

season. The point being that this proposal would be part of a much larger program to reduce predation on kokanee. Lake trout control alone is not a “silver bullet” toward solving the problem, but it is an important part of the equation to recover kokanee.

A second issue raised by the ISRPs review was a question regarding the use of this technology for other purposes and areas other than kokanee recovery in Lake Pend O’reille. Although this technology was proposed specifically for locating lake trout spawning beds in Lake Pend O’reille, underwater imagery can be a very useful and valuable component of exploratory, monitoring and evaluation aspects of many fisheries projects. This technology can provide valuable habitat, ecological, and/or fisheries information that is otherwise unattainable.

A camera equipped AUV can be instrumental in replacing indirect inferences about small scale ecological and fisheries phenomena in large water bodies with preferable quantitative, empirical imagery. In fact, favorable application of this technology could be very widespread, and could be effectively used in virtually any fisheries or aquatic ecology projects or programs that involve suitable submergent hydraulic conditions for recording underwater imagery (exceptions being waters with excessive depth, turbidity, or turbulence). Thus, when suitable waters are involved, creativity on the part of researchers or managers may be the limiting factor for successful implementation of this proposed technology.

FISHERY RESEARCH



LAKE PEND OREILLE FISHERY RECOVERY PROJECT

ANNUAL PROGRESS REPORT
March 1, 2004—February 28, 2005



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Lake Pend Oreille Fishery Recovery Project

Project Progress Report

2004 Annual Report

By

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ABSTRACT

The winter elevation of Lake Pend Oreille, Idaho was experimentally lowered during the winter of 2003-04 as part of a multiyear study to improve the spawning and incubation success of kokanee *Oncorhynchus nerka*. During the winter of 2003-04, the lake was drawn down to near minimum pool to allow wave action to clean and re-sort spawning gravels. An additional 25,155 m² of spawning gravel appeared to have been created along the shoreline that would be available for spawning kokanee for the following year by keeping the winter lake level 1.2 m higher in future years. However, kokanee egg-to-fry survival dropped to an estimated 2%, because adults were forced to crowd into limited areas where superimposition of redds occurred. These results demonstrated a contrasting range of benefits that could be achieved with proper lake level management.

We estimated kokanee biomass in Lake Pend Oreille declined from 11.4 kg/ha in 2003 to 7.0 kg/ha in 2004, the second lowest recorded for this lake. Kokanee production dropped for the second straight year to 9.6 kg/ha while yield of kokanee increased to 14.5 kg/ha between 2003 and 2004. These findings indicated that the predator/prey imbalance first noted in 1999 was continuing to worsen. We also monitored the opossum shrimp *Mysis relicta* population to help identify other factors that may affect kokanee. A long-term decline in shrimp density continued in 2004 with total shrimp densities at 413 shrimp/m². Shrimp densities were not well correlated to the egg-to-fry survival rate of kokanee ($r^2 = 0.00004$), strengthening the argument that shrimp abundance does not currently determine kokanee survival.

We attempted to develop a hydroacoustic technique to estimate the abundance of rainbow trout *Oncorhynchus mykiss* larger than 415 mm total length (TL) within the limnetic zone of Lake Pend Oreille. Knowing their abundance could help managers balance populations of predator and prey and maintain good fisheries. During the summers of 2003 and 2004, we used sonic tracking to search for eight rainbow trout, 11 lake trout *Salvelinus namaycush*, and 10 bull trout *S. confluentus* to determine the nighttime habitat used by these species. Bull trout and lake trout were mainly found along nearshore benthic areas and used mean depths of 23 and 27 m, respectively. Both species were occasionally located in the limnetic zone. Rainbow trout were exclusively located in the limnetic zone between the lake's surface and 25 m (mean depth = 8 m). We conducted mobile hydroacoustic surveys during August to estimate the abundance of pelagic fish >415 mm TL based on target strengths. We then compared the nighttime location of acoustic targets to the distributions of sonic tracked fish. On the echograms, fish >415 mm TL in the limnetic region were located between the 12 m and 35 m depths (mean = 23 m), and so overlapped the habitat used by all three predatory species. No fish >415 mm TL were detected by hydroacoustics in water <12 m deep. Therefore, our current downlooking hydroacoustic technique would appear to miss many of the shallow rainbow trout and include some lake trout and bull trout in the abundance estimates.

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INTRODUCTION

The kokanee population in Lake Pend Oreille once provided harvests of over a million fish, but is now approaching record low densities (Maiolie and Elam 1993). Beginning in 1996, the U.S. Army Corps of Engineers experimentally changed the winter lake levels of Lake Pend Oreille to improve the habitat for kokanee *Oncorhynchus nerka* spawning along the shorelines. Since then, winter lake levels have fluctuated from the low pool elevation of 625.1 m (2,051 ft) above mean sea level (MSL) to a higher winter elevation of 626.4 m (2,055 ft) MSL. Wave action was found to build clean gravel bars along some shorelines during the winters of full drawdown. Then during winters of higher water levels, kokanee could use these gravel bars for spawning. Lake Pend Oreille was lowered to its low pool elevation of 625.1 m during the winter of 2003-04 to allow wave action to improve the quality of shoreline spawning areas. We documented the effect on spawning habitat as well as the egg-to-fry survival rate during this year as part of this long-term experiment.

Maiolie et al. (2002) recommended developing a hydroacoustic method to estimate rainbow trout *Oncorhynchus mykiss* abundance. By having the ability to monitor kokanee and pelagic predator abundance annually, we may be able to implement management actions designed to help balance predator and prey populations and to improve kokanee survival rates. A proper balance between predator and prey populations is one component necessary to recover the kokanee population and fishery in Lake Pend Oreille, and it would compliment improvements in spawning habitat that were shown to increase egg-to-fry survival (Maiolie et al. 2002). During 2004, we compared the depth distribution of large hydroacoustic targets with the depths of sonic tracked rainbow, lake, and bull trout to determine the effectiveness of surveys.

STUDY AREA

Lake Pend Oreille is located in the northern panhandle of Idaho (Figure 1). It is the largest lake in Idaho and has a surface area of 38,300 ha, a mean depth of 164 m, and a maximum depth of 351 m. Pelagic habitat used by kokanee is considered to be 22,646 ha (Figure 1) (Bowler 1978). Summer pool elevation of Lake Pend Oreille is 628.7 m. Operation of Albeni Falls Dam on the Pend Oreille River keeps the lake level high and stable at the summer pool level (June-September) followed by a drawdown of the lake to 625.1 m or 626.4 m during fall and winter (Figure 2). 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, oligomesotrophic lake. Summer temperatures (May to October) averaged approximately 9°C in the upper 45 m (Rieman 1977; Bowles et al. 1987, 1988, 1989). Thermal stratification typically occurs from late June through September.

A diverse assemblage of fish species is present in Lake Pend Oreille. Native game fish include bull trout *Salvelinus confluentus*, westslope cutthroat trout *O. clarkii lewisi*, and mountain whitefish *Prosopium williamsoni*. Native nongame fish include pygmy whitefish *P. coulterii*, five cyprinids, two catostomids, and one cottid. Kokanee entered the lake in the early 1930s as downstream migrants from Flathead Lake, Montana and were well established by the 1940s. The estimated peak harvest of kokanee was 1.3 million fish in 1953 (Jeppson 1953). Other introduced game fish include Gerrard rainbow trout, lake whitefish *Coregonus clupeaformis*, and lake trout *Salvelinus namaycush*, in addition to several other cold, cool, and warmwater species.

PROJECT GOAL

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

PROJECT OBJECTIVES

- Objective 1. Recover kokanee abundance so that a harvest of 750,000 fish can be maintained on an annual basis.
- Objective 2. Have no net change in the amount of shoreline spawning gravel (maintain 160,000 m²) due to erosion or siltation during this experiment.
- Objective 3. Monitor baseline limnological factors that could influence the lake's fish populations.
- Objective 4. Balance the pelagic predator and prey populations at a ratio of less than 1 kg predator to 6 kg prey. This ratio is a starting point for predator-prey balancing; other objectives will help to define this ratio more specifically for Lake Pend Oreille.
- Objective 5. Redefine the point of balance for predators and prey in Lake Pend Oreille where kokanee survival drops below 50% for any year class.
- Objective 6. Research and implement methods for the removal of predatory fish that will not impact bull trout. Adjust the predator:prey ratio until the balance point is reached.
- Objective 7. Minimize the competition between bull trout and other predatory fish. Reduction in other predators and improvements in kokanee abundance would minimize competition for forage.

METHODS

Kokanee Population

Hydroacoustic Population Sampling

We conducted lakewide hydroacoustic surveys on Lake Pend Oreille to estimate the abundance of kokanee and large pelagic fish >410 mm total length (TL) (> -33 dB; Love 1971). Surveys were performed at night between August 23 and August 30, 2004. Surveys were only performed during night hours (noncrepuscular), because we previously determined that daytime hydroacoustic surveys in Lake Pend Oreille did not detect as many large targets (> -33 dB) as

night surveys, and kokanee schooled during daylight and were more difficult to enumerate (Bassista and Maiolie 2004; Bassista et al. 2005).

A Simrad EK60 portable scientific echo sounder equipped with a 120 kHz split beam transducer set to ping at 0.6 s intervals was used to perform mobile hydroacoustic surveys. The transducer was located 0.5 m under the lake surface and placed in a downlooking position off the port side of the boat. Based on this position, the hydroacoustic beam had a diameter of 1.2 m and 3.5 m at depths of 10 m and 30 m below the transducer, respectively. The echo sounder was calibrated annually for signal attenuation to the sides of the acoustic axis using Simrad's Lobe program.

A stratified systematic sampling design was used in our survey. We used a uniformly spaced, zigzag pattern of transects going from shoreline to shoreline as described by MacLennan and Simmonds (1992). The starting point of the zigzag pattern was chosen randomly so transect locations varied annually. Thirty transects were completed in the lake with ten transects in each of the southern (section 1), middle (section 2), and northern sections (section 3) of the lake (Figure 1). Transect lengths ranged from 3.5 km to 8.2 km and were located using a global positioning system (GPS). For all transects we utilized a 7.3 m boat and maintained a speed of approximately 1.3 m/s (boat speed did not affect our calculations of fish density).

We determined kokanee abundance using the echo integration techniques within Echoview software version 3.10.135.03. Targets were included if they met a set of specific criteria. Hydroacoustic traces (a single returned echo from a fish) were accepted if they were over -60 dB and the echo length was between 30% and 180% of the original pulse length at the point of 6 dB below the peak echo value. Additionally, the correction value returned from the transducer gain model could not exceed a two-way maximum gain compensation of 6.0 dB (therefore, this includes all targets within the 3 dB beam width). The targets were accepted if the maximum standard deviation of the minor and major axis angles was less than 0.6 degrees. Targets also had to be aggregated within a layer of fish from about 12 to 50 m to be considered a kokanee.

Once kokanee targets found throughout an echogram met the above criteria, density estimates of all kokanee in each transect were calculated. A box was drawn around the kokanee layer on each echogram to define the area sampled (usually between the 12 m and 50 m depths). We then echo integrated the area in the box to obtain the nautical area scattering coefficient (NASC) and analyzed the box to obtain the mean target strength of all returned echoes. Densities were then calculated by the equation:

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

where: NASC is the total backscattering in m²/nautical mile²
TS is the mean target strength in dB for the area sampled

This integration accounted for fish that were too close together to be detected as a single target (MacLennan and Simmonds 1992). The geometric mean density of kokanee was calculated for each lake section by first log transforming the transect densities (log [x+1]). Separate density estimates were made for fry and older aged kokanee. We then multiplied the geometric mean density of kokanee within each lake section by the area of that section.

We used *in situ* target strengths to split fry from the older age classes of fish using Echoview software version 3.10.135.03. Fish traces (a single returned echo off a single fish) were plotted on a bar graph of target strength versus frequency. We used the low point on the distribution curve to define the size break between fry and older age classes of kokanee and checked this size against the sizes of kokanee caught in our midwater trawl samples. Kokanee of ages 1 to 4 were not separated based on their target strengths.

Once we established density estimates for kokanee and pelagic fish >-33 dB on each transect, we calculated ninety percent confidence intervals for lakewide abundance estimates by standard expansion formulas for stratified sampling designs using log transformed data (Scheaffer et al. 1979):

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

where:

- \bar{x} = the estimated mean number of kokanee in the lake,
- t = the Student's t value,
- N_i = the number of possible samples in a section i,
- n_i = the number of samples collected in a section i,
- s_i = the standard deviation of the samples in strata i,

To estimate abundance of hatchery and wild fry, we used two different methods to ensure data were comparable to historic methods and to utilize a potentially more accurate technique. For the first method, we multiplied the total hydroacoustic estimate of fry in each section of the lake by the proportion of wild and hatchery fry collected in midwater trawl samples for that section (trawling described below). For our second method, hydroacoustic fry abundance was multiplied by the proportion of wild and hatchery fry collected in small-mesh fry net for each section of the lake (described below). For both methods, lake section totals were summed to get lakewide abundance estimates of fry. Pelagic targets between -57.0 and -45.0 dB were considered kokanee fry. Hatchery fry were identified based on the presence of cold-brand marks on otoliths verified by Washington Department of Fish and Wildlife.

To estimate the abundance of mature kokanee in Lake Pend Oreille, we multiplied the acoustic estimate of age-1-4 kokanee (-46 dB to -33 dB) in each lake section by the percentage of mature kokanee caught in the midwater trawl within that section. This estimate was divided by 2 to obtain an estimate of mature female kokanee. The number of mature female kokanee collected by hatchery crews was subtracted from the population estimate of mature female kokanee to obtain the number of wild female spawners. The wild spawner estimate was then multiplied by kokanee fecundity to obtain wild potential egg deposition (wild PED). The number of wild fry was divided by last year's wild PED to estimate wild egg-to-fry survival.

Hydroacoustic Estimates of Biomass, Production, and Yield

We calculated the biomass, production, and yield of the kokanee population in Lake Pend Oreille to look for possible evidence of high predation. Hydroacoustic population estimates, along with kokanee weights gathered from the trawl catch, were used for these calculations. Biomass was the total weight of kokanee within Lake Pend Oreille at the time of

our population estimate. It was calculated by multiplying the population estimate of each kokanee year class by the mean weight of kokanee in that year class. The year class weights were then summed for the lake's overall kokanee biomass.

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

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

We regressed both production and yield against kokanee biomass to determine where these two lines cross. At that point, production and yield were equal and biomass would stay stable, which could indicate predator and prey were in balance. Data from 1996 to 2003 were used to plot the trend lines, with the exception of 1997, which was a flood year (due to high mortality that was likely not predator related). Data from 2004 were added to the graph to see if it indicated a change in the predation level in the lake.

Midwater Trawling

We conducted midwater trawling in Lake Pend Oreille from August 10 to August 14, 2004. These dates were during the dark phase of the moon, which optimized the capture efficiency of the trawl (Bowler et al. 1979).

The lake was divided into three sections (Figure 3), and a stratified random sampling scheme was used to estimate kokanee abundance and density. We randomly selected 12 locations within each section and one haul was made in a randomly selected direction at that location. We located each trawl site using the GPS.

Rieman (1992) described in detail the sampling procedures for midwater trawling. However, the net used in our study was slightly different. For the second year, a fixed frame net (10.5 m long with a 3.01 m tall x 2.2 m wide mouth) was used. This net had a rigid steel frame that kept the mouth of the net open and, therefore, did not have otter boards preceding the net mouth. Mesh sizes (stretch measure) graduated from 32, 25, 19, and 13 mm in the body of the net to 6 mm in the cod end. We towed the net through the water at a speed of 1.62 m/s by an 8.8 m boat. We determined the vertical distribution of kokanee by using a Furuno Model FCV-582 depth sounder with a 10° transom mounted transducer. A stepwise oblique tow was

conducted along each transect to sample the entire vertical distribution of kokanee, with each step lasting for 3 min (a step corresponded to a 3 m depth strata).

Kokanee from each trawl sample were counted and placed on ice until the next morning when they were analyzed (fry were placed on dry ice to quickly freeze them). Age-1 to -4 kokanee were processed the next day without being frozen. Fry were kept frozen until analyzed. Length and weight were recorded for individual fish, and all kokanee over 180 mm were checked for maturity. Scales and otoliths were taken from 10 to 15 fish in each 10 mm size interval for aging, if available. The otoliths from 105 fry and 137 kokanee between the ages of 1 and 4 were sent to the Washington Department of Fisheries Otolith Laboratory for aging and identification of cold brands to detect hatchery fish.

Kokanee catch per trawl haul was divided by the volume of water filtered by the net to obtain density of kokanee caught. The age-specific density estimate for each section was expanded into a total population estimate using standard expansion formulas for stratified sampling designs (Scheaffer et al. 1979). Kokanee abundance was estimated using geometric ($\log [x+1]$) and arithmetic means (the geometric means probably provide a more accurate estimate of kokanee abundance; however, arithmetic means were calculated for comparisons to past data). The area of the southern and middle sections was calculated inside the 91.5 m contour, and the area of the northern section was calculated inside the 36.6 m contour because of shallower water. Area inside these contours represented the pelagic area of the lake where kokanee were found during late summer (Bowler 1978). For consistency, these same areas have been used each year since 1978; a total of 22,646 ha (Figure 3). Ninety percent confidence intervals (CI) were calculated for kokanee abundance estimates (see equation under Hydroacoustic Population Sampling).

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

Potential egg deposition was also calculated based on midwater trawl catch. Percent maturity within each 10 mm length group was multiplied by the population estimate for that length group (based on arithmetic means for consistency to past data) and then summed across length groups. We divided the estimate of mature kokanee by two to obtain an estimate of mature female kokanee (actual trawl catch was 15 mature males : 11 mature females). The number of mature females in the lake was then multiplied by the mean fecundity seen at the Sullivan Springs spawning station to estimate potential egg deposition. Mean fecundity was determined by dissecting 20 female kokanee from the beginning, middle, and end of the spawning run ($n = 60$). We subtracted the number of females spawned by hatchery personnel at the Sullivan Springs egg-take station and trap mortalities to determine the number of eggs spawned by wild fish (wild PED) based on trawling.

A stock-recruitment curve was drawn for the last generation of kokanee based on trawl data. The number of mature kokanee was graphed against the number of mature kokanee they produced and fitted with a Ricker type curve (Haddon 2001).

