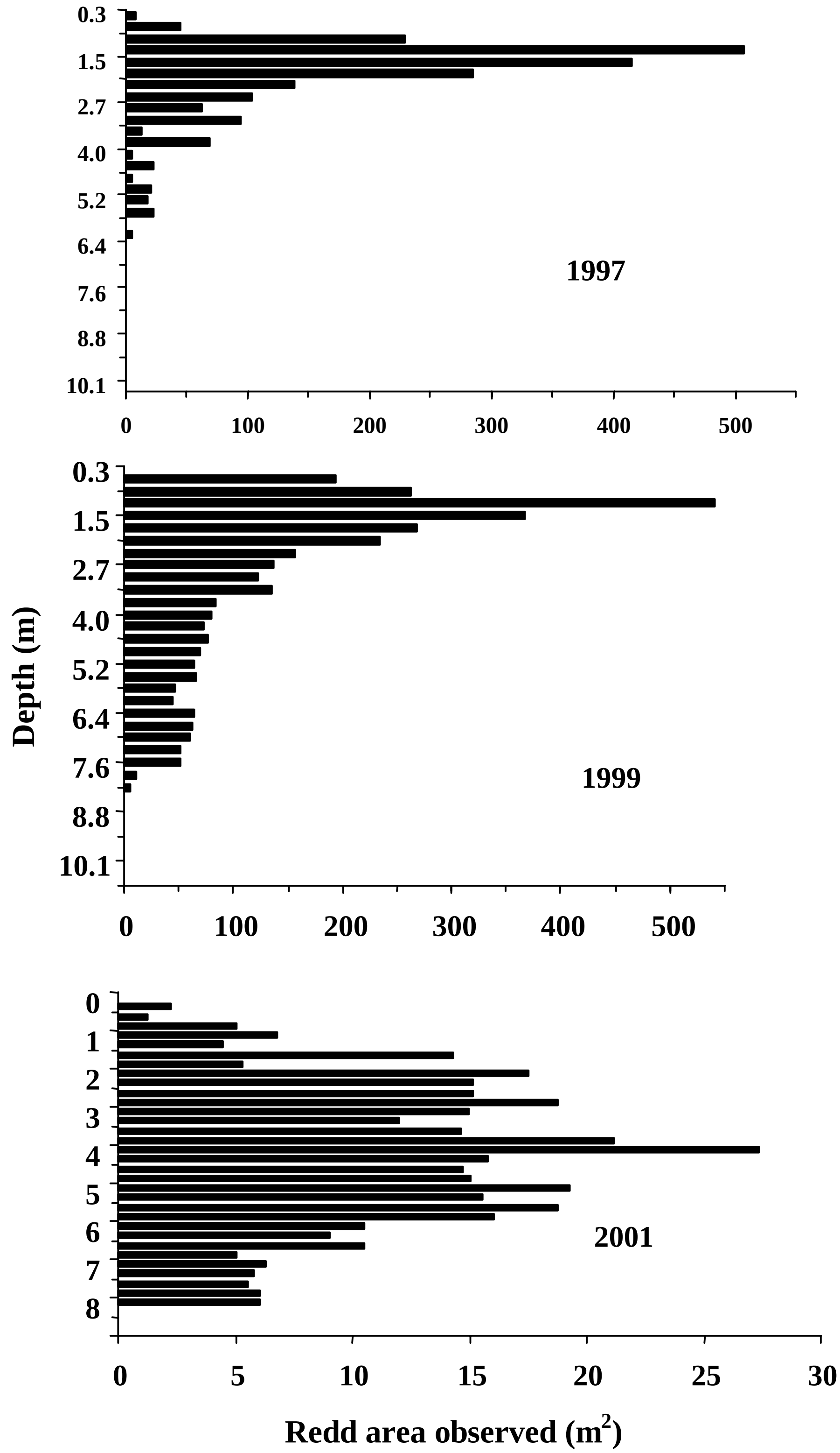


Figure 1.19. Depths of kokanee spawning on the shorelines of Lake Pend Oreille, Idaho. The lake's winter pool level was 1.2 m above minimum pool in 1997, 0.6 m above minimum pool in 1999, and at the minimum pool level in 2001.

Table 1.8. Secchi transparencies (m) at three locations in Lake Pend Oreille, Idaho in 1953, 1974, 1997, 1998, 1999, & 2000. Mean transparency is for April through October.

Southern station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Mean
1953	—	—	—	11.9	8.0	3.7	6.1	11.6	8.5	12.8	—	—	8.9
1974	—	—	—	8.8	7.6	3.7	3.9	9.2	9.1	9.3	—	—	7.4
1997	—	—	—	12.5	4.0	2.7	6.5	8.2	9.0	6.2	7.5	8.7	7.0
1998	16.5	17.0	13.5	9.0	6.0	4.0	5.5	11.0	9.5	7.7	8.5	10.0	7.5
1999	—	—	—	5.9	7.0	2.7	5.6	7.3	8.3	7.5	8.8	11.5	6.3
2000	11.5	—	19.5	5.5	5.9	7.2	9.4	11.4	9.5	8.0	10.0	13.5	8.1
Mid-lake station													
1953	—	—	—	—	—	3.7	6.1	10.7	12.2	12.2	—	—	—
1974	—	—	—	—	5.5	2.3	4.7	9.8	9.4	11.6	—	—	—
1997	—	—	—	16.5	5.2	2.0	5.0	7.9	6.8	8.0	9.0	10.0	7.3
1998	16.5	17.2	13.5	9.0	4.5	3.5	6.0	11.5	10.0	7.0	—	—	7.3
1999	—	—	—	13.3	5.5	2.5	6.5	6.9	7.0	7.5	8.0	13.1	7.0
2000	16.0	—	19.0	10.8	7.0	6.2	9.4	10.0	9.1	10.2	—	—	9.0
Northern station													
1953	—	—	—	3.0	3.7	0.9	6.4	9.4	11.0	10.4	—	—	6.4
1974	—	—	—	4.0	0.9	0.4	2.8	9.4	10.2	11.6	—	—	5.6
1997	—	—	—	5.3	0.7	1.0	4.0	8.5	5.8	5.5	6.2	7.9	4.4
1998	7.7	9.5	7.0	5.5	3.2	1.2	4.1	10.0	7.5	6.5	—	—	5.4
1999	—	—	—	5.9	4.0	2.8	5.0	6.0	7.5	7.5	8.0	7.1	5.5
2000	8.2	—	8.6	5.7	4.2	6.0	9.2	11.0	8.7	8.0	8.2	—	7.5
Total lake mean													
1953	—	—	—	—	—	2.77	6.20	10.57	10.57	11.80	—	—	—
1974	—	—	—	—	4.67	2.13	3.80	9.47	9.57	10.83	—	—	—
1997	—	—	—	11.43	3.30	1.90	5.17	8.20	7.20	6.57	7.5	8.8	6.23
1998	13.5	14.5	11.3	7.83	4.57	2.90	5.20	10.83	9.00	7.08	—	—	6.77
1999	—	—	—	8.37	5.50	2.67	5.70	6.73	7.60	7.50	8.2	10.5	6.29
2000	11.9	—	15.7	7.33	5.70	6.50	9.33	10.80	9.10	8.73	—	—	8.21

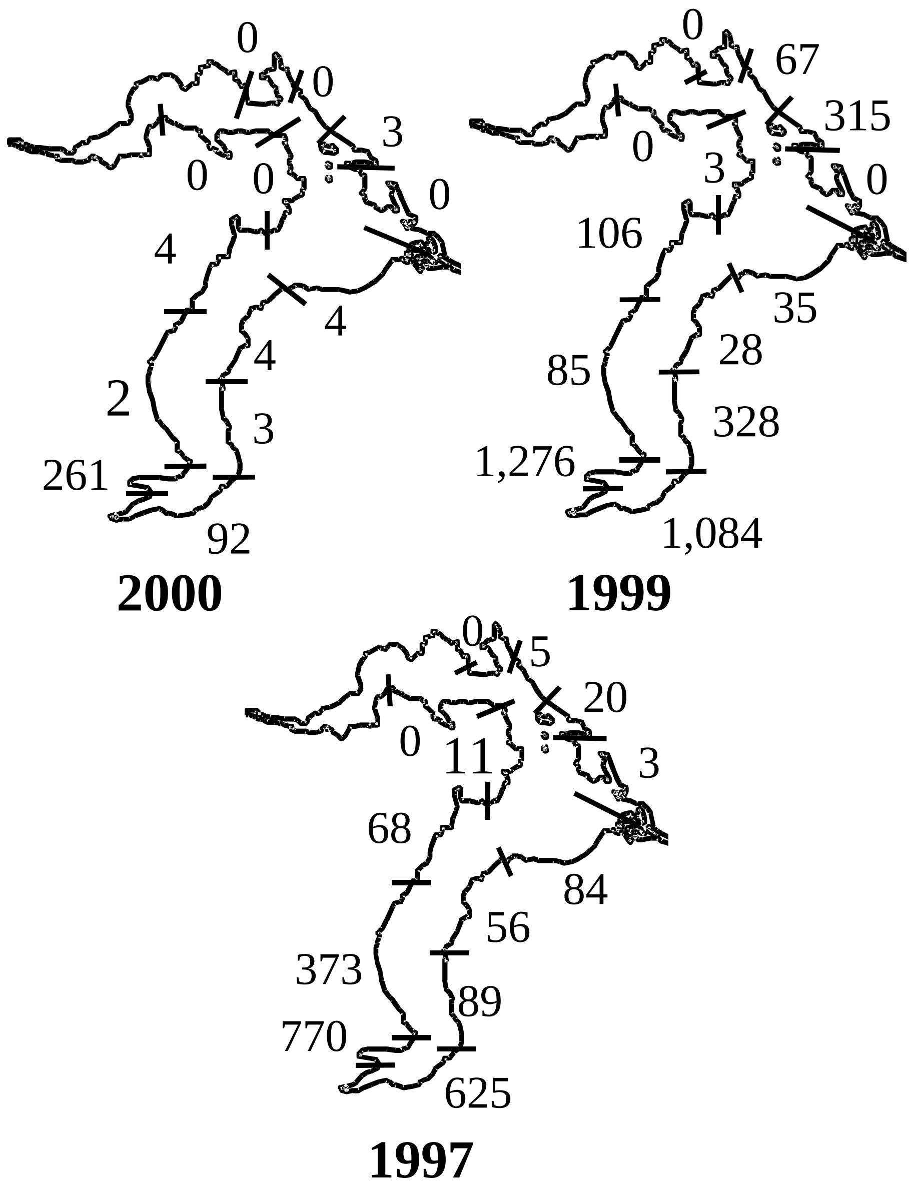


Figure 1.20. Map of Lake Pend Oreille showing area (m^2) of kokanee redds surveyed in each of the 14 survey sections in three different years.

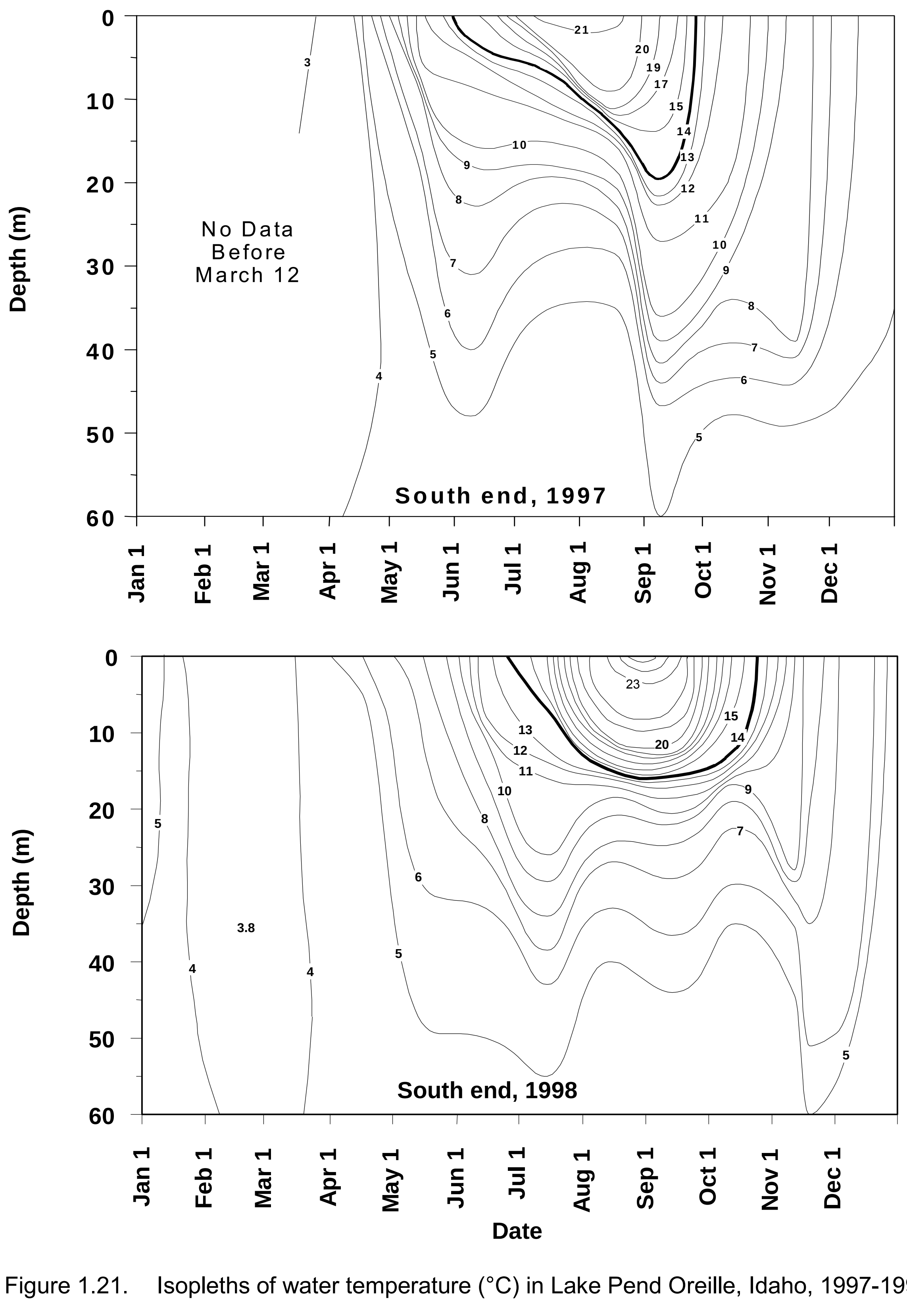


Figure 1.21. Isopleths of water temperature (°C) in Lake Pend Oreille, Idaho, 1997-1998.

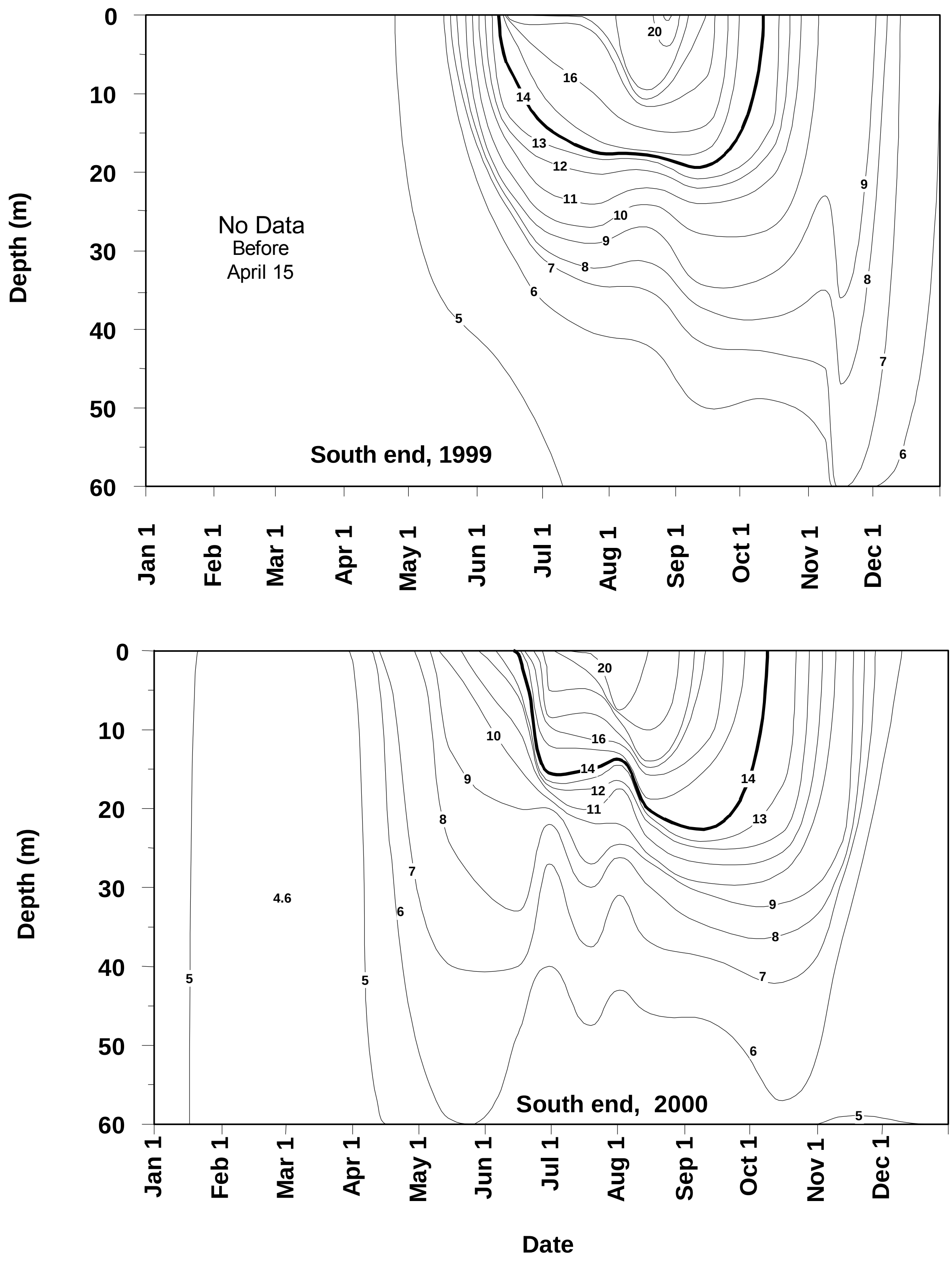


Figure 1.22. Isopleths of water temperature (°C) in Lake Pend Oreille, Idaho, 1999-2000.

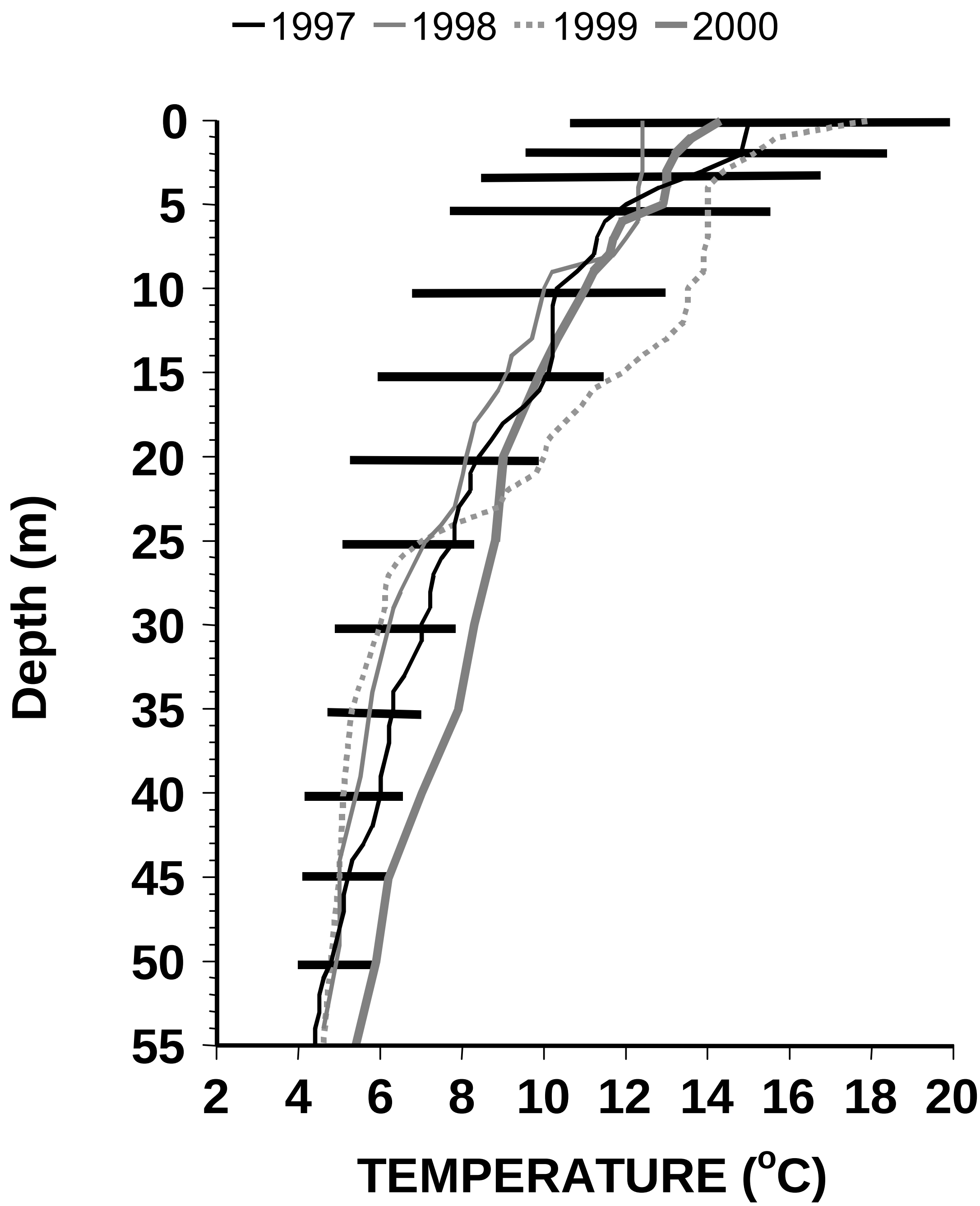


Figure 1.23. Mid-June temperature for 1997-2000 in the southern section of Lake Pend Oreille, Idaho. Horizontal black lines represent an eight-year range of June temperatures (1985-1992) at specific depths.

Table 1.9. Dates and number of days with water temperatures exceeding 14°C at the surface, at 10 m depth, and at 15 m on the south end of Lake Pend Oreille, Idaho, each year from 1997 to 2001.

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

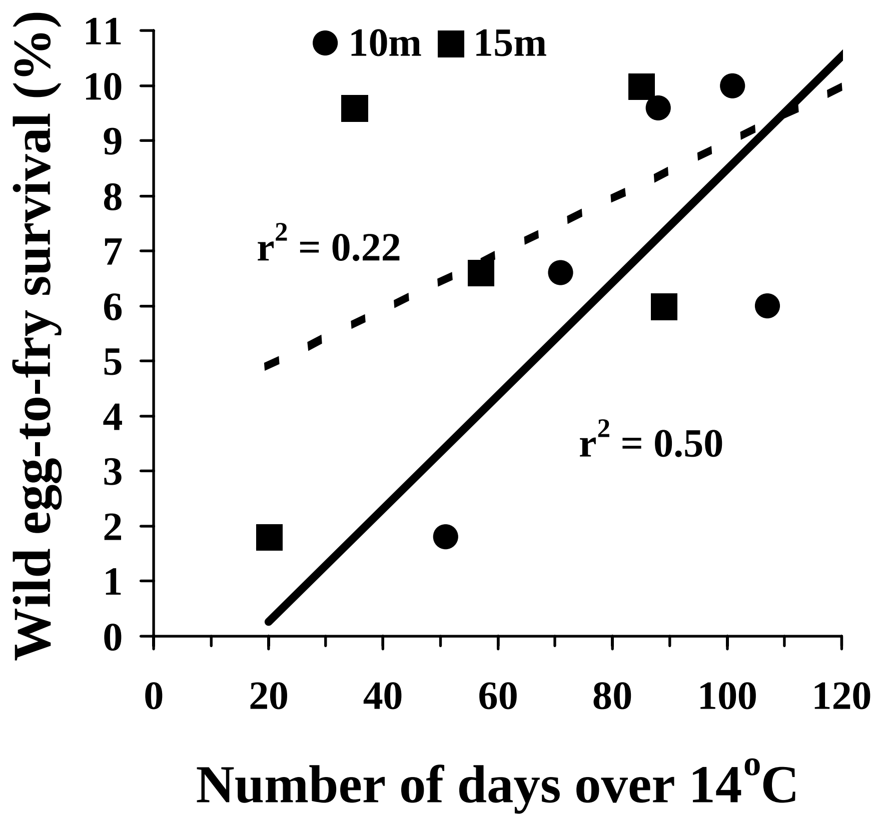


Figure 1.24. The relationship between the number of days during summer that the water temperature was over 14°C and the survival rate of wild kokanee fry in Lake Pend Oreille, Idaho. Two regressions are shown: one for the top 10 m of water (dots with the solid line), and one for the top 15 m of water (squares with the dashed line).

Hatchery Kokanee Stocking

The number of kokanee stocked annually by Cabinet Gorge and Clark Fork Fish hatcheries was regressed against wild egg-to-fry survival (Figure 1.25). The correlation was very weak (r^2 = 0.012) with good wild egg-to-fry survival rates occurring in years of both high or low hatchery stockings.

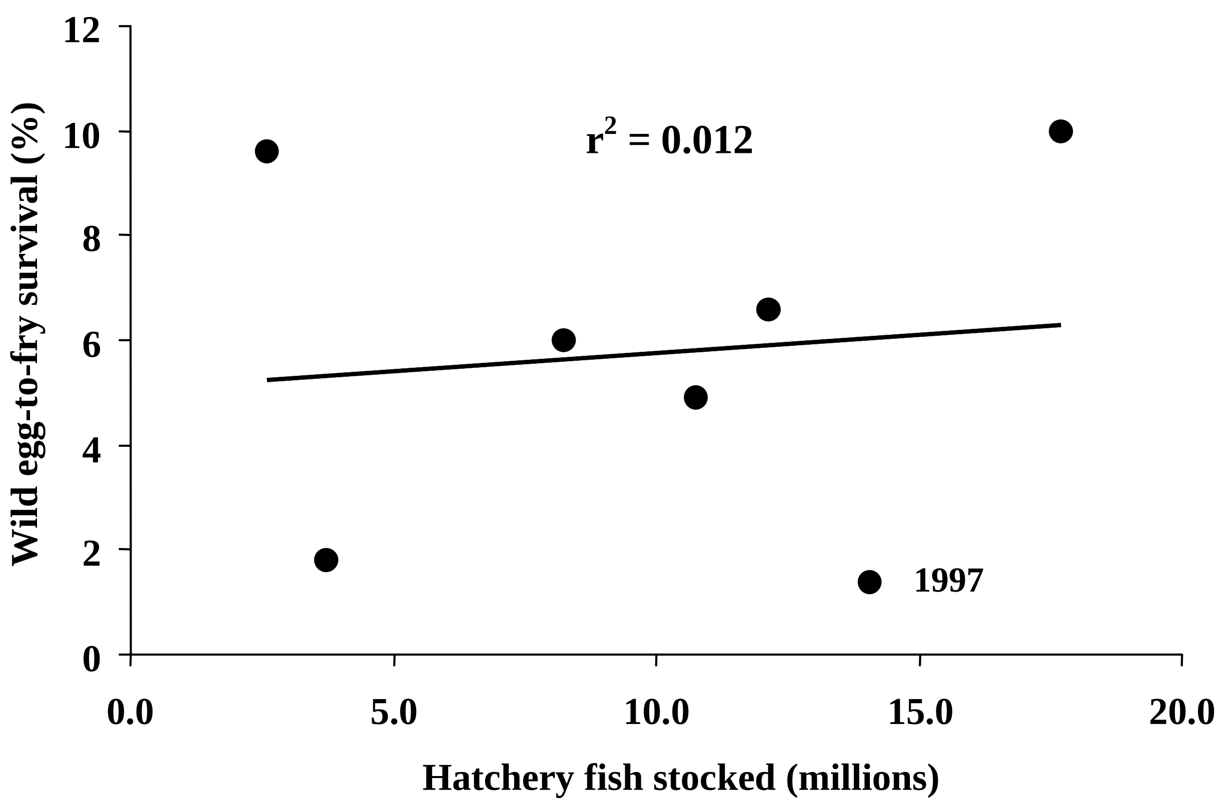


Figure 1.25. Relationship between the number of kokanee fry stocked in Lake Pend Oreille, Idaho and the egg-to-fry survival rate of wild-spawned kokanee from 1995 to 2001. The point for the flood year of 1997 was marked for clarity.

DISCUSSION

Winter elevations of Lake Pend Oreille were changed between 1996 and 2000 to see if survival of wild kokanee eggs would be enhanced. In the original proposal, an enhancement of 26% was the criteria for a successful test (Maiolie 1996). During this study, kokanee survival improved 157% (from a mean of 3.2% in 1995 and 1996 to a mean of 8.1% in 1998, 1999, 2000, and 2001) during the years with a raised winter lake elevation (Figure 1.16). Improvements of this magnitude were much better than anticipated and should be considered a success. Increases in survival of this magnitude could be sufficient to recover the kokanee population if it can be boosted out of the current predator trap that is causing high mortality on older age classes of kokanee (Chapter 3).

This study took an adaptive management approach; an identified limiting factor for this ecosystem was changed, and the results were monitored. The large increases in survival therefore constitute a “success” and can be considered positive advancement for future management. This approach was appropriate because it changed a factor in the ecosystem and then monitored the function of the entire ecosystem for an indication of improvement to kokanee survival. The study should not be viewed as a controlled experiment. Large lakes have no true control. We compared kokanee survival to past years knowing that they are not true controls. Many variables can change annually on any large lake system. We examined several of those variables in this chapter. Warmer water temperatures, Secchi depths, and the number of kokanee fry stocked into the lake were also not well correlated to kokanee egg-to-fry survival and were not thought to influence the outcome of the test. One variable that was correlated to kokanee survival was the number of adult kokanee in the population. Kokanee have been declining in Lake Pend Oreille for the past three decades. Their decline continued during this test. Lower year classes of adults could be expected to produce good survival rates. This is consistent with the original hypothesis that spawning areas are in limited supply. When the population declines, there is less superimposition of redds and egg-to-fry survival improves. In this study, the lake levels changed and kokanee survival improved. Other variables did not (and likely never will) remain constant throughout the test. The importance of other factors can be examined in the future by continued monitoring while changing lake levels.

Our expectation was to see two separate relationships as in Figure 1.18A. Kokanee egg-to-fry survival would remain high, even at high adult densities, under enhanced spawning conditions provided by effective lake level management. Varying the winter lake level enhances kokanee spawning in many widely separated areas of the lake. Thus, kokanee survival can be enhanced two ways. Egg survival is improved in individual redds, because gravel is clean and is of suitable size so that eggs can be buried where they are less likely to be preyed upon. Secondly, spawning takes place in expanded areas of the lake, which minimizes superimposition of redds and spreads the fry out where it would be more difficult for predators to effectively feed on a large segment of the population. Evidence for this was documented in the distribution of kokanee spawning. During the years of higher water levels, more kokanee spawn in areas outside of Scenic Bay. However, when the lake was drawn down to minimum pool, most of the kokanee spawning occurred within this one location. If shoreline spawning areas were in poor condition, egg-to-fry survival would be lower, especially at high adult densities where superimposition of redds would become more pronounced (lower line in Figure 1.18A). A second explanation for an increase in egg-to-fry survival was that adult kokanee density was driving the survival rates as seen in Figure 1.18B. This should be examined by determining wild fry survival when the number of spawning females is high and the winter lake levels have been raised to improve shoreline gravel (1.2 m higher than the previous year).

One past hypothesis for kokanee declines in Lake Pend Oreille was that opossum shrimp were delaying springtime zooplankton production, thereby causing high mortality of kokanee fry due to starvation. However, results of this lake level experiment tend to disprove this hypothesis. Egg-to-fry survival rates of 6-10% were estimated by hydroacoustics partitioned by the percent of wild fish in the trawl. Egg-to-fry survival rates were estimated as high as 14.9% in 2000 based on hydroacoustic estimates of fry abundance partitioned by the percent of wild kokanee in the fry net. These survival rates were considered to be very high and not show the impacts of intense competition for food resources. Secondly, kokanee survival increased markedly after lake levels changed. We would not have expected to see this response if opossum shrimp had truly reduced the carrying capacity of kokanee fry in the lake.

Winter lake levels were raised 0.6 and 1.2 m during this study. Kokanee survival under both of these levels was high compared to years of full drawdown. This indicated that either elevation change was sufficient to enhance spawning during years when the kokanee population was low, ranging from 33,000 to 197,000 mature female kokanee. The trend line in the regression of Figure 1.17 would indicate that 1.2 m increases in winter lake level would give a higher probability of better egg-to-fry survival. This is also consistent with the recommendations in Chapter 4. We would expect that raising the lake 1.2 m would show a more pronounced affect with a stronger adult population.

The fry net yielded higher density estimates of wild kokanee than the trawl net because the small mesh size prevented even the smallest wild fry from escaping. Using the hydroacoustic estimate of fry partitioned by the percent of wild fry in the fry net yielded possibly the most realistic estimate of wild egg-to-fry survival (6-15% in years of raised lake levels). These rates were considered high for a kokanee population. For comparison, in Sullivan Springs Creek, after stream improvements and limiting the spawning run to 10,000 kokanee, egg-to-emergent fry survival was calculated at 6.1% (Whitt 1958). This survival rate would be expected to drop considerably if the time period were extended to fall fry. Survival rates in our current lake level study, therefore, indicated excellent kokanee survival. The wild egg-to-fry survival rate for kokanee in Lake Pend Oreille was estimated at 1.3% in 1978 (Rieman and Bowler 1980) and 1.5% in 1990 (Paragamian et al. 1991). These studies were based on trawling and may not be directly comparable to the much higher survival rates estimated in the current study.

CONCLUSIONS

We found that the egg-to-fry survival of wild kokanee was markedly improved during the years of higher winter water levels. The major improvement in survival was of a magnitude sufficient to lead to increases in the kokanee population. Therefore, our conclusion is that lake level changes should continue as a means of recovering the kokanee population in Lake Pend Oreille.

RECOMMENDATIONS

1. In this study, winter lake elevations were raised and improved kokanee fry survival was documented (Figure 1.17). We therefore recommend periodically raising lake levels by 0.6 m (2 ft) to 1.2 m (4 ft) as an attempt to recover the kokanee population. This will

allow kokanee to spawn on gravel that has been washed and resorted by wave action. Highest pool levels should coincide with the strongest year classes of adult kokanee. (See Chapter 4 for additional recommendations on lake level changes.) Lake levels were lowered in 2001 to resort gravel on potential spawning areas (U.S. Army Corps of Engineers elevation records). We then recommend the lake be held higher in the winter of 2002-2003 when good year classes of adult kokanee are anticipated.

2. Kokanee in Lake Pend Oreille should be monitored annually by hydroacoustics, fry netting, and trawling similar to the approach used in this study. This time-series information would be invaluable in determining the continued response of kokanee to changes in lake level and to document their response to other environmental variables.

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CHAPTER 2: OPOSSUM SHRIMP INVESTIGATIONS

ABSTRACT

We monitored the opossum shrimp *Mysis relicta* population in Lake Pend Oreille from 1997 to 2001. Our goal was to determine if shrimp were influencing the outcome of the lake level tests (Chapter 1) or preventing the recovery of the kokanee population in the lake. We netted shrimp with a 1 m hoop net and a high-speed Miller sampler. Immature and adult shrimp densities ranged from 252 shrimp/m^2 in 1997 to 426 shrimp/m^2 in 1998 based on hoop net sampling. Shrimp densities were not well correlated to the egg-to-fry survival rate of naturally–produced kokanee ($r^2 = 0.03$), indicating they were not influencing the outcome of the lake level test. High survival rates of kokanee (9.6% from eggs to fry) were noted in 1998 when shrimp densities reached their highest point during this study (426 shrimp/m^2). Shrimp abundance estimates since 1973 indicated the population peaked in 1980; however, it has continued to decline to the present date. With these findings, we concluded that opossum shrimp are not currently limiting the kokanee population.

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INTRODUCTION

During the 1960s and 1970s, opossum shrimp *Mysis relicta* were introduced in lakes and reservoirs throughout the western United States, Canada, and Scandinavia to enhance the food base for sport fisheries (Lansenby et al. 1986). Several hundred lakes were stocked with opossum shrimp (Northcote 1991). Years later, shrimp were documented to have negatively impacted zooplankton populations in many of the lakes where they were introduced, which may have directly or indirectly affected the sport fish populations. However, opossum shrimp introductions were labeled a qualified success in some lentic ecosystems. Factors influencing the success included the shape of the lake, current conditions, nutrient status of the lake, temperature of the water, and presence of fish species that feed on opossum shrimp (Northcote 1991; Rieman and Falter 1981).

In an effort to increase food availability for juvenile kokanee *Oncorhynchus nerka*, Idaho Department of Fish and Game (IDFG) introduced opossum shrimp to Lake Pend Oreille from 1966 to 1970. Opossum shrimp established themselves in the lake after nine to ten years (Bowles et al. 1991). Starting in the mid-1960s, the number of kokanee harvested by anglers began a steady decline. In 2000, the kokanee fishery was closed due to low numbers of fish. In the early 1980s, kokanee declines were blamed on the establishment of opossum shrimp, which were thought to compete with the kokanee for food.

It was hypothesized that kokanee declines after 1975 were due to the introduction of opossum shrimp to Lake Pend Oreille, resulting in a reduction of the availability of food for newly emerged kokanee fry (Bowler and Rieman 1981). Egg-to-fry survival was estimated at 1.21% in 1978, suggesting that lack of food was causing poor survival of young kokanee, therefore resulting in poor recruitment to adults (Rieman and Bowler 1980). Older age classes of kokanee had good survival rates and did not appear to have been impacted by the introduction of the opossum shrimp.

The purpose of our investigation of opossum shrimp in Lake Pend Oreille was twofold. First, we evaluated whether or not dramatic changes in shrimp abundance influenced the outcome of the lake level experiment. Second, we further investigated the hypothesis that shrimp were limiting the kokanee population and keeping it from recovering to previous levels. Researchers at the University of Idaho conducted part of this work. Their results are included in their entirety as Chapter 2B.

METHODS

To better understand the influences of opossum shrimp abundance on the lake level experiment, *Mysis relicta* were sampled annually from 1997 to 2001. Shrimp avoid light through a diel vertical migration from the deep waters they inhabit during daylight hours to the epilimnion they inhabit at night. This migration is due not only to light levels and temperature, but also the need to curtail predation and take advantage of food intake opportunities (Gal et al. 1999). Due to this behavior, our opossum shrimp sampling occurred at night when the shrimp are closer to the surface of the lake. All sampling was conducted during the dark phases of the moon in June. This has been the standard sampling date for most of the previous work on shrimp and for all of our sampling since 1997. Vertical net tows and Miller sampling techniques were used to collect the shrimp (methods described below). The purpose of this dual sampling was to allow us to convert the older data sets, collected with the Miller sampler, into density estimates consistent with vertical net tows.

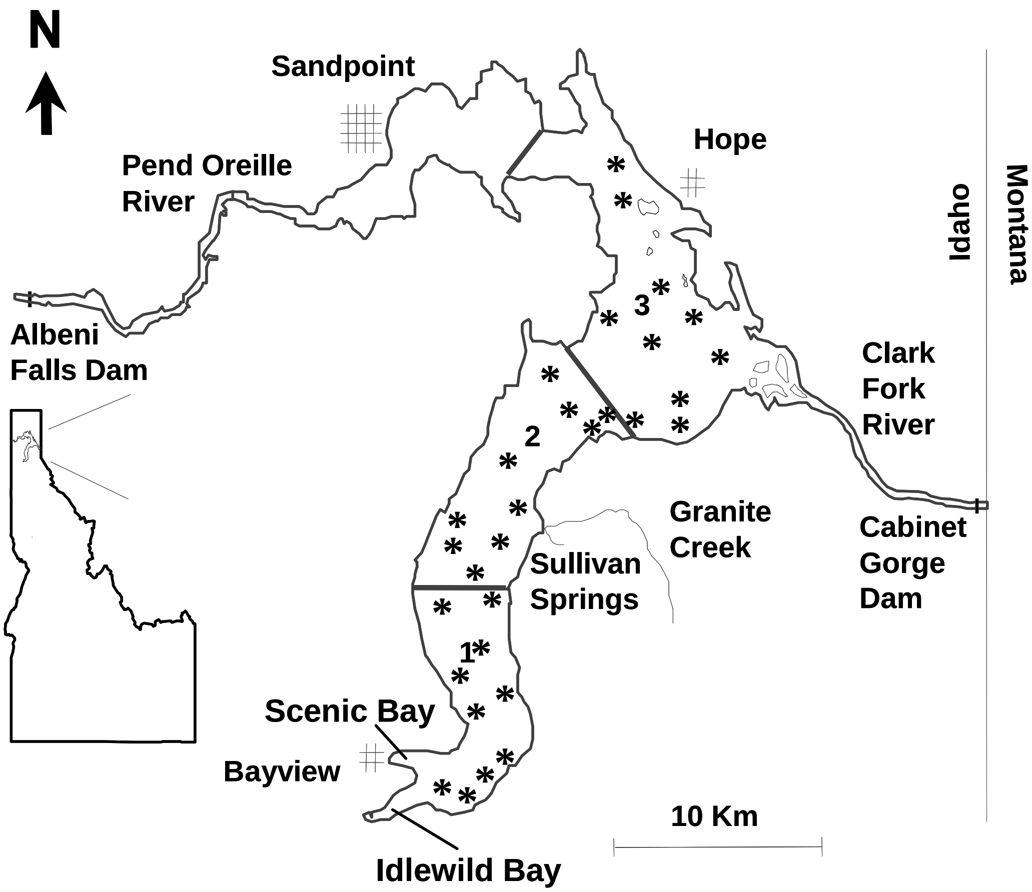
Opossum shrimp were measured from the tip of the rostrum to the end of the telson, excluding setae. They were classified into five categories according to maturity and gender: young-of-year, immature males and females, and mature males and females. These data were used annually to determine the opossum shrimp length frequency distribution (Figure 2.2). Young-of-year are generally less than 10 mm in length and have indistinguishable sex characteristics. Immature males are distinguishable by the presence of two thumb-like appendages located at the base of the legs on the eighth thoracic segment, by the elongation of the pleopod on the fourth abdominal segment, and by the infinitesimal development of the conical process, located on the distal end of the third segment of the antennular peduncle. In mature males, the conical process becomes more visible and setiferous. In mature breeding males, the fourth pleopod extends past the end of the telson. Female opossum shrimp are discernable by the formation of a brood pouch located on the underside of the seventh and eight thoracic segments. The brood pouch is small and light colored in immature females; however, mature brooding females exhibit brood pouches filled with, or recently emptied of, eggs, embryos, or larvae (Gregg 1976; Pennak 1978).

Vertical Net Tows

The vertical tow technique was used annually from 1997 to 2001 and during previous opossum shrimp sampling in 1995 and 1996 (Chipps 1997). Shrimp were collected using a hoop net that was 1 m in diameter and equipped with a flowmeter. Net mesh and cod-end bucket mesh measured 1000 um and 500 um, respectively. We lowered the net to a depth of 45.7 m (150 feet) and raised it at a rate of 0.5 to 0.7 m/s using an electric winch. Collected opossum shrimp were immediately placed in denatured ethanol for preservation. Eight sampling sites were randomly selected from each of the three sections of the lake in 1997, 1998, and 1999. Ten sampling sites were randomly selected from each lake section in 2000 and 2001 (Figure 2.1). Global positioning system (GPS) coordinates were used to locate each sampling site.

Miller Sampler

During 1999, we collected shrimp at 12 sites (four sites in each of the three sections) with the Miller sampler concurrently with the vertical tow nets by using a second boat. In 2000, 12 additional sites were sampled with both gear types (10 in the northern section and 2 in the middle section). The Miller sampler had a 104 mm diameter opening (0.00849 m^2) and 500 um mesh. The Miller sampler was lowered to 45.7 m and towed at 1.7 m/s. It was then raised 3 m at 10 s intervals until it reached the surface. A General Oceanics, Inc. flowmeter was positioned over the side of the boat at the beginning of each transect to measure the horizontal towing distance. Densities of shrimp collected by the two methods were compared by linear regression analysis to develop a conversion equation. The mean densities of opossum shrimp collected by the Miller sampler and the vertical tow were compared statistically with a student's t-test.



Section	Area (hectares)
1	6386
2	7776
3	8384

Figure 2.1. Map of Lake Pend Oreille, Idaho showing the opossum shrimp sampling locations used in June 2001.

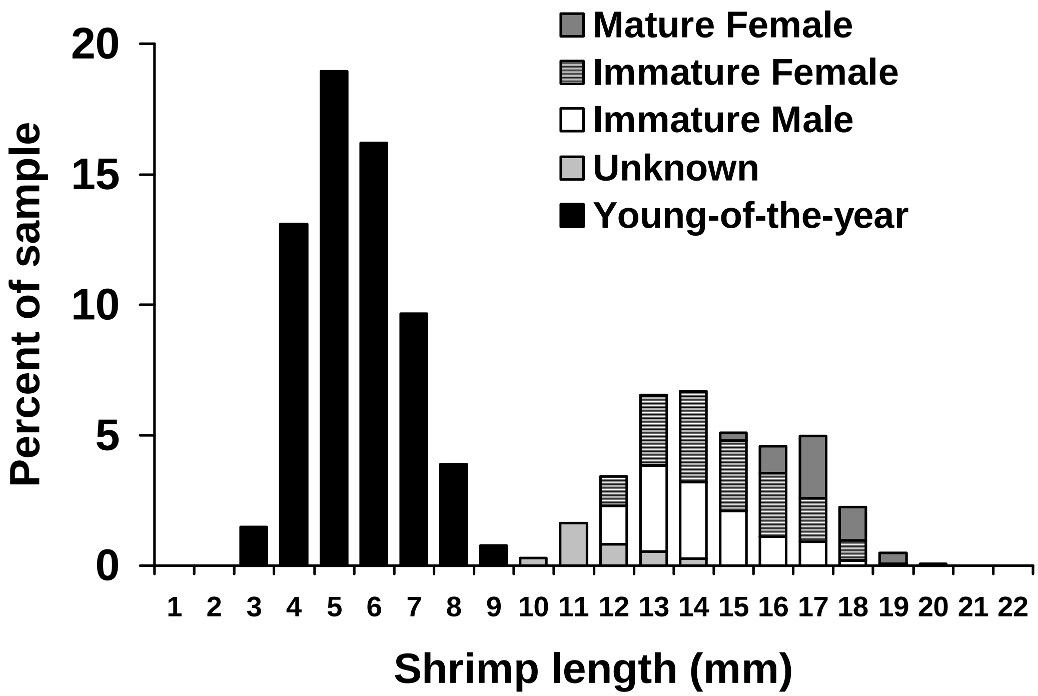


Figure 2.2. Opossum shrimp length frequency distribution during June 2001, on Lake Pend Oreille, Idaho.

RESULTS

Between 1997 and 2001, we estimated a mean density of all age classes of shrimp at 689 shrimp/m^2, with a range from 510 to 880 shrimp/m^2 (Figure 2.3). These estimates were lower than density estimates made in the early 1980s (Figure 2.3). From 1980 to 1985, the mean density of all age classes of opossum shrimp was 1,440 shrimp/m^2. Population estimates peaked during 1980 and showed a generally downward trend that continued through 2001 (Figure 2.3).

Our estimates of immature and adult shrimp (excluding young-of-the-year shrimp) peaked in 1998, one year after the 1997 flood, with a mean of 426 opossum shrimp/m^2, (Figure 2.4). From 1998 through 2001, immature and adult shrimp densities declined to 225 opossum shrimp/m^2.

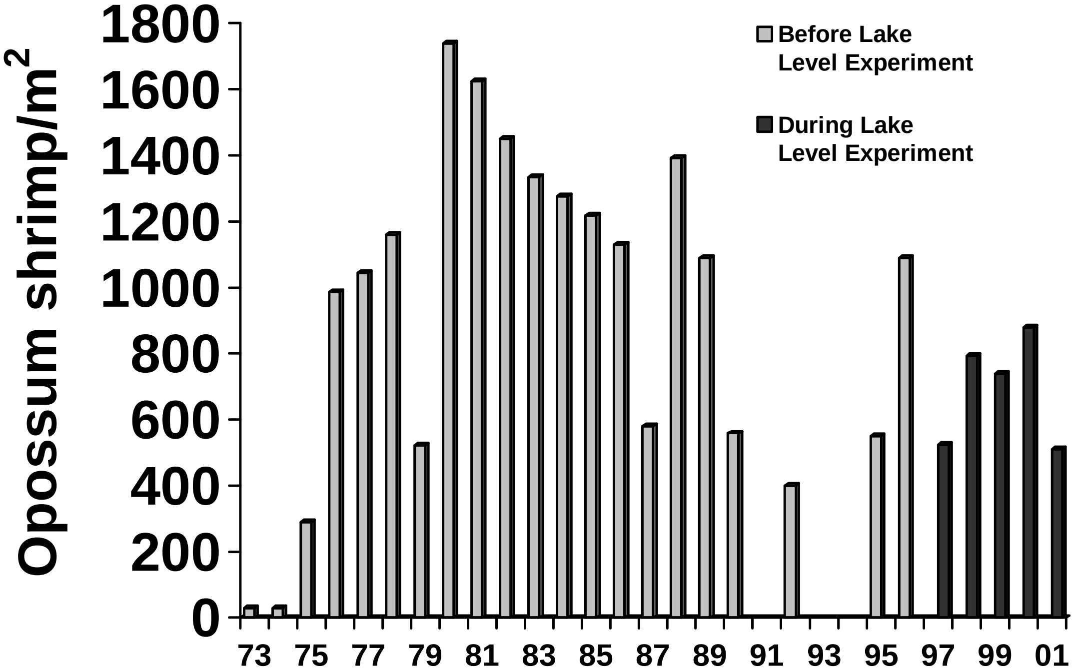


Figure 2.3. Annual mean density of opossum shrimp in Lake Pend Oreille, Idaho 1973-2001. Data collected before 1989 were obtained from Bowles et al. (1991), and data from 1995 and 1996 were from Chipps (1997). Shrimp densities from 1992 and earlier were converted from Miller sampler estimates to vertical net tow estimates by using the equation presented in Figure 2.7A. Gaps in the bar chart indicate no data were collected that year.

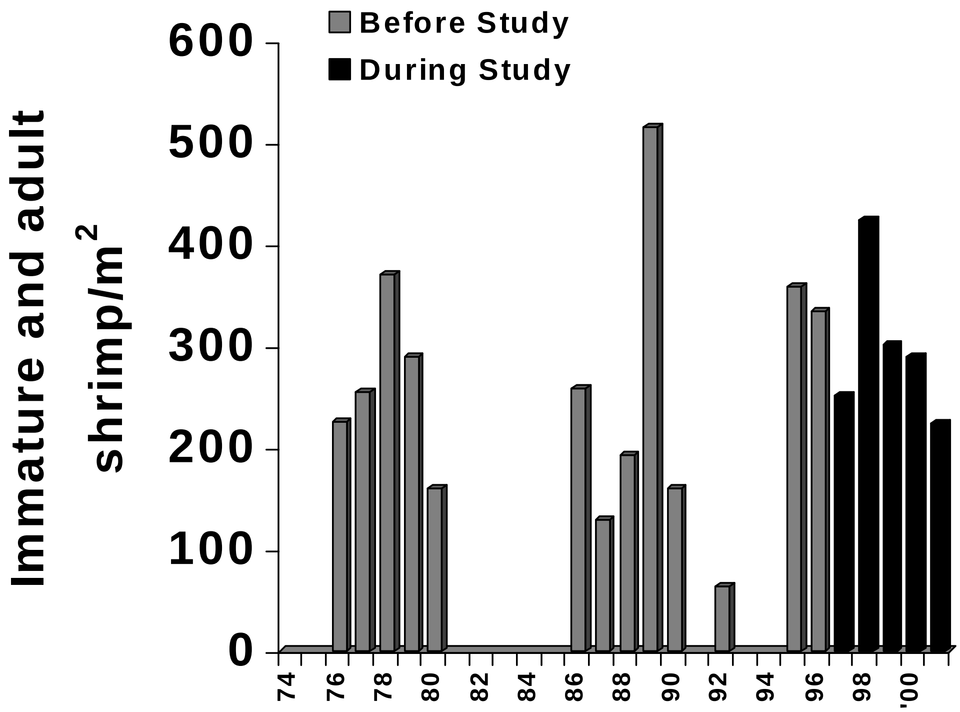


Figure 2.4. Density of immature and adult opossum shrimp/m^2 in Lake Pend Oreille, Idaho 1974-2001. Data collected before 1995 were converted from Miller sampler estimates to vertical net tow estimates by the equation in Figure 2.6B. Data from 1976-1980 are from Bowler and Rieman (1981) and data from 1986 to 1992 were from Paragamian and Ellis (1994). Gaps in the bar chart indicate no data were collected, or the young-of-the-year fraction could not be determined.

Trends in opossum shrimp densities within the three lake sections varied between 1997 and 2001 (Figure 2.5). With the exception of 1998, the opossum shrimp densities were generally less in the northern lake section. Young-of-the-year densities were consistently higher in the southern and middle sections of Lake Pend Oreille. Immature and adult shrimp densities were generally highest in the northern section of the lake (Table. 2.1). Shrimp densities declined to the lowest densities on record in the northern section during the flood year of 1997, but rebounded to the highest densities on record the following year (Figure 2.5).

Comparisons between 1999 Miller sampler and vertical tow data indicated a strong correlation of determination (r^2 = .82); however, a significantly higher (p = .0001) density of opossum shrimp was captured when using the Miller sampler (Figure 2.6).

Densities of immature and adult shrimp between 1995 and 2001 were poorly correlated with that year's estimate of survival rate for wild spawn kokanee eggs to wild kokanee fry (r^2 = 0.09) (Figure 2.7).

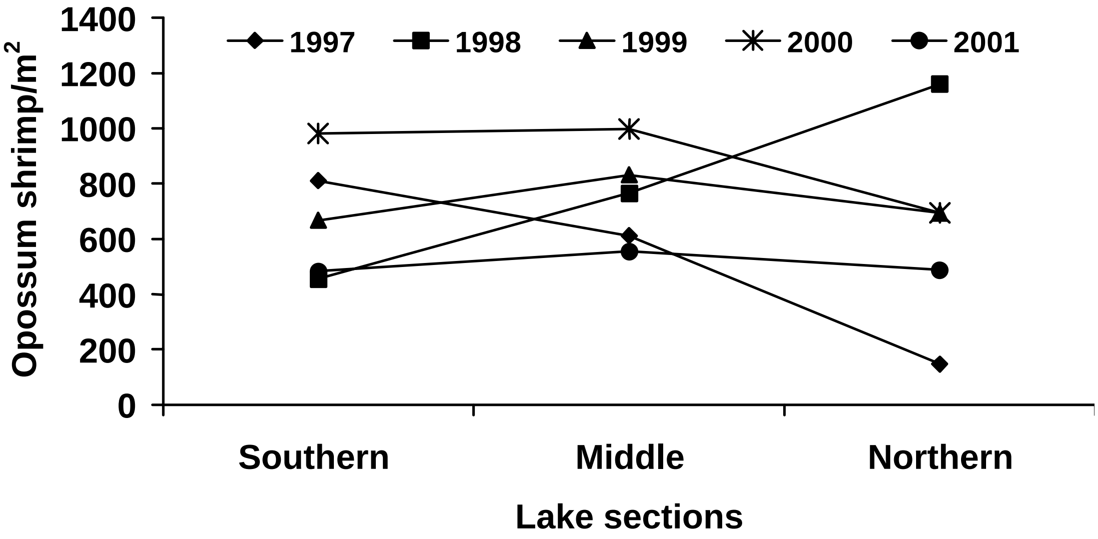
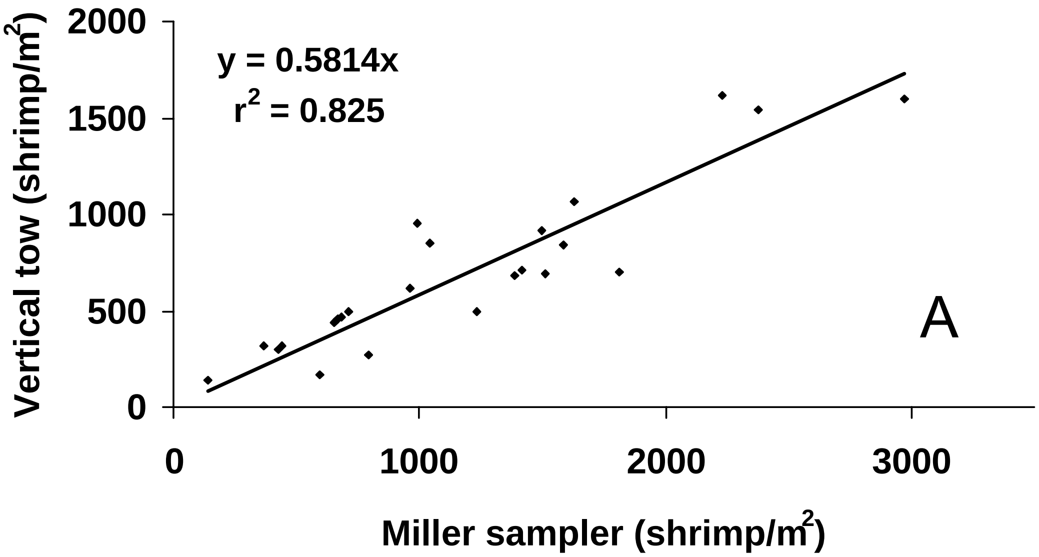


Figure 2.5. Mean density of all age classes of opossum shrimp/m^2 per lake section, Lake Pend Oreille, Idaho 1997-2001.

Table 2.1. Yearly mean density (shrimp/m^2) comparisons of young-of-the-year and immature/adult opossum shrimp per lake section in Lake Pend Oreille, Idaho, 1997-2001.

Lake Section and Life Stage	1997	1998	1999	2000	2001
Southern Section:					
Young-of-the-year	431.5	306.5	432.0	696.3	330.0
Immature and adult	379.8	148.6	234.6	283.5	155.2
Middle Section:					
Young-of-the-year	338.9	565.8	594.3	659.0	333.9
Immature and adult	273.4	198.9	237.1	338.2	221.1
Northern Section:					
Young-of-the-year	44.0	230.3	293.5	449.0	205.2
Immature and adult	102.4	929.8	412.3	245.2	281.5



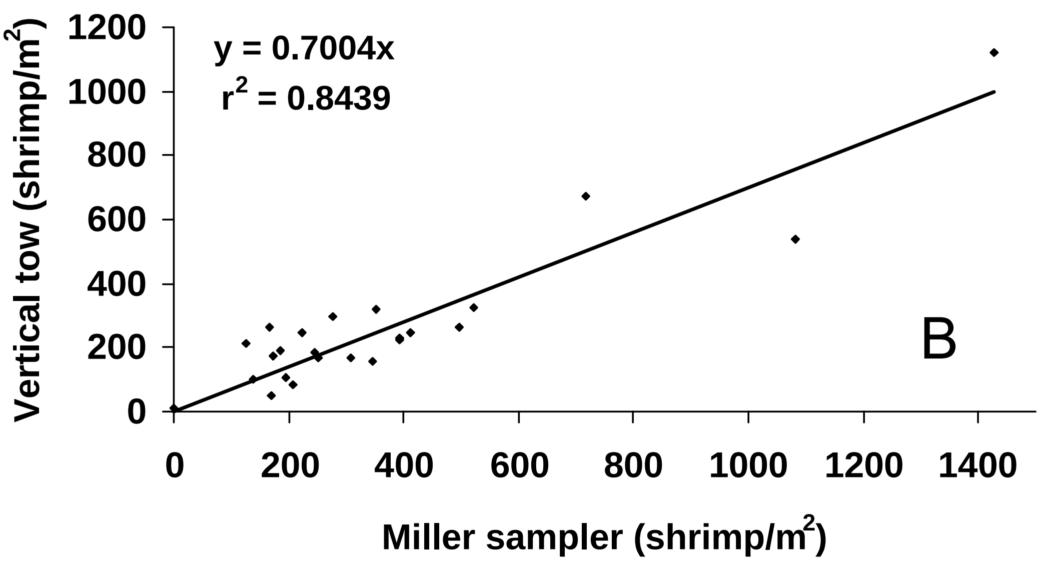


Figure 2.6. Comparison of shrimp density estimates collected with a Miller sampler and vertical net tows in Lake Pend Oreille, Idaho 1999 and 2000. Figure A is a linear regression utilizing all shrimp and Figure B uses only adult and immature shrimp (excludes young-of-the-year shrimp). The y-intercepts were set at zero.

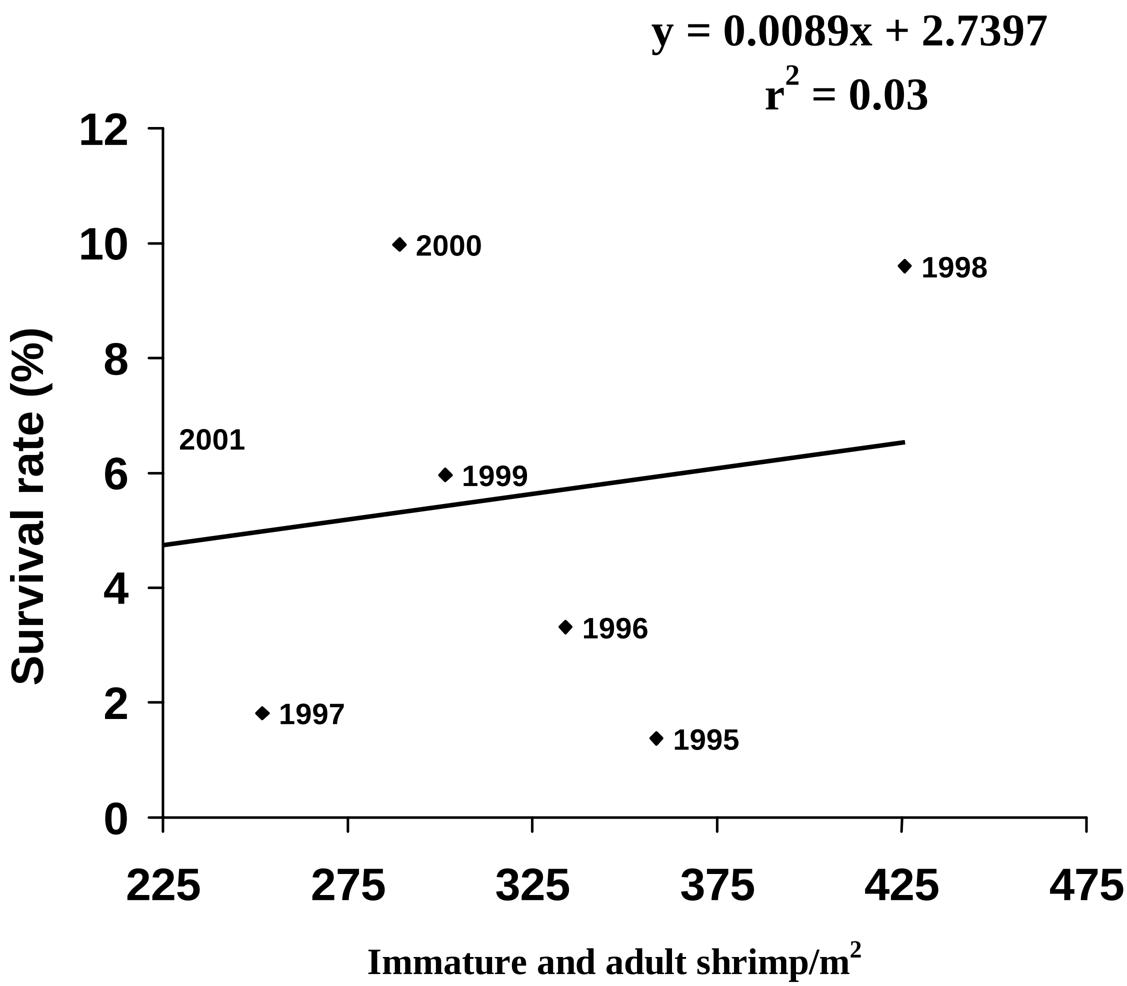


Figure 2.7. Correlation between mean opossum shrimp densities and the survival rate from kokanee eggs to fry in Lake Pend Oreille, Idaho 1995-2001.

DISCUSSION

We found little correlation between kokanee egg-to-fry survival and immature/adult shrimp abundance (Figure 2.7). These life stages of shrimp would be most likely to compete with kokanee if food were a limiting factor. Chipps (1997) found that young-of-the-year shrimp exert little predation mortality on crustacean zooplankton and do not become potential competitors with kokanee until they reach a length of >8 mm. Excellent kokanee survival was found in 1998 when the shrimp population was high and also in 2000 when the shrimp population was lower. Conversely, poor kokanee survival was seen in 1997 when the shrimp population was low and in 1995 when the shrimp population was relatively high. The fact that the kokanee population responded dramatically to lake level changes (Chapter 1) regardless of shrimp abundance demonstrated that shrimp were not limiting the survival of kokanee fry.

The original hypothesis was that newly emerged kokanee fry were starving shortly after emergence because opossum shrimp had delayed the bloom of cladocern zooplankton by approximately one month in some years (Rieman and Bowler 1980). However, the blooms of copepods had not been delayed. Clark (1999) found that the most important item in the diet of newly emerged kokanee in May to June 1998 was the copepod *Cyclops bicuspidatus thomasi* (Chapter 2B), which was also the most abundant prey item in the lake at that time. This food habits study demonstrated that kokanee fry are not dependent on a diet of cladocerns, and in fact, the study shows that kokanee are feeding on the more common types of plankton that were still readily available after the establishment of opossum shrimp.

Net pen experiments also demonstrated that kokanee survival was not being impacted by food availability due to competition with opossum shrimp. Clark (1999) (Chapter 2B) placed newly emerged kokanee fry in net pens in Lake Pend Oreille in 1998. One set of net pens had a large enough mesh to allow kokanee to feed on the ambient levels of zooplankton without the addition of supplemental food to the pen. The other set of pens held newly emerged kokanee fry that were allowed to feed on the ambient food, but were also given additional zooplankton. Kokanee mortality did not occur in either pen. In fact, kokanee growth was not significantly different between the two pens despite the supplemental feeding.

Rieman (1981) obtained results similar to those mentioned above. In Rieman's experiment, button-up fry were placed in net pens from early April to early July. The fry were not given additional food and had to rely on ambient zooplankton. Rieman's net pen tests also showed "negligible" mortality of kokanee held at ambient zooplankton levels in Lake Pend Oreille. The first four experiments had 97% survival; the next five experiments had 100% survival. Rieman stated "the potential for mortality of juvenile kokanee due directly to starvation appears to be low."

It was not hypothesized that opossum shrimp were impacting kokanee older than the fry stage. Kokanee older than fry continued to survive well until the mid-1990s. Based on trawl data obtained from 1977 to 1998 (excluding the flood year of 1997) in Lake Pend Oreille, survival rates of kokanee from age-0 to age-1 averaged 52%; age-1 to age-2 averaged 80%, and age-2 to age-3 averaged 79%. This compares favorably with Coeur d'Alene Lake from 1991 to 1999 (excluding the flood year of 1996). During this time, survival averaged 49%, 82%, and 62%, respectively, for the same year classes (Fredericks and Horner 2001). Coeur d'Alene Lake does not contain opossum shrimp; however, kokanee predators in the form of chinook salmon are present there, and the lake provides a popular kokanee fishery. The same trawling gear was used in Spirit Lake between 1989 and 2000 (data was not collected in 1992 and 1996). The mean survival rate from age-1 to age-2 was 56%, and a mean survival rate from age-2 to age-3 was 40% (Fredericks and Horner 2001). Spirit Lake does not contain opossum shrimp or major kokanee predators, and it provides a very popular fishery for kokanee. These data indicate good kokanee survival in Lake Pend Oreille after the fry stage, in spite of the presence of opossum shrimp.

The history of kokanee declines in Lake Pend Oreille also sheds some doubt on the hypothesis that opossum shrimp were limiting the kokanee population. Bowles et al. (1991) illustrates the decline in angler's catch of kokanee in comparison to the densities of opossum shrimp in Lake Pend Oreille. Kokanee catch had declined 64% between 1964-1974, from 22 fish/ha in 1964 to 8 fish/ha, respectively. By 1974, shrimp densities in the lake were still exceedingly low. By 1976, when shrimp abundance first increased to over 1,000 shrimp/m^2, kokanee harvest had already declined to approximately 6 fish/ha. This large decline in kokanee harvest in the decades before the establishment of opossum shrimp must have been caused by some factors other than the introduction of opossum shrimp.

Between 1952 and 1966, Maiolie and Elam (1993) found a strong inverse relationship ($r^2 = -0.71$) between the drawdown of Lake Pend Oreille after November 15, when kokanee spawning begins in earnest, and the harvest of kokanee five years later. This negative trend was highly significant ($p = 0.005$). These results implicated lake level management in the early declines of the kokanee stock.

In Chapter 1 of this report, we discussed how lake level management continued to impact the kokanee populations after 1966 by making much of the spawning gravel unavailable to shoreline spawning kokanee. After 1966, the lake was drawn down to its minimum pool level during most years. Fredericks et al. (1995) found that only 35,460 m^2 of suitable spawning gravels were below the water line when the lake was held at its minimum pool elevation of 625.1 m. When the lake is maintained at a winter level of 626.7 m, 231,134 m^2 of gravel remains available for spawning. Reduction in the amount of suitable spawning areas would have limited the kokanee populations to a low level that would be in balance with this amount of spawning habitat and would have contributed to the kokanee declines between 1966 and 1996. Changes in the winter lake level from 1995 to 2000 were positively correlated with kokanee egg-to-fry survival (see Chapter 1). This finding also suggests that lake levels, not opossum shrimp, were limiting the kokanee population.

Although competition with shrimp did not appear to be limiting the kokanee population throughout this study, it is possible that competition could be an important factor if the kokanee population expands toward a "recovered" level. In this study, the density of kokanee was so low that food was not a limiting factor. Standing stocks of kokanee in 1977 and 1978 were 13-17 kg/ha. Rieman and Bowler (1980) concluded that those densities of kokanee "did not have a significant cropping effect on available food," and "density-dependent interactions related to food do not appear to be important." During those years, immature and adult shrimp densities were similar to current opossum shrimp densities. Rieman and Bowler (1980) did document a decline in the mean length of Daphnia in certain areas of the lake, which suggested significant cropping pressure at the relatively high density of 30 to 40 kg/ha. We estimated that the lake contained 4 kg/ha of kokanee in 1999 and 6 kg/ha of kokanee in 2000. We, therefore, expect that kokanee standing stocks could increase by at least several fold before food limitations occur.

CONCLUSIONS

We conclude that opossum shrimp are not currently limiting the kokanee population or causing the ongoing declines in kokanee abundance. We also find that changes in opossum shrimp abundance did not nullify the outcome of the lake level experiment. Shrimp population was both high and low during years of higher winter lake levels, and shrimp abundance did not correlate with kokanee survival. A review of the history of shrimp sampling also shows that shrimp did not cause the early declines in the kokanee population from 1966 to 1975, which was before they became well established in the lake.

RECOMMENDATIONS

1. We recommend continuing efforts to recover the kokanee population through lake level changes and other management actions. Our findings do not support the conclusion that the kokanee population is being limited by opossum shrimp.

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CHAPTER 3: KOKANEE PREDATION

ABSTRACT

We examined the predator and prey (kokanee) relationship in Lake Pend Oreille to determine if it is in balance. Hydroacoustics surveys were conducted to estimate the population of large pelagic fish over 415 mm (-33 dB) that were likely to be predators (rainbow trout, lake trout or bull trout). Midwater trawling and hydroacoustics were used to estimate kokanee production, yield, and survival rates. Rough estimates of large pelagic fish remained relatively stable at 13,000 to 17,000 fish between 1998 and 2001, which indicated no large decline due to the liberalized sport fish regulation changes in 2000. Kokanee biomass declined from 344 metric tons in 1995 to 149 metric tons in 2001, illustrating a continuing decline in the kokanee population. Kokanee survival rates between age-1 and age-2 fish dropped substantially from 79% in 1996 to 27% in 2001, which were attributed to predation. Even with the declines in the kokanee biomass, kokanee yield (the weight of all kokanee that died between years) remained high at 314 metric tons. Based on linear modeling of the empirical data, yield would need to decline by 24% to balance with kokanee production. The imbalance between the kokanee prey base and predators appeared to have arisen in 1997 when high spring run-off caused abrupt declines in kokanee abundance. After this time, dispensatory mortality appeared to cause a further decline in the kokanee population.

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INTRODUCTION

When the Lake Pend Oreille Project was originally designed in 1994 and 1995, there was speculation that predation may be causing declines in the kokanee population. Survival rates of all age classes of kokanee had been monitored for 18 years prior to the implementation of the project. These data indicated good survival rates of kokanee older than fry; however, the population was still declining. The Northwest Power Planning Council addressed the possibility that predation may be causing the declines in the kokanee population by requesting investigations into the uncertainties related to predator abundance and predation levels in Lake Pend Oreille.

Idaho Department of Fish and Game and the University of Idaho collaborated to conduct studies on predation in Lake Pend Oreille. The kokanee population was closely monitored by Idaho Department of Fish and Game, with research emphasis on kokanee survival rates between age classes, kokanee production rates, and kokanee yield. The University of Idaho focused their research efforts on estimating predator abundance, determining predator food habits, and using a bioenergetic model to approximate the number of kokanee consumed by predators. The University of Idaho studies are included in their entirety at the end of this chapter (Chapter 3B).

METHODS

Surveys for Large Pelagic Fish

We conducted hydroacoustic surveys of Lake Pend Oreille each year between 1995 and 2001, within two weeks of the annual mid-water trawling. Survey methods were described in detail in Chapter 1. An analysis method called "trace tracking" was used to identify the predators. To be considered a pelagic predator, the fish must have a target strength larger than -33 dB (a size equal to a 415 mm salmonid [Love 1971]), must be detected (pinged) at least twice, not move more than 30 cm vertically between detections, and not be missed by more than 1 ping during the tracking. In addition, the fish must be located in a minimum water column depth of 70 meters and be at least 10 meters from the bottom. Hydroacoustic transects were not used in areas where the majority of the lake bottom was within 70 meters of the surface. This phase of our investigation only included the open, pelagic region of the lake. Future investigations will include analysis in the littoral areas; which will likely contain a more diverse species community and require additional methods of sampling.

Kokanee Population Estimates and Survival Rates

The catch of our annual midwater trawling (see Chapter 1) was used to determine the percent frequency of each age class of kokanee between age-1 and age-5 for each section of the lake. Hydroacoustic estimates were multiplied by this percentage to estimate year class abundance. Age-0 kokanee were estimated directly from the echograms. We estimated annual survival rates for each year class of kokanee by dividing a year class by its abundance the previous year. By closely monitoring changes among and between age classes, we were able to estimate the effect predation may have on the kokanee population in Lake Pend Oreille.

Population estimates based on trawling were calculated directly from the catch in the mid-water trawl sampling. Fish numbers within each age group and within each transect (haul) were divided by the volume of water filtered by the net within the kokanee layer, to calculate age-specific density estimates (fish/m^3). These density estimates were multiplied by the thickness of the kokanee layer in meters, and multiplied by 10,000 to calculate density estimates in fish/ha for each age class of kokanee. Average density was calculated for each lake section and multiplied by the area of the section to estimate kokanee abundance within each section. Section estimates were summed to estimate a whole-lake population abundance. 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 lake where kokanee are found during late summer (Bowler 1978). For consistency, these same areas have been used each year since 1978. Ninety percent confidence intervals were calculated on the kokanee abundance estimates (Scheaffer et al. 1979). Survival rates were calculated by dividing the abundance estimate of each age class of kokanee by its abundance the previous year.

We conducted standardized midwater trawling in Lake Pend Oreille on August 22-29, 1995; September 8-12, 1996; September 29 to October 4, 1997; August 17-24, 1998; September 7-10, 1999; August 28 to September 1, 2000; and August 13-16, 2001. In addition, trawling was conducted by similar methodology during 1994 under a different project proposal (Maiolie et al. 1994). Trawling dates were during the dark phase of the moon, which optimized the capture efficiency of the trawl (Bowler et al. 1979).

Biomass, Production, Yield

We calculated the biomass, production, and yield of the kokanee population in Lake Pend Oreille to look for evidence of high predation. Biomass is the total weight of kokanee within Lake Pend Oreille. It was calculated by multiplying the population estimate of each year class of kokanee times the mean weight of kokanee in that year class.

Production was defined as the growth in weight of the kokanee population regardless of whether the fish was alive or dead at the end of the year (Ricker 1975). To determine production of an age class of kokanee between two years, we use a three-step equation for each age class of kokanee. First, we subtracted the mean weight per fish of each kokanee year class of the previous year from the current year's mean weight of each age class (to get the increase in weight). Second, we averaged the population estimates between the two years. Lastly, we multiplied the increase in mean weight by the average population estimate for each age class. We then summed the results for all of the year classes to determine the production for the entire population. These calculations assume a linear rate of mortality throughout the year.

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

Bioenergetic Modeling

From 1997 through 1999, researchers from the University of Idaho estimated the rate of predation on the kokanee populations in Lake Pend Oreille (Chapter 3B, Vidergar 2000). To estimate the population abundance of rainbow trout, bull trout, and lake trout, a mark-and-recapture tagging program was established. Volunteer anglers used spaghetti tags to mark fish if they were over ≥406 mm fork length during the two-year study. Tag number, fork length, species, approximate location of catch, depth of catch, date of catch, and name of angler were recorded before each fish was released. Recapture efforts for rainbow trout was performed during November of 1998, August 20 to November 4, 1998 for bull trout and April 25 to May 1, 1999 for lake trout.

In addition to the tagging effort, University of Idaho researchers also collected fish with monofilament gillnets during the daylight hours of November 1-4, 1998 and electrofished from June to November of 1998. To identify food items in the stomachs of rainbow trout, bull trout, lake trout ≥406 mm, and northern pikeminnow ≥100 mm, stomach samples were collected using lavage techniques. To estimate how many kokanee were consumed by rainbow trout, bull trout, and lake trout ≥406 mm, University of Idaho researchers utilized the computer model *Fish Bioenergetics 3.0* (Chapter 3B).

RESULTS

Surveys for Large Pelagic Fish

We calculated relatively stable estimates of large pelagic fish using hydroacoustic surveys. Estimates ranged from 13,000 to 17,000 annually (Table 3.1). All of these fish were in the open water of the lake where water depths were greater than 70 m and were more than 10 m above the lake's bottom. The highest abundance estimates were located in the northern section of the lake (section 3) and were 1.5 to 5 times higher than the other sections. The species of these fish is unknown; however, we believe they were not kokanee because of their large size (>-33 dB, 415 mm). Depth distribution of many of these fish was deeper than is typical for kokanee, and they were in water <10°C, which was commonly colder than the preferred kokanee temperature for kokanee (Figure 3.1).

Table 3.1. Abundance of large pelagic fish determined by hydroacoustic surveys in Lake Pend Oreille, Idaho, 1998-2001.

Year	Section 1	Section 2	Section 3	Lake Total
2001	1,130	638	11,527	13,295
2000	2,023	3,156	10,310	15,489
1999	2,426	2,039	11,297	15,762
1998	4,930	5,070	7,294	17,294

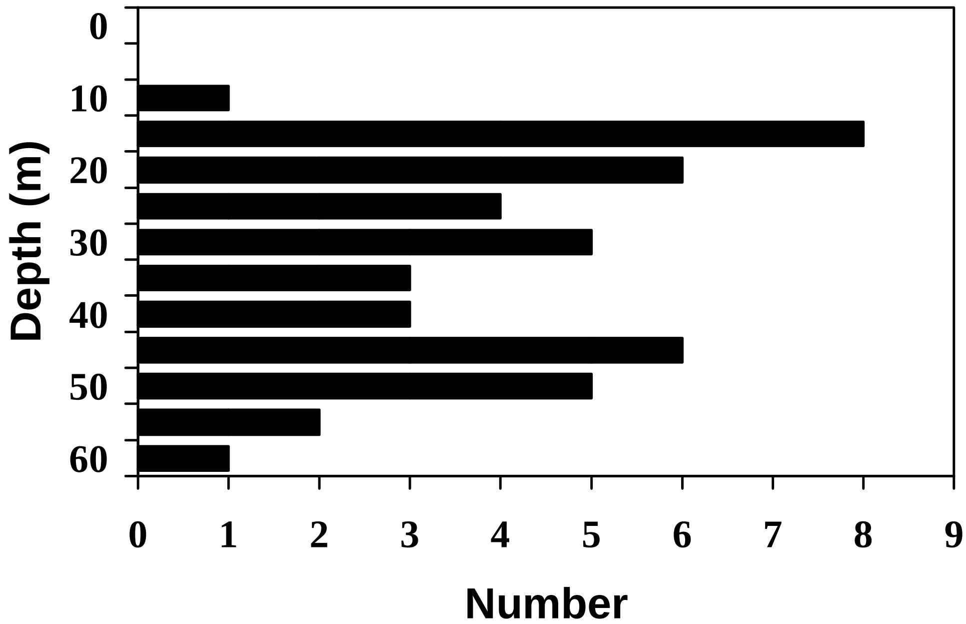

Figure 3.1. Depth distribution of fish larger than –33 dB (415 mm) in Lake Pend Oreille, Idaho in hydroacoustic surveys conducted between 1998 and 2001.

Kokanee Population Estimates and Survival Rates

Population estimates of kokanee based on hydroacoustics, and partitioned by the percent frequency in the trawl catch, indicated the highest population of age-1 to age-5 kokanee occurred in 1996, with an estimated 7.328 million kokanee (Table 3.2). A general declining trend in kokanee abundance occurred after 1996, with the lowest population estimate occurring in 1999, with an estimated 2.819 million kokanee (90% CI: ± 17.8%). Population estimates then increased between 1999 and 2001 to 4.902 million (90% CI: ± 9.5%). Throughout the five-year study, we consistently observed higher kokanee populations in the northern section (Section 3) of Lake Pend Oreille (Table 3.2). The percent frequencies of each age class of kokanee in each section of the lake, as determined by midwater trawling, are presented in Table 3.3. These were multiplied by the hydroacoustic estimates of age-1 to age-5 kokanee to estimate kokanee abundance in each age class (Table 3.4).

Estimates of each age class of kokanee based volumetrically on the trawl catch are presented in Table 3.5. Age-4 kokanee were found to be very low in 1997 (40,000) and 2001 (30,000). Fry abundance was estimated to be very low in the flood year of 1997 (2.23 million) and the following year (0.72 million).

We calculated the survival rates between each age class of kokanee both in the trawl catch and based on the hydroacoustic estimate to look for the impacts of predation. From 1996 to 1999, we observed a steady decline in the percent survival of age-1 to age-2 kokanee, as survival dropped from 79% to 18%, respectively (Table 3.6 and Figure 3.2). A slight increase in survival was observed in 2000 and 2001 as survival increased to 22% and 27%, respectively.

Survival rate from age-2 to age-3 (Figure 3.3) and from age-3 to age-4, showed declines in the flood year of 1997, rebounded in 1998, 1999, and 2000, and then sharply declined in 2001.

Table 3.2. Hydroacoustic population estimates (millions) of kokanee ages 1-5 in three sections of Lake Pend Oreille, Idaho from 1995 through 2001.

Year	Section 1	Section 2	Section 3	Total for Lake	90 % C.I.
2001	0.980	1.479	2.443	4.902	± 9.5%
2000	0.871	1.032	1.935	3.838	± 14.2%
1999	0.762	0.240	1.817	2.819	± 17.8%
1998	0.933	0.823	3.272	5.028	± 16.7%
1997	1.234	1.316	3.211	5.761	± 15.8%
1996	2.208	2.384	2.736	7.328	± 18.6%
1995	2.951	1.171	2.746	6.868	± 11.8%

Table 3.3. Percent of each age class of kokanee in each section of Lake Pend Oreille, Idaho as determined by trawling, 1995-2001.

	Percent Frequency				
Year/Section	Age-1	Age-2	Age-3	Age-4	Age-5
2001					
Section 1	75.93	19.79	0.54	2.32	1.42
Section 2	70.94	27.51	0.39	0.91	0.26
Section 3	89.67	9.65	0.00	0.37	0.31
2000					
Section 1	57.71	10.43	13.64	17.85	0.37
Section 2	77.88	6.48	10.74	4.62	0.28
Section 3	94.32	2.00	2.10	1.58	0.00
1999					
Section 1	8.52	14.48	25.43	47.29	4.28
Section 2	15.25	18.25	27.74	34.99	3.77
Section 3	43.00	14.02	17.52	22.94	2.52
1998					
Section 1	2.68	20.59	63.57	13.16	[a]
Section 2	45.31	18.57	32.39	3.73	[a]
Section 3	56.32	14.56	27.07	2.05	[a]
1997					
Section 1	29.29	37.69	29.25	3.77	[a]
Section 2	34.06	41.02	19.85	5.07	[a]
Section 3	65.47	26.80	7.64	0.09	[a]
1996					
Section 1	24.20	47.51	16.81	11.48	[a]
Section 2	33.77	54.25	6.95	5.03	[a]
Section 3	66.49	24.63	4.94	3.94	[a]
1995					
Section 1	23.69	43.20	29.78	3.33	[a]
Section 2	73.61	10.76	7.43	8.20	[a]
Section 3	81.61	10.71	2.99	4.69	[a]

[a] Age-5 data was unavailable.

Table 3.4. Hydroacoustic population estimate of each age class of kokanee in each section of Lake Pend Oreille, Idaho partitioned by trawling age class percentages, 1995-2001.

Year/Section	**Age-1**	**Age-2**	**Age-3**	**Age-4**	**Age-5**
2001					
Section 1	0.744	0.194	0.005	0.023	0.014
Section 2	1.049	0.407	0.006	0.013	0.004
Section 3	2.191	0.236	0	0.009	0.007
Total	3.984	0.837	0.011	0.045	0.025
2000					
Section 1	0.503	0.091	0.119	0.155	0.003
Section 2	0.804	0.067	0.111	0.047	0.003
Section 3	1.825	0.039	0.041	0.030	0.000
Total	3.132	0.197	0.271	0.232	0.006
1999					
Section 1	0.065	0.110	0.194	0.360	0.033
Section 2	0.037	0.044	0.066	0.084	0.009
Section 3	0.781	0.255	0.318	0.417	0.046
Total	0.883	0.409	0.578	0.861	0.088
1998					
Section 1	0.025	0.192	0.593	0.123	[a]
Section 2	0.373	0.153	0.267	0.030	[a]
Section 3	1.843	0.476	0.886	0.067	[a]
Total	2.241	0.821	1.746	0.220	
1997					
Section 1	0.361	0.465	0.361	0.047	[a]
Section 2	0.448	0.540	0.261	0.067	[a]
Section 3	2.102	0.861	0.245	0.003	[a]
Total	2.911	1.866	0.867	0.117	
1996					
Section 1	0.534	1.049	0.371	0.254	[a]
Section 2	0.805	1.294	0.165	0.120	[a]
Section 3	1.819	0.674	0.135	0.108	[a]
Total	3.158	3.017	0.671	0.482	
1995					
Section 1	0.699	1.275	0.879	0.098	[a]
Section 2	0.862	0.126	0.087	0.096	[a]
Section 3	2.241	0.294	0.082	0.129	[a]
Total	**3.802**	**1.695**	**1.048**	**0.323**	

[a] Age-5 data was unavailable.

Table 3.5. Population estimates (millions) of kokanee, by age-class, in Lake Pend Oreille, Idaho, 1995-2001. Estimates were obtained by midwater trawling.

Year	Age-0	Age-1	Age-2	Age-3	Age-4	Age-5	Total	Density fish/ha	Standing Stock kg/ha
2001	5.43	3.69	0.63	0.01	0.03	0.02	9.81	435	5.36
2000	8.37	2.50	0.17	0.24	0.22	0.01	11.51	510	6.20
1999	3.80	0.23	0.14	0.20	0.29	0.03	4.69	209	3.87
1998	0.72	0.89	0.33	0.73	0.10	0	2.77	123	4.60
1997	2.23	1.15	0.77	0.38	0.04	0	4.57	203	4.20
1996	5.42	3.57	3.14	0.67	0.48	0	13.28	589	16.22
1995	4.62	3.10	1.17	0.69	0.21	0.03	9.82	434	10.92

Table 3.6. Survival rates (%) between kokanee year classes estimated by midwater trawling and hydroacoustics, 1996-2001. Year refers to the year the older age class in the survival estimate was collected.

Year	Age Class							
	0 to 1		1 to 2		2 to 3		3 to 4	
	Trawl	Acoustics	Trawl	Acoustics	Trawl	Acoustics	Trawl	Acoustics
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	—
1989	16	—	72	—	88	—	97	—
1988	47	—	65	—	45	—	81	—
1987	47	—	73	—	63	—	77	—
1986	64	—	66	—	43	—	[a]	—
1985	39	—	70	—	[a]	—	[a]	—
1984	70	—	53	—	[a]	—	[a]	—
1983	59	—	18	—	[a]	—	[a]	—
1982	119	—	47	—	[a]	—	[a]	—
1981	80	—	79	—	[a]	—	[a]	—
1980	50	—	73	—	[a]	—	[a]	—

[a] Unable to calculate survival rate since age-3 and -4 kokanee were not separated prior to 1986.

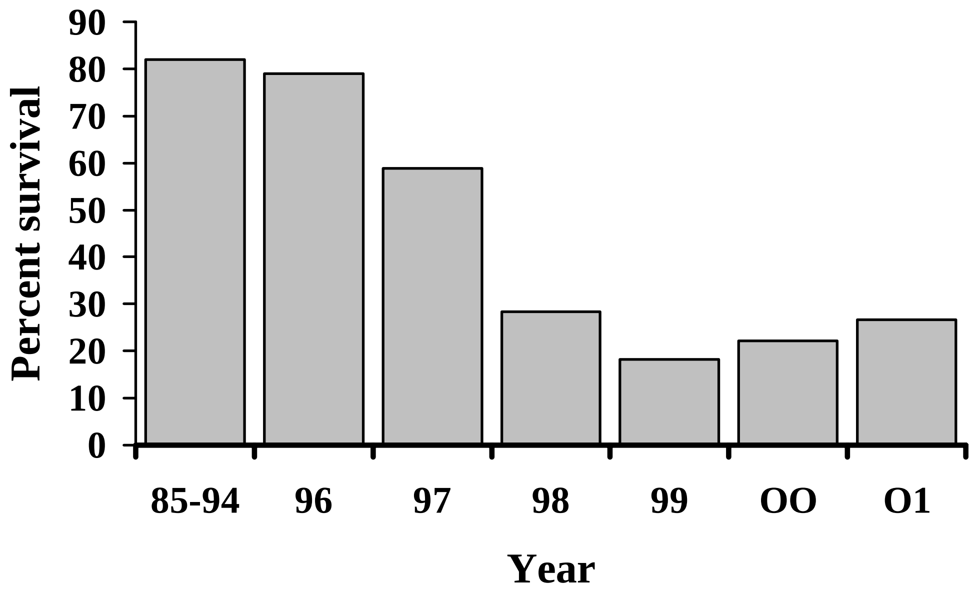

Figure 3.2. Percent survival of age-1 to age-2 kokanee in Lake Pend Oreille, Idaho from 1985 to 2001. Data from 1996 to 2001 was based on hydroacoustic surveys that were partitioned into age classes based on the percent frequency of trawl catches. Data from 1985 to 1994 was based on midwater trawling.

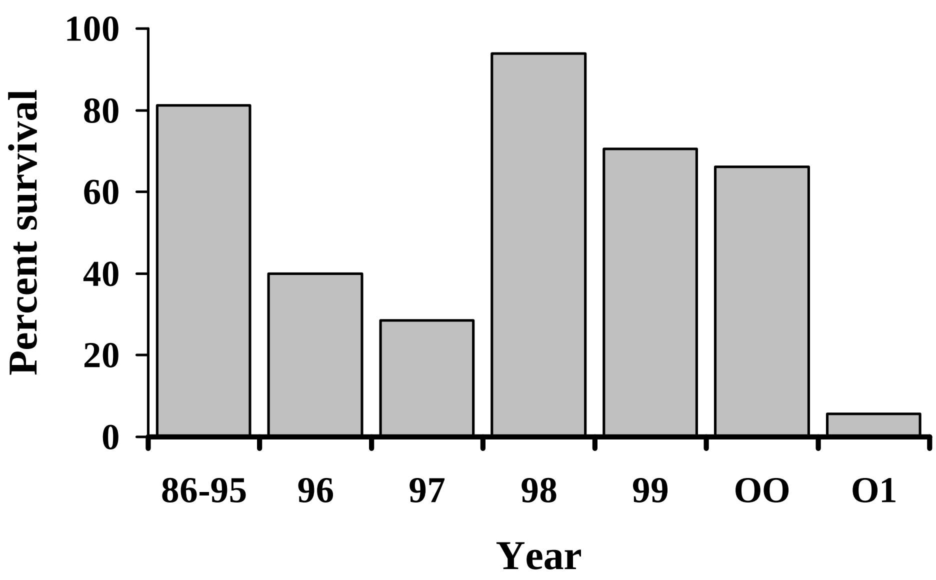

Figure 3.3. Percent survival of kokanee from age-2 to age-3 in Lake Pend Oreille, Idaho from 1985 to 2001. Data from 1996 to 2001 was based on hydroacoustic surveys that were partitioned into age classes based on the percent frequency in trawl catches. Data from 1986 to 1995 was based on midwater trawling.

Biomass, Production, Yield

The biomass of kokanee in Lake Pend Oreille declined 58% from 1996 to 2001 (Table 3.7). We also observed a decline in kokanee production during the study, from 278.4 t in 1996 to 250.1 t in 2001. In 1997, the occurrence of a 100-year flood increased the yield over the previous year by 22% to 354.3 t (Table 3.7). In 1998, yield dropped back to 208.5 t and then started a gradual increase to where it has now surpassed the 1996 yield of 274.7 t. In 2001, yield reached the high for a normal water year of 313.5 t. In 1997, 1999, 2000, and 2001, yield was higher than production, which resulted in a decline of kokanee biomass (Figure 3.4).

We plotted production and yield against biomass to determine the relationship (Figure 3.4). Yield negatively correlated with changes in biomass, whereas production was positively correlated to biomass. The two trend lines crossed at a point where biomass equals about 300 t.

Table 3.7. Biomass, production and yield (metric tons) of kokanee in Lake Pend Oreille, Idaho 1996-2001.

Year	Biomass	Production	Yield
2001	148.2	250.1	313.5
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		

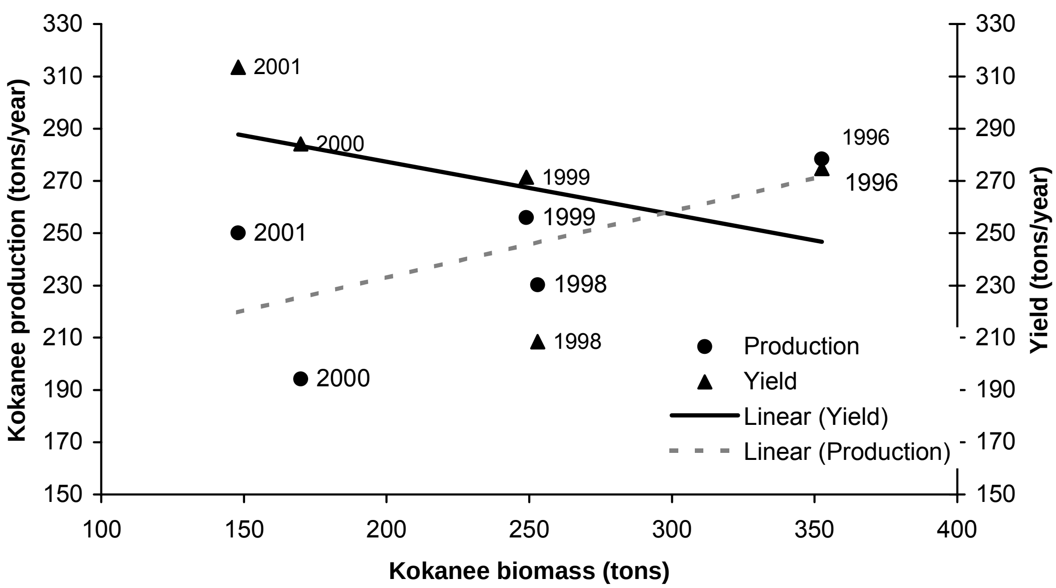

Figure 3.4. Kokanee biomass, production, and yield (metric tons) for Lake Pend Oreille, Idaho 1996-2001, excluding 1997 due to 100-year flood.

Bioenergetic Modeling

From April 1997 to April 1999, researchers from the University of Idaho studied the bioenergetics of Lake Pend Oreille (Chapter 3B, Vidergar 2000). During the study, they estimated that there were over 14,000 rainbow trout (0.64/ha), 12,000 bull trout (0.54/ha), and 1,700 lake trout (0.08/ha) present in Lake Pend Oreille. The predator population, therefore, consisted of 51% rainbow trout, 43% bull trout, and 6% lake trout. Kokanee were the primary food item of rainbow trout, bull trout, and lake trout, comprising 77%, 66%, and 87% of their diet by weight, respectively.

Bioenergetic modeling was used to determine that collectively these three predators consumed more than 153.5 t (tonnes) of kokanee in 1998. We estimated that kokanee production was 230.3 t in 1998. Predators, therefore, consumed 67% of the annual production that year, and kokanee biomass dropped by 25 t from 1997 to 1998 (Table 3.7).

DISCUSSION

Predation levels on kokanee in Lake Pend Oreille appeared to be too high considering the depressed levels of the kokanee population. Survival rates of kokanee from eggs-to-fry have improved substantially during the lake level study (Chapter 1); however, survival from age-1 to age-2 greatly declined (Figure 3.2). Low survival of kokanee from age-1 to age-4 prevented kokanee from recovering after the flood during 1997. Very high abundance of fry in 2000 and 2001 may help this situation. These strong year classes of kokanee may satiate the predators and still remain numerically strong, allowing a good year class to reach maturity. However, a reduction in predation levels is still warranted in anticipation of future weak year classes of kokanee.

The kokanee population in the lake had been declining for over three decades. When it reached a low level in 1985, we began heavily supporting the population with hatchery stocking. This appeared to stop the downward trend in kokanee abundance and likely sustained a substantial predator population. Most age classes of kokanee had relatively poor survival during the 1997 flood year (Table 3.6). Age-1 to -2 kokanee survival dropped to 59%, age-2 to -3 survival dropped to 29%, and age-3 to -4 survival dropped to 17%. The biomass of the population dropped 124 t, a decline of 35%. Instead of recovering after the 1997 flood year, kokanee survival continued to decline between age-1 and age-2. These two-year classes were the size groups of kokanee most often found in the stomachs of the lake's predators (Chapter 3B). It appears a "bottleneck" has developed in the kokanee population; numerically strong year classes of kokanee were reduced in number between age-1 and age-2. Because of low abundance of older age classes of kokanee, predators may be focusing their foraging efforts on this age group. These findings also suggest that age-1 to -2 survival could be used as an index of kokanee predation. Survival rates of age 1 to age 2 kokanee below 50% appear indicative of an out-of-balance population.

We analyzed the echograms for the presence of fish larger than kokanee, which were likely to be rainbow trout, bull trout, or possibly lake trout (all of which are kokanee predators). Our estimates remained relatively stable each year with a predator population estimate of 13,000 to 17,000 fish, but we caution that they should only be considered rough estimates due to the wide variability between transects. These estimates were similar to predator population estimates for rainbow trout or bull trout made by mark-and-recapture techniques (Chapter 3B). It was interesting to note that the estimates of large pelagic fish did not decline substantially during 2000 or 2001 (Table 3.1) when fishing regulations changed to liberalize the harvest of rainbow trout and lake trout. (Kokanee yield increased between 2000 and 2001, indicating a possible increase in predation levels [Table 3.7].) Large pelagic fish were often found at depths greater than 30 m where water temperatures were below 10°C. We suspect that some of these fish may be bull trout or lake trout, although the species is currently unknown and can only be hypothesized. A project was proposed for 2002 that would help to identify these fish. Our current work would indicate that it is feasible to conduct annual population estimates of large fish in the pelagic region of Lake Pend Oreille. This information would be invaluable in our ongoing efforts to balance predators and prey.

Our graphs of kokanee production and yield (Figure 3.4) can be used as an empirical model to balance predator and prey. We interpret these findings to mean that predator and prey would be balanced if the kokanee population biomass were increased to 300 t (at the current abundance of predators). The figure could also be interpreted as indicating predator and prey would balance if predators were reduced to the point where kokanee yield was lowered by 70 t or 27% (at the current abundance of kokanee).

CONCLUSIONS

We conclude that predation levels in Lake Pend Oreille are too high for the current kokanee prey base. The predation problems were likely caused by low abundance of kokanee, not a recent expansion of the predator populations. Predation appears to be affecting the kokanee survival rate especially between the age-1 and -2.

RECOMMENDATIONS

1. We strongly recommend developing management strategies that would reduce predation levels in Lake Pend Oreille.

2. Hydroacoustic survey methods should be developed to provide annual estimates of rainbow trout, bull trout, and lake trout.

3. We also recommend continued efforts to restore kokanee spawning habitat as an important method to balance predator and prey.

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CHAPTER 4: SHORELINE SPAWNING SUBSTRATES

ABSTRACT

Idaho Department of Fish and Game recommended changes to the winter lake level of Lake Pend Oreille in an effort to provide more suitable spawning gravel on the shorelines. We monitored the shoreline gravel to determine if its quality declined during our study and to evaluate the effect of wave action on the existing shoreline substrates. Of primary interest was the quality of the gravel between the elevations of 625.1 m (2051 ft) and 626.1 m (2054 ft), since this was the substrate inundated by raising winter lake levels. We observed a gradual increase of cobble and a reduction in gravel at most sample locations. After five years of raised lake levels, many areas that previously contained gravel became unsuitable for kokanee spawning. We also monitored the effect of wave action at five beaches. A trench was filled with crushed white limestone from the waterline to a depth of 2 m. The disturbance of the limestone was monitored in February, March, and May of 2000. We found that gravel in water less than 1 m deep was likely to be displaced by wave action, which indicated the potential for poor survival of kokanee eggs at shallow depths. Two other studies examined the effects of wave action on shoreline substrate. Colored gravel was placed at various elevations at five different sites. The movement of the gravel was measured after a period of time to determine both horizontal and vertical movement caused by the combination of lake level changes and wave action. The gravel movement was highly variable among sample locations, but some distinct patterns were observed. Gravel was typically displaced from its point of origin and accumulated within narrow horizontal bands along the shoreline. These bands were generally just above the current waterline and resulted largely from periods of high wind and wave activity. Based on the results of these experiments, we conclude that lake level management was highly influential in determining the quantity and quality of shoreline gravel that was available for spawning kokanee.

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INTRODUCTION

This study examined the effects of changing lake levels on the quality of shoreline gravel usable for kokanee spawning. Studies by Rowan et al. (1992) showed that the distribution of fine sediment along the shoreline was determined by wave action and shoreline slope. Our work recognized that wave action also influences the distribution of shoreline gravel that is important for kokanee spawning. Previous studies in 1994 found that most of the shoreline gravel was left above the waterline when the lake was drawn down during the fall (Fredericks et al. 1995). Beginning in 1996, the winter elevation was kept higher to inundate additional shoreline spawning areas. We then monitored the quality of the gravels over a period of seven years. Our original intent was to determine if siltation was gradually destroying the quality of these shoreline areas or if they were remaining productive spawning areas.

METHODS

Gravel Sampling

We sampled five shoreline sites at the following locations: in Garfield Bay; near the mouth of Trestle Creek; north of the mouth of North Gold Creek; at Hope; and within Ellisport Bay (Figure 4.1). Each site was first surveyed in 1992, which established a baseline of conditions that existed during years of full drawdown of the lake level (Maiolie and Elam 1993). Each of these sites was a historical location for kokanee spawning (Jeppson 1960). Sampling was conducted annually from 1998 to 2001 during July and August. At that time, the lake was at its summer, full-pool level.

All gravel samples were collected while Scuba diving. We tied a rope to the shoreline at each transect location and stretched it out into the lake perpendicular to the shore. Two scuba divers swam parallel to the rope and visually identified bands of similar substrate composition. Flagging was tied to the rope to mark the distance between the top and the bottom of each substrate band. Two random samples of substrate were collected from each substrate band. Divers scooped approximately two liters of substrate into a container and sealed it underwater to eliminate the loss of fine material during transport to the surface. A different methodology was used at Garfield Bay. At this location, divers collected a sample every 1.2 m along the transect that extended from the 625 m elevation (just below the low pool level) to an elevation of 628.6 m (near the full pool level reached during summer). Data from 1992 has been included in our analysis to serve as a baseline comparison of substrate composition before the onset of the lake level experiment.

Each sample was individually bagged, labeled, and oven dried. We then screened the substrate through soil sieves (63.5 mm, 31.75 mm, 16.00 mm, 9.50 mm, 6.35 mm, 2.00 mm, and 0.84 mm). The substrate retained on each screen was weighed and calculated as a percent (by weight) of the total sample. We defined “cobble” as substrates that were 31.75 mm or greater, “gravel” as substrates between 31.75 to 6.35 mm, and “fines” as the substrates smaller than 6.35 mm.

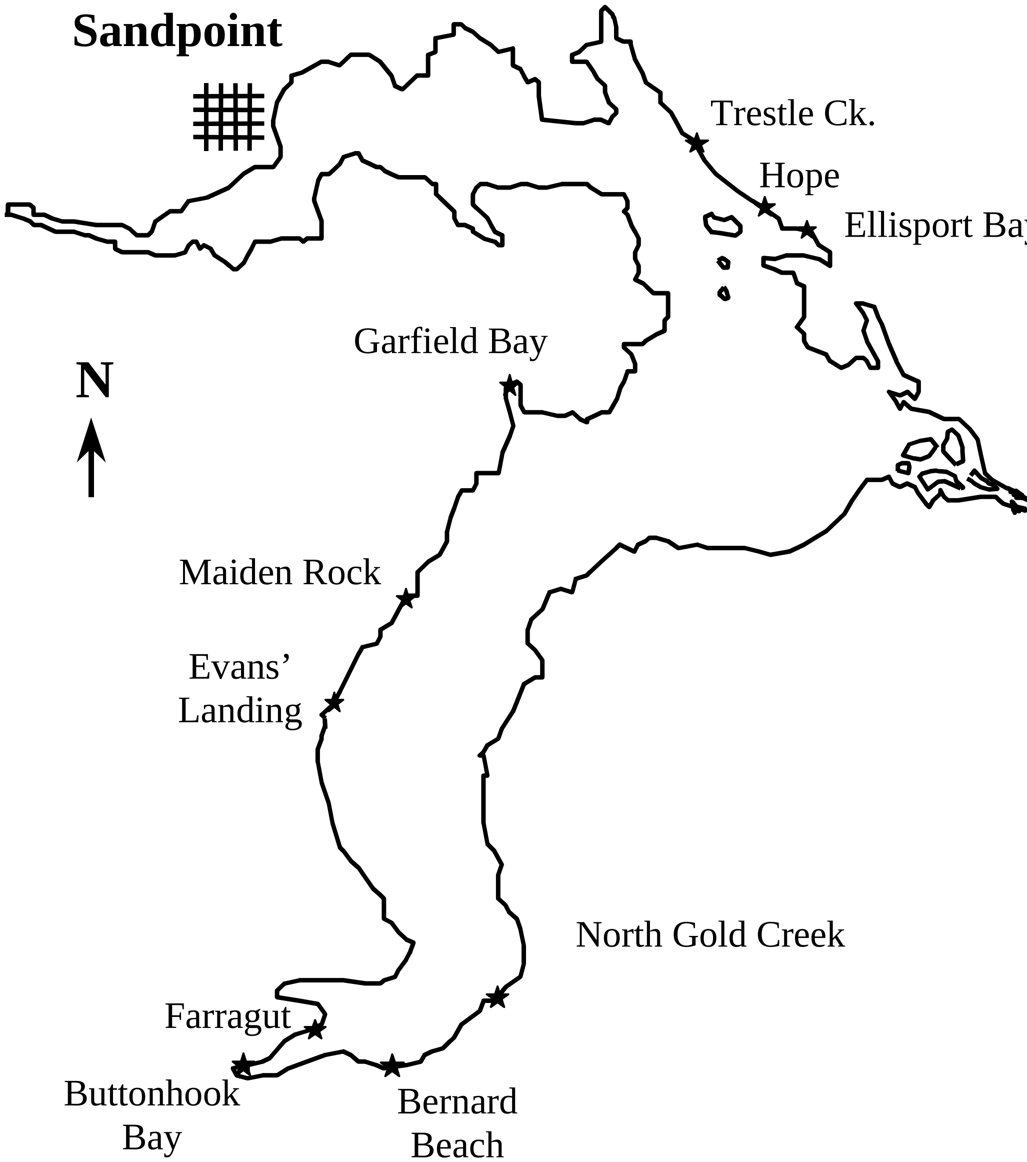

Figure 4.1. Map of Lake Pend Oreille illustrating locations where gravel sampling and experiments occurred.

White Line Studies

Between November 17, 1999 and December 14, 1999, white gravel was placed at five lakeshore locations to determine the depth that wave action and its associated scouring would affect shoreline gravel. Kokanee eggs spend the entire winter in the gravel, and their survival would be unlikely if the gravel was moved and the eggs became dislodged. Crushed white limestone with a mean size of 20 mm was placed at Bernard Beach, Maiden Rock, Hope, Buttonhook Bay, and near the Farragut State Park boat ramp (Figure 4.1). This size of gravel was selected to represent spawning substrate used by kokanee. A trench approximately 8 cm deep and 13 cm wide was excavated from the shoreline at each sampling site and filled with the white gravel. The gravel strip was perpendicular to the shoreline and ran from the waterline to a depth of about 2 m. The top and bottom of each white line was marked with a large rock painted with fluorescent orange paint to establish the original position of the line.

Each site was inspected on February 23, March 20, and May 1, 2000 to monitor the effects of wave action on the white gravel. The depth from the water surface to the top of the white gravel was measured during each inspection. Photos were taken in February and March. The final inspection in May occurred after the lake level had risen 0.7 m. We measured the depth of disturbance as well as the depth to which the white line was destroyed. In addition, the portion of the lines which were disturbed or destroyed were excavated by hand to determine if the gravel had been completely dislodged or if it had been covered by the surrounding substrates.

Colored Gravel Movement

The movement of shoreline gravel was monitored through the use of brightly painted gravel placed on potential spawning beaches at Evan's Landing, Bernard Beach, Trestle Creek, Maiden Rock, and Ellisport Bay (Figure 4.1).

In September 2000 while the lake level was near full pool, we placed about 18 L of fluorescent yellow gravel at an elevation of 627.55 m and 18 L of fluorescent orange gravel at 626.64 m at the Bernard Beach, Evan's Landing, and Trestle Creek sample locations (Figure 4.1). As the lake was lowered during September and November, the colored gravel was dispersed by wave action. We allowed the lake to reach its low winter elevation and returned to measure the vertical and horizontal movement of the colored gravel in November.

We conducted an additional study beginning in February 2001 after the lake level had dropped to its final winter level of 625.7 m. At specific locations on the shorelines of Bernard Beach, Maiden Rock, and Ellisport Bay, we placed approximately 10 L of fluorescent green gravel 15 cm above the waterline and 10 L of silver gravel 30 cm below the waterline. We returned to these sites monthly to document gravel movements throughout the winter.

During these studies, lake elevations were obtained on a daily basis from the U.S. Army Corps of Engineers. The vertical movement of each gravel piece was measured using a surveyor's transit and stadia rod. The horizontal distance that gravel moved was measured with a 61 m measuring tape. Only visibly exposed pieces of colored gravel were measured, and each was removed to eliminate the possibility of measuring it twice.

RESULTS

Gravel Sampling

Ellisport Bay

From 1998 to 2001, during the second to fifth winters of higher water levels, we observed a gradual increase in the percent of cobble substrate and a decrease in the percent of gravel and fines between the elevations of 624.7 and 627.7 m (Figure 4.2). At 625.1 to 625.7 m, the percent of cobble in our samples increased from 47.8% in 1999 to 94.5% in 2001 (Figure 4.3). This was an increase of 75.5% from the 1992 value. The percent of gravel progressively declined from 26.4% in 1998 to 5.4% in 2001. This was a 31% decrease since 1992. We observed an increase in the percent of fines from 6.5% in 1998 to 30.8% in 1999, with a decline to 0.1% in 2001.

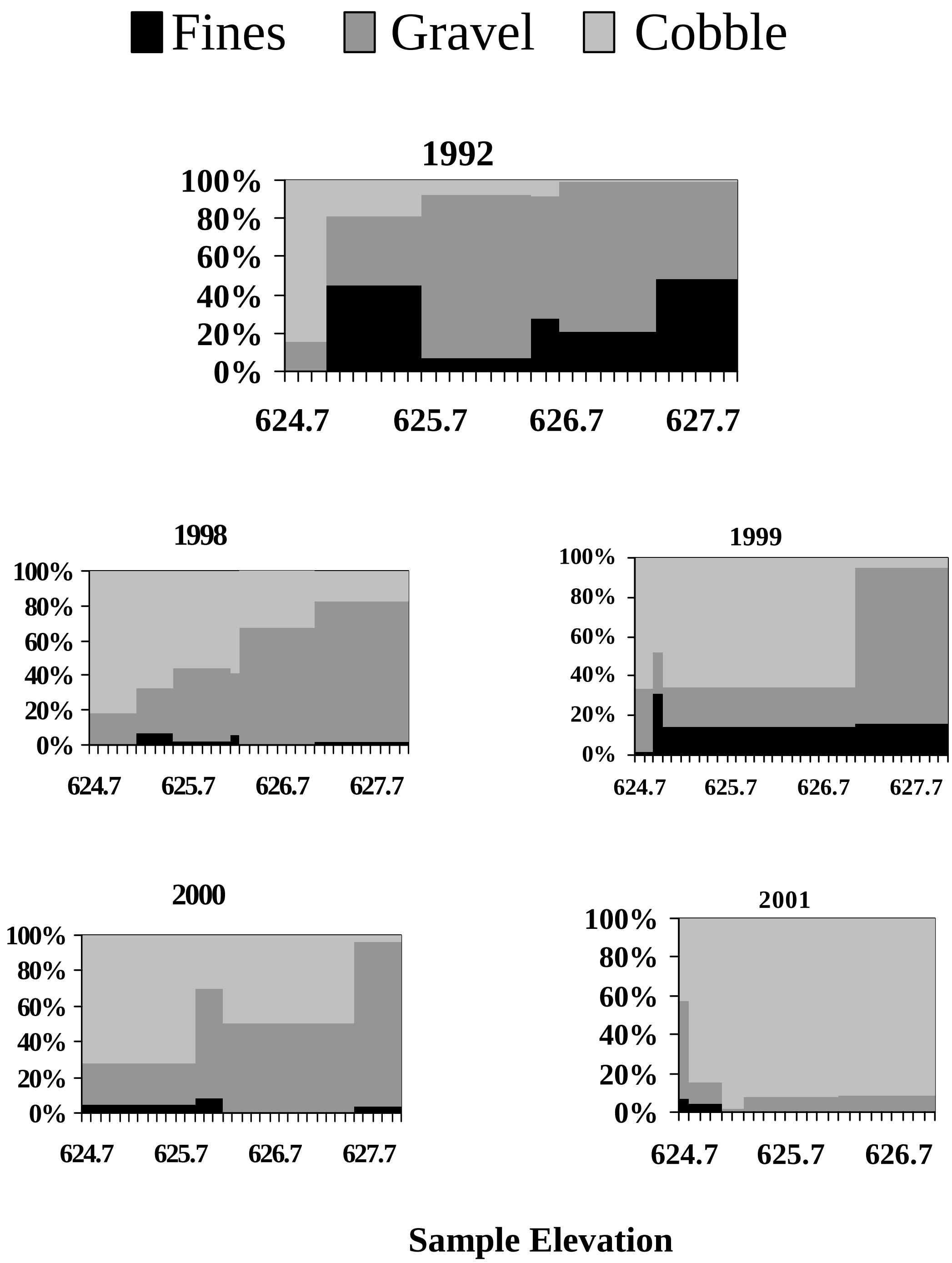

Figure 4.2. Comparison of substrate composition between 624.7 and 627.7 m at Ellisport Bay, 1992, 1998-2001 Lake Pend Oreille, Idaho.

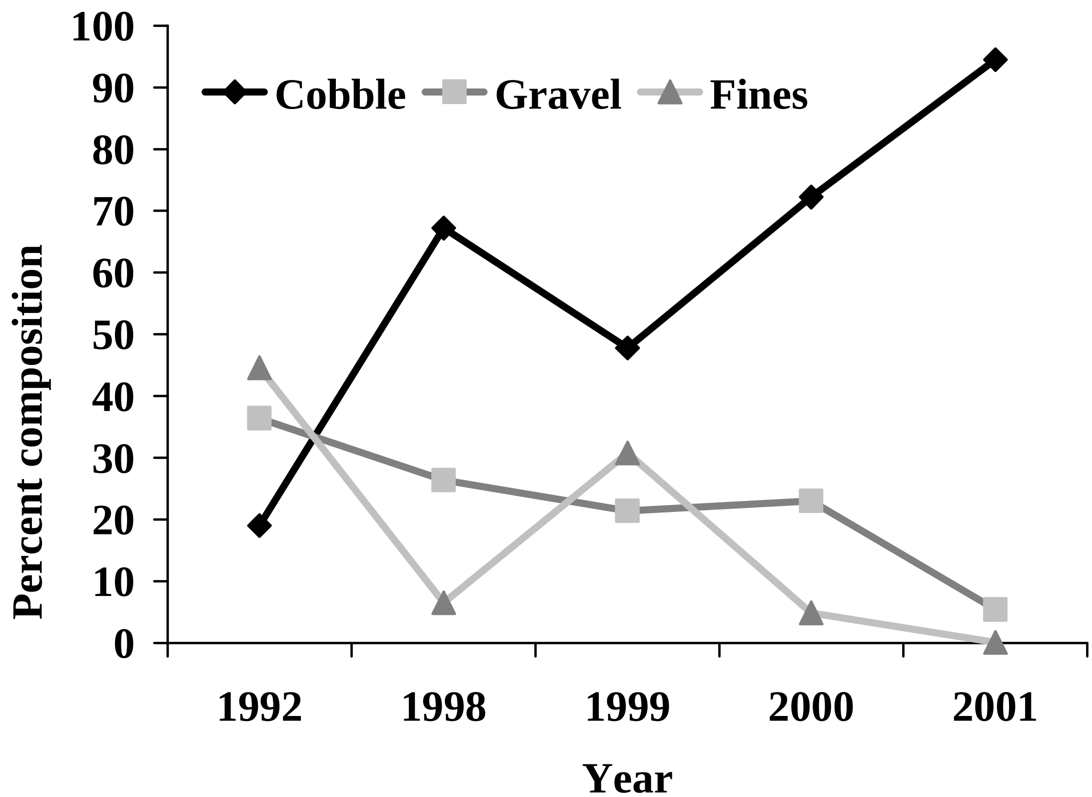

Figure 4.3. Comparison of substrate composition between 625.1 and 625.7 m at Ellisport Bay, 1992, 1998-2001 Lake Pend Oreille, Idaho.

Trestle Creek

The substrate composition on the Trestle Creek shoreline showed a general decline in the amount of potential spawning gravel during this study (Figure 4.4). Between the elevations of 625 m and 626 m, the percent of gravel declined from 43% in 1992 to 18% in 1998 to 24% in 1999 to 4% in 2000 to 17% in 2001 (Figure 4.5). The percent of cobble increased from 59.9% in 1998 to 93.2% in 2000 and then declined to 47% in 2001. The percent of fines decreased from 22.2% in 1998 to 2.5% in 2000, but then increased to 35.8% in 2001.

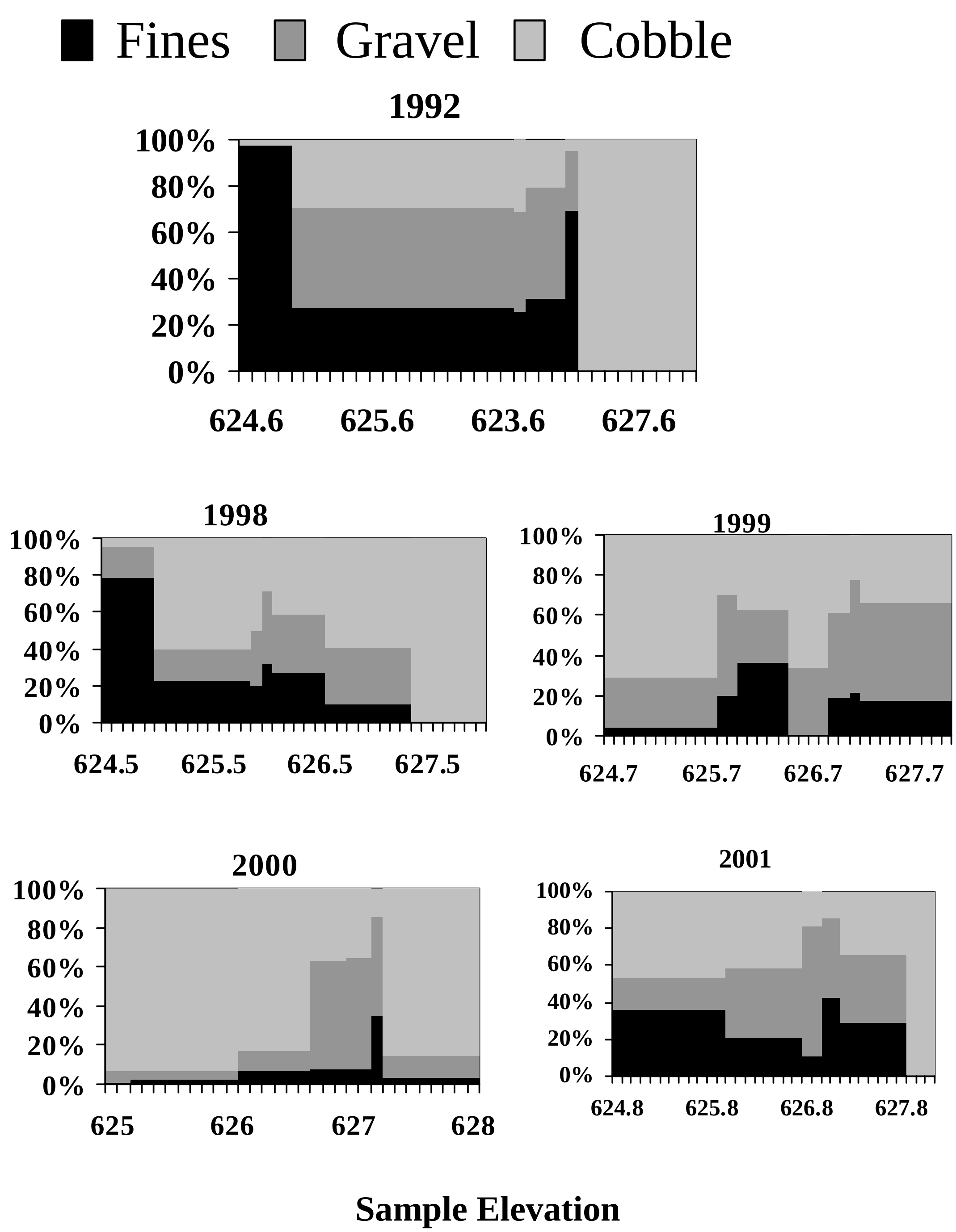

Figure 4.4. Comparison of substrate composition between 624.7 and 627.7 m at Trestle Creek, 1992, 1998-2001 Lake Pend Oreille, Idaho.

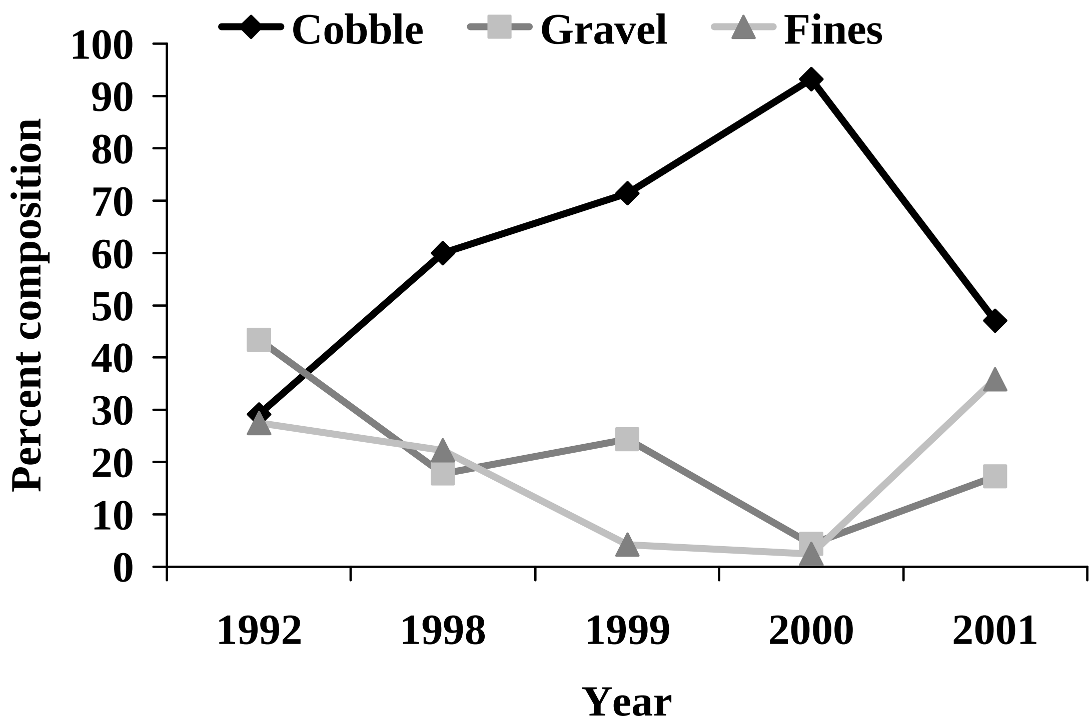

Figure 4.5. Comparison of substrate composition between 625.1 and 625.7 m at Trestle Creek, 1992, 1998-2001 Lake Pend Oreille, Idaho.

Garfield Bay

Between the study elevations, the lowest amount of gravel and the greatest quantity of cobble was observed in 1998 (Figure 4.6). From 625.1 to 625.7 m, gravel increased from 3.3% in 1998 to 12.9% in 2001; however, this is still below the 1992 value of 14.6% (Figure 4.7). Fines increased from 4.1% in 1998 to 18% in 1999, and then dropped to 5.6% in 2001. The percent of cobble was highest in 1998 with 92.62% and gradually decreased to a low point of 75.43% in 2000. This value was still 15% higher than 1992 (Figure 4.7).

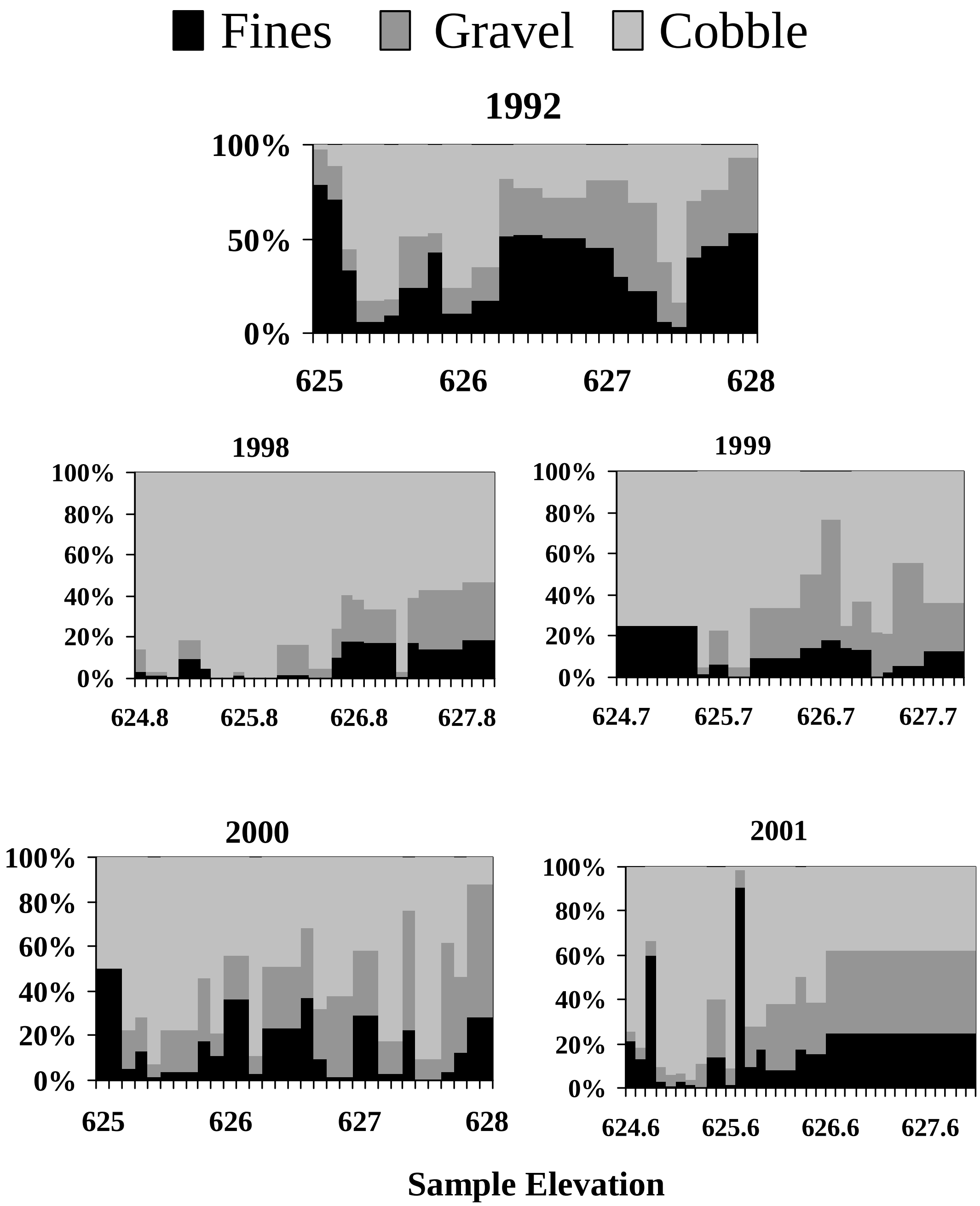

Figure 4.6. Comparison of substrate composition between 624.7 and 627.7 m at Garfield Bay, 1992, 1998-2001 Lake Pend Oreille, Idaho.

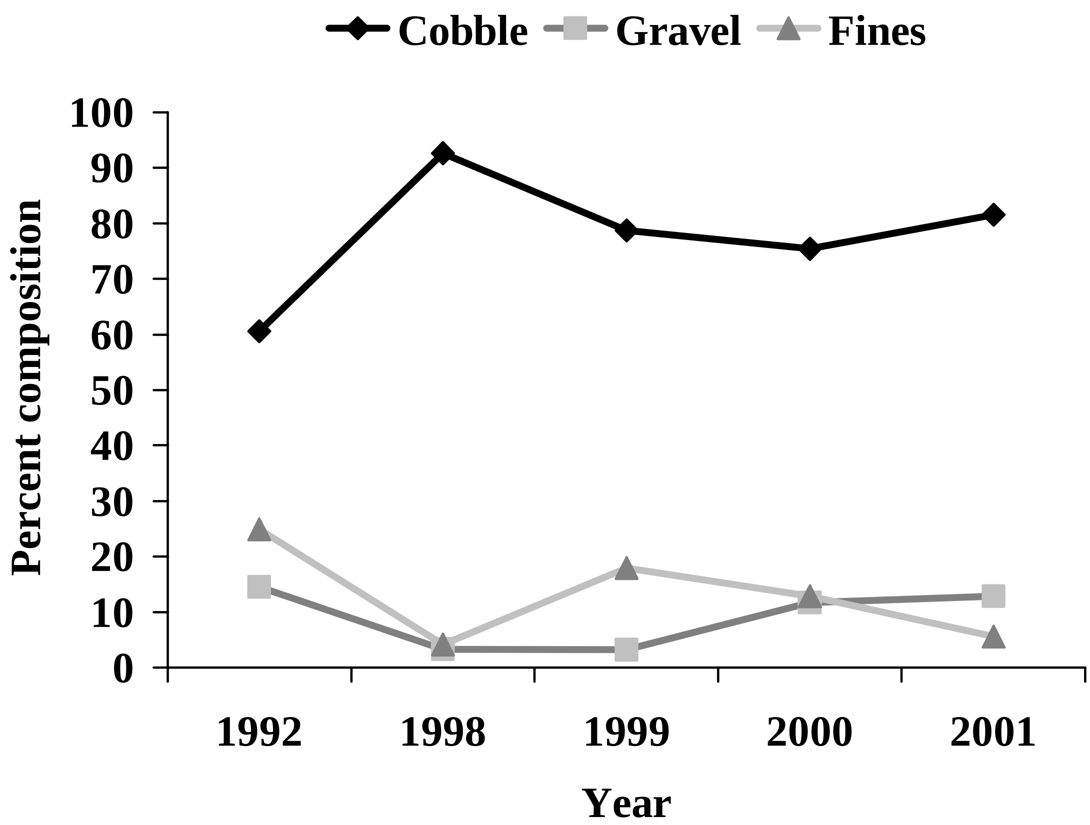

Figure 4.7. Comparison of substrate composition between 625.1 and 625.7 m at Garfield Bay, 1992, 1998-2001 Lake Pend Oreille, Idaho.

Hope

We observed an increase in gravel in a narrow band between 626.5 m and 627.3 m during years of higher winter lake levels, with a net decrease at other elevations (Figure 4.8). Between 625.1 to 625.7 m, we observed an increase in cobble from 89.2% to 100% in 2000 and 2001 (Figure 4.9). The percent of gravel and fines decreased from 2.25% and 8.55%, respectively, in 1998 to 0% in both 2000 and 2001.

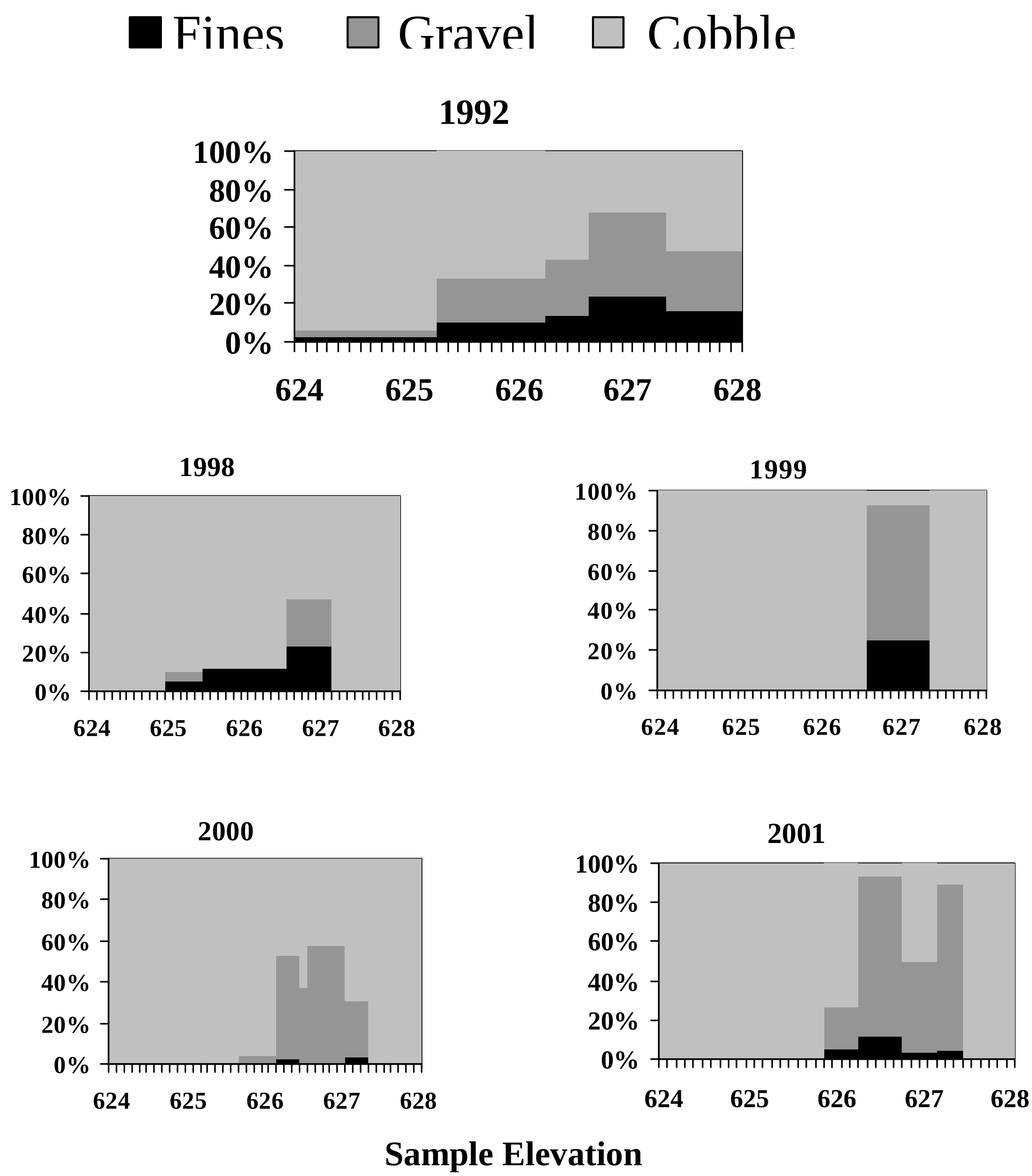

Figure 4.8. Comparison of substrate composition between 624.7 and 627.7 m at Hope, 1992, 1998-2001 Lake Pend Oreille, Idaho.

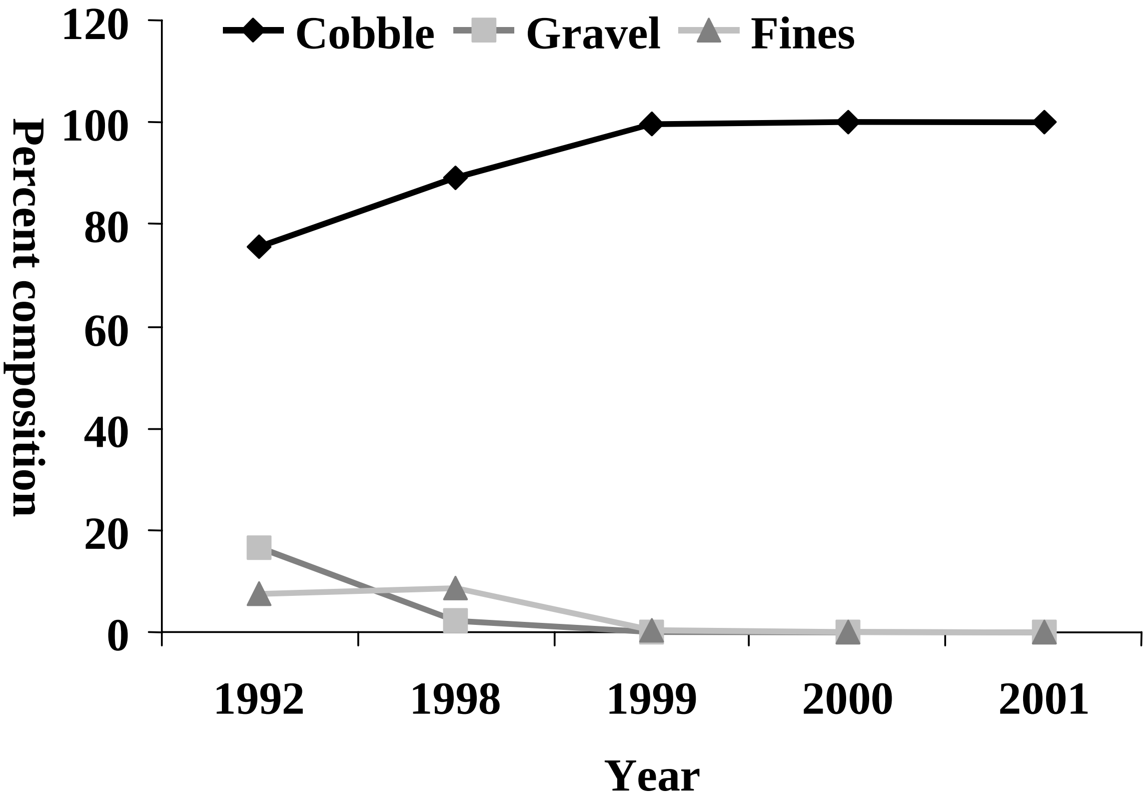

Figure 4.9. Comparison of substrate composition between 625.1 and 625.7 m at Hope, 1992, 1998-2001 Lake Pend Oreille, Idaho.

North Gold Creek

The substrate composition at this sampling location was highly variable between years (Figure 4.10). During the study, the creek channel changed course several times and cut across the transect area. Between 625.1 and 625.7 m, we observed a steady decrease in cobble from 19.5% in 1998 to 0% in 2000, with a rapid increase to 52.8% in 2001(Figure 4.11). On the contrary, gravel increased from 26.4% in 1998 to 44.8% in 2000, with a drop to 32.3% in 2001. The percent of fines also increased between 1998 and 1999 from 54.1% to 67.3%, respectively, but then dropped in 2001 to 14.9%. The final 2001 values for cobble, gravel, and fines were very similar to the prestudy 1992 values of 56.3%, 36.3%, and 7.4%, respectively (Figure 4.11).

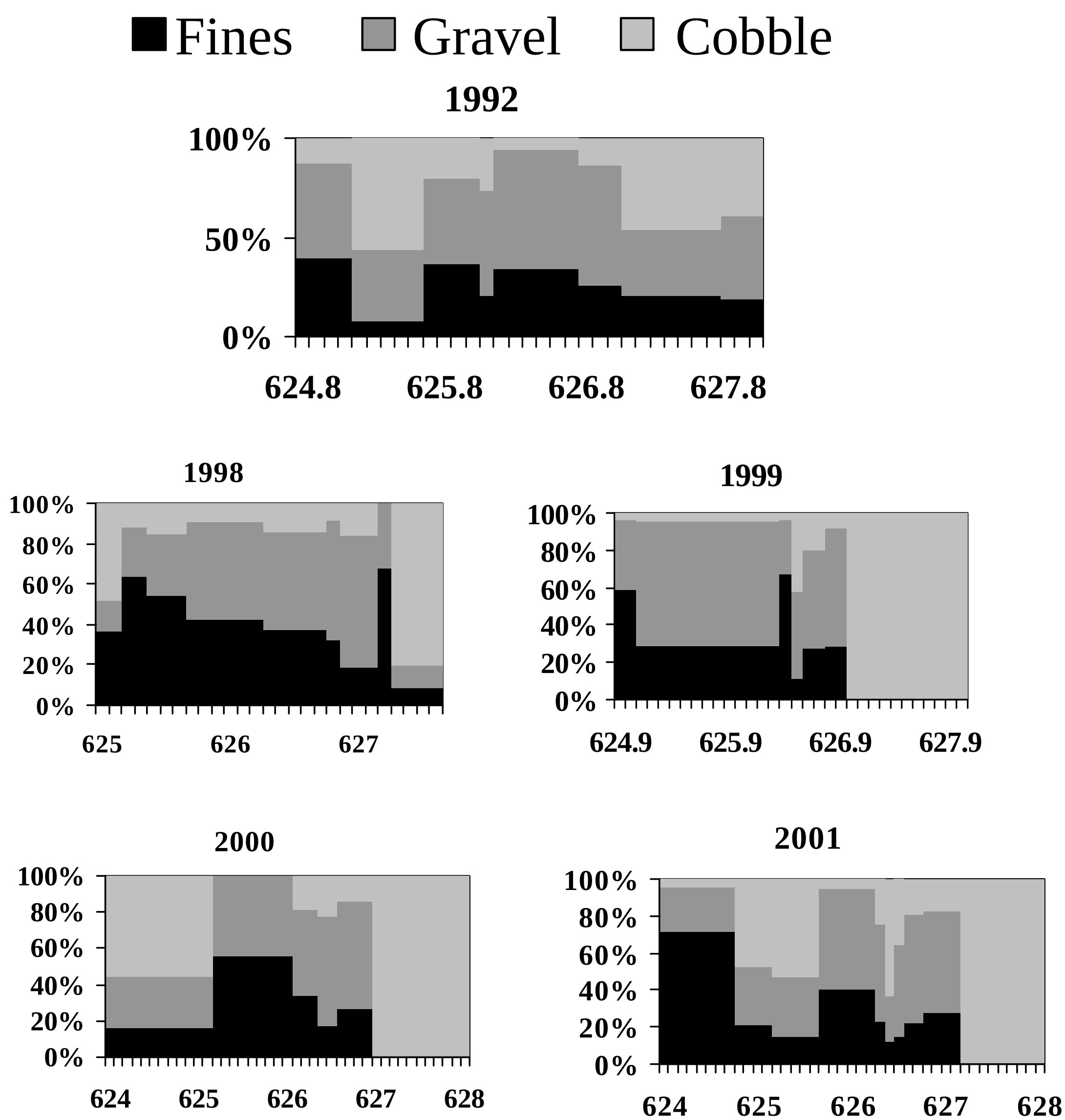

Figure 4.10. Comparison of substrate composition between 624.7 and 627.7 m at North Gold Creek, 1992, 1998-2001 Lake Pend Oreille, Idaho.

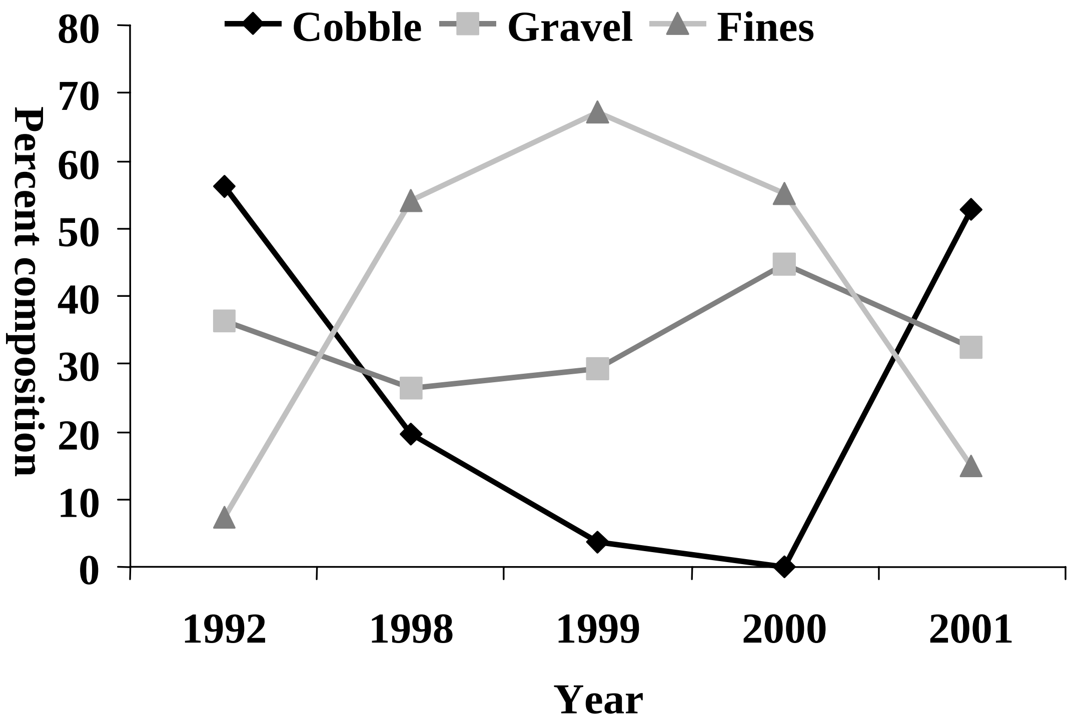

Figure 4.11. Comparison of substrate composition between 625.1 and 625.7 m at North Gold Creek, 1992, 1998-2001 Lake Pend Oreille, Idaho.

Table 4.1. The location, date, and depth (m) to which white gravel placed on the shoreline in Lake Pend Oreille, Idaho was disturbed by wave action.

Site of White Line Placement	Date of Initial Placement	Date of Inspection		
		February 23, 2000	March 20, 2000	May 01, 2000
Farragut State Park	11-17-99	0.46	0.73	0.88
Bernard Beach	11-18-99	0.67	0.70	0.67
Maiden Rock	11-18-99	1.13	1.40	1.43
Hope	12-09-99	0.55	Not determined	0.49
Buttonhook Bay	12-14-99	0.00	0.02	0.08

White Line Study

White gravel placed on the shorelines gave a clear indication of the depth to which wave action affected gravel-sized rocks. At deeper depths, the gravel stayed in place and was easily observable throughout the winter. However, the white rocks were clearly displaced to varying depths at the shallow end of the lines (Table 4.1 and Figure 4.12).

The Maiden Rock location showed gravel disturbance to the deepest depth (1.43 m). This site is located along the western side of the lake and exposed to southern winds. The Buttonhook Bay site showed the least amount of gravel displacement. It was sheltered from wind and wave action from every direction and showed only 8 cm of disturbance during the winter. The depth of wave action was intermediate at the other sites. Gravel at the Farragut site was displaced to a water depth of 0.88 m, Bernard Beach to a depth of 0.67 m, and the site at Hope to a depth of 0.49 m (Table 4.1). An indication of the speed with which the shoreline gravel can be displaced is given by an observation made at the Hope site within 24 hours of placement. Upon returning to the site the following morning, two members of the crew estimated that wave action from a storm the previous night had already displaced the line to a depth of about 0.5 m. The depth of disturbance did not change appreciably for the remainder of the winter.

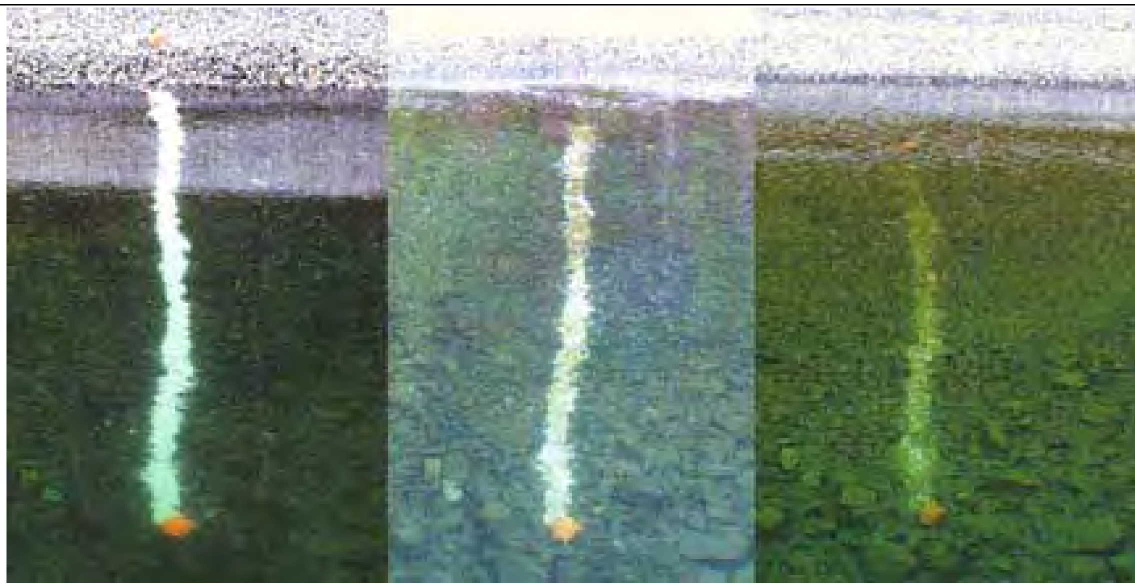

Figure 4.12. White gravel line constructed at Bernard Beach on Lake Pend Oreille, Idaho. First photo taken immediately after construction on November 18, 1999. Middle photo taken on January 20, 2000, and last photo taken on March 30, 2000. In the last photograph the orange rock at the top of the gravel line had moved.

Colored Gravel Movement

Bernard Beach

The majority of the yellow gravel was deposited in a narrow band between 20 and 50 cm above the spot of original placement (Figure 4.13); however, some yellow gravel was spotted more than 1 m above the original placement site. The mean elevational change for yellow gravel was 0.47 m above original placement (or +0.47 m). Very few pieces had moved below placement. The yellow gravel traveled as much as 11 m horizontally. The orange gravel moved greater than 12 m horizontally in a narrow band slightly above placement, and vertically from 0.76 m below placement (-0.76 m) to 0.52 m above placement (+0.52 m). The mean elevation change for orange gravel was +0.28 m (Table 4.2).

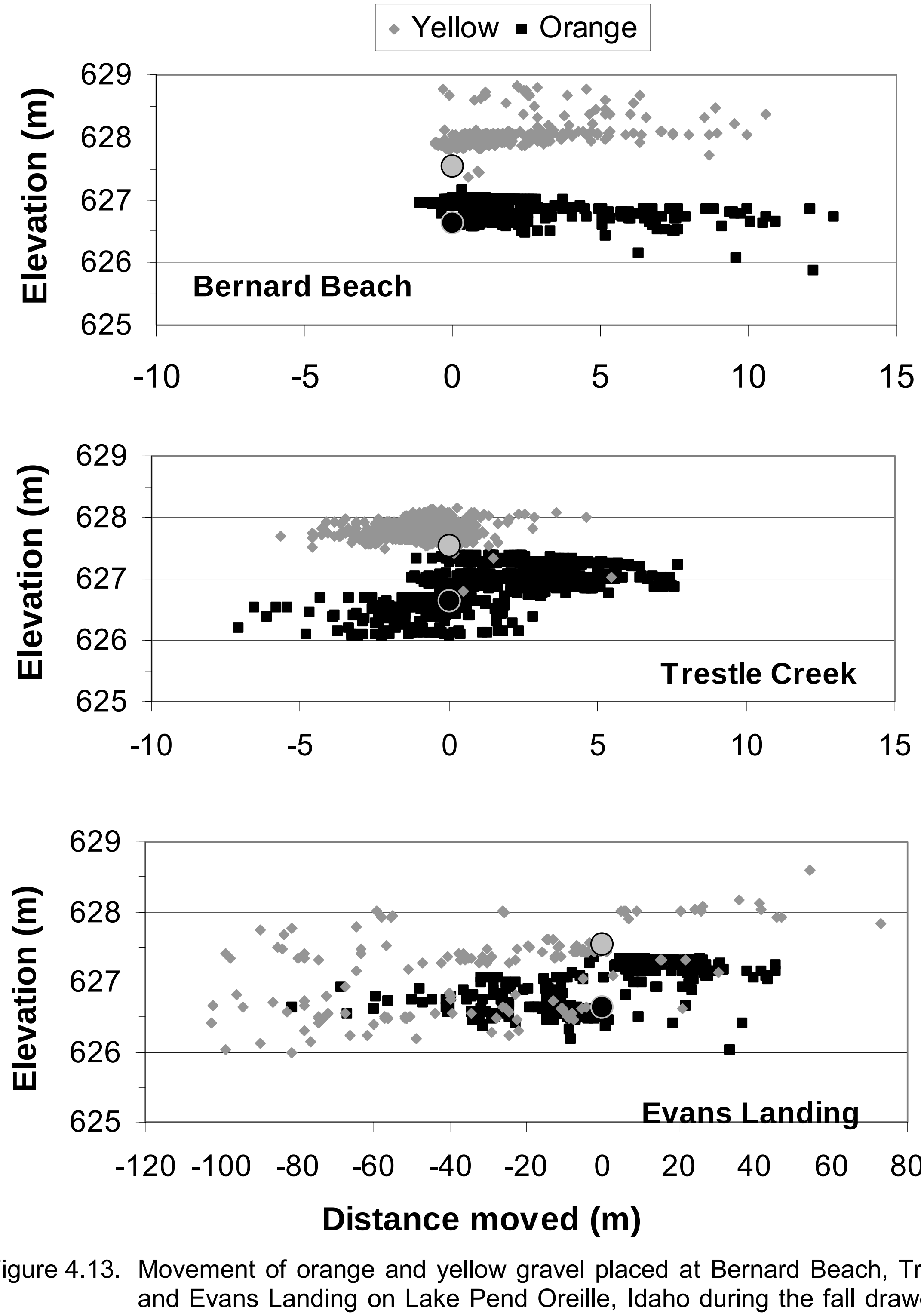

Figure 4.13. Movement of orange and yellow gravel placed at Bernard Beach, Trestle Creek, and Evans Landing on Lake Pend Oreille, Idaho during the fall drawdown period from September 2000 to November 2000. Shaded circles mark the points of initial placement of gravel.

Table 4.2. Selected statistics on the distribution patterns for colored gravel placed at various locations around Lake Pend Oreille, Idaho during the fall drawdown period, 2000. At the time of placement, the lake surface was at 628.6 m above mean sea level (full pool). Yellow gravel was placed at 627.58 m and orange gravel placed at 626.67 m. The lake was allowed to drop to winter pool (625.8) before gravel movements were measured.

Site, group, # recovered	% moving up	% staying at elev.*	% moving down	Max elev. Increase (m)	Max elev. Decrease (m)	Mean elev. change (m)	Mean horizontal change	Maximum horizontal movement	Total horizontal spread
Bernard Beach, yellow, n = 344	98.84	0.87	0.29	1.28	0.18	+ 0.47	+ 1.80	10.58	11.19
Evans Landing, yellow, n = 159	15.72	25.16	59.12	1.04	1.55	- 0.42	- 31.58	102.71	175.58
Trestle Creek, yellow, n = 1,746	38.49	61.34	0.17	0.60	0.74	+ 0.16	- 0.51	5.7	11.20
Bernard Beach, orange, n = 741	82.00	17.30	0.70	0.52	0.76	+ 0.28	+ 1.45	12.86	13.99
Evans Landing, orange, n = 334	57.8	35.3	6.9	0.85	0.61	+ 0.29	- 2.14	81.38	126.64
Trestle Creek, orange, n = 1,742	26.6	66.7	6.7	0.75	0.57	+ 0.12	+ 0.5	7.7	14.8

* - Remained within 0.15m (up or down) of original placement elevation

Trestle Creek

Yellow gravel was observed to travel vertically as much as 0.74 m and spread horizontally across a range of approximately 11 m (Table 4.2). The vertical movement of the orange gravel was between +0.75 and -0.57 m in two distinct bands, one above placement and the other below, with a 15 m range of horizontal movement. These two bands are on opposite sides of the point of origin as can be seen in Figure 4.13, indicating that they were formed by separate storm events with wave activity moving in opposite directions.

Evan’s Landing

We observed the most sporadic spreading of the yellow gravel at this site (Figure 4.13). Yellow gravel showed a range of horizontal movement of approximately 176 m and vertical movement as great as +1.04 m and -1.55 m (Table 4.2). The orange gravel was also highly disturbed at this site, with a range of horizontal movement of approximately 126 m and vertical movement from +0.85 to –0.61 m.

Bernard Beach

Fluorescent green and silver gravel showed the most extreme movement at this site due to exposure to northern winds. At this location, silver gravel moved up to 234 m horizontally and vertically between +1.01 m and -0.91 m (Table 4.3). The green gravel spread approximately

170 m horizontally, and vertically from +0.64 to -1.34 m. Both colors were deposited in three distinct bands, as can be seen in Figure 4.14.

Table 4.3. Selected statistics on the distribution patterns for colored gravel placed at various locations around Lake Pend Oreille, Idaho during the winter low water period, February 7 to April 5, 2001. At the time of placement, the lake was at winter low pool (625.8 m above mean sea level). Green gravel was placed 0.15 m above the waterline, and silver gravel was placed 0.3 m below the waterline. Wave action was allowed to redistribute the gravel for approximately two months before movements were measured.

Site, group, # recovered	% moving up	% staying at elev.*	% moving down	Max elev. Increase (m)	Max elev. Decrease (m)	Mean elev. change (m)	Mean horizontal change	Maximum horizontal movement	Total horizontal spread
Bernard Beach, green, n = 119	16.0	16.8	67.2	+0.64	-1.34	-0.38	+69.72	166.72	169.77
Maiden Rock, green, n = 220	10.5	52.7	36.8	+0.58	-0.70	-0.12	+29.42	73.45	111.97
Ellisport Bay, green, n = 143	14.7	20.3	65.0	+0.33	-0.37	-0.14	+ 9.38	31.09	31.09
Bernard Beach, silver, n = 139	58.3	10.0	31.7	+1.01	-0.91	+0.12	+82.51	172.51	234.20
Maiden Rock, silver, n = 275	85.4	14.6	0	+1.04	-0.03	+0.35	+27.07	72.82	80.44
Ellisport Bay, silver, n = 40	25.0	75.0	0	+0.25	0	+0.12	+0.10	0.76	1.22

* - Remained within 0.15m (up or down) of original placement elevation.

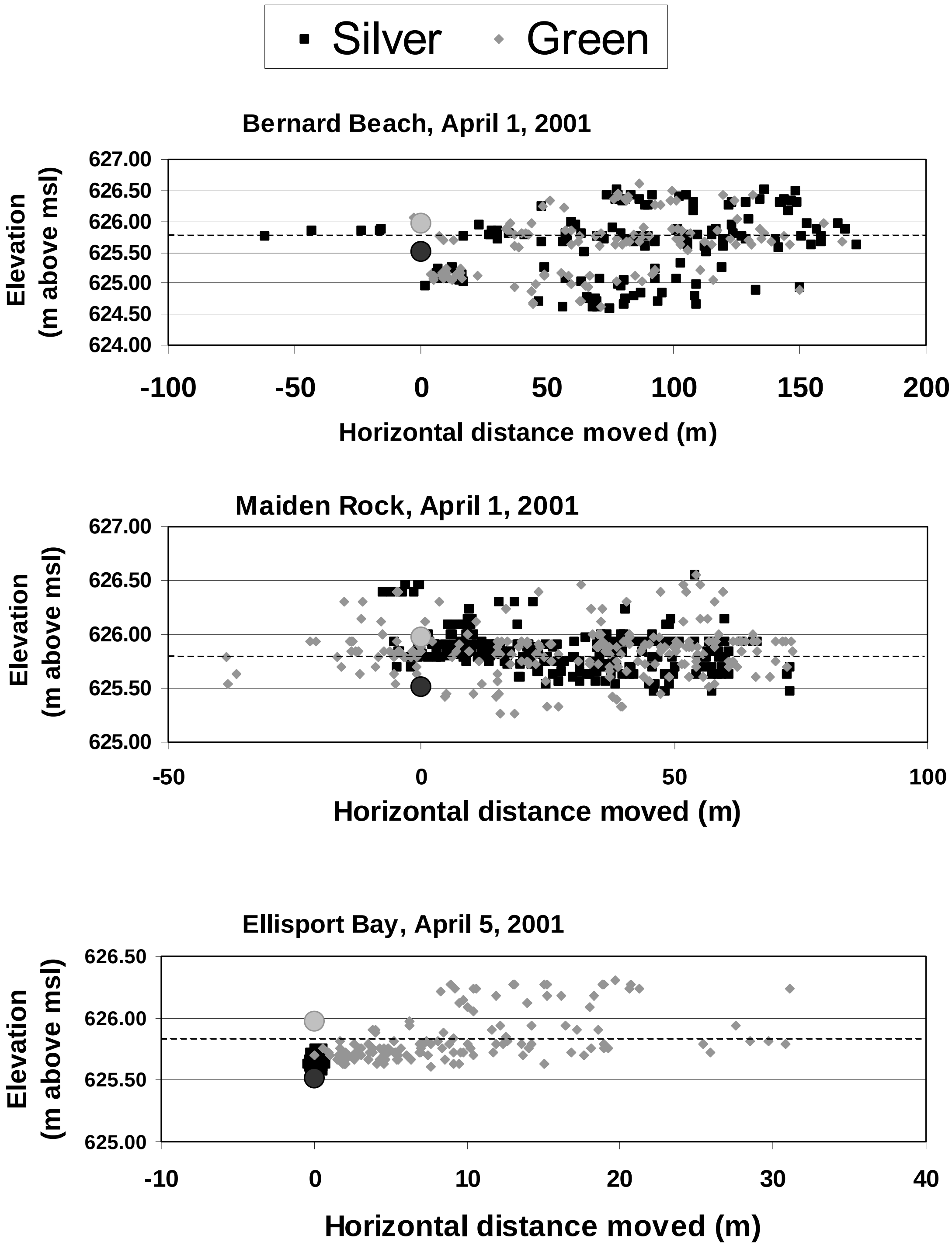

Figure 4.14. Movement of green and silver gravel placed at Bernard Beach, Maiden Rock, and Ellisport Bay on Lake Pend Oreille, Idaho during the winter low-water period from February 7 to April 5, 2001. Shaded circles mark points of original placement of gravel, and dashed lines represent the waterline at the time of placement.

Maiden Rock

A maximum horizontal movement of about 73 m was observed at this location for both green and silver gravel (Figure 4.14). Green gravel moved vertically 0.58 m up and 0.7 m down from the original location of deposition, with a mean change of -0.12 m. Silver gravel was measured to move +1.04 m to –0.03 m vertically, with a mean change of +0.35 m and a total horizontal spread of over 80 m (Table 4.3). The majority of gravel was deposited at or just above the waterline.

Ellisport Bay

This location was the least affected by waves during this study. The fluorescent green gravel exhibited a maximum horizontal movement of 31 m. Vertical movement of 0.3 m up and 0.5 m down the shoreline was also noted (Table 4.3). The silver gravel did not move a measurable distance horizontally and only 0.1 m vertically (Figure 4.14).

A great deal of variability was noted in movements among the various sites, but some distinct patterns were observed. Gravel tended to be dispersed within narrow bands along the shoreline. These bands were generally just above the current waterline and were created primarily during high wind and wave events of relatively short duration. During the yellow and orange drawdown test, the presence of separate bands of gravel was noticed at different elevations and in different directions along the shoreline (Figure 4.13). At many sites during the green and silver low water test (Figure 4.14), a number of bands had developed at different elevations, both above and below the waterline.

DISCUSSION

The original concern was that siltation would, in time, make the newly inundated shoreline gravel unusable (gravel between 625.1 m and 626.1 m). Our findings show that a gradual siltation of spawning gravels did not occur with higher water levels. Instead, we found a trend toward a reduction in silt and gravel and an increase in cobbles at most shoreline spawning areas at these depths. The result of having winter water levels higher for five consecutive years was an armoring of the shoreline at these depths; which turned potential spawning sites into cobble areas with substrate that was mostly too large for kokanee to build redds.

The key area of shoreline during this study was the newly inundated substrate in historic spawning areas (areas between the elevations of 625.1 m [2051 ft] and 626.1 m [2054 ft]). This area was submerged from 0.3 to 1.2 m during the first three winters by keeping the water level 1.2 m higher. Kokanee used the gravels in this area even during the first year of changed lake levels, particularly the deeper edge at elevation 625.1 m (Chapter 1). After about three years of higher water levels, these areas showed noticeable declines in the quantity of spawning gravel (Figures 4.3, 4.5, 4.7, 4.9). During the last two years of this study (2000 and 2001), the lake was held 0.6 m higher than normal (625.8 m). The deepest of the newly inundated gravel was then only 0.6 m below the surface, where wave action could scour this gravel at any but the most protected sites.

The white line study showed the effect of wave action on the shorelines. Gravel on the shorelines down to a maximum depth of 1.4 m (at the Maiden Rock site) was disturbed, and it was unlikely that eggs buried within this gravel would have survived. Depth of the wave action varied considerably between sites. Wave action at the most protected sites would not have disturbed eggs in Buttonhook Bay that were spawned at depths greater than 0.1 m. These findings suggested that holding the lake level up 1.2 m higher would provide benefits to kokanee spawning in most areas of the lake. Holding the lake, for example, 0.6 m higher would provide good gravel under 0.6 m of water on many of the lake shoreline areas, but in many locations the eggs would be dislodged by wave action.

The colored gravel was placed on the shorelines between the high and the low pool levels to see if the fall drawdowns would pull the gravel down the banks to the low water line. Gravel was found to move as much as 100 m horizontally, but generally moved less than 1 m in elevation. It was common to find the colored gravel had been pushed uphill. Wave action on the shorelines had considerable energy, and the net movement of the gravel could go either direction (Tables 4.2 and 4.3). Of the six gravel samples monitored (two at each location), five had positive (uphill) mean movement, while the sixth (Evans' Landing) had a negative (or downhill) net movement.

Colored gravels that were placed immediately above and below the waterline at low pool also showed the effects of along-shore currents. Gravel moved more than 170 m horizontally along Bernard Beach, showing that the substrates in these spawning areas are fairly dynamic (Table 4.3). These gravels can remain relatively free from silt because they are being resorted with every major storm event. We also noted a pattern of gravel to build into bars just above the waterline. This is consistent with the trend we noted in depletion of gravels in the area below the waterline at places like Ellisport Bay (Figure 4.2).

This study began by changing the lake levels to put the shoreline gravels underwater. Kokanee immediately used the newly available gravel for spawning and had good survival. Changing lake levels, however, modified the locations of those gravels after several years. Holding the lake 1.2 m higher for three winters and then 0.6 m higher for two winters allowed the gravel to be pushed up to the water line and build into bars that would be unusable by spawning kokanee. By the end of this study, lake levels needed to be lowered again to the low pool level (625.1 m) to allow gravel bars to reform at a lower elevation. Studies utilizing the painted gravel (Figure 4.14) showed that declining water levels pulled some of the gravel downward on the beaches. These deeper gravels could then be inundated again by keeping lake levels higher in subsequent years.

This study shows that gravels on the beaches are very mobile, and if given the right conditions, gravel bars build rather quickly (a few days of high winds). The challenge in the future will be to balance the benefits of lake level changes for fish with the associated formation and degradation of spawning areas. The early operation of the dam gives a strong clue as to how this could be done. Minimum lake levels from 1955 to 1966 showed a pattern of considerable variation. One year the lake would be lowered to its low pool elevation, the next year it would be higher, and the following year at an altogether different elevation. Based on the current study we would expect that during the low water years, gravel bars probably formed at the water line and then were inundated the following year when the drawdowns were reduced. The result of varying the winter lake levels in the 1950s and 1960s was that three generations of kokanee were produced that were numerically strong enough to provided a mean harvest of 1 million fish annually. Therefore, the recommendation of this study, to raise and lower winter lake levels to improve spawning areas, has been used in the past and produced good results.

The testing in this study, and the recommendation to vary winter lake levels by 1.2 m, were consistent with the operating rule curves established for Albeni Falls Dam. Other options, such as varying lake levels in a more natural pattern, were not tested. Such changes may warrant testing in the future if changes to the rule curves could be made.

CONCLUSION

We conclude that lake level management affects the amount of shoreline gravel available for kokanee spawning. It also determines where, and at what elevation, the gravel bars will form. These spawning areas, in turn, control the abundance of kokanee in the lake. Kokanee abundance determines the kokanee fishery, and to a large extent, the rainbow trout and lake trout fishery. In short, proper lake level management determines the quality of the sport fishing on the lake.

RECOMMENDATIONS

1. We recommend a minimum of 1.2 m variations in the minimum pool level of Lake Pend Oreille between years. During years with lower pool levels, gravel bars will form near the water lines. During higher water years, these gravel bars will be inundated to form high quality kokanee spawning areas in some sections of the lake.

2. To get the maximum benefit for the kokanee population, water levels should be raised for three consecutive years followed by one winter of low pool level. The kokanee population can currently be described as collapsing. For the short term (one or two generations of kokanee), the approach of three years up and one year down provides the greatest benefit. Egg-to-fry survival would be enhanced in the winters of high water level benefiting that year class of kokanee. During the winter of lower water levels, gravels would be cleaned and resorted, but egg-to-fry survival would likely return to a lower level. A pattern of one year up and one year down should be considered after the population becomes more stable as a method to maximize our understanding of the effect of lake levels on kokanee population dynamics, if questions remain. The experimental design would be more powerful with equal numbers of test and control samples.

3. In the future, the years of full drawdown to 625.1 m should be timed to coincide with weak year classes of kokanee. Less spawning gravel may be needed during those years and it may be available at deep-water sites.

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CHAPTER 5: WATERFOWL AND VEGETATION

ABSTRACT

We monitored winter waterfowl abundance and riparian vegetation as part of our studies on changing lake levels. Waterfowl were counted annually between 1997 and 2001 from a fixed-wing aircraft during the first week of January. Their numbers were highly variable with a range in the total count of ducks, geese, and swans from 10,073 during the winter of 1997 to 31,520 in 1998. No clear relationship was found between lake levels and waterfowl utilizing the lake. Ice cover on other area waters, weather conditions, and region-wide population fluctuations likely influence waterfowl abundance. Riparian vegetation was documented photographically in 1998 and 1999. Reducing the fall drawdown from 3.5 m to 2.3 m had no visually noticeable effect on shoreline riparian vegetation. It did not recolonize the drawdown zone during the time of this study. The drawdown zone is underwater during summer and exposed to drying and freezing during winter, making it an inhospitable environment for most wetland vegetation.

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INTRODUCTION

Researchers were asked to monitor shoreline vegetation and waterfowl on Lake Pend Oreille as part of the current study. One of the initial reviewers thought that changes in winter lake elevation could result in expansion of the riparian vegetation, which in turn would cause increases in the wildlife usage of the shoreline. A quick and simple approach to monitor vegetation was therefore conducted to determine if shoreline areas were being recolonized. We were also requested to monitor waterfowl to see if changing lake levels caused large-scale changes in their usage of the lake. Prior to this study, annual waterfowl surveys showed highly variable numbers. It was decided that these surveys should continue, regardless of the variability, to document possible effects.

METHODS

Waterfowl Counts

During the first week in January, from 1997 to 2001, wildlife biologists flew in a fixed-wing aircraft and counted waterfowl in the vicinity of the lake. Survey areas included the Clark Fork River (Idaho portion), Pend Oreille River (Idaho portion), and Lake Pend Oreille. The classification of waterfowl was divided into dabblers, divers, mergansers, geese, and swans.

Riparian Area Analysis

We monitored the shoreline riparian areas of the lake to determine if riparian vegetation would colonize the drawdown zone. A photographic record of shoreline vegetation was collected from nine shoreline locations around Lake Pend Oreille, including Farragut State Park, Leiberg Point, Idlewilde Bay, Bernard Beach, Sand Creek, Denton Slough, Long Bridge shoreline, Trestle Creek, and West Trestle Creek. These photographs were taken to document any obvious changes in riparian vegetation in the drawdown zone. Photographs were taken in December of 1998 and 1999 during the second and third years of lake level changes.

RESULTS

Waterfowl Counts

We observed a range in the total count of ducks, geese, and swans from 10,073 during the winter of 1997 to 31,520 during the 1998 season (Figure 5.1; Table 5.1). The count of ducks (including dabblers, divers, and mergansers) ranged from 9,690 in the winter of 1997 to 30,787 in 1998. The count of geese ranged from 201 in the winter of 1996 to 2,700 in 1999. The count of swans ranged from 73 in 1997 to 194 during the 1999 season (Table 5.1).

Riparian Areas

Higher winter lake levels did not cause a recolonization of vegetation in the drawdown zone during this study. Since the drawdown zone is underwater during the summer growing season and exposed to freezing temperatures during winter, it remains an inhospitable habitat for riparian vegetation (Figure 5.2). No visual differences were noted between 1998 and 1999.

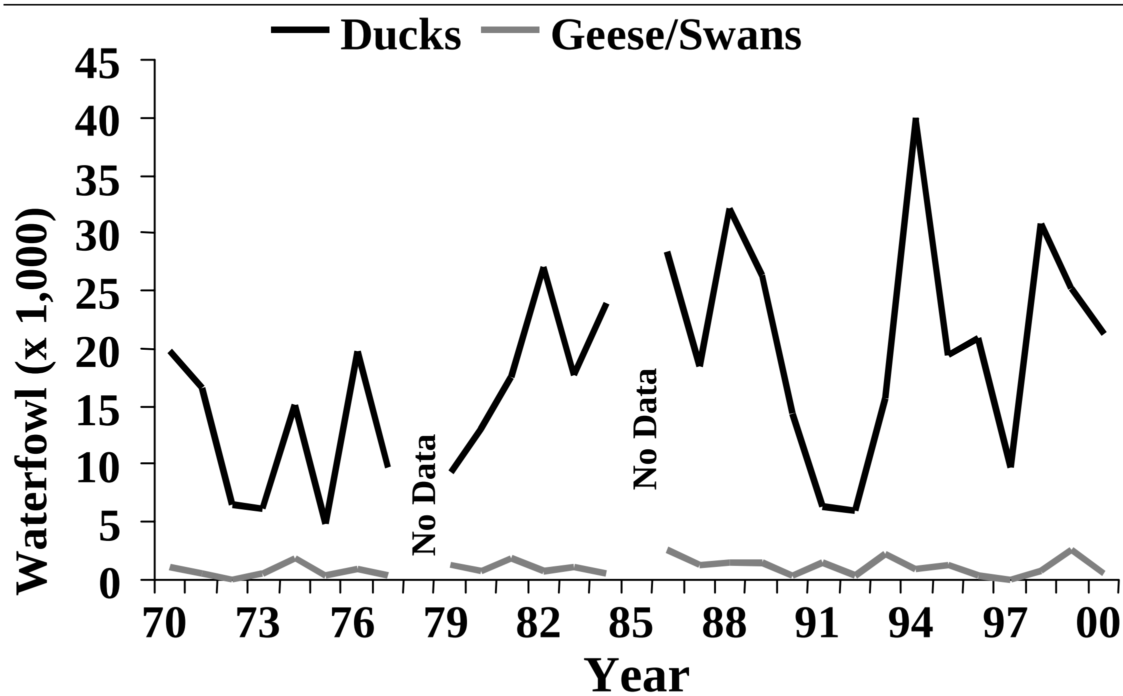

Figure 5.1. Estimated mid-winter waterfowl abundance on Lake Pend Oreille, the Pend Oreille River, and the Clark Fork River, Idaho. Points are shown for each winter season (e.g., the 2000 count was conducted in January of 2001).

Table 5.1. Midwinter waterfowl counts on Lake Pend Oreille, Idaho. Surveys were conducted from an aircraft in early January of each winter season, 1997-2001.

Year	Ducks	Geese	Swans	Total
1996-97	20,932	201	130	21,263
1997-98	9,690	310	73	10,073
1998-99	30,787	635	98	31,520
1999-00	25,161	2,700	194	28,055
2000-01	21,300	405	150	21,855

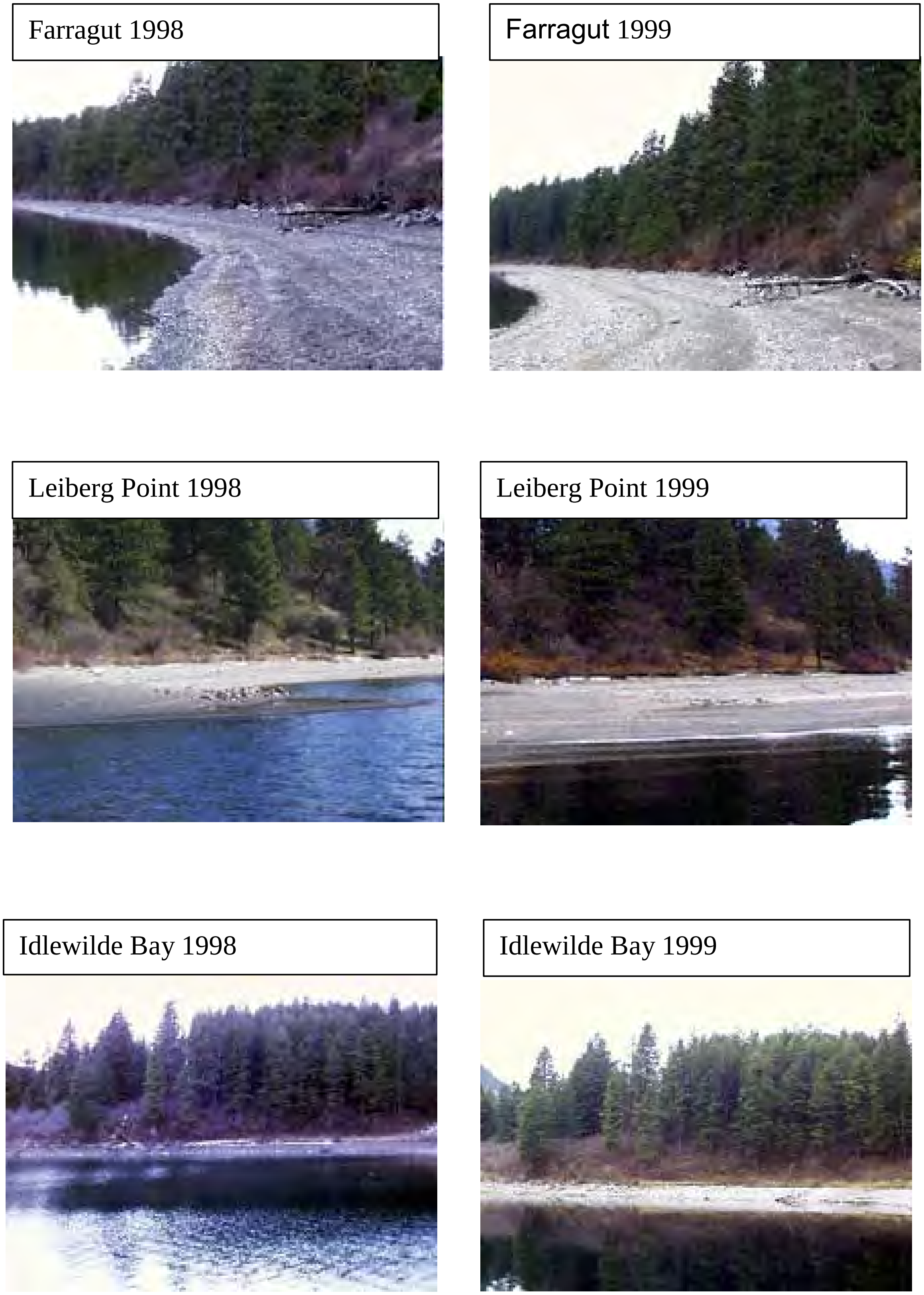

Figure 5.2. Photographs of riparian vegetation at selected sites around Lake Pend Oreille, Idaho 1998 and 1999.

Bernard 1998

Bernard 1999

Denton Slough 1998

Denton Slough 1999

Sand Creek 1998

Sand Creek 1999

Figure 5.2 Photographs of riparian vegetation at selected sites around Lake Pend Oreille, Idaho 1998 and 1999 (Continued).

Long Bridge 1998

Long Bridge 1999

Trestle Creek 1998

Trestle Creek 1999

West Trestle Creek 1998

West Trestle Creek 1999

Figure 5.2 Photographs of riparian vegetation at selected sites around Lake Pend Oreille, Idaho 1998 and 1999 (Continued).

DISCUSSION

Waterfowl counts were highly variable before and during the lake level study. It was, therefore, difficult to relate them to lake level changes. Waterfowl counts could have varied with regional population fluctuations, ice cover on other local waters, and weather conditions. There was some concern that a higher winter pool level would make it more difficult for waterfowl to feed on aquatic vegetation. Yet, in the first and third years of the study, waterfowl abundance was relatively high.

We observed no expansion of the riparian area around Lake Pend Oreille into the drawdown zone as a response to the changes in the lake levels. The drawdown zone remained nearly barren. Prior to the construction of Albeni Falls Dam, this area of the lakeshore was well vegetated, at least in some areas. Under a pattern of natural lake levels, which would rise in the spring and decline during the summer, the banks would be exposed during the growing season and allow emergent vegetation to grow. Vegetation likely stabilized the banks and prevented erosion. Each May and June, 3.5 vertical meters, roughly 30 to 60 horizontal meters, of vegetation would be flooded by spring runoff. This likely provided a considerable boost to the productivity of near-shore species such as cutthroat trout and forage species such as redside shiners *Richardsonius balteatus.*

CONCLUSIONS

Riparian vegetation and winter waterfowl abundance have at this time no documented link to the lake level changes made during this study.

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