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FISHERY RESEARCH

LAKE PEND OREILLE PREDATION RESEARCH

ANNUAL PROGRESS REPORT

April 1, 2002—March 31, 2003

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IDFG Report Number 04-10
February 2004

Lake Pend Oreille Predation Research

Project Progress Report

2002 Annual Report

By

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To

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ABSTRACT

During August 2002 we conducted a hydroacoustic survey to enumerate pelagic fish >406 mm in Lake Pend Oreille, Idaho. The purpose of this survey was to determine a collective lakewide biomass estimate of pelagic bull trout *Salvelinus confluentus*, rainbow trout *Oncorhynchus mykiss*, and lake trout *S. namaycush* and compare it to pelagic prey (kokanee salmon *O. nerka*) biomass. By developing hydroacoustic techniques to determine the pelagic predator to prey ratio, we can annually monitor their balance. Hydroacoustic surveys were also performed during December 2002 and February 2003 to investigate the effectiveness of autumn and winter surveys for pelagic predators. The inherent problem associated with hydroacoustic sampling is the inability to directly identify fish species. Therefore, we utilized sonic tracking techniques to describe rainbow trout and lake trout habitat use during our winter hydroacoustic survey to help identify fish targets from the hydroacoustic echograms. During August 2002 we estimated there were 39,044 pelagic fish >406 mm in Lake Pend Oreille (1.84 f/ha). Based on temperature and depth utilization, two distinct groups of pelagic fish >406 mm were located during August; one group was located between 10 and 35 m and the other between 40 and 70 m. The biomass for pelagic fish >406 mm during August 2002 was 73 t (metric ton). This would account for a ratio of 1 kg of pelagic predator for every 2.63 kg of kokanee prey, assuming all pelagic fish >406 mm are predators. During our late fall and winter hydroacoustic surveys, pelagic fish >406 mm were observed at lake depths between 20 and 90 m. During late fall and winter, we tracked three rainbow trout (168 habitat observations) and found that they mostly occupied pelagic areas and predominantly stayed within the top 10 m of the water column. During late fall (one lake trout) and winter (four lake trout), we found that lake trout (184 habitat observations) utilized benthic-nearshore areas 65% of the time and were found in the pelagic area only 35% of the time. Lake trout were found at depths between 10 and 90 m (average was approximately 30 m). Based on hydroacoustic surveys of pelagic fish >406 mm and habitat use of sonic tagged rainbow trout and lake trout during late fall and winter, we conclude that hydroacoustic sampling during those times would be ineffective at acquiring an accurate pelagic predator population estimate and recommend conducting abundance estimates for pelagic predators when Lake Pend Oreille is thermally stratified (i.e. August).

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INTRODUCTION

The biomass of kokanee *Oncorhynchus nerka* (ages 1-5) available to Lake Pend Oreille (LPO) predators dropped from an estimated 338 tonnes in 1996 to 217 tonnes in 1997 (Maiolie et al. 2002). The suspected cause of this decline was a record high spring runoff in 1997, which may have triggered kokanee to move out of the LPO system. Also, high dissolved gas levels (≥120% in the top 3 meters) in the northern end of the lake may have killed kokanee located near the surface. Since high numbers of age-1 and older kokanee were found in the northern section of the lake (Maiolie et al. 2002), the flood was a likely cause for the initial drop in kokanee numbers. In 1999, kokanee survival from age-1 to age-2 had dropped to <20%, well below the average of 80% during the period between 1985 and 1996. In 2000, kokanee were still declining, and biomass was reduced to 188 tonnes. Based on lower kokanee biomass and poor survival rates, researchers believe that LPO predators may be too numerous to allow the prey base to recover to historic levels.

In an effort to reduce predators, specific fishery rule changes were implemented in February of 2000. The kokanee fishery was closed to all harvest, and the bag limit for lake trout *Salvelinus namaycush* was eliminated. Harvest and size limits were changed for rainbow trout *Oncorhynchus mykiss* (from two fish >510 mm to six fish of any size) and the fishing season for rainbow trout from a boat was opened year-round instead of the last Saturday in April to the end of November. In addition, the Clark Fork River below the Railroad Bridge at Clark Fork, Idaho was open all year with the same limits as the lake. These management actions were imposed to reduce mortality on kokanee in an effort to rebuild the stock.

A potential problem with the lake trout population and its impact on native bull trout, a federally protected species under the Endangered Species Act, is a recent occurrence in the Lake Pend Oreille system. The most current creel data suggests that lake trout harvest in Lake Pend Oreille is increasing. Creel surveys performed in 1953, 1978, and 1985 show that creel clerks checked no lake trout (Fredericks et al. 2001). However, in 1991, creel clerks checked 43 lake trout (sample too small for harvest estimate), and in 2000, they checked 384, which led to a harvest estimate of 4,707 lake trout. The high incidental take of lake trout by rainbow trout anglers during the 2000 creel census would also suggest an increase in the population. It is not known how much apparent increase in lake trout is due to increased fishing effort specifically targeting lake trout, although only 8% of all trout anglers said they were specifically fishing for lake trout during the 2000 creel census (Fredericks et al. 2001). Regardless, work done by Donald and Alger (1993) and Fredenberg (2002) suggests that lake trout are a serious threat to bull trout *Salvelinus confluentus* populations in northwestern lake systems. With possible increasing lake trout numbers and a reduced forage base for top predators in Lake Pend Oreille, lake trout may pose a threat to the persistence of native bull trout through direct competition.

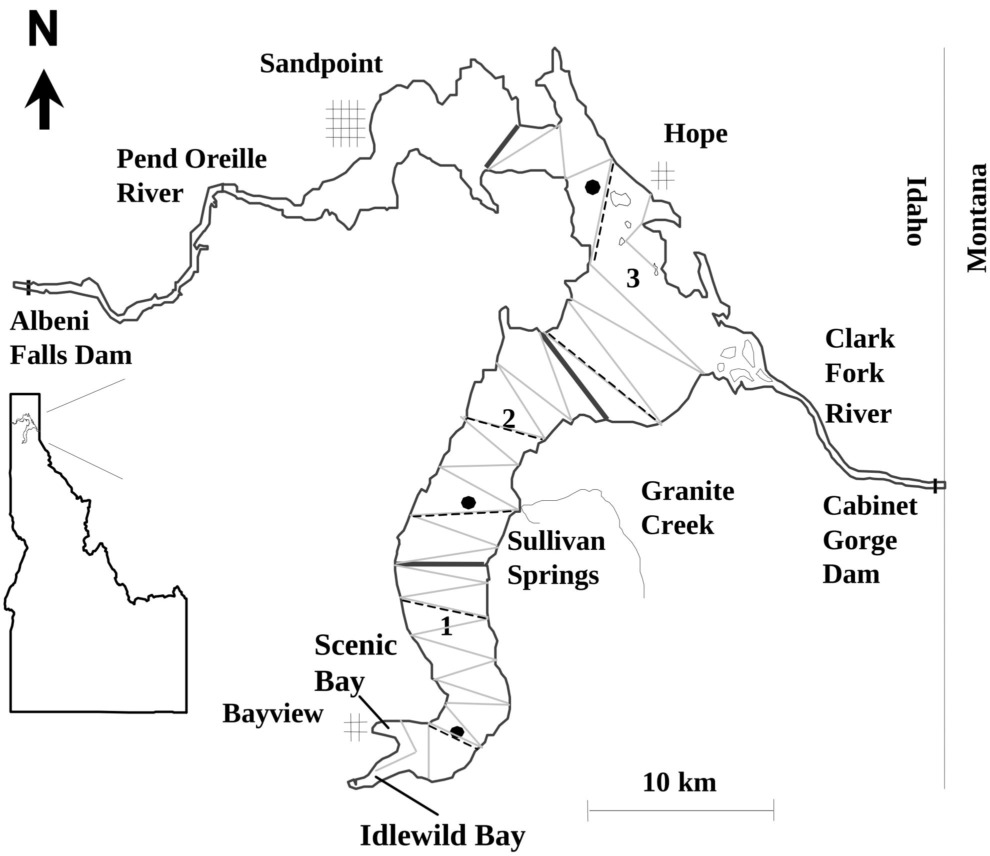
The purpose of our research (April 2002—March 2003) was to develop a hydroacoustic method to monitor pelagic fish populations, specifically predatory rainbow trout, bull trout, and lake trout greater than 406 mm. We also wanted to determine the optimal time to conduct a hydroacoustic population estimate; therefore, we investigated seasonal depth utilization of predators using sonic tracking techniques. Lastly, we wanted to examine the pelagic predator and pelagic prey biomass ratio to see if these trophic levels are off balance.

STUDY AREA

Lake Pend Oreille is located in the northern panhandle of Idaho. 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. It is a natural lake but has two hydroelectric facilities that influence lake levels. Cabinet Gorge Dam, located upstream on the Clark Fork River, modifies water flow into the lake and blocks historical upstream spawning and rearing areas for salmonids. Albeni Falls Dam, located downstream on the Pend Oreille River, regulates the top 3.5 m of the lake (Figure 1). Summer pool elevation (July-September) is about 628.7 m, and winter pool level is typically between 625.1 to 626.4 m.

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 occurs from late June to September and the thermocline is typically found between 10 and 24 m. Surface temperatures may reach as high as 24°C during extremely hot summers. Steep, rocky slopes characterize most of the shoreline, which is largely undeveloped. The majority of fish habitat occurs in the pelagic area of the lake. Littoral areas are mostly characterized by having a very steep bottom, although there are some areas that are characterized by gradual or moderately sloping bottoms (found mostly in the northern end of the lake and in bays).

Historically, bull trout and northern pikeminnow *Ptychocheilus oregonensis* were the top two native predatory fish in Lake Pend Oreille (Hoelscher 1992). The historic native prey population was probably made up of mountain whitefish *Prosopium williamsoni*, pygmy whitefish *Prosopium coulteri*, slimy sculpin *Cottus cognatus*, suckers *Catostomus sp*., peamouth *Mylocheilus caurinus*, and redside shiner *Richardsonius balteatus,* as well as juvenile salmonids (bull trout and westslope cutthroat trout *Oncorhynchus clarki lewisi*). Sometime in the early 1920s, lake trout were introduced, and in 1941 Gerrard strain rainbow trout from Kootenay Lake, British Columbia, Canada were introduced. Presently, the top four predator fish are rainbow trout, bull trout, lake trout, and northern pikeminnow. Other fish that make up the remainder of the predator community are northern pike *Esox lucius*, brown trout *Salmo trutta*, smallmouth bass *Micropterus dolomieu*, largemouth bass *Micropterus salmoides*, and walleye *Stizostedion vitreum* (Hoelscher 1992). Introduced kokanee, which migrated down from Flathead Lake, Montana via the Clark Fork River in the 1930s (Maiolie et al. 2002), have become well established and are the principal forage item for rainbow trout, lake trout, and bull trout >406 mm (Vidergar 2000). Northern pikeminnow >305 mm utilize kokanee for about half of their total consumed food items (Vidergar 2000).



Section	Area (hectares)
1	6486
2	7776
3	8384

Figure 1. Map of Lake Pend Oreille, Idaho showing prominent landmarks, limnology stations, and the three hydroacoustic strata (sections 1, 2, and 3). Grey lines mark the location of summer (August) hydroacoustic transects, and dashed lines represent winter transects conducted in 2002 (December) and 2003 (February). Inserted table depicts the area of kokanee habitat in each section.

PROJECT GOAL

Lake Pend Oreille Predation Research aims to identify a functioning balance of predator (bull trout, rainbow trout, and lake trout) and prey (kokanee) populations so that kokanee are not extirpated from Lake Pend Oreille and continue to provide bull trout with an ample supply of forage.

METHODS

Pelagic Predator Abundance and Depth Distribution

To determine the summer abundance and seasonal depth distribution of pelagic fish >406 mm, we designed and performed a lakewide hydroacoustic survey. Pelagic fish abundance was only determined during the summer of 2002, and we determined pelagic fish depth distribution during the summer and fall of 2002 and during the winter of 2003. A fish was considered pelagic if it was in water >70 m and found no closer than 10 m from the bottom. If a fish was found close to shore and in water <70 m and not within 10 m of the bottom, it was classified as littoral. A fish was considered benthic if it was found within 10 m of the bottom, regardless of depth. Benthic fish were only examined for depth distribution during the summer of 2002 as a preliminary investigation for future benthic work. Neither littoral nor benthic fish were used in the population estimate. Pelagic fish >406 mm are mainly thought to be the top three predators of Lake Pend Oreille (bull trout, rainbow trout, and lake trout). Other fish (>406 mm) that may make up the pelagic community are *Catostomus sp*., lake whitefish *Coregonus clupeaformis*, mountain whitefish, northern pikeminnow, brown trout, westslope cutthroat trout, and yellow perch *Perca flavescens*.

A stratified uniform hydroacoustic survey was developed to enumerate pelagic predator abundance (this report) simultaneously with kokanee abundance (Lake Pend Oreille Fishery Recovery Project). Our survey design separated Lake Pend Oreille into three, nonoverlapping strata (sections 1, 2, and 3). Within each strata, we utilized a uniformly spaced zigzag pattern of transects (Figure 1). Transects were run from shoreline to shoreline and ranged from 3.36 km to 10.3 km. Twelve transects were established in Section 1, ten in Section 2, and nine in Section 3. Only six transects were used to determine pelagic predator abundance in Section 3, because the majority of habitat found in three of those transects did not meet our pelagic criteria (i.e., >50% of the total area in the transect must have water depths >70 m). Transects were sampled with hydroacoustic gear during both day and night between August 19 and 23 using a 7.3 m boat. Boat speed during hydroacoustic transects was approximately 1 m/s, and transect start and end points were located using a Global Positioning System (GPS unit). For each hydroacoustic survey performed, water temperature measurements were taken at every meter from the surface down to 60 m using a calibrated Yellow Springs Instruments (YSI) model 52 Oxygen and Temperature meter in each lake section.

A Simrad EY500 portable echo sounder equipped with a 120 kHz split beam transducer (7.1° beam) set to ping at 1.0 s intervals was used for the hydroacoustic survey. The echo sounder was calibrated on May 30, 2002 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 each survey, and gains were adjusted to achieve the correct target strengths.

Pelagic predator density (f/ha) for each transect was calculated using Simrad EP500 Post Processing software version 5.2. All transects were analyzed using Pelagic Layer Integration with target strength (TS) and volume back-scattering strength (Sv) thresholds set to –60 decibels (dB). Only echoes that registered –33 dB (406 mm) (Love 1971) or greater and met our pelagic criteria were used in the density estimate. Both single and multiple tracked echoes were considered fish. Density estimates were log transformed (log [x+1]) and then averaged for each lake strata. An overall mean density estimate was determined for the entire sample area. Day and night density estimates (non-log transformed) were tested for differences using a paired t-test with the alpha set at 0.05. We used SYSTAT® 10 software to perform the analysis.

A population estimate was determined for each lake strata (section) by taking the geometric mean density (f/ha) for each section and multiplying it by each section's total surface area (ha). Lake section population estimates were added together to determine a lakewide population estimate.

A 90% confidence interval (CI) was calculated for the mean lake-wide density estimate using the following equation:

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

where $\overline{X}$ = mean f/ha (log transformed),
t = Student's t value,
N = total number of possible transects,
s = standard deviation, and
n = actual number of transects.

Once we calculated the 90% CI, we converted the estimate and the density back into an antilog. The antilog ± CI was subtracted from the antilog density estimate and then divided back into the antilog density estimate to give us a ± percent (%) CI. The % CI was used to determine the numeric CI for our lakewide population estimate (Appendix A).

Depth distribution of pelagic predators was determined during August and December of 2002 and during February of 2003. Six hydroacoustic transects were surveyed (two for each lake section) during fall and winter sampling (Figure 1). Benthic depth distribution of fish >406 mm was determined only during August of 2002. For each echogram (image produced by a hydroacoustic transect, Figure 2), we first located all fish that were ≥-33 dB and then determined if the fish was occupying pelagic, littoral, or benthic habitats. For each fish, we examined size information (dB) and depth. All transects and sections were combined to determine lake wide habitat use of pelagic and benthic fish (>406 mm) during both day and night periods.

Diel depth distributions for all sizes of fish from the pelagic area were examined for seasonal differences. Size and depth data for individual echograms were acquired using Echoview software. Echoview allows the user to select specific areas (e.g., just the pelagic area) of the echogram and then export the data to a spreadsheet. During this process, we used both single and multiple pinged targets (fish) from the echogram. Size and depth data were then graphed using a scatter plot to examine diel differences in pelagic habitat selection.

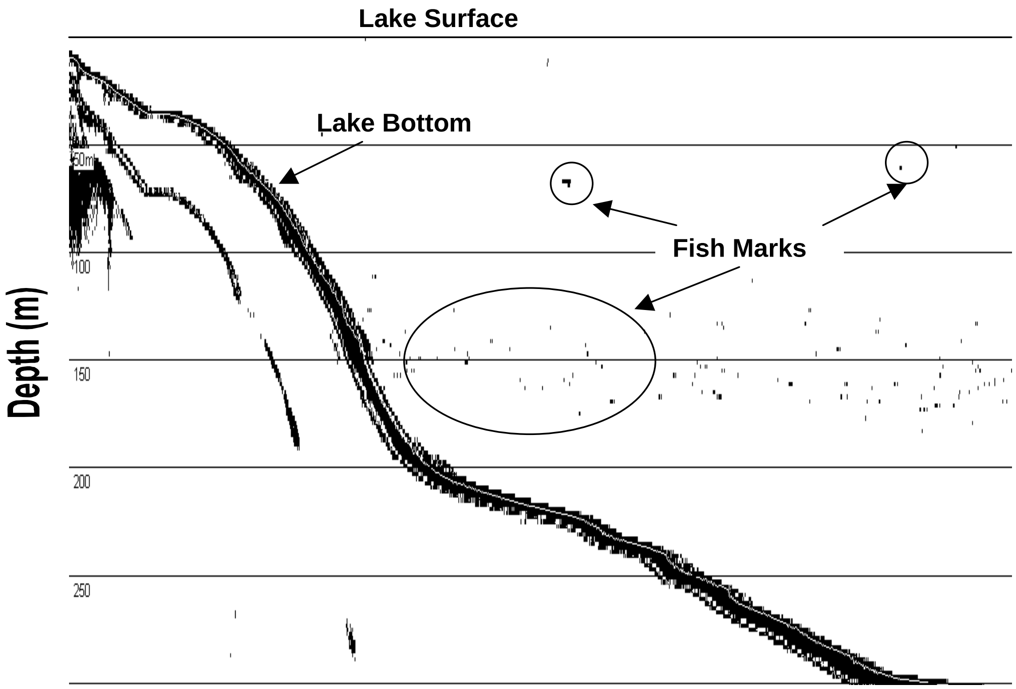


Figure 2. Section of a daytime hydroacoustic echogram collected during August 2002 in Lake Pend Oreille, Idaho.

Pelagic Fish Species Composition

Pelagic fish species composition (all sizes of fish) was determined by conducting standardized midwater trawling in Lake Pend Oreille from September 3-6. Detailed sampling equipment and procedures are described by Rieman (1992) and Maiolie et al. (2002). Trawling was only performed throughout the vertical distribution of kokanee (minimum depth = 15.8 m and maximum depth = 37.8 m) based on the location of pelagic fish schools located with an echo sounder during trawling. Fish were either identified in the field or put on ice and verified in the laboratory.

Predator Collection and Sonic Tag Insertion

Ten depth sensitive transmitters (Sonotronics DT-97-L) were used to determine pelagic predator (rainbow trout and lake trout) habitat use. Each transmitter (sonic tag) measured 86 mm in length, 18 mm in diameter, and weighed 19 g out of water. Battery life of each transmitter is approximately 12 months and has a detection range of up to 3 km. Each transmitter is uniquely coded and emits a sonic signal at a frequency of 75 kHz. Each transmitter was factory calibrated for depth and has a guaranteed accuracy range of ±2% of full-scale pressure (psi). The 10 tags we used had a full-scale pressure range of 334.8 psi to 356.7 psi (approximate accuracy range of ±4.2 m).

In order to determine how well the 10 transmitters (tags) performed, we conducted a calibration test. Each tag was lowered to 15, 30, and 45 m using a downrigger with a marked cable and an 8-pound lead ball connected to the end of the cable. When the tags reached their test depth, we measured the transmitter's ping interval using a directional hydrophone (Sonotronics DH-2) and receiver (Sonotronics USR-96). Measurements were collected from a boat that was located 100 to 200 m away from the transmitter. Actual tag depth was plotted against the measured tag depth, and linear regression was used to determine how well the two depths correlated. If tag depths varied by more than 4.2 m, the tags were sent back to the manufacturer for recalibration.

Before inserting transmitters into Lake Pend Oreille fish, surgery protocols were developed and tested. Nine test fish, eight brown trout and one northern pikeminnow (all fish >430 mm), were collected via electrofishing on the Clark Fork River below Cabinet Gorge Dam in Idaho. Test fish were implanted with dummy transmitters and held and monitored in raceways at the Cabinet Gorge Fish Hatchery. After two weeks of monitoring, we removed the transmitters, resutured each fish, and released them back into the Clark Fork River.

Rainbow and lake trout utilized for sonic tag insertion were collected during the fall/winter of 2002 and the winter of 2003. Only fish >3 kg were used for tagging to ensure the tag weight did not exceed the manufactures guideline of 2% of body weight. Recreation anglers provided live fish during October and November of 2002. Fish were also captured using monofilament gillnets (90 mm mesh size, 175 mm stretch) during January 2003. Fish were held in suspended net pens for ≥12 h prior to sonic tag insertion.

Sonic transmitters were soaked in a diluted iodine solution (approximately 30%) for at least 10 min before insertion. Fish were removed from our suspended net pens and checked for any signs of stress that would deter us from performing surgery. Fish were anesthetized using a clove oil and lake water solution (1.5 ml of clove oil to 80 liters of lake water). The clove oil was first dissolved in a small amount (<6 ml) of alcohol and then mixed thoroughly with lake water using a small, battery-powered aerator. Fish were anesthetized until a complete loss of equilibrium and swimming motion was observed (typically 4-5 min). Fish were then transferred to a surgery table, dorsal side down, where a clove oil-lake water solution was continuously pumped over the gills.

Immediately after the fish was placed on the surgery table, the cutting area was wiped with an iodine solution, and a 4-5 cm incision was made parallel to the mid-ventral line, anterior to the pelvic girdle, and below the posterior end of the pectoral fin. Thumb forceps were used to ensure the scalpel did not damage the viscera while making the incision. The sonic transmitter was gently inserted posteriorly toward the pelvic girdle. A small amount of liquid tetracycline was applied to the incision before suturing. The incision was closed using four separate monofilament sutures (Ethicon Prolene 3-0, 45 cm, cutting FS-1 polypropylene suture). The area was blotted dry using a gauze pad, and a small amount of tissue adhesive (Nexaband® Liquid-formulated cyanoacrylate) was applied to the incision. The fish was then immediately placed in a fresh water live well to recover. After the fish retained its equilibrium and swimming motion, it was placed back into the suspended net pen. The fish were held for an additional 24 h before being released. An attempt was made to release fish at their original capture site.

Predator Sonic Tracking

Predator tracking was performed during late fall 2002 (November 7 to December 21) and winter 2002-2003 (December 22 to March 20) to determine habitat use of rainbow and lake trout to help identify hydroacoustic targets >406 mm found on echograms. Due to safety and concerns about equipment performance (e.g., hydrophone performs poorly in wavy/noisy environments), tracking effort was limited to days when optimal weather conditions were present. An attempt was made to locate all fish on a weekly basis during both daytime and evening hours. Crepuscular hours were avoided since we do not conduct hydroacoustic surveys during that time period. More intensive tracking (daily during day and night) was performed between February 3 and 13 to coincide with our winter hydroacoustic survey. All tracking was carried out in a 6.3 m boat using a directional hydrophone (Sonotronics DH-2) and portable receiver (Sonotronics USR-96). Once a fish was located, we made every attempt to get as close to it as possible before recording a habitat observation. A habitat observation consisted of the following data: time of day, date, general location, latitude and longitude, transmitter ID, transmitter ping interval (depth of fish), lake depth under fish, distance from shore, and temperature of fish depth. When a fish was located, we either made one habitat observation and then moved on to search for another fish, or we maintained a stationary position near the fish and made one observation every 15 minutes for up to 4 h, depending on weather conditions and/or time constraints. Once an observation was complete, a fish was classified into one of our predefined habitat types: pelagic, littoral, or benthic (see methods for Pelagic Predator Abundance and Depth Distribution for habitat type description). Fish location (position and distance from shore) was determined by using a GPS unit and a digital navigation chart of Lake Pend Oreille (Nobeltec Visual Navigation Suite 6.0). Water temperature of the fish was acquired using a dissolved oxygen and temperature meter (YSI model 52). Lake depths were determined by an echo sounder.

Predator Impacts

A lakewide biomass estimate of pelagic fish >406 mm was calculated to determine the biomass ratio (kg) of pelagic predators to pelagic prey (kokanee). To achieve a pelagic predator biomass estimate, we assumed that: 1) all pelagic fish >406 mm identified by hydroacoustics were pelagic predators, and 2) the majority of pelagic predators are thought to be rainbow trout (thus, we used rainbow trout length/weight data for all fish). Length data were obtained by converting the nighttime hydroacoustic target strength measurement (dB) of fish, processed during August 2002 (n = 80), into fish length (mm) using the following equation from Love (1971):

$$TS = -19.1 \, \text{Log} \, L + 0.9 \, \text{Log} \, \lambda - 34.2$$

where TS = target strength (dB)
L = fish length in ft, and
λ = acoustic wavelength in ft.

Length frequency results of all nighttime hydroacoustic data were aggregated into 25-26 mm (1 inch) size groups starting with 406 mm (Appendix B). The percent frequency of each size group was determined from the total number of hydroacoustic targets found in each size group. The total number of fish for each size group was determined by multiplying the lakewide pelagic predator population estimate by the percent of each age group (Appendix B). To obtain a biomass estimate, we converted each rainbow trout size group (using the midpoint of each length group, i.e. 419 mm, 445 mm etc.) into a weight using the following equation from Irving (1986):

$$W = 0.000126 \text{ X } L^{3.385}$$

where W = weight (lbs) and
L = length (inches),

and multiplied it by the total number of fish for each age group. A total biomass estimate for all sizes of kokanee was determined by Maiolie et al. 2004 (in press). All fieldwork to acquire predator and prey abundances were performed simultaneously so direct comparisons could be made.

To examine pelagic predator impacts on the kokanee population in Lake Pend Oreille, we utilized kokanee biomass, production, and yield as determined by Maiolie et al. 2004 (in press) and then compared all three to our pelagic predator biomass estimate. 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). Yield refers to the total biomass lost from the population due to all forms of mortality (Ricker 1975). Kokanee biomass, production, and yield have been tracked annually from 1996 to 2002 (Maiolie et al. 2002; Maiolie et al. 2004 in press), excluding data from 1997 (flood year). Both yield and production were regressed against kokanee biomass to begin to define the point at which predation exceeds the prey populations ability to provide forage.

RESULTS

Pelagic Predator Abundance

During August 2002, we estimated there were 39,044 (range 28,651 to 51,604 ±90% CI) pelagic fish >406 mm throughout our sample area (Table 1). Section 3 had the highest number of large pelagic fish, followed by Section 2 and Section 1, respectively. We estimated the lakewide density of large pelagic fish was 1.84 f/ha (range 1.35 to 2.43, ±90% CI). Density estimates were 2.88 f/ha in Section 3, 1.96 f/ha in Section 2, and 0.35 f/ha in Section 1 (Table 1). Seventy seven percent (77%) of the population was comprised of fish between 406 mm and 560 mm; 19% was comprised of fish between 561 mm and 760 mm, and the remaining 4% was comprised of fish >760 mm.

We found no significant difference ($p = 0.436$) between our day and night lakewide density estimates. However, our lakewide nighttime population estimate (39,044) was 60% greater than our lakewide daytime estimate (11,624), and nighttime surveys estimated more fish in sections 2 and 3, while estimates were similar in Section 1 (Figure 3). Additionally, 90% CIs were >50% for our daytime estimate (-65% and +85%) but much less for our nighttime estimate (-27% and +32%).

Twenty-eight acoustic transects were used to determine pelagic predator abundance estimates (Table 2). Transect density (f/ha) estimates ranged from 0.00 (no fish >406 mm detected) to 11.98. The highest pelagic fish densities (>3.0 f/ha) were found in transects 2-6 through 2-10 and transects 3-5 and 3-6. Section 1 had the most transects with 0.00 density estimates (five transects).

Table 1. Pelagic predator density and population estimates with 90% Confidence Intervals for Lake Pend Oreille based on hydroacoustic sampling in August 2002.

	Density (f/ha)	Population (# of fish)
Section 1	0.35	2,110
Section 2	1.96	15,327
Section 3	2.88	21,607
Lake Wide (±90% CI)	1.84	39,044
	(1.35 to 2.43)	(28,651 to 51,604)

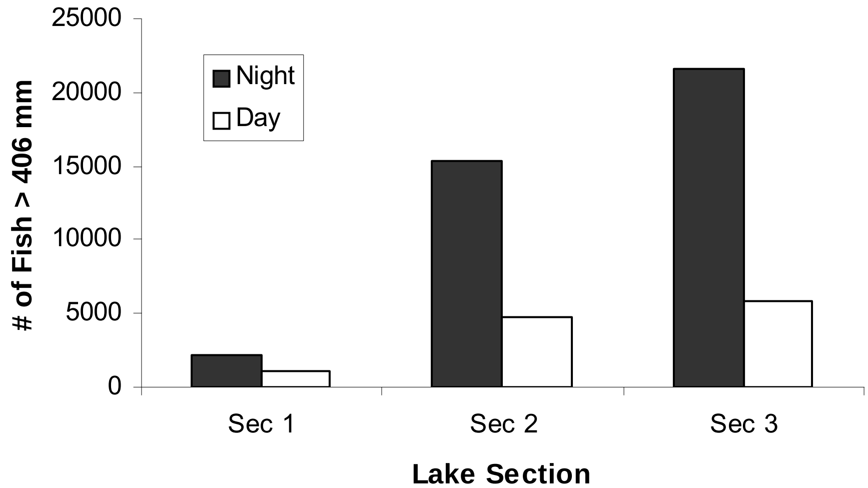


Figure 3. Comparison of daytime and nighttime population estimates for each sampling section of Lake Pend Oreille during August 2002.

Table 2. Density estimates of fish over 406 mm (-33 dB) in the pelagic zone of Lake Pend Oreille, Idaho recorded per hydroacoustic transect during August 2002. Estimates were made at night and based on single and multiple echoes from fish in water with a bottom depth of >70 m.

Section 1		Section 2		Section 3	
Transect number	Fish/ha	Transect number	Fish/ha	Transect number	Fish/ha
1-1	0.21	2-1	1.15	3-1	2.32
1-2	0.00	2-2	0.00	3-2	0.79
1-3	0.36	2-3	1.52	3-3	2.56
1-4	1.06	2-4	1.23	3-4	1.61
1-5	0.00	2-5	0.37	3-5	3.76
1-6	1.85	2-6	2.92	3-6	11.98
1-7	0.00	2-7	3.32	3-7	*
1-8	1.03	2-8	5.68	3-8	*
1-9	0.00	2-9	5.49	3-9	*
1-10	0.32	2-10	3.34		
1-11	0.53				
1-12	0.00				

* Transects 3-7, 3-8, and 3-9 do not contain density estimates because the majority of habitat found in those transects did not meet our pelagic criteria (i.e. >50% of the total area in the transect must have water depths >70 meters).

Pelagic Fish Depth Distribution

Summer 2002

Depth distribution of pelagic fish (all sizes) was determined for each acoustic transect during both day and night in August (example of one transect is shown in Figure 4). In general, the majority of opossum shrimp *Mysis relicta* (targets <25 mm) and fish between 25 and 400 mm showed an upward vertical migration to above 50 m during the night and then migrated down and remained in depths below 100 m during the day. This trend was noted for each acoustic transect in which we recorded data below 100 m. Water temperatures above 50 m ranged from approximately 18°C on the surface to 5.4°C at 50 m. Water temperatures were <5°C below 100 m.

Pelagic fish >406 mm were found between depths of 5 and 80 m during both day and night surveys (Figure 5). Two groups of fish were observed during the survey. One group of fish was located between 10 and 35 m, and another group was located between 40 and 70 m. The shallower group of fish (<35 m) was mostly (97%) found in transects with very deep water (>215 m; all transects in Section 1 and 2, and in transects 3-1 through 3-4). The deeper group of fish (>35 m) was mostly (64%) found in transects 3-5 and 3-6 where depths do not exceed 120 m. The remaining 36% was from deep water fish observed in six transects in Section 2 and three transects in Section 3 (excluding 3-5 and 3-6). No deep-water pelagic fish >406 mm were observed in Section 1. Fish from the shallow group were found above 20 m during the day, whereas fish were more dispersed throughout the upper water column above 35 m during the night (Figure 5). A portion (42%) of the deep daytime group of fish was found below 60 m, whereas all of the nighttime fish were between 40 and 55 m (Figure 5). Fish in the shallow group occupied temperatures between 7 and 16°C, while fish from the deeper group were in water <7°C and concentrated in the northern end of the lake.

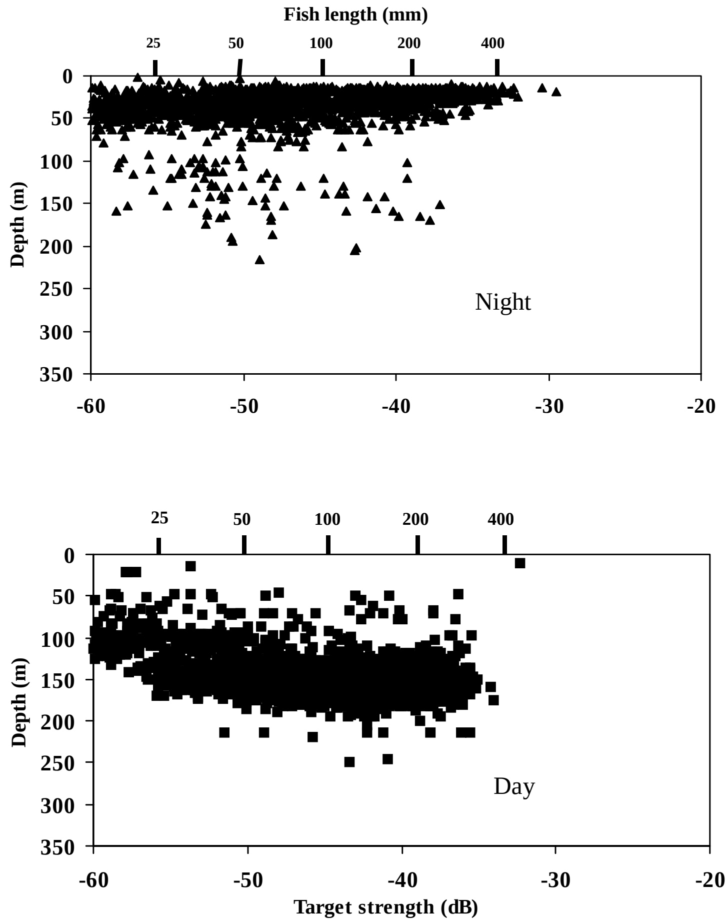


Figure 4. Comparison of day (bottom) and night (top) pelagic fish distribution collected from a hydroacoustic transect in Section 3 of Lake Pend Oreille during August 2002.

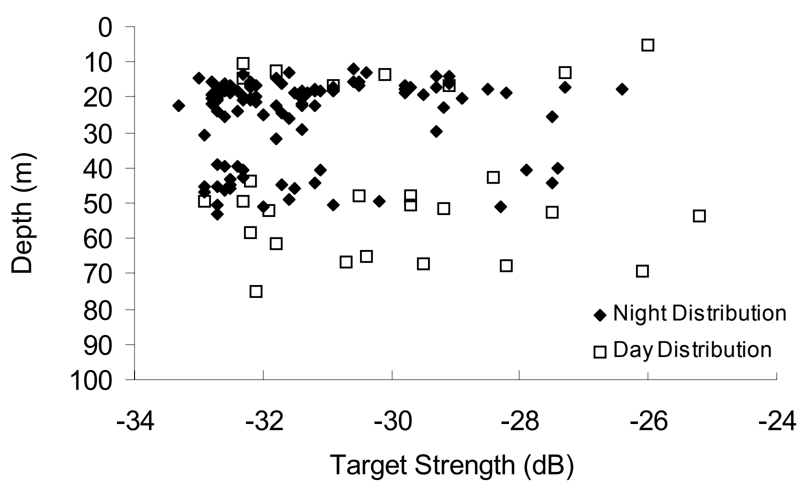


Figure 5. Day and night depth distribution of all pelagic fish >-33 dB recorded from 12 hydroacoustic transects in Lake Pend Oreille during August 2002.

Fall 2002

Fall pelagic fish (all sizes) depth distribution was determined from 12 acoustic transects collected on December 6 (two transects from each lake section during both day and night). Figure 6 depicts an example of two (day and night) acoustic transects collected in Section 3. Pelagic fish 25-200 mm were found throughout the water column in depths between 40 and 160 m during the day. Fish >200 mm were found in depths between 30 and 70 m during the day. During nighttime hours, the majority of fish >25 mm were found in depths between 10 and 40 m, though a small percentage of fish 25-200 mm were found between depths of 50 and 80 m. Water temperature profiles ranged from 7.0°C in the upper 50 m to 6.0°C below 60 m.

Pelagic fish >406 mm were found throughout the water column between 20 and 90 m during the fall of 2002 (Figure 7). Fifteen fish were observed from 12 transects (six transects at night and six during the day). One group of pelagic fish was located between 20 and 50 m in 7.0°C water temperature during both day and night. The other group of fish was located in depths between 70 and 90 m in 6.0°C water temperature during daytime acoustic transects. No fish were recorded in the top 20 m of the water column.

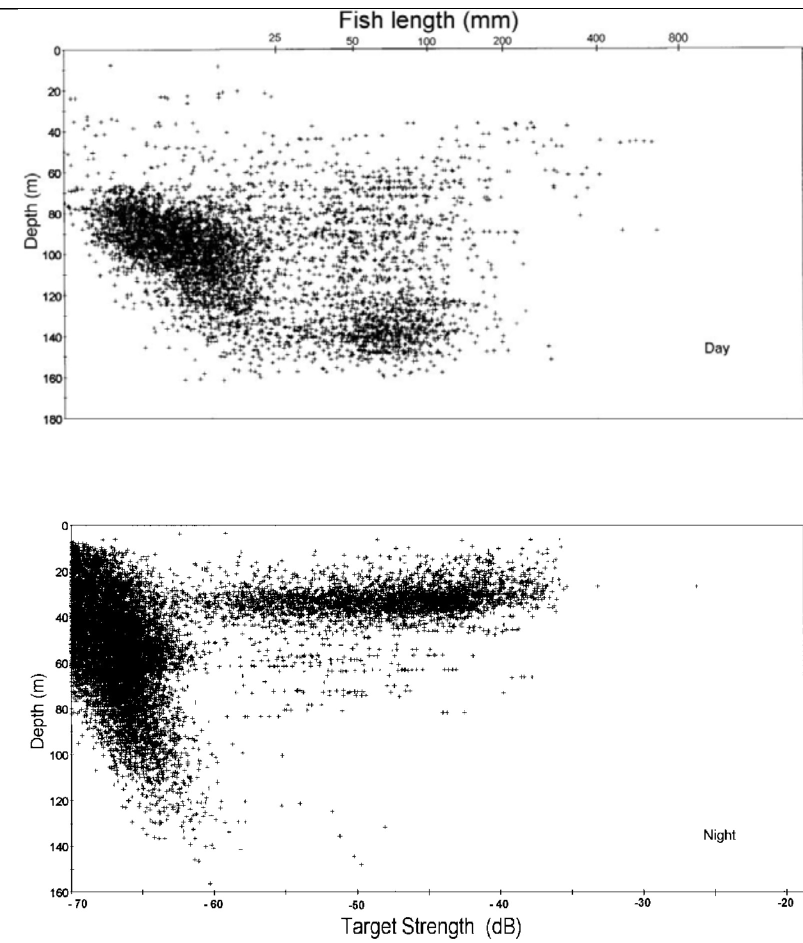


Figure 6. Comparison of day (top) and night (bottom) pelagic fish and mysis shrimp (<-60 dB) distribution collected from a hydroacoustic transect in Section 3 of Lake Pend Oreille on December 6, 2002.

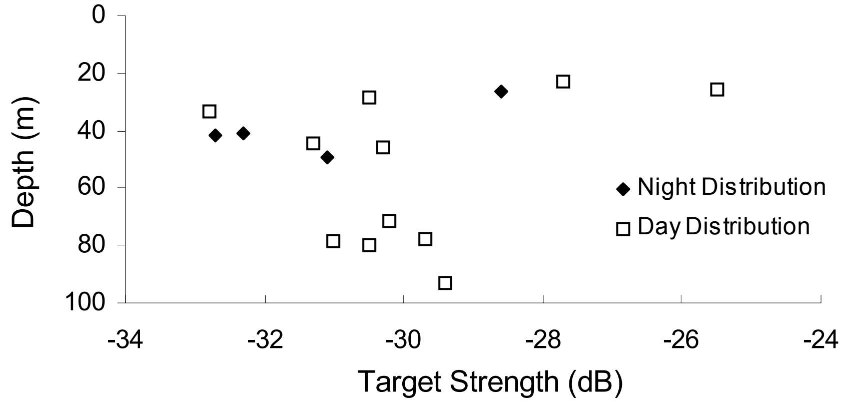


Figure 7. Day and night depth distribution of all pelagic fish >-33 dB recorded from 12 hydroacoustic transects in Lake Pend Oreille on December 6, 2002.

Winter 2003

Depth distribution of pelagic fish (all sizes) during winter was determined from 12 acoustic transects collected on February 12 (two transects from each lake section during both day and night). Most fish migrated above 80 m during the night and remained in deep water (>80 m) during daytime hours (Figure 8). During the day, fish >270 mm were only observed above 100 m, whereas the majority of fish between 25 and 270 mm were located between 40 and 160 m. During the night, most of the fish >200 mm were found between 20 and 40 m, whereas most of the fish between 25 and 200 mm were located between 20 and 80 m. Water temperature throughout the water column was largely isothermal but ranged from 4.4 to 4.8°C for all three lake sections.

Pelagic fish >406 mm (n = 16), during winter, were mainly located between 30 and 60 m during both day and night (Figure 9). Two daytime fish were observed at depths below 70 m. No nighttime fish were observed below 60 m. No fish were observed in the top 30 m of the water column.

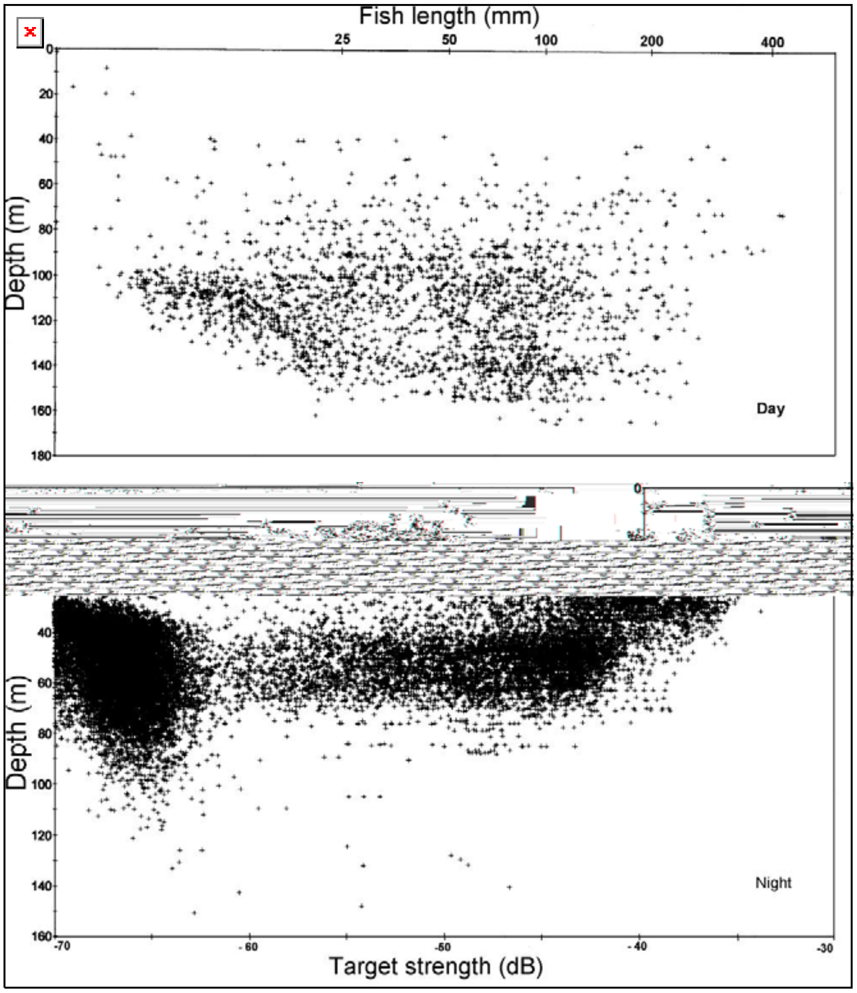


Figure 8. Comparison of day (top) and night (bottom) pelagic fish and mysis shrimp (<-60 dB) distribution collected from a hydroacoustic transect in Section 3 of Lake Pend Oreille on February 12, 2003.

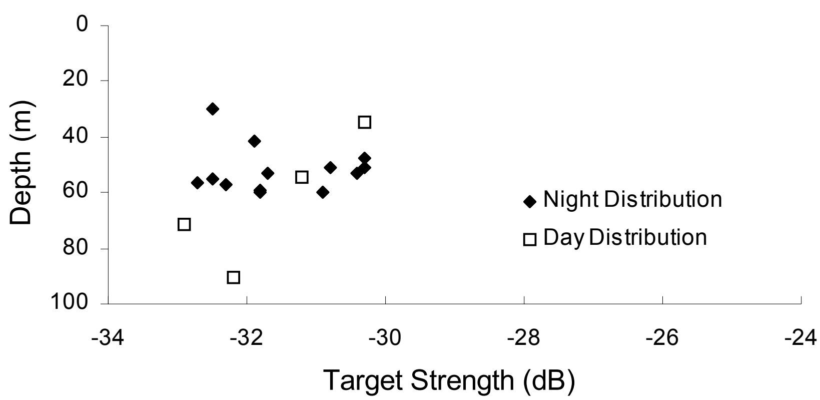


Figure 9. Day and night depth distribution of all pelagic fish >-33 dB recorded from 12 hydroacoustic transects in Lake Pend Oreille during February 2003.

Pelagic Fish Species Composition

Based on nighttime midwater trawl surveys in Lake Pend Oreille, kokanee made up the majority of the pelagic fish community found at water depths <40 m during August 2002 (Figure 10). Kokanee (all age groups) comprised 98%, 97%, and 100% of the composition in sections 1, 2, and 3, respectively. Lake whitefish, westslope cutthroat trout, and juvenile *Salvelinus sp*. made up the rest of the pelagic community. No fish >400 mm were captured out of 733 fish collected.

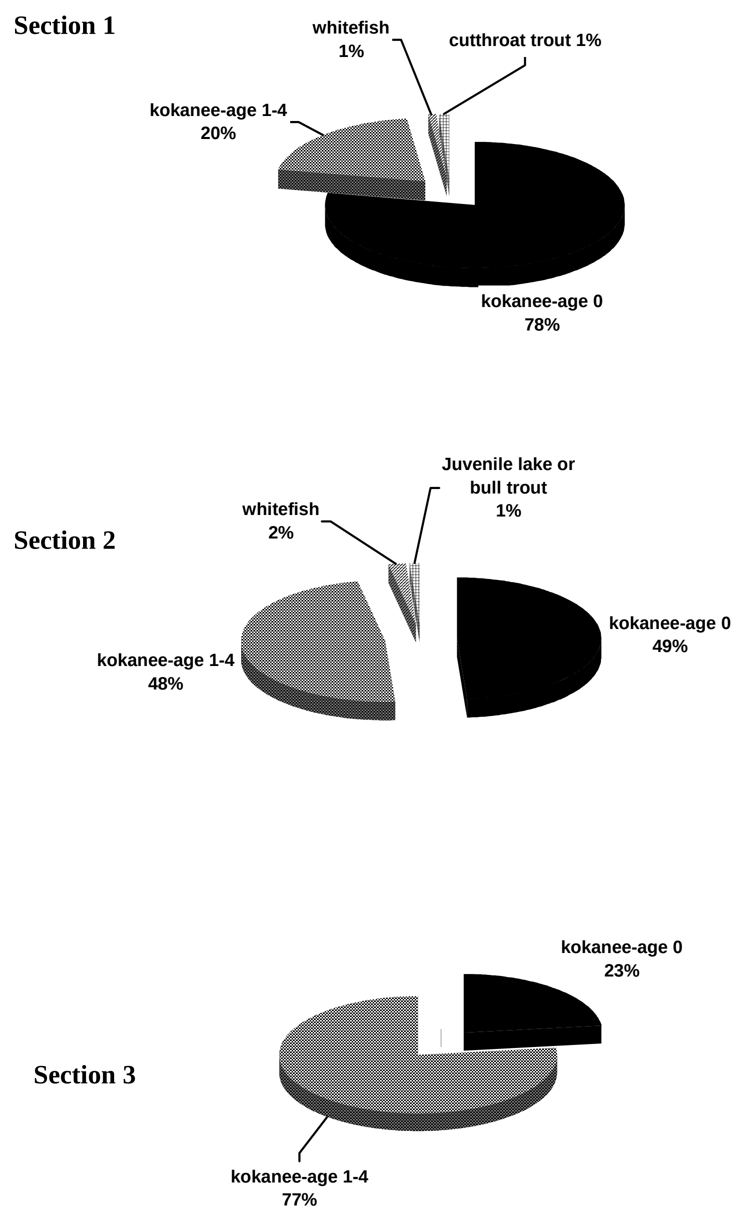


Figure 10. Pelagic species composition from the three sections of Lake Pend Oreille based on midwater trawling surveys in August 2002.

Benthic Fish Distribution

Benthic fish >406 mm recorded on all August hydroacoustic transects (lakewide) during both day and night (n = 453 fish) were combined into one scatter plot (Figure 11). The majority of benthic fish (88%) were found between 20 and 50 m. Only 2% of the benthic fish were found above 20 m, while the remaining 10% were found at depths below 50 m. Five benthic fish were recorded at or below 200 m.

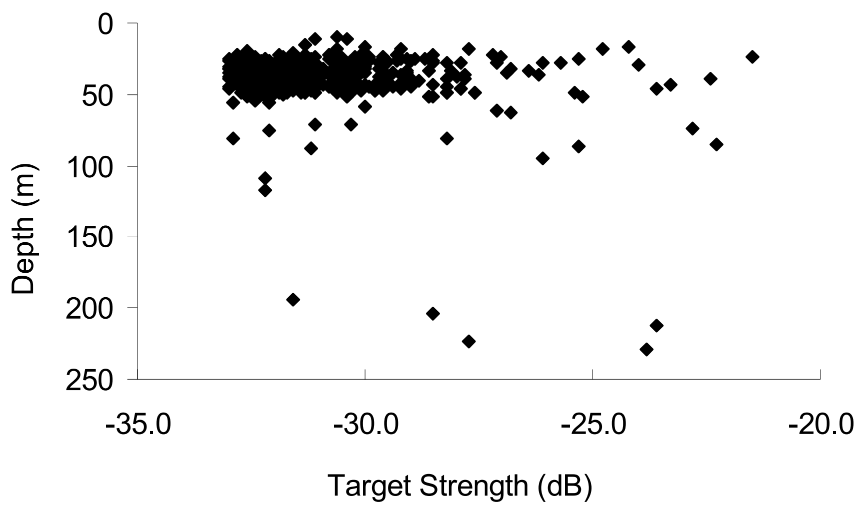


Figure 11. Acoustic depth distribution of all benthic fish > -33 dB from Lake Pend Oreille during August 2002. Graph contains both day and night survey data (n = 453).

Predator Tagging and Tracking

Sonic Transmitter Calibration

Prior to transmitter insertion, we tested the performance of the transmitters and receiver. Three depths were tested (15, 30, and 45 m) and transmitter values ranged from 14.3 to 15.8 m, 29.8 to 32.0 m, and 44.8 to 47.5 m for each test interval, respectively. Transmitter-measured values were highly correlated to known tag depth values (r^2 = 0.99) and no transmitter deviated from the manufacturer's guaranteed accuracy range.

Fish Tagging Effort

From October 17, 2002 to January 23, 2003, 15 sonic tag surgeries were performed on large (>2262 g) rainbow trout and lake trout (Table 3). Of the 15 surgeries, seven fish (three rainbow trout and four lake trout) survived and were tracked during the 2002-2003 late fall and winter seasons. Four of the surgeries resulted in mortality within 24 hours (all four were rainbow trout captured by hook and line). Three rainbow trout that were released after the 24 h holding period either died or expelled their tag within two weeks. One lake trout was creeled four days after it was released, and the angler returned the tag to us.

Table 3. Fish utilized for sonic tag insertion. Rainbow trout (rbt) and lake trout (lkt) were captured either by hook and line (H and L) or by monofilament gillnets (gillnet). Fish sex is denoted by male (m), female (f), or unknown (unk).

Species	Sex	TL (mm)	Wgt (g)	Capture Method	Date	Status	Tag ID
rbt	f	673	4196	H and L	10/17/02	Died after release	10-10-10-10
rbt	m	675	3402	H and L	10/26/02	In lake	6-7-8-9
rbt	f	680	3674	H and L	10/26/02	Died within 24 h of surgery	—
rbt	f	662	3742	H and L	10/26/02	Died within 24 h of surgery	—
lkt	unk	625	2268	H and L	10/27/02	In lake	9-9-9-9
rbt	f	680	3429	H and L	11/4/02	Died after release	6-6-7-7
rbt	m	787	5488	H and L	11/22/02	Died within 24 h of surgery	—
rbt	f	748	4717	H and L	11/22/02	Died after release	8-8-9-9
rbt	f	770	5397	H and L	11/24/02	Died within 24 h of surgery	—
lkt	m	570	3401	H and L	11/24/02	Fish creeled on 11/29/02*	—
rbt	f	690	3429	H and L	11/25/02	In lake	6-6-6-6
rbt	m	790	6690	H and L	11/25/02	In lake	7-7-7-7
lkt	unk	671	2993	gillnet	1/23/03	In lake	6-6-9-9
lkt	unk	862	6010	gillnet	1/23/03	In lake	8-8-8-8
lkt	unk	835	6781	gillnet	1/23/03	In lake	7-8-9-9

*Tag was turned in by a fishermen and used at a later date.

Fish Tracking Effort

Our fall tracking effort started on November 7 and ended on December 21. We tracked a total of seven days (1 d equals approximately 7 hours of tracking). All of our tracking effort during the fall was done in daylight hours.

Our winter tracking session started on December 22 and ended on March 20 (winter calendar season). We tracked a total of 41 days during the winter season (88 d) and made 184 and 168 habitat observations of lake trout and rainbow trout, respectively. Sixty percent of this tracking effort was made during the day (25 d), and 40% of our effort focused on night surveys (16 d). The most intense tracking effort occurred from February 3-13 when we tracked fish daily (night and day) to coincide with our winter hydroacoustic survey.

Rainbow Trout Late Fall and Winter Habitat Use

Rainbow trout were found exclusively in the pelagic area during both day and night. Rainbow trout were found in shallower depths during the night (mean = 0.73 m, SD = 1.58, range = 0.30-15.21 m) compared to during the day (mean = 2.83 m, SD = 5.15, range = 0.30-28.95 m) (Figure 12). Their mean distance from shore was 1.72 km (SD = 1.17, range = 0.05-

5.51 km) and mean distance from the lake bottom was 203.34 m (SD = 90.06, range = 14.93-370.92 m) for both day and night (data combined). The mean temperature utilized during nighttime hours was 4.96°C (SD = 0.35, range = 4.72-7.24°C) and was 5.45°C (SD = 0.73, range = 4.52-7.38°C) during daytime hours.

Lake Trout Winter Habitat Use

Lake trout utilized all three of our predefined habitat types: pelagic, littoral, and benthic (Figure 13). During the day, lake trout were observed in benthic locations 49% of the time but were also found in pelagic areas (32%) and littoral areas (19%). During the night, lake trout were observed in benthic areas 37% of the time, in pelagic areas 35% of the time, and in littoral areas 28% of the time.

During the winter, benthic lake trout were found at similar mean depths during night (41.61 m, SD = 20.98, range = 22.25-92.05 m) and day (42.82 m, SD = 19.72, range = 10.66-89.30 m). They were also found at similar mean temperatures during night (4.75°C, SD = 0.44, range = 4.00-5.55°C) and day (4.66°C, SD = 0.30, range = 4.00-5.28°C). Benthic lake trout were found closer to shore at night (mean = 185.45 m, SD = 87.52, range = 75.00-370.00 m) compared to day (mean = 238.31 m, SD = 129.26, range = 75.00-556.00 m).

Lake trout found in the pelagic and littoral areas during the winter were generally in shallower depths than benthic fish. Littoral fish utilized a mean depth of 29.53 m (SD = 3.43, range = 27.12-37.79 m) during the night and 33.08 m (SD = 4.87, range = 27.43-41.14 m) during the day. Pelagic fish were found at a mean depth of 30.48 m (SD = 3.63, range = 26.21-39.92 m) during the night and 32.71 m (SD = 11.86, range = 18.28-73.75 m) during the day. Overall mean temperatures for both littoral and pelagic lake trout ranged from 4.72°C to 5.21°C for day and night. Littoral fish were found closer to shore during the night (mean = 95.25 m, SD = 48.89, range = 35.00-185.00 m) as compared to during daytime hours (mean = 293.77, SD = 106.07, range = 120.00-370.00 m). Pelagic fish were found further offshore at night (mean = 1,454.85 m, SD = 870.81, range = 555.00-2778.00 m) than during the day (mean = 975.11, SD = 811.00, range = 32.2-2770.00 m).

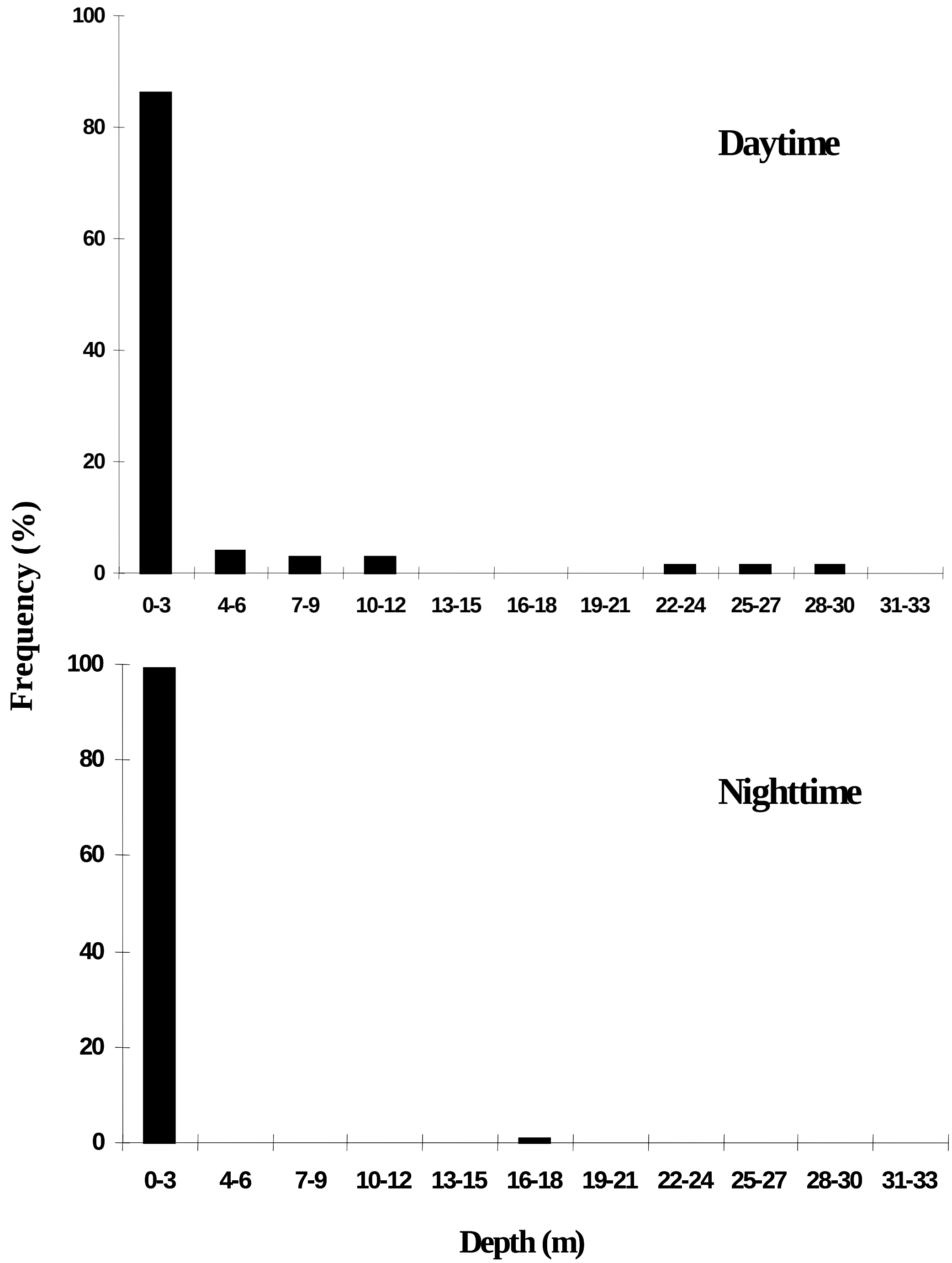


Figure 12. Winter habitat use of rainbow trout in Lake Pend Oreille based on sonic tracking results from December 22, 2002 to March 20, 2003.

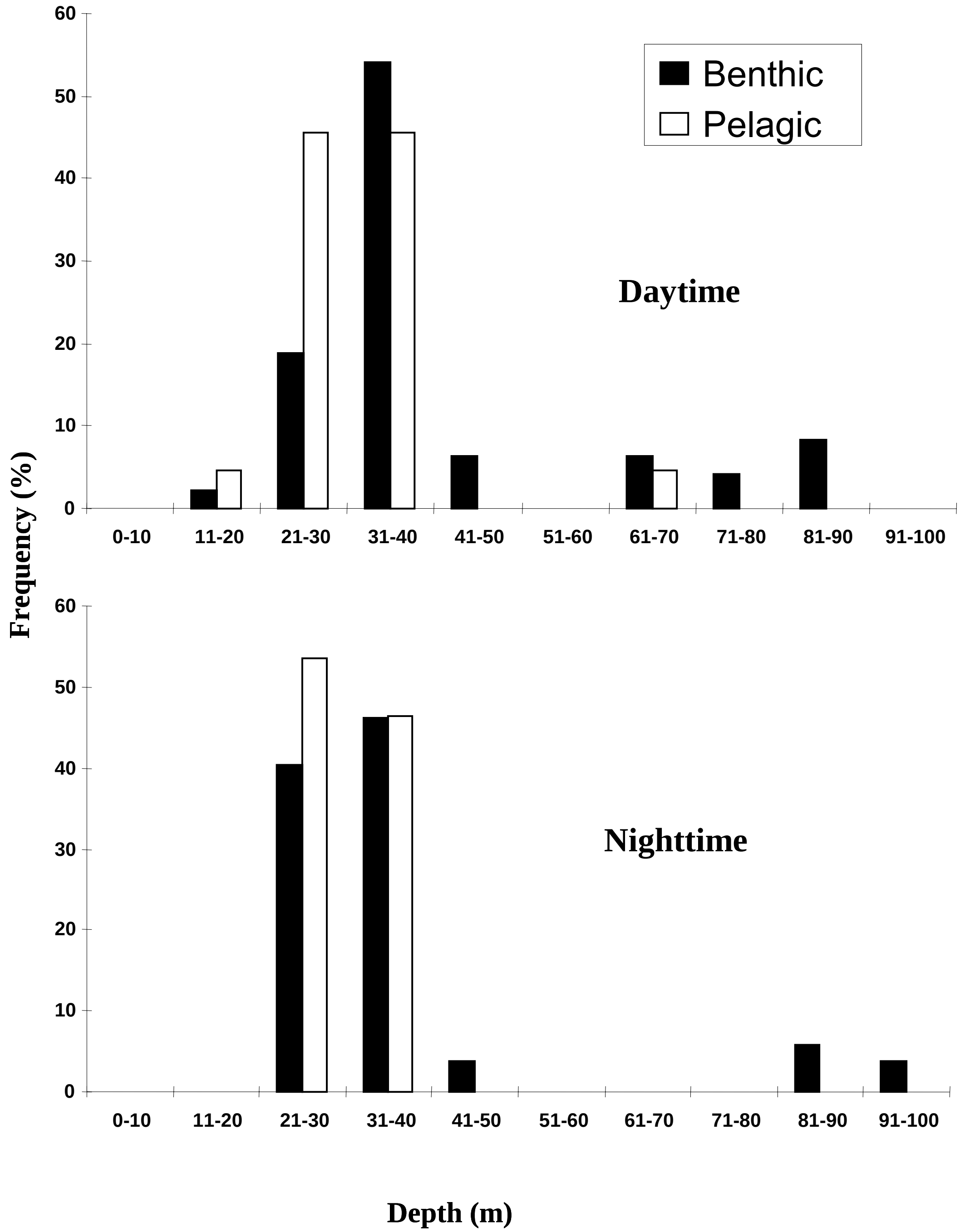


Figure 13. Winter depth use of benthic and pelagic (includes littoral observations) lake trout in Lake Pend Oreille based on sonic tracking results from December 22, 2002 to March 20, 2003. The graphs depict both day and night percent frequency habitat use of each given depth strata.

Predator Impacts

Predator and Prey Ratio

Biomass of pelagic predators (all pelagic fish >406 mm) during August 2002 was 73.2 t (Table 4). The kokanee biomass (all sizes) was estimated to be 193 t (Maiolie et al. 2004 in press). Based on these biomass estimates, the August 2002 ratio of pelagic predator to pelagic prey (predator:prey) is 1:2.63 (i.e., assuming all pelagic fish >406 mm are predators).

Table 4. Biomass calculation of pelagic fish >406 mm. The number of pelagic predator/length group was determined by a nighttime hydroacoustic survey performed in August 2002 (see Appendix B).

Lgt group (mm)	Mean wgt (kg)/lgt group	# Pelagic predator/lgt group	Biomass (kg)/lgt group
406	0.76	6345	4797.53
432	0.92	7809	7206.00
457	1.11	4392	4892.26
483	1.33	5369	7145.79
508	1.58	2440	3847.22
533	1.85	2440	4520.28
559	2.16	1464	3163.37
584	2.50	976	2443.3
610	2.88	1464	4220.26
635	3.30	2440	8053.77
660	3.75	976	3669.51
686	4.76	488	2184.04
711	4.95	488	2414.76
737	5.18	488	2528.57
787	6.75	488	3292.19
813	7.33	488	3579.20
914	10.83	488	5283.81
	Totals	39,044	73,241.91

Biomass, Production, and Yield

During 2002, kokanee production (263.70 t) was higher than kokanee yield (233.50 t) (Maiolie et al. 2004 in press) (Figure 14), while the ratio of pelagic predator biomass to prey biomass (kg) was estimated to be 1:2.58. Since 1996, kokanee yield has been slightly negatively correlated (r^2 = 0.013) with increasing biomass, whereas production has been positively correlated (r^2 = 0.286) to increasing biomass (Figure 14). The two trend lines crossed at a point where biomass equals about 275 t.

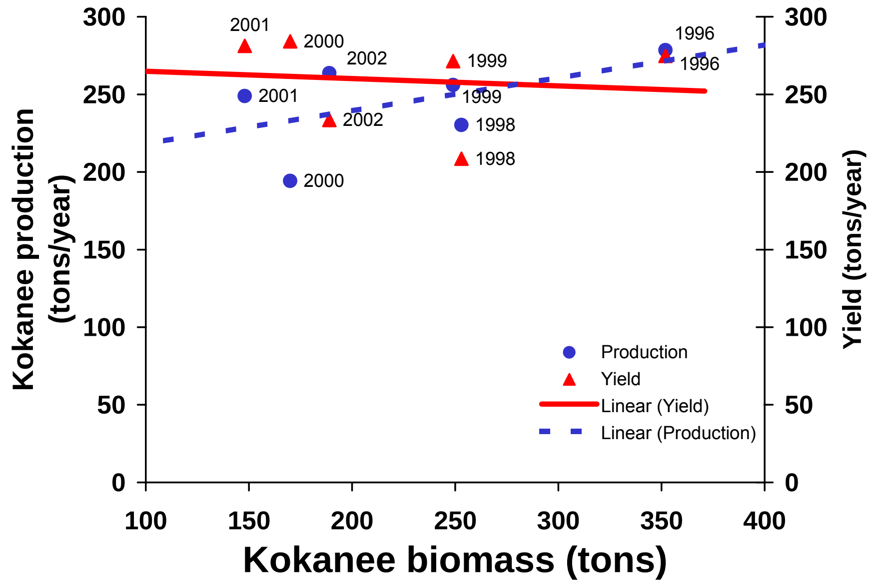


Figure 14. Kokanee biomass, production, and yield for Lake Pend Oreille, Idaho 1996-2002, excluding 1997.

DISCUSSION

Our 2002 population estimate of pelagic fish >406 mm is higher than a previous estimate of total predator (bull trout, lake trout, and rainbow trout) abundance in Lake Pend Oreille. Utilizing a mark and recapture survey, Vidergar (2000) estimated that the lake contained 28,533 (1.26 f/ha) predators >406 mm (14,607 rainbow trout, 12,134 bull trout, and 1,792 lake trout). During our 2002 summer hydroacoustic survey (five days) we estimated there were 39,044 (1.84 f/ha) pelagic fish >406 mm. A major difference between the two estimates is that Vidergar's (2000) numbers are species specific, while our numbers only report those fish in the pelagic area of the lake (at least 10 m off bottom and in water >70 m) and are not species specific (i.e., unidentified acoustic fish targets). Determining summer habitat use of predators in future sampling seasons will be vital in completing the intended objectives and tasks of this study.

By examining habitat use (depth, temperature, etc.) of hydroacoustic fish targets, we located two distinct groups of pelagic fish (>406 mm) during the summer of 2002. One group, located in the upper water column (10-35 m) over deep water (>215 m), was more numerous (26,637 fish) compared to the second group (12,407 fish), which was found in deeper water (>40 m). Most of the fish from the second group (12,100 fish) were located in the northern section of the lake where bottom depths do not exceed 120 m. We speculate that these deeper fish may be lake whitefish based on gillnet catches in this area (Idaho Department of Fish and Game files). If so, they are not likely to be a major kokanee predator. Though it is premature to categorize one group as pelagic predators and one group as nonpredators (e.g., lake whitefish), the portion of the population located in the shallow group (26,637 fish) more closely resembles

Vidergar's (2000) total predator estimate of 28,533 fish. Future work should be directed towards identifying the species composition of these groups and verifying it is an annual occurrence.

In 2002, kokanee survival rates for age-1 to age-2 and from age-2 to age-3 were below 50% (Maiolie et al. 2004 in press), which may indicate an imbalance of the predator and prey populations, since these age classes of kokanee are most vulnerable to Lake Pend Oreille predators (Vidergar 2000). If we assume that all of the fish from our population estimate are predators, then we would have a predator to prey biomass ratio of 1:2.63. Even if we assume the shallow group of fish were all predators and excluded the deeper group of fish, the predator and prey population may still be imbalanced with a ratio of 1:3.81 (predator biomass of shallow group is 50.6 t). Johnson and Martinez (2000) noted an imbalance of predator (lake trout) to prey (kokanee) to occur when piscivorous fish biomass was 60% of total pelagic fish biomass or at a predator to prey ratio of <1:2. The systems that Johnson and Martinez (2000) were studying were sustained through both predator and prey stocking, which allowed an imbalance to annually occur. In Lake Pend Oreille, predators are naturally recruited into the system, at perhaps a stable rate, and may continue to keep survival rates of older kokanee age classes below 50%. Interestingly, kokanee survival from age-1 to age-2 and age-2 to age-3 both increased by 16.8% and 10.2%, respectively, from 2001 to 2002 (Maiolie et al. 2004 in press). As we refine our pelagic predator population estimate, it is imperative to monitor kokanee survival rates as well as kokanee biomass. Kokanee population data combined with a refined pelagic predator estimate may help us determine predation impacts in Lake Pend Oreille.

By performing hydroacoustic surveys in the fall and winter, we found that hydroacoustic sampling for a pelagic predator population estimate during these times would most likely produce an underestimate of the total pelagic predator population in Lake Pend Oreille. During our hydroacoustic surveys, we did not detect any pelagic fish above 20 m in the fall survey or above 30 m in the winter survey. Although we have limited tracking data during the fall (seven tracking days from November 7 to December 21), rainbow trout (n = 3) were found exclusively in the top 10 m of the water column in the pelagic area. This coincides with angler reports of catching fish on the surface throughout the fall (Lake Pend Oreille Idaho Club members, personal communication). During winter months, tagged rainbow trout only utilized pelagic areas in the top 10 m of the water column. Tagged lake trout preferred depths of 30-35 m but were only found in pelagic areas 35% of the time during the night, so a significant portion of the population would not be included in our pelagic predator population estimate. Since rainbow trout were located in the top 10 m of the water column, we may be scattering fish as we perform our mobile hydroacoustic survey. Past research performed on fish scattering from approaching vessels (MacLennan and Simmonds 1992) suggests that this is possible. One way to avoid scattering fish is to utilize side-scan hydroacoustic gear. However, by using a side-scan system it would be difficult to accurately estimate biomass, because the aspect of the fish is unknown and, therefore, size estimates are imprecise. During August when Lake Pend Oreille is thermally stratified, rainbow trout prefer to occupy cooler (<14°C) water temperatures (Scott and Crossman 1973). This should concentrate fish below at least 10 m and possibly discourage the bias of scattering.

Though sonic tracking of large predators is labor intensive, we found it to be an effective technique at acquiring habitat use data. The advantage of physically locating a tagged fish as opposed to detecting it using a remote and stationary hydrophone system or by use of archival tags was the ability to determine if a fish was occupying benthic or pelagic habitats. Since it is not known whether lake trout or rainbow trout in Lake Pend Oreille exclusively use pelagic areas, predator tracking was very useful in providing this information. Rainbow trout in Lake Washington (two sample fish) predominantly used nearshore pelagic areas and made occasional excursions across the lake while only utilizing the top 10 m of the water column during the fall (Warner and Quinn 1995). We found similar results in regards to depth use, though Lake Pend Oreille rainbow trout mostly utilized the offshore pelagic area. Lake trout, on the other hand, are commonly thought to inhabit deep, cooler waters of lake systems and have been noted to occupy both pelagic and benthic areas, depending on local conditions (Scott and Crossman 1973). For our study we needed to determine habitat use of lake trout, since our population estimate is only made from the pelagic area. We now have a better understanding of lake trout habitat utilization by the use of sonic tracking equipment, and continued tracking during the spring and summer of 2003 along with gill netting will help refine our pelagic predator population estimate.

CONCLUSIONS

This is the first year of progress for a 3-year study; thus, these findings are very preliminary. Locating rainbow trout on or near the surface in late fall and throughout winter does suggest that hydroacoustic surveys during those times would be ineffective. We found our summer pelagic fish population estimate to be higher than a previous predator estimate, and we conclude that our estimate may contain a portion of nonpredators (e.g., lake whitefish).

RECOMMENDATIONS

1. Continue to sonic track fish >406 mm to determine the species composition of the larger targets seen on the hydroacoustic echograms.

2. Test the use of neutrally buyout gill nets suspended in pelagic areas to determine species composition of pelagic fish (>406 mm) communities.

3. Discontinue fall and winter hydroacoustic surveys, since they will likely miss most of the rainbow trout population.

4. Continue to estimate kokanee biomass along with predator biomass. By calculating kokanee survival rates along with predator:prey ratios, we may be able to determine what ratio represents a balanced population.

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APPENDICES

Appendix A. Values used to calculate a 90% confidence interval for our nighttime pelagic fish >406 mm population estimate in Lake Pend Oreille during August 2002.

Confidence Interval for Predators
>-33 dB Single Trace During Nighttime Acoustic Survey

Section 1

$\bar{x}$ = 0.133121	Section area (m^2) = 58,834,000
s = 0.15398	Depth mid fish and width of beam = 30 m = 3.743 m
N_1 = 3,391.0	$\bar{x}$ Length of transects = 4,634.9
N_1^2 = 11,498,883	Avg transect area = 17,348.49
FPC = 0.996461218	
n = 12	$N_1^2(FPC)\frac{s^2}{n}=$ 22,639.21

Section 2

$\bar{x}$ = 0.472125	Section area (m^2) = 77,983,000
s = 0.275733	Depth mid fish and width of beam = 30 m = 3.743 m
N_2 = 3537.1	$\bar{x}$ Length of transects = 5889.7
N_2^2 = 12,511,097.63	Avg transect area = 22,045.147
FPC = 0.9971728	
n = 10	$N_2^2(FPC)\frac{s^2}{n}=$ 94,851.62

Section 3

$\bar{x}$ = 0.588823	Section area (m^2) = 75,033,000
s = 0.293992	Depth mid fish and width of beam = 30 m = 3.74 m
N_3 = 2,502.9	$\bar{x}$ Length of transects = 8,008.3
N_3^2 = 6,264,729.74	Avg transect area = 29,975.19
FPC = 0.997603	
n = 6	$N_3^2(FPC)\frac{s^2}{n}=$ 90,028.33

n = number of samples in that section
N = Total number of times possible in that section
$t_{27}^{90} =$ 1.703

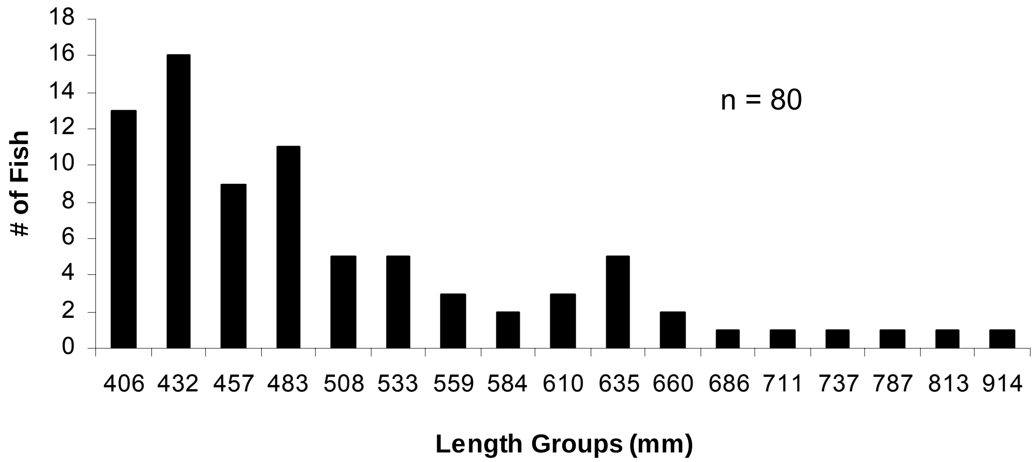
$\sum N^2(FPC)\frac{s^2}{n}=$ 207519.145

$\bar{x} \pm t^{90} * \sqrt{\frac{1}{N^2}\sum N^2(FPC)} =$

90% CI = 0.45381 ±0.08226 (0.37153 to 0.53605)
90% CI for fish density = 1.84309 f/ha (-27%, +32%) (2.43613 f/ha to 1.35261 f/ha)

Section 1 = 2,110 fish
Section 2 = 15,327 fish
Section 3 = 21,607 fish
Total = 39,044 (-27%, +32%) or (28,651 to 51,604)

Appendix B. Length frequency histogram of all nighttime pelagic fish > 406 mm (n = 80) recorded during an August 2002 hydroacoustic survey. The bottom table shows the actual number of fish used for each age group to calculate a biomass estimate (see Table 4).



Total # of Pelagic Fish >406 mm	Length Group (mm TL)	% of Fish/Length Group	# of Fish/Length Group
39,044	406	16.25%	6345
	432	20.00%	7809
	457	11.25%	4392
	483	13.75%	5368
	508	6.25%	2440
	533	6.25%	2440
	559	3.75%	1465
	584	2.50%	976
	610	3.75%	1464
	635	6.25%	2440
	660	2.50%	976
	686	1.25%	488
	711	1.25%	488
	737	1.25%	488
	787	1.25%	488
	813	1.25%	488
	914	1.25%	488