FISHERY RESEARCH

LAKE PEND OREILLE RESEARCH, 2013

LAKE PEND OREILLE FISHERY RECOVERY PROJECT

ANNUAL PROGRESS REPORT
January 1, 2013—December 31, 2013

Prepared by:
Nicholas C. Wahl, Senior Fishery Research Biologist
Andrew M. Dux, Principal Fishery Research Biologist
William J. Ament, Senior Fishery Technician
and
William H. Harryman, Senior Fishery Technician

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Nicholas C. Wahl
Andrew M. Dux
William J. Ament
and
William H. Harryman

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

To

U.S. Department of Energy
Bonneville Power Administration
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Portland, OR 97283-3621

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INTRODUCTION

Lake Pend Oreille once provided the largest Kokanee *Oncorhynchus nerka* fishery in the state of Idaho. Between 1952 and 1966, Kokanee harvest averaged 1 million per year with up to 523,000 angler-hours (Jeppson 1953; Maiolie and Elam 1993). Beyond providing a popular sport fishery, Kokanee serve as the primary forage for predatory salmonids including ESA-listed Bull Trout *Salvelinus confluentus* and Gerrard-strain Rainbow Trout *O. mykiss*. On a Kokanee-based diet, Bull Trout (14.5 kg) and Rainbow Trout (16.8 kg) have reached world record sizes in Lake Pend Oreille, and angling for these trophy-sized predators contributed a major portion of the annual effort (46% in 1980, Ellis and Bowler 1981). These two predatory trout species are reliant upon a Kokanee prey base in Lake Pend Oreille.

Kokanee harvest dramatically declined after 1966, and by 1985 the annual harvest was only 71,200 Kokanee with 179,000 angler-hours (Bowles et al. 1987; Maiolie and Elam 1993). The Idaho Department of Fish and Game (IDFG) closed the Kokanee fishery in 2000 due to low adult Kokanee abundance. Drawdowns of the lake during fall and winter for flood control and power production contributed to the initial Kokanee decline by dewatering redds and reducing the availability of quality spawning habitat (Maiolie and Elam 1993). Additionally, mysid shrimp *Mysis diluviana* were introduced as a Kokanee forage base, but likely reduced Kokanee production through competition for zooplankton resources (Nesler and Bergersen 1991). Despite the closure of the fishery, the Kokanee population continued to decline to near collapse in 2007, mainly due to an increase in the Lake Trout *S. namaycush* population (Maiolie et al. 2002; Maiolie et al. 2006a; Schoby et al. 2009b).

Two strategies have been implemented to restore the Kokanee population. The first strategy assumed Kokanee spawning habitat to be a limiting factor (Maiolie and Elam 1993). Since 1996, the U.S. Army Corps of Engineers manipulated the winter drawdown of Lake Pend Oreille to either 625.1 or 626.4 m above mean sea level (MSL) to enhance Kokanee spawning and egg incubation success. The second strategy was directed at reducing predation on Kokanee. Beginning in 2000, IDFG removed all harvest limits on Lake Trout, followed by the removal of Rainbow Trout *O. mykiss* harvest limits in 2006. In addition to regulation changes, IDFG implemented an Angler Incentive Program (AIP), which paid anglers to harvest Lake Trout and Rainbow Trout. The Rainbow Trout portion of the AIP did not reduce the species' abundance and therefore was discontinued in 2013 (Wahl et al. 2015). To further reduce Lake Trout abundance, IDFG has contracted with Hickey Brothers Research, LLC (Bailey's Harbor, Wisconsin) since 2006 to fish gill and trap nets in Lake Pend Oreille.

Since reaching record lows in 2007, Kokanee abundance and biomass have increased annually, primarily in response to predator reduction (Wahl et al. 2015). For the first time in 14 years, a limited-harvest (six fish limit) fishery was reopened in 2013. Project activities in 2013 focused on evaluating Kokanee population responses to the restoration strategies. Also, two studies were conducted in collaboration with the University of Idaho to examine the premise and recruitment metric underlying the surface elevation management strategy and mysid shrimp and zooplankton dynamics in relation to Kokanee. Lake Trout research was conducted to help improve the efficiency of Lake Trout netting operations and to evaluate the potential influence that removals have had on the population. Finally, we evaluated the implementation of the Lake Trout removal program.

STUDY AREA

Lake Pend Oreille is located in the northern panhandle region of Idaho (Figure 1). It is the state's largest and deepest lake, with a surface area of 32,900 ha, a mean depth of 164 m, and a maximum depth of 357 m. Only four other lakes in the United States have a greater maximum depth. The Clark Fork River, located on the northeast shore of the lake, is the largest tributary to the lake. Outflow from the northwest shore of the lake forms the Pend Oreille River. Lake Pend Oreille is a temperate, oligotrophic lake in which thermal stratification typically occurs from late June to September (Maiolie et al. 2002) with epilimnetic temperatures averaging about 9°C (Rieman 1977). Operation of Albeni Falls Dam on the Pend Oreille River keeps the surface elevation high and stable at 628.7 m above MSL during summer (June-September), followed by surface elevations of 626.4 m to 625.1 m during fall and winter. Littoral areas are limited and most shorelines are steeply sloped. Detailed maps of tributaries and shoreline areas referenced in this report can be found in Appendix A.

A diverse assemblage of fish species is present in Lake Pend Oreille. Native game fish include Bull Trout**,** Westslope Cutthroat Trout *O. clarkii lewisi*, and Mountain Whitefish *Prosopium williamsoni.* Native nongame fishes include Pygmy Whitefish *P. coulterii*, Slimy Sculpin *Cottus cognatus*, five cyprinid species, and two catostomid species. The most abundant nonnative game fish is Kokanee with both early-run (August-September spawn) and late-run (November-December spawn) strains present. Mature Kokanee from both runs spawn in tributaries, and the more numerous late-run Kokanee also spawn along the lake shoreline. Other abundant nonnative game fish include Rainbow Trout, Lake Trout, Lake Whitefish *Coregonus clupeaformis*, and Smallmouth Bass *Micropterus dolomieu*. Less abundant nonnative game fishes include Northern Pike *Esox lucius*, Brown Trout *Salmo trutta*, Largemouth Bass *M. salmoides*, Yellow Perch *Perca flavescens*, and Walleye *Sander vitreus* (Hoelscher 1992).

Historically, Bull Trout and Northern Pikeminnow *Ptychocheilus oregonensis* were the primary native predators in Lake Pend Oreille (Hoelscher 1992). The historical native prey population included Mountain Whitefish, Pygmy Whitefish, Slimy Sculpin, suckers *Catostomus spp*., Peamouth *Mylocheilus caurinus*, and Redside Shiner *Richardsonius balteatus*, as well as juvenile salmonids (Bull Trout and Westslope Cutthroat Trout). Presently, the predominant pelagic predatory species are Lake Trout, Rainbow Trout, and Bull Trout.

PROJECT OBJECTIVES

1. Restore Kokanee abundance to a population level that can support an average annual harvest of 300,000 fish and catch rates of 1.5 fish per hour by 2015.

2. Provide Kokanee with adequate spawning habitat to allow for population restoration.

3. Reduce the Lake Trout population to pre-1999 abundance and ensure long-term suppression keeps the population below this level. Below this abundance threshold, negative influences of Lake Trout on the Kokanee and Bull Trout populations are expected to be minimal.

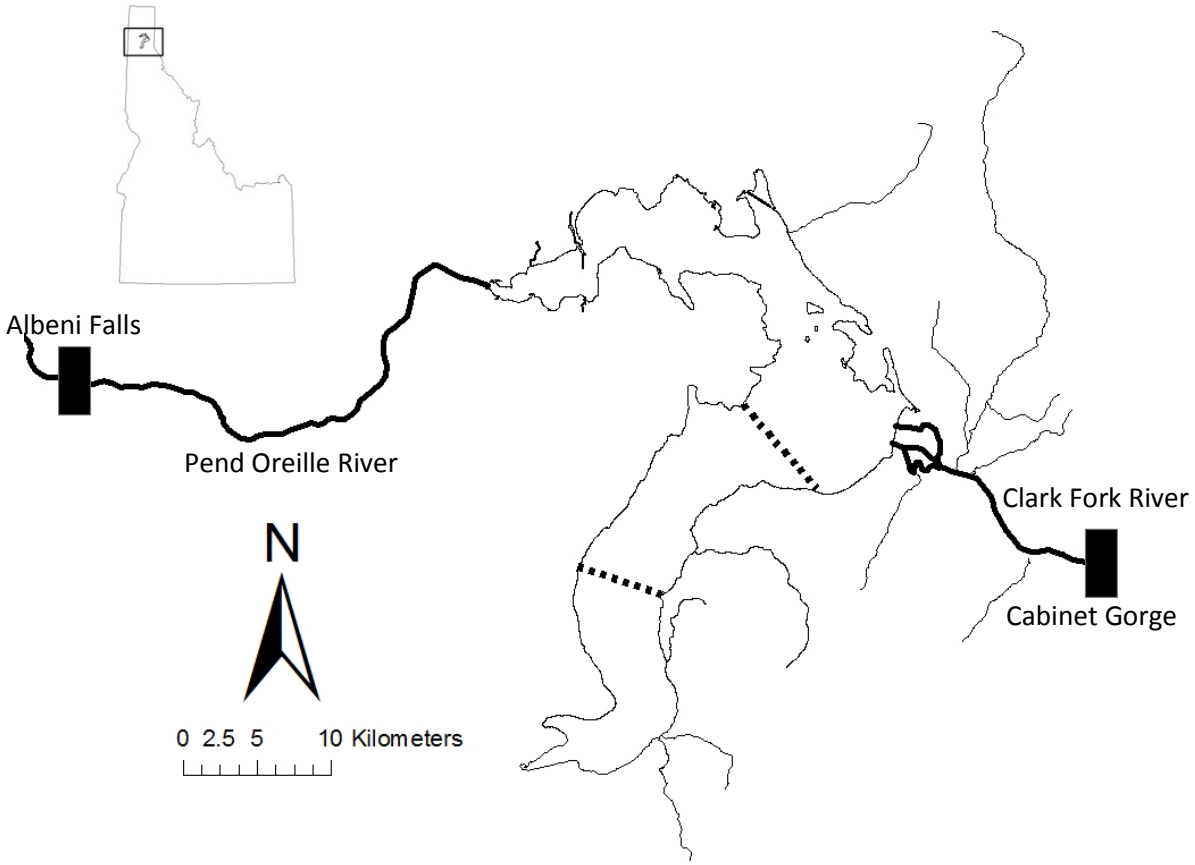

Figure 1. Map of Lake Pend Oreille, Idaho showing the three lake sections (separated by dashed lines) and primary Kokanee spawning tributaries. The main inflow and outflow rivers (Clark Fork River and Pend Oreille River) and dams (Cabinet Gorge Dam and Albeni Falls Dam) are shown.

CHAPTER 1: KOKANEE RESEARCH

ABSTRACT

During 2013, we examined the response of Kokanee *Oncorhynchus nerka* to restoration efforts. We conducted hydroacoustic surveys and midwater trawling during August and September to assess the Kokanee population status. Total Kokanee abundance was 19.7 million (872 Kokanee/ha), and is comprised of 11.8 million fry (5.7 million wild and 6.1 million hatchery) and 8.0 million Kokanee ages 1-4. Kokanee biomass was 627 metric tonnes (t), with annual Kokanee production at 518 t, resulting in a production to biomass ratio of 0.8:1. Survival from age-1 to age-2 was 112% and 83% for wild and hatchery Kokanee, respectively. In 2013, peak index counts of wild shoreline-spawning Kokanee and early- and late-run tributary-spawning Kokanee were the highest recorded since 1972. Kokanee abundance increased, and biomass was more than double the highest estimate recorded since 1996. We documented a collapse of the mysid shrimp population in 2012, and though their density increased somewhat in 2013, the population remained well below the historical average density. In 2013, two subcontracted research projects with the U.S. Geological Survey and the University of Idaho were completed, and another research project with the University of Idaho was continued. The completed University of Idaho project indicated that shoreline-spawning Kokanee did not benefit from the higher winter surface elevations created under the current surface elevation management strategy.

Authors:

Nicholas C. Wahl
Senior Fishery Research Biologist

Andrew M. Dux
Principal Fishery Research Biologist

William J. Ament
Senior Fishery Technician

William H. Harryman
Senior Fishery Technician

INTRODUCTION

Numerous factors have contributed to the decline of Kokanee *Oncorhynchus nerka* from their historical abundance. The extent and timing of winter drawdowns of Lake Pend Oreille (Figure 1, Appendix A) was implicated as the most detrimental factor contributing to the decline (Maiolie and Elam 1993), so in the 1990s, a strategy was developed to address the problems associated with lake drawdowns. Since 1996, the winter surface elevation of Lake Pend Oreille has been manipulated to test whether a higher winter surface elevation could improve Kokanee egg incubation success, estimated as egg-to-fry survival. With rare exceptions, the U.S. Army Corps of Engineers has maintained the winter surface elevation at either 625.1 or 626.4 m above mean sea level (MSL; Figure 2). Improved egg-to-fry survival has been documented from the higher winter surface elevation (Maiolie et al. 2004; Maiolie et al. 2006b), and modeling in 2009 further corroborated the increased egg-to-fry survival at 626.4 MSL (Wahl et al. 2011b). However, we have questioned the reliability of the egg-to-fry survival estimator to truly measure egg incubation success. For these reasons, better evaluation of the surface elevation manipulation strategy was necessary to determine whether it should continue to be implemented.

Along with winter lake drawdowns, other factors have also negatively impacted the Kokanee population. The introduction of mysid shrimp *Mysis diluviana* in the 1960s likely contributed to the Kokanee decline (Martinez and Bergersen 1991; Nesler and Bergersen 1991), but the extent to which this factor is limiting is presently unknown. A newer threat to Kokanee restoration emerged in the early 2000s. At that time, predation by an increasing Lake Trout *Salvelinus namaycush* population became the primary limiting factor for Kokanee restoration (Maiolie et al. 2006b). An aggressive predator removal program was initiated in 2006 to address this issue (Hansen et al. 2008).

Since reaching record lows in 2007, Kokanee abundance and biomass have increased annually in response to predator reduction, and an unexplained mysid shrimp collapse in 2012 may have accelerated observed Kokanee increases (Wahl et al. 2015). With Kokanee biomass at its highest since the mid-1990s, a limited harvest fishery (six fish daily limit) was reopened in 2013. The more robust Kokanee population will provide opportunities for investigating mysid shrimp and Kokanee competition and evaluation of hatchery stocking practices.

During 2013, we evaluated the response of the Kokanee population to restoration efforts (e.g., predator and lake surface elevation manipulations). Additionally, we completed a multiyear study in cooperation with the University of Idaho aimed at examining Kokanee spawning ecology. The goals of this study were to (1) evaluate the procedure for estimating lakeshore spawning Kokanee egg-to-fry survival, and (2) use laboratory and *in situ* incubation experiments to directly measure the relationship between Kokanee egg incubation success and spawning habitat characteristics. We also completed a multiyear project in collaboration with the U.S. Geological Survey (USGS) that involved mapping bathymetry and substrate along portions of shoreline important for Kokanee spawning. In addition, mysid shrimp trend monitoring was conducted along with the continuation of a graduate project with the University of Idaho that was designed to better understand mysid shrimp and zooplankton dynamics in Lake Pend Oreille.

METHODS

Kokanee Population Dynamics

Abundance and Survival

We conducted a lakewide hydroacoustic survey on Lake Pend Oreille to estimate the abundance and survival rate of Kokanee. Hydroacoustic surveys were performed at night between August 26 and 30, 2013 with six to eight survey transects in each lake section (see Figure 1). Further protocol details have been described by Wahl et al. (2011a). Prior to the surveys, we calibrated the echo sounder for signal attenuation to the sides of the acoustic axis using Simrad's EK60 software (Simrad Fisheries, Lynnwood, WA). We estimated kokanee abundance with echo integration techniques using Echoview software version 5.2.70.21467 (Echoview Software Pty Ltd, Hobart, Tasmania). This technique calculated densities along each transect using the following equation (see Parker-Stetter et al. 2009):

$$\rho = \left(\frac{NASC}{4\pi 10^{\frac{TS}{10}}}\right) 0.00292$$

where ρ is density (number of fish per hectare), *NASC* is the total backscattering (m^2/nautical $mile^2$), and *TS* is the mean target strength in decibels for the area sampled. To estimate lakewide Kokanee abundance, we calculated a mean Kokanee density estimate for each section. We then multiplied the mean density in each lake section by the area therein to obtain an abundance estimate for each section. Finally, we summed abundance in each of the three sections to estimate the total Kokanee abundance. Further descriptions on the criteria used to analyze the hydroacoustics data can be found in Wahl et al. (2010).

Once density estimates for Kokanee were determined, we calculated 90% geometric confidence intervals (CI) for using standard formulas for stratified sampling designs (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 $\bar{x}$ is the estimated mean density of Kokanee in the lake (fish/ha), t is the Student's t value, N_i is the number of possible samples in section i, n_i is the number of samples collected in section i, and s_i is the standard deviation of the samples in section i. Confidence intervals were then converted to total abundance based on the total area of the three lake sections.

We were able to separate Kokanee fry (<100 mm) from the older age-classes using the Echoview software. To separate hydroacoustics data into those older Kokanee age-classes (age-1 through age-4), we used the results of midwater trawling. Trawling occurred during September 1-6, 2013. These dates were during the dark phase of the moon, which optimized the capture efficiency of the trawl (Bowler et al. 1979). The trawl net had graduated mesh increments ranging from 13 to 32 mm stretch, and sampling procedures for midwater trawling have been described by Rieman (1992) and Wahl et al. (2011a). To sample Kokanee fry for assessing origin (hatchery or wild), we also conducted a midwater trawl survey using a smaller mesh trawl net (0.8 x 1.6 mm bar) previously described (Wahl et al. 2011a).

We collected Kokanee from each trawl transect, placed them on ice, then placed them in a freezer for storage. To process Kokanee, we thawed out sample bags corresponding to each transect, counted the fish, recorded total length (mm) and weight (g), and checked for sexual maturity. We removed scales and otoliths from 10-15 fish in each 10 mm size interval, and otoliths from all fry. The scales were aged by two independent readers, and otoliths were used to determine hatchery or wild origin (see below). From these data, we created an age/origin-length key to assign an age and origin to every fish captured. Next we estimated the mean density of each Kokanee age-class within a lake section using the assigned ages and origins of fish. We then used these proportions of each age-class of Kokanee in a lake section to separate the age-1 through age-4 hydroacoustics data in that section. After repeating this process for each section, we totaled the values to generate lakewide age-specific abundance estimates. From these age-specific abundance estimates, we calculated annual survival for each age-class (i.e., from one age class to the next).

Hatchery and Wild Abundance

All Kokanee produced at the Cabinet Gorge Fish Hatchery since 1997 have been marked using thermal mass-marking techniques (or cold branding) described by Volk et al. (1990). Therefore, all hatchery-origin Kokanee otoliths had distinct thermal marks which were used to identify brood year and origin (hatchery vs. wild). Hatchery personnel initiated thermal treatments five to ten days after fry entered their respective raceways and sacrificed ten fry from each raceway to verify thermal marking success. We sent otoliths of Kokanee collected during trawling to the Washington Department of Fish and Wildlife Otolith Laboratory where personnel checked them for thermal marks. Methodologies for checking thermal marks are described in Wahl et al. (2010).

To estimate the proportion of wild and hatchery Kokanee, we first calculated the proportion of wild and hatchery Kokanee fry within each 10 mm length group to estimate the overall proportion of wild and hatchery fry in each lake section. We then multiplied the proportion of wild fish by the hydroacoustic population estimate for fry in that section. Finally, we summed these values to estimate the abundance of wild fish in the entire lake.

Biomass, Production, and Mortality by Weight

We calculated the biomass, production, and mortality by weight of the Kokanee population in Lake Pend Oreille to assess the effects of predation. Biomass was the total weight of Kokanee within Lake Pend Oreille at the time of our population estimate, calculated by multiplying the population estimate of each Kokanee age-class by the mean weight of Kokanee assigned to that age-class. Finally, we summed the calculated weights of age-classes to obtain estimates of total Kokanee biomass in the lake.

Production was 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 a Kokanee age-class between years, we first calculated the increase in mean weight of a cohort since the previous year and averaged the abundance estimates for that cohort between the two years. Next we multiplied the increase in mean weight by the average cohort abundance. This process was repeated for all cohorts, and we summed the results for all of the age-classes to determine population-wide production (i.e., within the entire lake). Production P for year t is estimated using the formula

$$P_t = \sum (w_{it+1} - w_{it}) \times \left(\frac{n_{it+1} + n_{it}}{2}\right)$$

where *w* is the weight and *n* is the abundance estimate of cohort *i* in year *t*. These calculations assumed linear rates of growth and mortality throughout the year. Hayes et al. (2007) provided additional details on methods for estimating production.

Mortality by weight refers to the total biomass lost from the population due to all forms of mortality (e.g., natural, predation) between years (Ricker 1975). To estimate annual mortality by weight for an age-class, we calculated the mean weight of fish in a cohort between years. We then subtracted that cohort's population estimate in the current year from the previous year to determine the number of fish lost. Finally, we multiplied the mean weight by the number of fish lost to estimate the mortality by weight for each age-class. Results were summed across all age-classes to estimate total yield for the Kokanee population. Mortality by weight *Y* for year *t* is estimated using the formula

$$Y_t = \sum (n_{it+1} - n_{it}) \times \left(\frac{w_{it+1} + w_{it}}{2}\right)$$

where *n* is the abundance estimate and *w* is the weight of cohort *i* in year *t*. Linear rates of growth and mortality throughout the year were assumed.

Spawning Kokanee Index Counts

We counted spawning Kokanee along standardized tributary and shoreline index transects where spawning was documented historically (Jeppson 1960). Surveys at index transects built upon annual trend data dating back to 1972. Seven tributaries were surveyed by walking from their mouth to the most upstream point visually determined to be used by Kokanee. Additionally, nine index transects were surveyed for shoreline-spawning Kokanee. For all surveys, we counted all Kokanee, whether alive and dead. Some index transects were surveyed more than once, and the highest counts were used. These counts provide a coarse-scale index rather than a total estimate of spawning Kokanee abundance. Surveys for early-run Kokanee occurred in three streams on September 20 and 23, 2013, and surveys for late-run Kokanee occurred in seven streams during the week of November 25, 2013. Shoreline surveys were completed during the weeks of November 25 and December 9, 2013.

We removed otoliths from 60 late-run Kokanee carcasses in Sullivan Springs Creek to estimate the hatchery proportion and hatchery age composition of the run. Methods for otolith removal, preparation, and reading thermal marks were similar to those described above for trawl-captured Kokanee.

To assess the distribution and relative density of Kokanee spawning outside of index transects, we conducted a shallow-water survey along the lake shoreline. Surveys were conducted on days with limited wind during December 2-20, 2013. An observer was positioned on the bow of a boat that followed a path along the shoreline of the lake. We visually characterized areas of shoreline as having minimal (<10 fish per 100 m), moderate (10-50 fish per 100 m), high (>50 fish per 100 m), or no spawning activity as indicated by observing live fish or redds. Areas were all georeferenced using a handheld GPS. The presence of dead Kokanee was also recorded but was not used as evidence of spawning.

Fry Release Study

Hatchery-origin Kokanee fry released in 2013 received one of three different thermal marks to identify specific release groups. The first batch of fry was released in Sullivan Springs Creek, which is the usual stocking location. The additional two groups of fry were released on the west shore of Lake Pend Oreille at Talache Landing. The release date differed for these groups (June 3, July 1-2, 2013) to assess whether Kokanee experience differential survival based on release timing.

Estimating fry abundance within each of these two release groups was conducted by estimating the abundance of all hatchery fry in each lake section as described above. Then, the proportion of each release group in both trawl surveys combined was used to estimate the abundance of each release group. For survival calculations, we estimated the proportions of each release group that was still in the lake during fall surveys.

Surface Elevation Management Evaluation

Kokanee Spawning Ecology Project

We finalized collaborative work with the University of Idaho on a Kokanee spawning ecology graduate study that was initiated in 2011. A full description of the methods can be found in Whitlock (2013).

Shoreline Habitat Mapping

We contracted the USGS and collaborated with their staff to create bathymetric and substrate composition maps for shoreline habitats along portions of Lake Pend Oreille. This study focused primarily on the southern and western shorelines, which are known to be important areas for Kokanee spawning. Data collection was conducted during 2011-13. Results from this study were reported in a USGS map publication that is currently in the final stages of review (Barton and Dux *In Review*)

Limnological Research

Mysid Shrimp Trend Monitoring

We sampled mysid shrimp on June 10-12, 2013 to estimate their density within Lake Pend Oreille. All sampling occurred at night during the dark phase of the moon, when mysid shrimp are found at shallower depths (Boscarino 2009). We collected mysids at eight sites per lake section using a 1 m hoop net. Further details can be found in Wahl et al. (2011a).

During laboratory analysis, mysid shrimp were classified and enumerated as either young-of-the-year (YOY) or immature and adults. We estimated density by the number of mysid shrimp enumerated in each sample per volume of water filtered. We calculated the arithmetic mean and 90% confidence interval for each portion of the population. Confidence intervals were estimated similar to those used for Kokanee abundance above.

Mysid Shrimp and Zooplankton Dynamics

A graduate project was continued with the University of Idaho to assess spatiotemporal patterns in both mysid shrimp and zooplankton abundance. Detailed methods for this study will be available upon completion of the final report from the University of Idaho.

RESULTS

Kokanee Population Dynamics

Abundance and Survival

In 2013, we estimated a total of 19.7 million Kokanee (17.3-22.5 million, 90% CI) or 872 fish/ha in Lake Pend Oreille, based on our hydroacoustic survey. This included 11.8 million Kokanee fry (10.3-13.4 million, 90% CI; Table 1, Figure 3), 2.0 million age-1, 4.4 million age-2, 1.5 million age-3, and 65,000 age-4 Kokanee (Table 2, Figure 3). During the midwater trawl survey, we sampled 1,092 Kokanee that varied in total length from 30-272 mm (Figure 4) and in weight from 0.2-189 g.

Hatchery and Wild Abundance

During spring 2013, the Cabinet Gorge Fish Hatchery released 11.5 million thermally marked Kokanee fry into Lake Pend Oreille. Out of these, 4.8 million late-run fry were stocked into Sullivan Springs Creek. Additionally, 3.2 million late-run fry were stocked at Talache Landing along the west shore, half on June 3 and half on July 1-2. An additional 3.3 million late-run and 0.2 million early-run Kokanee were released at other stream and lakeshore locations around the lake.

Wild Kokanee fry made up 64%, 61%, and 20% of the fry net catch in the southern, middle, and northern sections, respectively (Table 1). Based on these proportions, we estimated the wild fry population at 5.7 million (Table 1). Also, we estimated that wild Kokanee comprised 38%, 62%, 51%, and 27% of age-1, age-2, age-3, and age-4 abundance estimates, respectively (Table 2). We estimated Kokanee survival at 23% from fry to age-1, 99% from age-1 to age-2, 85% from age-2 to age-3, and 15% from age-3 to age-4 (Table 3).

Biomass, Production, and Mortality by Weight

Based on the hydroacoustic estimates of Kokanee abundance, Kokanee biomass was 627 metric tonnes (t) and production was 518 t (Figure 5). Total mortality by weight was 206 t, which was 312 t lower than production (Figure 5).

Spawning Kokanee Index Counts

In 2013, we observed a maximum of 21,614 Kokanee spawning at the nine shoreline index transects. Half of these fish (10,857) were on the shoreline near the town of Bayview in Scenic Bay, and another 10,000 fish were observed along the shoreline at Lakeview (Table 4). We observed a maximum peak of 21,479 late-run Kokanee spawning in tributaries of Lake Pend Oreille, with the majority spawning in South Gold Creek (13,330) and North Gold Creek (4,028; Table 5). Hatchery fish comprised 98% of late-run Kokanee in Sullivan Springs Creek with an age composition of 5% age-2 and 95% age-3. Additionally, the highest observed abundance of

early-run Kokanee was 22,124 with 14,500 in South Gold Creek and 779 in North Gold Creek (Table 6).

Kokanee spawning was widespread, but the majority was documented in the southern half of the lake (Figure 6). The largest concentrations were found in the two southern-most bays, the Bernard Beach area, the shoreline near Evans Landing, and in the proximity of Granite Creek. Some additional spawning was also observed along the northern shore from Hope to Trestle Creek (Figure 6).

Fry Release Study

During the fall, we estimated 0.70 million Kokanee fry survived from the early release at Talache Landing and 1.08 million Kokanee fry survived from the late release. Based on the number released, survival was estimated to be 44% for the early (June 3) release and 65% for the late (July 1-2) release.

Surface Elevation Management Evaluation

Kokanee Spawning Ecology Study

This research was completed in 2013 by a graduate student at the University of Idaho. Over the course of two years, egg boxes were placed at a total of 66 individual sites. Depth and substrate size were not important predictors of Kokanee egg survival, but the presence of downwelling did enhance survival. For full details see Whitlock (2013).

Shoreline Habitat Mapping

Mapping and videography found a mix of substrate types. Most importantly, a band of substrate exists between the surface and 610 MSL that generally has low levels of sedimentation. Below this elevation appears to be a depositional area around the lake with high levels of fine sediments over top of other types of substrate. A final map publication was drafted and is in the final stages of USGS review (Barton and Dux *In Review*).

Limnological Research

Mysid Shrimp Trend Monitoring

We estimated a mean density of 136 mysid shrimp/m^2 during June 2013 (Table 7; Figure 7). This included 7 immature and adult mysids/m^2 (90% CI of $\pm$ 21%; Table 7; Figure 8) and 129 YOY mysids/m^2 (90% CI of $\pm$ 17%; Table 7; Figure 8).

Mysid Shrimp and Zooplankton Dynamics

This research is being conducted by a graduate student at the University of Idaho. Full details of this study are being prepared and will be provided in a final report.

DISCUSSION

Kokanee Population Dynamics

In the past year, Kokanee have continued to respond favorably to management actions. Kokanee abundance was the highest since hydroacoustic surveys began in 1995. Additionally, individual year-class abundances ranged from 1.5 to 13 times stronger than one generation prior. Although age-1 abundance decreased in 2013, it was only 24% lower than the age-1 abundance in 2011, a cohort that resulted in a near record-high abundance of age-3 Kokanee in 2013. Recent abundance trends, combined with survival rates exceeding 60% for age-1 through age-3 for the past three years, suggest that Kokanee have responded positively to restoration efforts. During 2011 and 2012, we documented increased age-1 Kokanee abundance, but were concerned because other comparably strong age-1 cohorts did not survive well to older ages in recent years. However, in 2013 the age-1 through age-3 cohorts were all strong, indicating higher survival. Successive years of high survival and strong cohorts have allowed the Kokanee population to build to current abundance. We are optimistic that Lake Trout suppression will lead to continued high survival and higher abundances of mature Kokanee.

From 1996 to 2011, Kokanee production was relatively constant, ranging from 174 t to 254 t. However, during 2004-2007, Kokanee mortality by weight was on average 59 t higher than production, leading to decreases in Kokanee biomass. Pronounced increases in the production to biomass ratio during this period were vital to slowing the decline of the Kokanee population (Wahl et al. 2010). However from 2008 to 2013, Kokanee production was on average 80 t higher than mortality by weight, and biomass in 2013 reached the highest level on record. Kokanee production has increased almost two-fold since 2010, although with a nearly four-fold increase in biomass, the production to biomass ratio declined to 0.8:1. Continuation of the Lake Trout reduction program should help Kokanee production to remain above mortality by weight and lead to further increases in Kokanee biomass.

Counts of spawning Kokanee at index transects do not provide estimates of Kokanee abundance, but do provide a useful way to coarsely assess trends in spawning escapement and spatial distribution. Counts of late-run spawning Kokanee increased following a near record-low in 2007 and increased consistently during 2010-12. In 2013, index counts of late-run Kokanee were the highest on record, three times higher than the previous three-year average. Spawning Kokanee count data suggest that escapement in 2013 was over ten times higher than one generation earlier. Higher spawning escapement has also been correlated with more Kokanee spawning at index transects outside of Scenic Bay, which has been the primary spawning area used by Kokanee in recent years. Additionally, during the lakewide spawning survey we documented spawning at non-index transects that had not been occupied in recent years. Similar to previous lakewide shallow-water surveys for shoreline-spawning Kokanee, the majority of spawning activity in 2013 was documented at the southern end of the lake. However, lakewide shallow-water surveys done in the past found that less than 25% of spawning activity occurred north of Capehorn and Lakeview near the southern end of the lake (Maiolie et al. 2002). In 2013, we observed a higher proportion of spawning north of these points. As Kokanee density continues to increase, we anticipate the spatial extent of spawning will expand further.

Most of the early-run Kokanee returning to tributaries have been individuals that strayed from Sullivan Springs Creek where they were stocked as fry in during 2004-09. The exception was South Gold Creek, where otolith analyses have found that the majority of spawning Kokanee in this tributary were of wild origin (Wahl et al. 2011b; Wahl et al. 2013). Stocking early-run fry was discontinued in 2010, so spawning Kokanee in 2013 were comprised of only

wild-origin fish. Previously we stated that early-run Kokanee were unlikely to substantially contribute towards restoration goals (Wahl et al. 2011a), and over the long term, we still believe this is the case for most tributaries. However, South Gold Creek returns increased in 2013 to more than double the previously highest recorded count of spawning Kokanee in this tributary. Early-run Kokanee supplementation may provide a benefit to the recreational fishery, and the consistently high returns to South Gold Creek suggest this may be a good place to trap spawning Kokanee for a hatchery egg-take.

Survival of the late hatchery Kokanee release group in 2013 was higher than the early release group. This survival relationship matched previous research that found Kokanee fry stocked later had higher survival due to higher zooplankton abundances (Paragamian and Bowles 1995). During the current fry release study, survival of the late release group has varied from lower, equal to, and higher than the early release group. We are unsure how high runoff in 2011 or the collapse of mysid shrimp in 2012 may have affected the survival of the two Kokanee release groups. Overall, this three-year study was inconclusive and more stable conditions are needed to acquire informative results. However, gaining a better understanding of annual zooplankton dynamics may provide more insight into Kokanee fry survival and the timing and location of stocking.

Surface Elevation Management Evaluation

Kokanee spawning ecology research conducted in collaboration with the University of Idaho found that shoreline-spawning Kokanee did not benefit from higher winter surface elevations (Whitlock 2013). Location of egg boxes, above or below the low winter surface elevation, and median substrate diameter did not influence egg incubation success. Only the minimum dissolved oxygen recorded at an egg box and the presence or absence of downwelling water currents significantly influenced survival of Kokanee eggs to the pre-emergent stage (Whitlock 2013). Survival was more than three times higher in areas that contained downwelling (Whitlock 2013). These areas of downwelling, found primarily along the recharge area of the Spokane Valley-Rathdrum Prairie Aquifer in Scenic and Idlewilde bays (Drost and Seitz 1978, Hsieh et al. 2007), were thought to have provided well-oxygenated water to embryos during the incubation period. Based on these results we recommend discontinuing holding the winter surface elevation at 626.4 MSL for the benefit of Kokanee. For a full analysis of the results see Whitlock (2013). Other options for increasing Kokanee spawning habitat, such as a gravel addition, may be more appropriate. Potential areas to conduct this work can be determined by using the results of Whitlock (2013) and Barton and Dux (*In Review*).

Limnological Research

Mysid shrimp abundance in Lake Pend Oreille cycled through growth, decline, and stability since their introduction in 1966. A similar pattern of population fluctuation occurred in other western lakes after mysid introductions (Beattie and Clancey 1991; Richards et al. 1991). Mysid shrimp abundance in Lake Pend Oreille remained relatively stable during 1997-2011. However, the mysid shrimp population in Lake Pend Oreille collapsed in 2012. In 2013, the abundance of YOY mysid shrimp increased, while the immature and adult portion of the population decreased an additional 76%. We are unsure what mechanism caused the collapse and whether mysid shrimp will return to their historical densities, but it appears as though mysid shrimp will remain at a low abundance at least through 2014. Considering the implications mysid shrimp have on the Lake Pend Oreille food web, mysid shrimp monitoring in coming years remains essential. Additionally, research to better understand food web interactions in Lake Pend Oreille may be possible if mysids remain at low abundance.

RECOMMENDATIONS

1. Continue to reduce Lake Trout abundance using targeted gill and trap netting and incentivized angler harvest.

2. Continue to assess the Kokanee population response to predator removal.

3. Monitor the mysid shrimp abundance to determine if the collapse documented in 2012 persists.

4. Complete the collaborative graduate project with the University of Idaho exploring mysid and zooplankton dynamics.

Table 1. Abundance estimates and 90% confidence intervals (CI) for Kokanee fry (millions) based on hydroacoustic surveys in Lake Pend Oreille, Idaho in 2013. Percentage of wild, late-run hatchery (KL-H), and early-run hatchery (KE-H) fry was based on the proportions of fry caught using a fry net.

	Southern Section	**Middle Section**	**Northern Section**	**Lakewide Total**	**90% CI**
Total	4.0	3.8	3.9	11.8	10.3-13.4
Percent wild fry in fry trawl	64	61	20	—	
Percent KL-H in fry trawl	36	39	78	—	
Percent KE-H in fry trawl	0	0	2		
Wild fry abundance estimate	2.6	2.3	0.8	5.7	

Table 2. Age-specific abundance estimates for Kokanee in Lake Pend Oreille, Idaho, 2013. Estimates were generated from hydroacoustic data that were separated into age-classes based on midwater trawling. Percentage of wild, early-run hatchery (KE-H), and late-run hatchery (KL-H) were based on the proportions of each caught in the trawl net.

Area	**Age-1**	**Age-2**	**Age-3**	**Age-4**	**Total**
Northern Section					
Percent of age-class by trawling	40.4	49.2	10.1	0.3	
Population estimate (millions)	1.07	1.30	0.27	0.01	2.65
Middle Section					
Percent of age-class by trawling	18.2	58.4	22.5	0.9	
Population estimate (millions)	0.54	1.73	0.67	0.03	2.96
Southern Section					
Percent of age-class by trawling	16.7	57.5	24.7	1.2	
Population estimate (millions)	0.40	1.36	0.58	0.03	2.37
Total population estimate (millions)	2.00	4.40	1.52	0.06	7.98
90% confidence interval (millions)					6.56-9.72
Percent wild	38	62	50	26	
Percent KL-H	62	38	50	74	

Table 3. Survival rates (%) between Kokanee year classes estimated by hydroacoustics, 1996-2013. Year refers to the year the older age class in the survival estimate was sampled.

	Age class			
Year	**Fry to 1**	**1 to 2**	**2 to 3**	**3 to 4**
2013	23	99	85	15
2012	40	68	98	9
2011	25	26	62	55
2010	30	35	23	19
2009	29	77	59	8
2008	15	32	40	83
2007	19	10	11	0
2006	23	13	12	13
2005	46	14	24	25
2004	22	36	30	19
2003	35	58	68	73
2002	31	44	17	366
2001	28	27	6	17
2000	52	22	66	40
1999	24	18	71	49
1998	37	28	94	26
1997	42	59	29	17
1996	44	79	40	46

Table 4. Counts of Kokanee spawning along the shorelines of Lake Pend Oreille, Idaho. Numbers shown indicate the highest count and should be interpreted as a coarse-scale index of spawning Kokanee abundance rather than a total estimate. Dashes represent index transects that were not counted.

Year	Bayview	Farragut Ramp	Idlewilde Bay	Lakeview	Hope	Trestle Cr. Area	Sunnyside	Garfield Bay	Camp Bay	Anderson Point	Total
2013	10,857	550	25	10,000	77	45	0	60	0	—	21,614
2012	4,117	0	15	300	0	0	0	120	0	—	4,552
2011	4,214	35	124	1,500	0	0	0	20	0	—	5,893
2010	4,865	0	0	3,500	0	0	0	113	0	—	8,478
2009	2,635	36	1	0	0	6	0	9	0	—	2,687
2008	663	6	0	0	0	0	0	0	0	—	669
2007	325	0	0	0	0	0	0	0	0	—	325
2006	1,752	0	0	0	17	0	0	12	0	—	1,781
2005	1,565	0	5	1	0	1	0	66	0	—	1,638
2004	2,342	0	100	1	0	0	0	34	0	—	2,477
2003	940	0	0	0	0	20	0	0	0	—	960
2002	968	0	0	0	0	0	0	0	0	—	968
2001	22	0	0	0	0	0	0	0	1	—	23
2000	382	0	0	2	0	0	0	0	0	—	384
1999	2,736	4	7	24	285	209	0	275	0	—	3,540
1998	5,040	2	0	0	22	6	0	34	0	—	5,104
1997	2,509	0	0	0	0	7	2	0	0	—	2,518
1996	42	0	0	4	0	0	0	3	0	—	49
1995	51	0	0	0	0	10	0	13	0	—	74
1994	911	2	0	1	0	114	0	0	0	—	1,028
1993	—	—	—	—	—	—	—	—	—	—	—
1992	1,825	0	0	0	0	0	0	34	0	—	1,859
1991	1,530	0	—	0	100	90	0	12	0	—	1,732
1990	2,036	0	—	75	0	80	0	0	0	—	2,191
1989	875	0	—	0	0	0	0	0	0	—	875
1988	2,100	4	—	0	0	2	0	35	0	—	2,141
1987	1,377	0	—	59	0	2	0	0	0	—	1,438
1986	1,720	10	—	127	0	350	0	6	0	—	2,213
1985	2,915	0	—	4	0	2	0	0	0	—	2,921
1978	798	0	0	0	0	138	0	0	0	0	936
1977	3,390	0	0	25	0	75	0	0	0	0	3,490
1976	1,525	0	0	0	0	115	0	0	0	0	1,640
1975	9,231	0	0	0	0	0	0	0	0	0	9,231
1974	3,588	0	25	18	975	2,250	0	20	0	50	6,926
1973	17,156	0	0	200	436	1,000	25	400	617	0	19,834
1972	2,626	25	13	4	1	0	0	0	0	0	2,669

Table 5. Counts of late-run Kokanee spawning in tributaries of Lake Pend Oreille, Idaho. Numbers shown indicate the highest count and should be interpreted as a coarse-scale index of spawning Kokanee abundance rather than a total estimate. Dashes represent index transects that were not counted.

Year	S. Gold	N. Gold	Cedar	Johnson	Twin	Mosquito	Lightning	Spring	Cascade	Trestle	Total
2013	13,330	4,028	501	0	1,720	—	—	1,738	—	162	21,479
2012	5,900	2,672	135	—	—	—	—	—	—	—	8,707
2011	7,057	1,536	91	0	0	—	—	440	—	14	9,138
2010	3,115	1,121	26	1	64	—	—	3,522	—	0	7,849
2009	1,257	227	10	0	93	—	—	301	—	15	1,903
2008	278	0	2	0	3	—	—	8	—	0	291
2007	0	0	0	0	0	—	—	0	—	0	0
2006	414	61	21	0	0	—	—	60	—	14	570
2005	5,463	615	1	0	1,244	—	—	—[a]	—	76	7,399
2004	721	2,334	600	16	6,012	—	—	3,331[a]	—	0	9,683
2003	591	0	0	0	—	—	—	626	—	9	1,226
2002	79	0	0	0	0	—	—	0	—	0	79
2001	72	275	50	0	0	—	—	17	—	0	414
2000	17	37	38	0	2	0	0	0	0	0	94
1999	1,884	434	435	26	2,378	—	—	9,701	5	423	15,286
1998	4,123	623	86	0	268	—	—	3,688	—	578	9,366
1997	0	20	6	0	0	—	—	3	—	0	29
1996	0	42	7	0	0	—	—	17	—	0	66
1995	166	154	350	66	61	—	0	4,720	108	21	5,646
1994	569	471	12	2	0	—	0	4,124	72	0	5,250
1992	479	559	—	0	20	—	200	4,343	600	17	6,218
1991	120	550	—	0	0	—	0	2,710	0	62	3,442
1990	834	458	—	0	0	—	0	4,400	45	0	5,737
1989	830	448	—	0	0	—	0	2,400	48	0	3,726
1988	2,390	880	—	0	0	—	6	9,000	119	0	12,395
1987	2,761	2,750	—	0	0	—	75	1,500	0	0	7,086
1986	1,550	1,200	—	182	0	—	165	14,000	0	0	17,097
1985	235	696	—	0	5	—	127	5,284	0	0	6,347
1978	0	0	0	0	0	0	44	4,020	0	0	4,064
1977	30	426	0	0	0	0	1,300	3,390	0	40	5,186
1976	0	130	11	0	0	0	2,240	910	0	0	3,291
1975	440	668	16	0	1	0	995	3,055	0	15	5,190
1974	1,050	1,068	44	1	135	0	2,350	9,450	0	1,210	15,308
1973	1,875	1,383	267	0	0	503	500	4,025	0	18	8,571
1972	1,030	744	0	0	0	0	350	2,610	0	1,293	6,027

[a] Cabinet Gorge Hatchery transferred 3,000 spawning Kokanee from the hatchery ladder to Spring Creek.

Table 6. Counts of early-run Kokanee spawning in tributaries of Lake Pend Oreille, Idaho. Numbers shown indicate the highest count and should be interpreted as a coarse-scale index of spawning Kokanee abundance rather than a total estimate. Early-run Kokanee counts in east shore tributaries began in 2008; prior to this, only Trestle Creek was surveyed. Dashes represent index transects that were not counted.

Year	S. Gold	N. Gold	Cedar	Trestle	Total
2013	14,500	779	—	6,845	22,124
2012	2,470	553	—	1,336	4,359
2011	5,900	1,737	328	872	8,837
2010	6,240	2,169	1,352	3,817	13,578
2009	2,231	631	13	362	3,237
2008	592	181	27	50	850
2007	—	—	—	124	124
2006	—	—	—	327	327
2005	—	—	—	427	427
2004	—	—	—	682	682
2003	—	—	—	2,251	2,251
2002	—	—	—	1,412	1,412
2001	—	—	—	301	301
2000	—	—	—	1,230	1,230
1999	—	—	—	1,160	1,160
1998	—	—	—	348	348
1997	—	—	—	615	615
1996	—	—	—	753	753
1995	—	—	—	615	615
1994	—	—	—	170	170
1992	—	—	—	660	660
1991	—	—	—	995	995
1990	—	—	—	525	525
1989	—	—	—	466	466
1988	—	—	—	422	422
1987	—	—	—	410	410
1986	—	—	—	1,034	1,034
1985	—	—	—	208	208
1978	—	—	—	1,589	1,589
1977	—	—	—	865	865
1976	—	—	—	1,486	1,486
1975	—	—	—	14,555	14,555
1974	—	—	—	217	217
1973	—	—	—	1,100	1,100
1972	—	—	—	0	0

Table 7. Densities of mysid shrimp (per m^2), by life stage (young of year [YOY], and immature/adult), in Lake Pend Oreille, Idaho June 10-12, 2013.

Lake Section	YOY/m^2	Immature/adult/m^2	Total mysid shrimp/m^2
Northern	79	5	84
Middle	166	7	173
Southern	148	9	157
Lakewide average	112	7	136

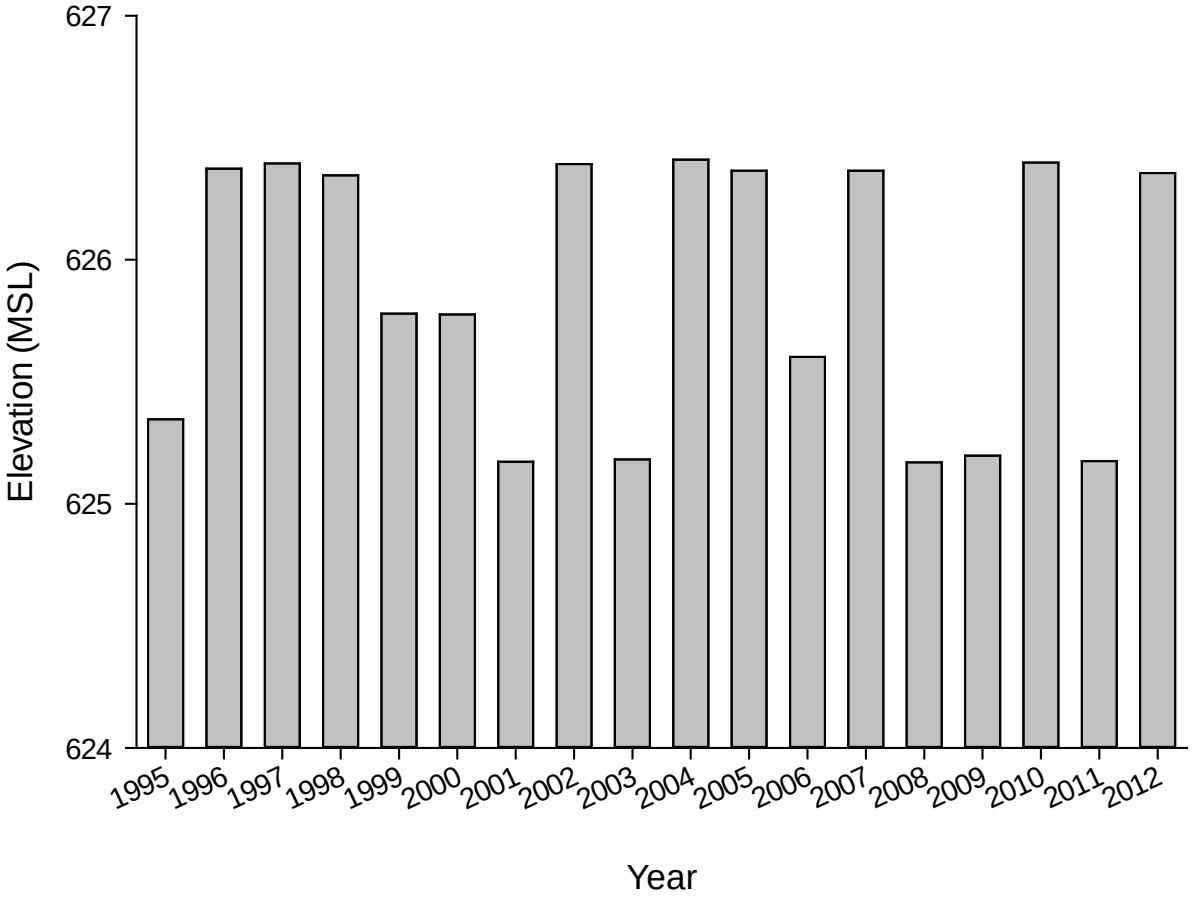

Figure 2. Minimum winter pool surface elevation in meters above mean sea level (MSL) during years of surface elevation experiment in Lake Pend Oreille, Idaho. The year shown represents the year the lake was drawn down (i.e., 1995 for winter 1995-1996).

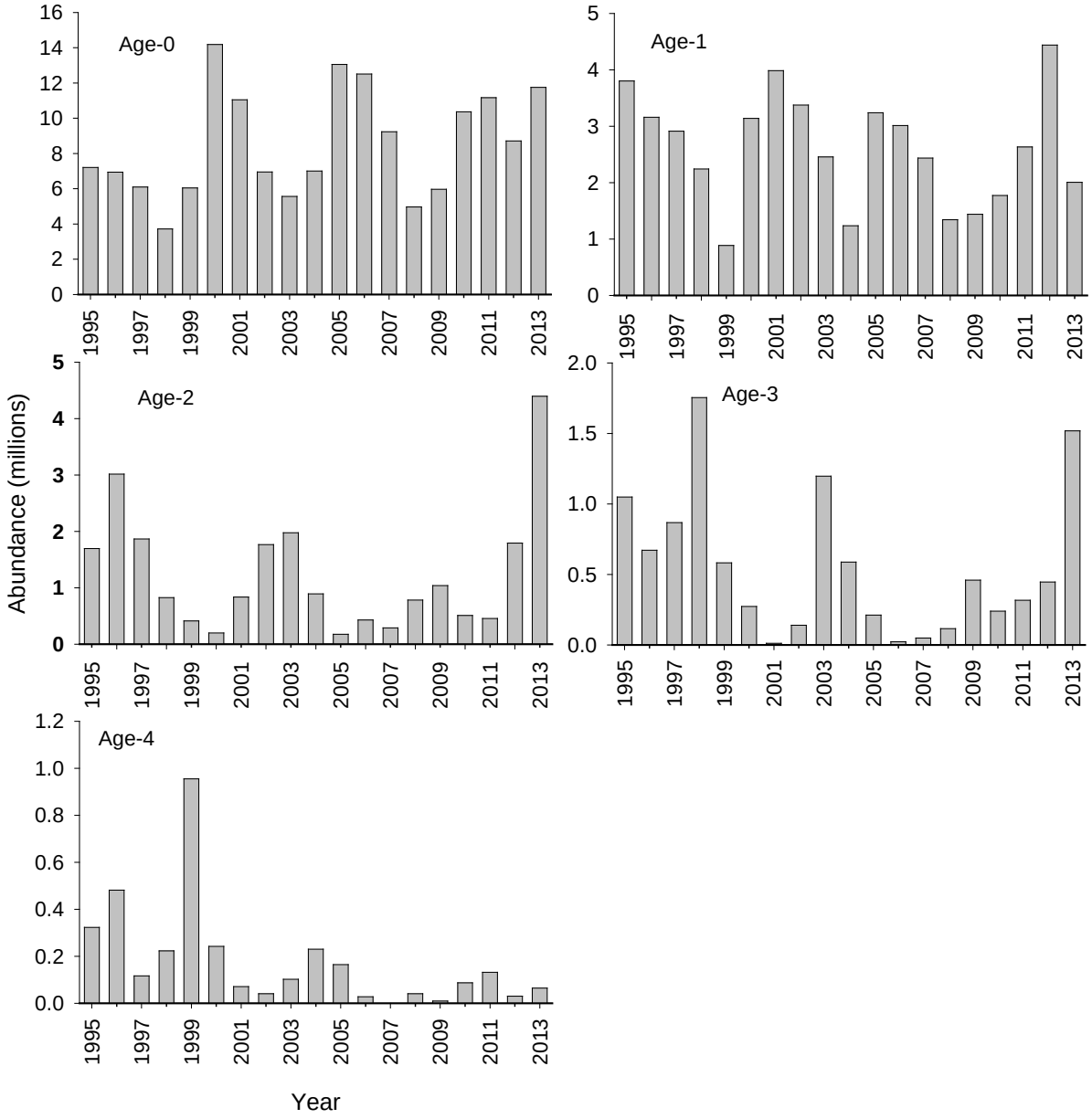

Figure 3. Kokanee age-specific abundance estimates based on hydroacoustic surveys conducted from 1996 to 2013.

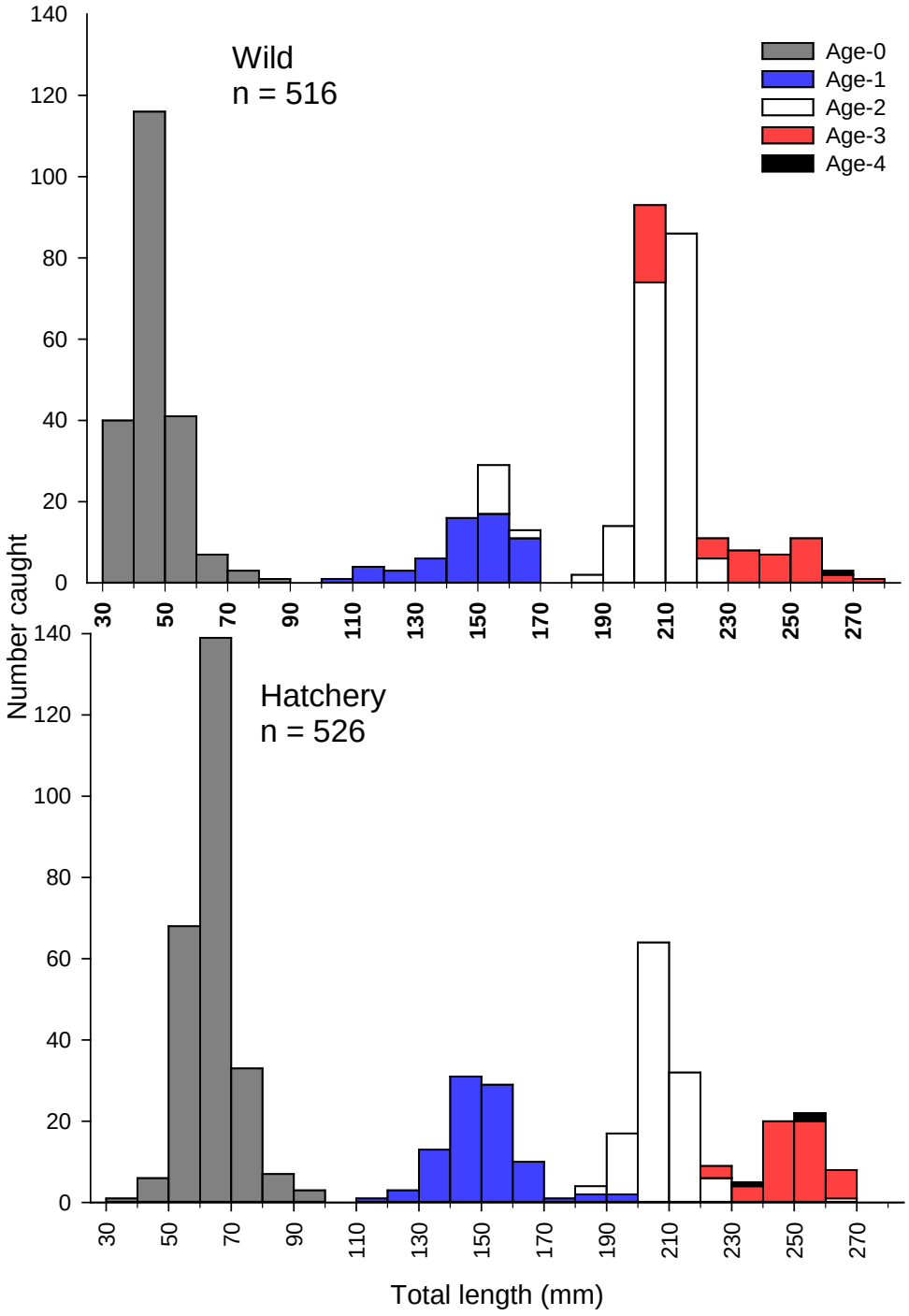

Figure 4. Length-frequency distribution of individual age-classes of wild and hatchery Kokanee caught by midwater trawling in Lake Pend Oreille, Idaho during September 2013.

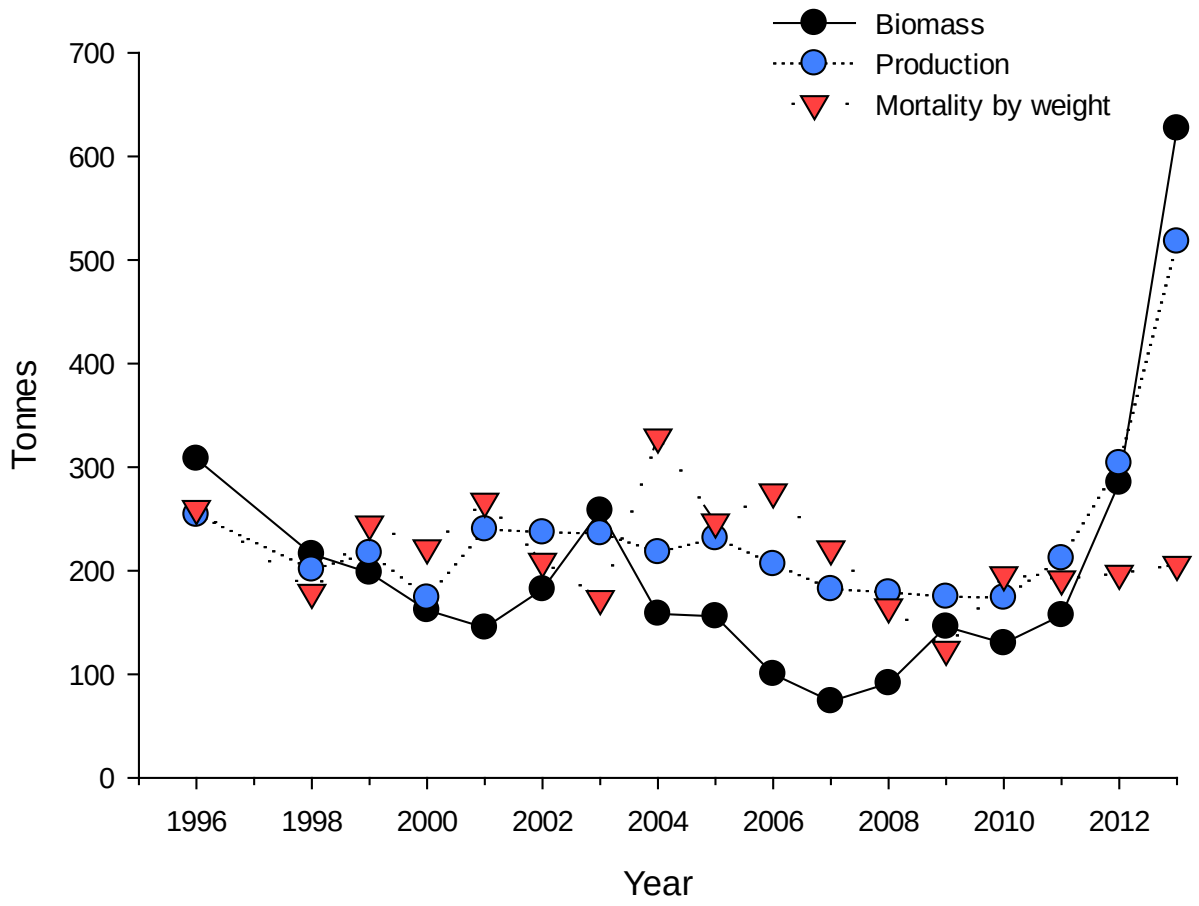

Figure 5. Kokanee biomass, production, and mortality by weight (metric tonnes) in Lake Pend Oreille, Idaho from 1996-2013, excluding 1997 due to a 100-year flood event.

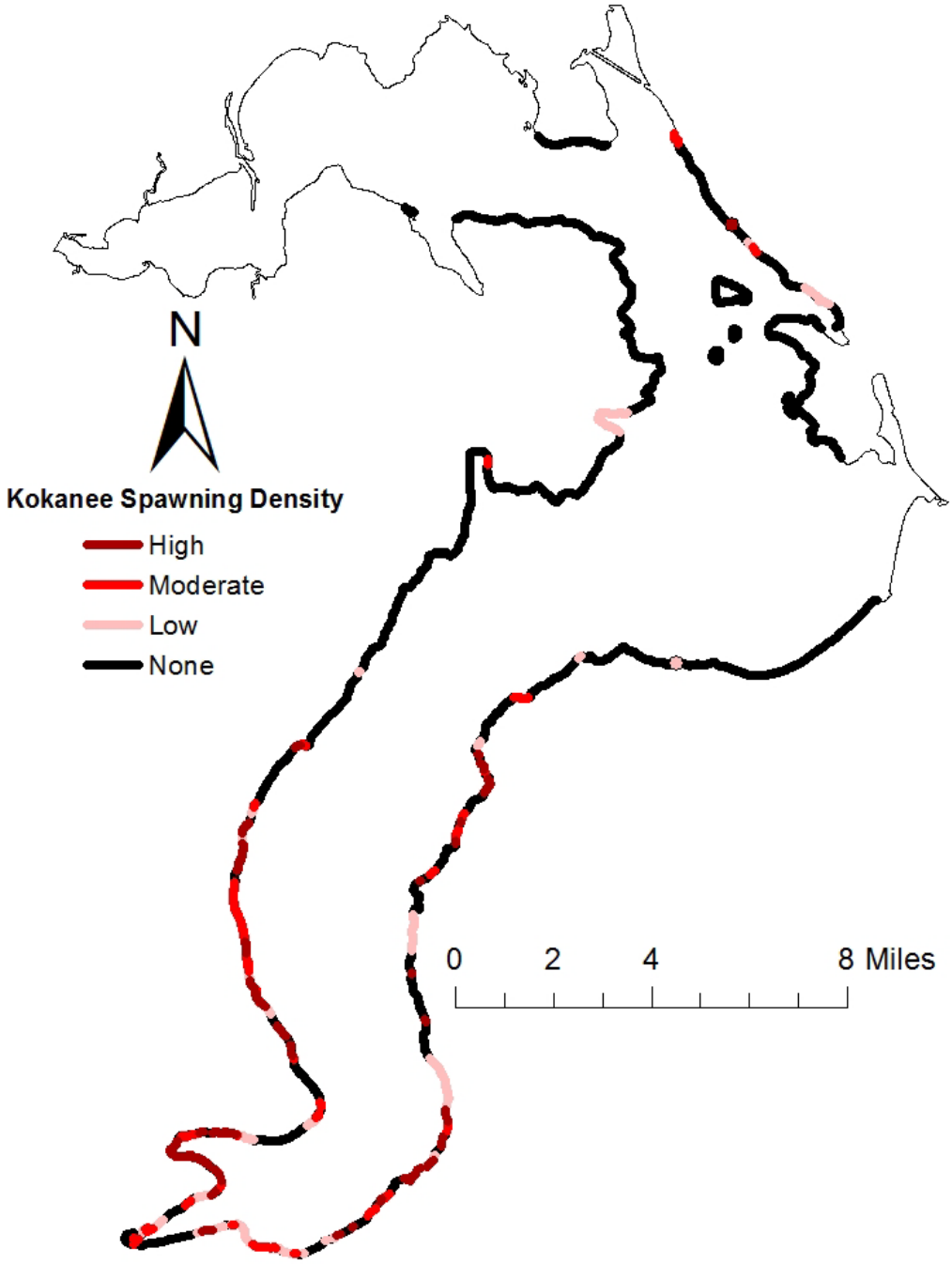

Figure 6. Kokanee spawning density distribution along the shoreline of Lake Pend Oreille during December 2-20, 2013. Areas of shoreline represented by the thinner black line were not surveyed. Minimal (<10 fish/100 m), moderate (10-50 fish/100 m), and high (>50 fish/100 m) spawning densities were determined by observing live fish or redds.

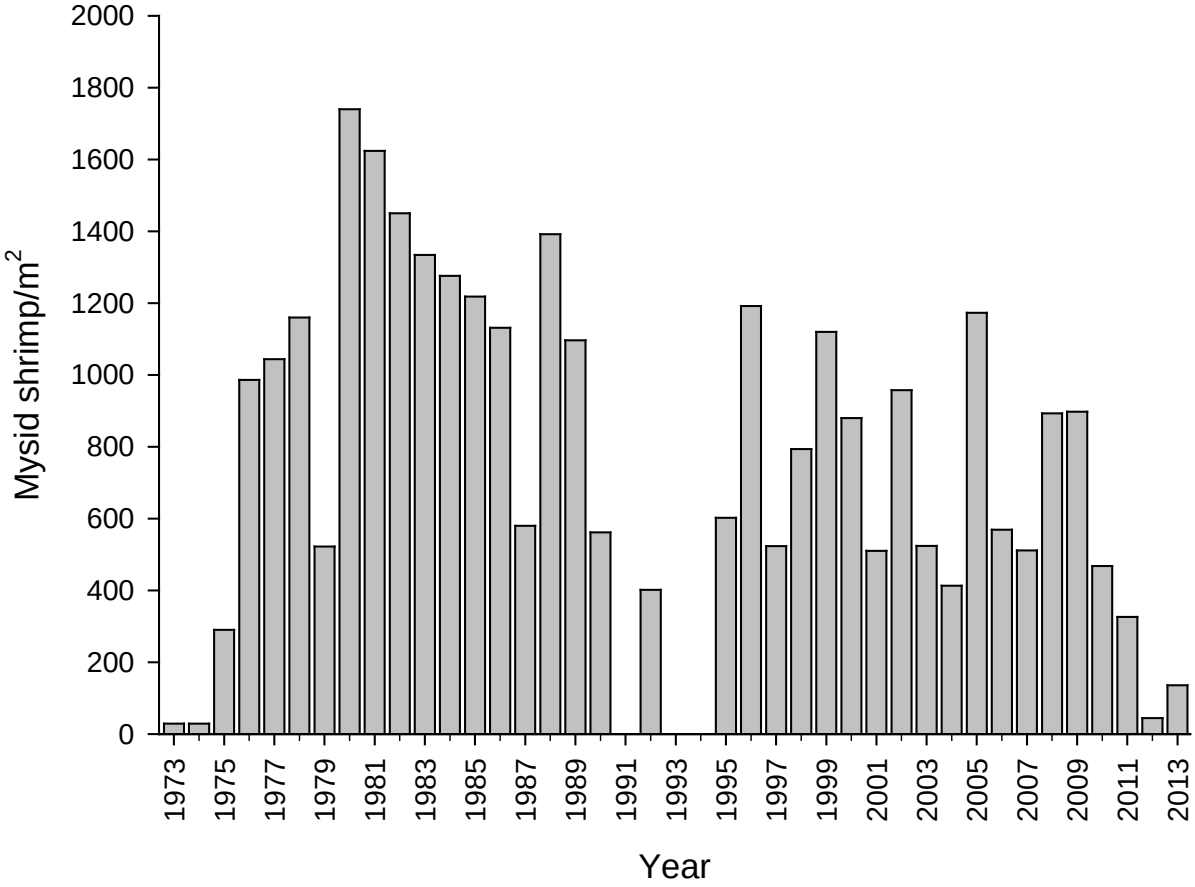

Figure 7. Annual mean density of mysid shrimp in Lake Pend Oreille, Idaho from 1973-2013. Data collected before 1989 were obtained from Bowles et al. (1991), and data from 1995 and 1996 were from Chipps (1997). Mysid densities from 1992 and earlier were converted from Miller sampler estimates to vertical tow estimates by using the equation y = 0.5814x (Maiolie et al. 2002). Mysids were first introduced in 1966.

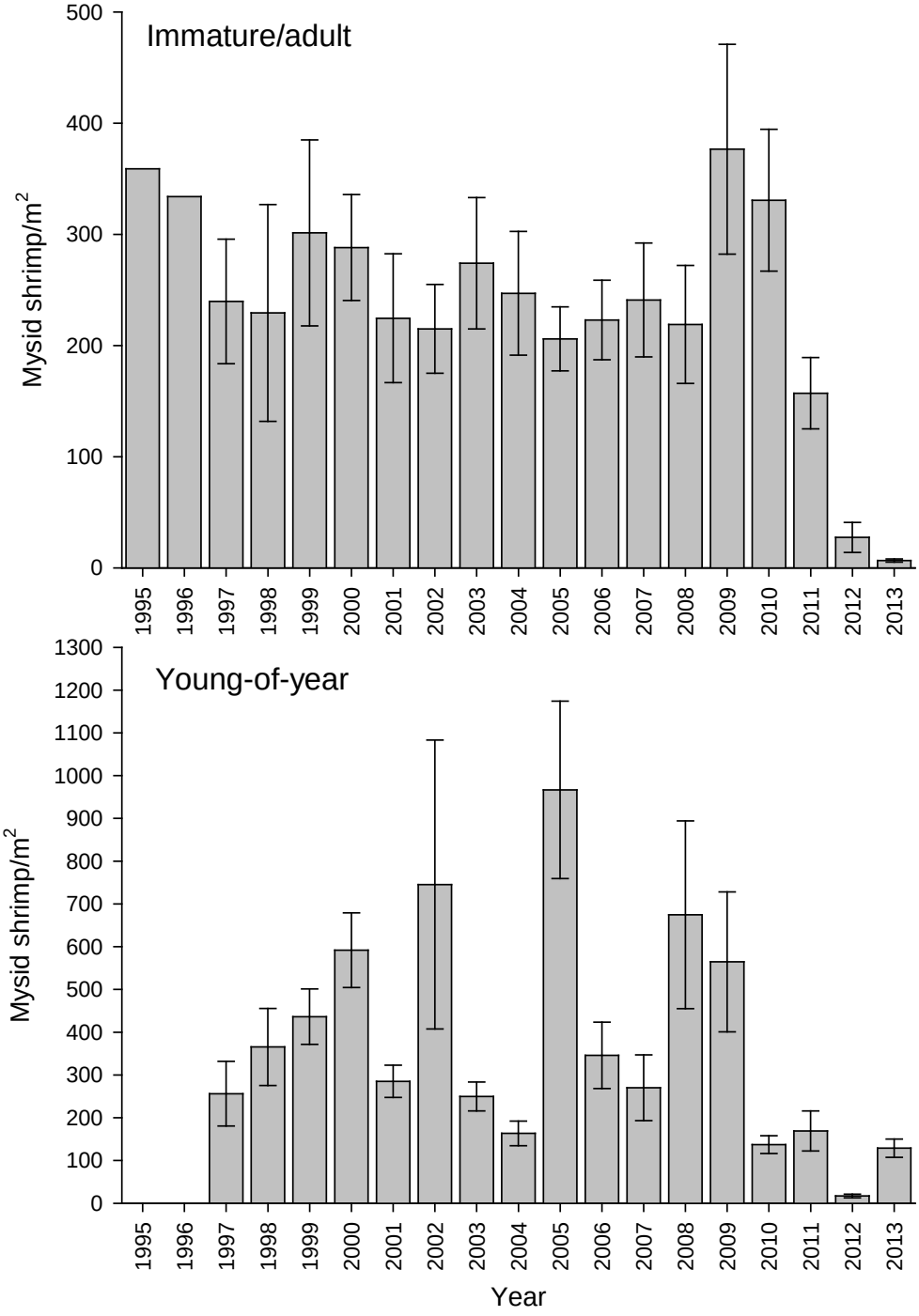

Figure 8. Density estimates of immature/adult and young-of-the-year mysids in Lake Pend Oreille, Idaho 1995-2013. Error bounds identify 90% confidence intervals around the estimate. Immature and adult densities from 1995 and 1996 were obtained from Chipps (1997).

CHAPTER 2: LAKE TROUT RESEARCH

ABSTRACT

The Kokanee *Oncorhynchus nerka* population in Lake Pend Oreille has been threatened by high predation over the past decade and was on the verge of total collapse in 2007. To increase Kokanee survival, Lake Trout *Salvelinus namaycush* removal actions were implemented, including commercial netting and an angler incentive program. We used mobile telemetry receivers to follow acoustically-tagged mature Lake Trout to spawning sites where we could target spawning aggregations with gill nets and maximize removal efficiency. During September and October 2013, we tracked 26 Lake Trout with mobile telemetry once or twice per week to identify spawning aggregations. Two additional tracking events occurred along the entire shoreline of the lake, and we used three stationary receivers (one at each known spawning site) to document movement among spawning sites. We located 25 lake trout a total of 95 times using mobile telemetry and 92% visited at least one of the three spawning sites. By combining both mobile and stationary telemetry data, we determined that 83% of lake trout visited multiple spawning sites in 2013, and 38% visited all three. In October 2013, we tagged an additional 26 adult Lake Trout ranging in size from 526 to 907 mm total length for tracking in 2014. A total of 1,793 Lake Trout was caught and removed from spawning sites by the contract netters in 2013, including 545 mature females and 1,038 mature males.

Authors:

Nicholas C. Wahl
Senior Fishery Research Biologist

Andrew M. Dux
Principal Fishery Research Biologist

INTRODUCTION

Lake Trout *Salvelinus namaycush* were stocked in numerous lakes throughout western North America during the late 1800s and early 1900s (Crossman 1995), including Lake Pend Oreille (Figure 1, Appendix A) in 1925. Lake Trout present a threat to other salmonids, including Kokanee *Oncorhynchus nerka* and Bull Trout *S. confluentus*. Bull Trout are particularly susceptible to negative interactions with Lake Trout, and Bull Trout populations generally cannot be sustained after Lake Trout introduction without human intervention (Donald and Alger 1993; Fredenberg 2002). Nearby Priest and Flathead lakes share similar characteristics with Lake Pend Oreille and exemplify the impact Lake Trout can have on Bull Trout and Kokanee populations. In both of these lakes, Bull Trout were reduced to a small fraction of their historical abundance, and Kokanee suffered complete collapse after the introduction of Lake Trout (Bowles et al. 1991; Stafford et al. 2002). Other lakes in the western United States have experienced similar detrimental effects to native fish and valued sportfish populations following Lake Trout introductions (Martinez et al. 2009). Lake Trout population modeling was conducted in 2006 and indicated that the Lake Trout population in Lake Pend Oreille was doubling every 1.6 years and would reach 131,000 adult fish by 2010 (Hansen et al. 2008). This modeling suggested that changes similar to those seen in Flathead and Priest lakes were eminent without immediate management action. This led the Idaho Department of Fish and Game (IDFG) to implement an aggressive predator removal program (netting and incentivized angling) in 2006 in an attempt to substantially reduce or collapse the Lake Trout population in Lake Pend Oreille (see Wahl and Dux 2010 for details). Although unintentional, commercial overharvest has led to collapse of various Lake Trout populations throughout their native range, including the Great Lakes and Great Slave Lake (Keleher 1972; Healey 1978; Hansen 1999).

During 2007 and 2008, telemetry research identified two Lake Trout spawning sites in Lake Pend Oreille (Schoby et al. 2009a; Wahl and Dux 2010). Intensive gill netting at these sites since 2008 has yielded high amounts of mature Lake Trout and substantially increased the annual mortality rate on the reproductive segment of the population. In 2010, a third Lake Trout spawning site was identified (Wahl et al. 2011b). Telemetry research has continued annually, but the tags deployed for 2012 research all had battery failures prior to data collection (Wahl et al. 2015). We continued telemetry research in 2013 to further evaluate whether Lake Trout spawning distribution changed in response to netting. Telemetry research also provided real-time data to guide netting during the spawning period.

METHODS

Lake Trout Telemetry

To evaluate Lake Trout spawning distribution, we have tracked mature Lake Trout using acoustic telemetry since 2007. We surgically implanted acoustic transmitters (MM-M16-33 TP, Lotek Wireless Inc., Newmarket, Ontario) equipped with temperature and depth (effective to 100 m) sensors into the abdomen of mature Lake Trout (see Wahl and Dux 2010 for surgical procedures).

Lake Trout tracked during 2013 were captured for tag insertion during fall 2012 (see Wahl et al. 2015 for details). Additionally, we captured and tagged Lake Trout at spawning sites during fall 2013 for 2014 telemetry research. These fish were captured using gill and trap nets operated by Hickey Brothers, LLC. To ensure sexual maturity, we tagged only Lake Trout that were ripe or were greater than 600 mm (IDFG, unpublished data).

We used paired, boat-mounted directional hydrophones and a MAP 600RT P2 receiver (Lotek Wireless Inc., Newmarket, Ontario) to mobile-track tagged Lake Trout. This system incorporated MAPHOST software, which allowed simultaneous decoding of multiple signals and provided direction of arrival of the transmitters' acoustic signals. Further description of field methodologies for telemetry can be found in Wahl et al. (2011a). Additionally, to more intensively evaluate movement among the three spawning sites, we submerged a WHS 3050 stationary receiver (Lotek Wireless Inc., Newmarket, Ontario) at each spawning site. The receivers were in position for the entire spawning period (September and October) and were programmed to run continuously.

Lake Trout Spawning Site Assessment

Gill nets set by Hickey Brothers Research, LLC as a part of the removal effort were also used to assess changes in Lake Trout spawning characteristics (i.e., size and relative abundance). Gill nets used to capture Lake Trout were 274 m long, 2.0-4.0 m tall and contained a single stretch mesh of 10.2, 11.4, or 12.7 cm. Several nets were tied together to form a gang that was set in a serpentine pattern that paralleled shore. Gill nets were set around dawn and retrieved in the late-morning (typically 4-6 hour sets). We enumerated and measured total length of all Lake Trout captured in gill nets. Sex and sexual maturity were determined for most of the Lake Trout captured throughout the spawning period. Catch rates were calculated as the number of Lake Trout captured per 274 m net. No time component was included in these catch rates because Lake Trout catch has typically not increased with the duration of net sets (IDFG, unpublished data). We compared length-frequency distributions between 2012 and 2013 using a Kruskal-Wallis test.

RESULTS

Lake Trout Telemetry

During the spawning period (September-October), we tracked the entire lake twice with twice-weekly tracking of the spawning sites in between the whole-lake events. Additionally, the three stationary receivers were positioned near the spawning sites from August 30 to October 30, 2013. Twenty-six tagged Lake Trout were still at-large at the beginning of the 2013 spawning period, and four of these were harvested by the contract netters at the spawning sites.

During the spawning period, we located 25 Lake Trout a total of 95 times using mobile telemetry; one lake trout was only detected on the stationary receivers. Overall, 24 of the 26 at-large Lake Trout visited at least one of the three spawning sites. Lake Trout were concentrated along the Windy Point, Bernard Beach, and Evans Landing spawning sites (Figure 9). However, only two fish were located along the Bernard Beach spawning site, compared to 17 fish each at the Evans Landing and Windy Point spawning sites. Additionally, Lake Trout were widely distributed along the Evans Landing spawning site from Capehorn to Talache Landing, a distance of 14 km. During their deployment, the stationary receivers recorded 73,387 detections from 22 tagged Lake Trout. From the combination of mobile telemetry and stationary receiver detections, we documented extensive Lake Trout movement during the spawning period. Of the 24 Lake Trout that were located at a spawning site during 2013, 20 fish (83%) visited at least one other site during the spawning period. Additionally, nine Lake Trout (38%) visited all three spawning sites.

For 2014 telemetry research, we tagged 26 mature Lake Trout from October 16-21, 2013, with 21 captured in gill nets (nine at Evans Landing, eight at Bernard Beach, and four at Windy Point). The remaining five Lake Trout were captured in a trap net at Pearl Island. Tagged Lake Trout averaged 686 mm total length (range = 526-907 mm). A complete list of tagged Lake Trout at-large during the 2013 tracking season is provided in Appendix B.

Lake Trout Spawning Site Assessment

During 29 days of the Lake Trout spawning period, a total of 404 individual 274 m gill nets (110,825 m of net) was set at the spawning sites. We captured 1,793 Lake Trout (4.2 Lake Trout per net; 3.4-5.1 = 95% CI) and examined 1,755 fish for sex and maturity. Of those fish, 545 were mature females with a mean total length (TL) of 741 mm (SE = 3.4; range = 517-1007; Figure 10) and 1,038 were mature males with a mean TL of 670 mm (SE = 2.4; range = 422-990; Figure 10). The remaining 172 Lake Trout were immature. This resulted in a sex ratio of 1.9 mature males per mature female. The length-frequency distribution of Lake Trout captured in 2013 did not differ from the distribution in 2012 (p = 0.157).

DISCUSSION

Lake Trout Telemetry

During 2013, Lake Trout in Lake Pend Oreille used the same three spawning sites that were identified in the past (Wahl et al. 2011b; Wahl et al. 2013), though spawning aggregations have become progressively less distinct each year. The most important change we documented in 2013 was a spawning aggregation on the western shore as far north as Talache Landing. In previous years, Lake Trout along the Evans Landing spawning site were all detected south of Maiden Rock, 1.5 miles south of Talache Landing. Because we did not have telemetry data in 2012, we do not know whether this was a gradual expansion of the Evans Landing spawning site or if Lake Trout have colonized a new stretch of shoreline adjacent to a previously-known spawning site.

During 2007-09, we observed almost no movement of Lake Trout among the three spawning sites, but since 2010 we documented that several Lake Trout made repeated trips among spawning sites. The use of stationary receivers in 2011 and 2013 has improved the resolution of these data because of the increased number of detections compared to mobile telemetry alone. We are unsure of the effect that netting has had on the observed movement patterns in Lake Pend Oreille in recent years. Gill nets set at spawning sites may have directly prevented aggregations from forming through the removal of spawning adults or by hindering access to the spawning locations. Additionally, multiple years of high netting exploitation at spawning sites may have removed a large enough portion of the spawning Lake Trout that aggregations were comprised of fewer individuals and fish were more easily disturbed by a similar amount of gill net effort.

Although spawning aggregations have become more dispersed and fish moved among sites more than in the early years of our telemetry research, the fish were still vulnerable to netting. Even if Lake Trout were not at a single spawning site for the duration of the spawning period, they moved to other spawning sites where netting also occurred. There would be travel time through areas where netting did not take place, but if overall Lake Trout travel rate was higher at the sites than in the past, this might provide a netting advantage where Lake Trout were more likely to encounter a net. Additionally, we do not know whether gill net disturbances

negatively influenced spawning success by fish that were not captured and removed, but the apparent influence of gillnetting on fish distribution highlights the importance of continued telemetry research. Determining where Lake Trout are most concentrated within each spawning site will be important for identifying the most effective location to set gill nets as fish shift their distribution during the spawning period. More importantly, continued telemetry research is needed to assess whether disturbances from netting cause fish to seek new spawning sites, especially given this species' ability to colonize new areas (Gunn 1995). Having telemetry data to guide netting efforts also increases confidence that netting is occurring in areas of highest fish density when fish are present, which will become more important as Lake Trout abundance and catch rates continue to decline.

Lake Trout Spawning Assessment

Total catch of Lake Trout at spawning sites increased in 2013, but compared to overall trends in the data during 2008-13, catch in 2012 may have been artificially low. The lack of telemetry data in 2012 did not allow us to guide netting to spawning aggregations. Also, gill net effort in 2012 was over 50% higher than in any other year, and we are unsure if high densities of gill nets at the spawning sites prevented aggregations from forming. Despite the variation in catch over the past three years, the length-frequency distributions during 2008-13 indicate that all size-classes of mature Lake Trout have been vulnerable to removal efforts. Further, the size structure of Lake Trout caught at spawning sites continues to suggest fewer large Lake Trout are present in the population. Most importantly, the length-frequency distributions of gill net catches did not show any large year-classes recruiting to gill nets set at spawning sites. This indicates that a large proportion of fish in these cohorts was removed prior to reaching maturity.

Over the past several years, we have effectively used data from gillnetting at Lake Trout spawning sites to assess the spawning segment of the population. Length-frequency in 2013 suggested that the level of effort expended has been sufficient to achieve desired effects at all of the spawning sites. This is particularly important given that the Evans Landing spawning site has not been targeted for as many years as the other two sites, and we documented fish along a new stretch of shoreline in 2013. Though the peak of the length-frequency distribution has shifted towards smaller Lake Trout since 2011, the peak is similar to the distribution during 2008-10. We are unsure what has caused the shift in length-frequency, but it does not appear to be related to large cohorts reaching maturity.

Differences in the duration of time spent at spawning sites, age at maturity, and alternate year spawning in females can skew sex ratios at Lake Trout spawning sites to over 90% males (Martin and Olver 1980; Dux et al. 2011). However, the sex ratio in Lake Pend Oreille has never been highly skewed, ranging from 57% males in 2011 (Wahl et al. 2013) to 67% males in 2008 (Wahl and Dux 2010). We are unsure of the rate of alternate year spawning by females in Lake Pend Oreille, but telemetry has shown that most (92%) Lake Trout implanted with transmitters at spawning sites in fall 2012 were located at a spawning site in fall 2013. With nearly all Lake Trout visiting a spawning site each year and 50% of both male and female Lake Trout maturing around age-10 (Wahl et al. 2015) we would not expect to see a highly skewed sex ratio in Lake Pend Oreille.

Overall, the use of telemetry to guide gill net placement at Lake Trout spawning sites has been a useful tool over the past several years which has maximized the efficiency of removal efforts. Without telemetry, exploitation of spawning Lake Trout would be reduced, as was the case in 2012 (Wahl et al. 2015), which would reduce the effectiveness of the Lake Trout removal program as a whole. With Lake Trout maturing at age-10 and maximum ages in Lake

Pend Oreille beyond age-20, it may take a few more years to fully collapse the population. However, the spawning segment of the population has been drastically reduced since 2008, and netting juveniles has become more effective in the last several years. We must continue removal efforts in a similar fashion to reach collapse, and using telemetry to guide gill net placement on spawning aggregations will be a key component.

RECOMMENDATIONS

1. Continue to use gill nets to remove spawning Lake Trout from the spawning sites identified in the past.

2. Track Lake Trout during spawning using mobile telemetry to verify traditional spawning sites are being used and new spawning sites are not colonized. Use patterns identified in spawning distribution to guide gill net placement during 2014.

3. Use stationary telemetry receivers to examine movement among the three spawning sites.

4. Continue to periodically evaluate Lake Trout population dynamics, especially growth, fecundity, and age composition, to determine the influence the removals are having on the population.

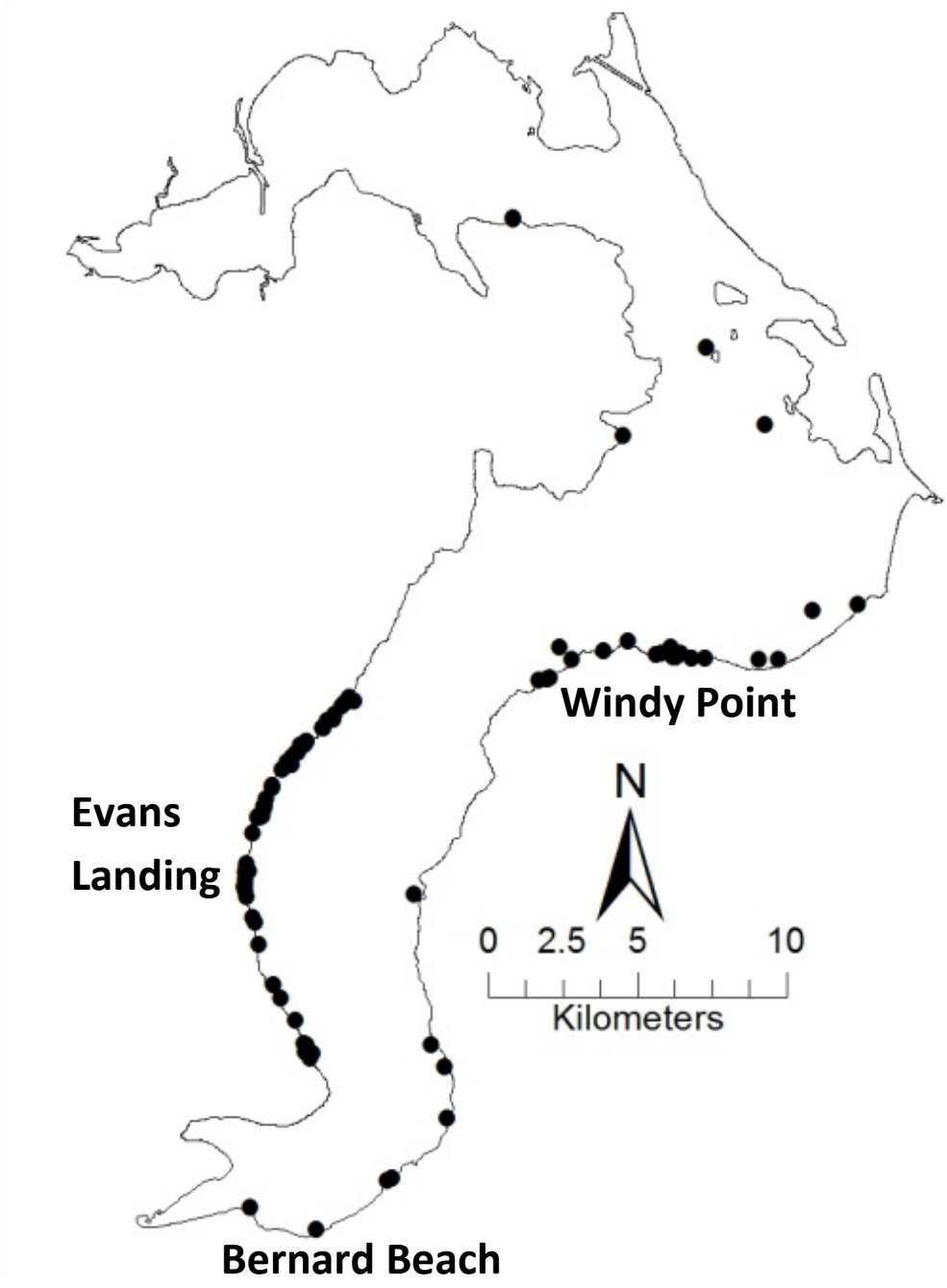

Figure 9. Locations of acoustic-tagged Lake Trout during the spawning period (September 9 to October 9, 2013) in Lake Pend Oreille, Idaho. Each dot represents one location for an individual fish.

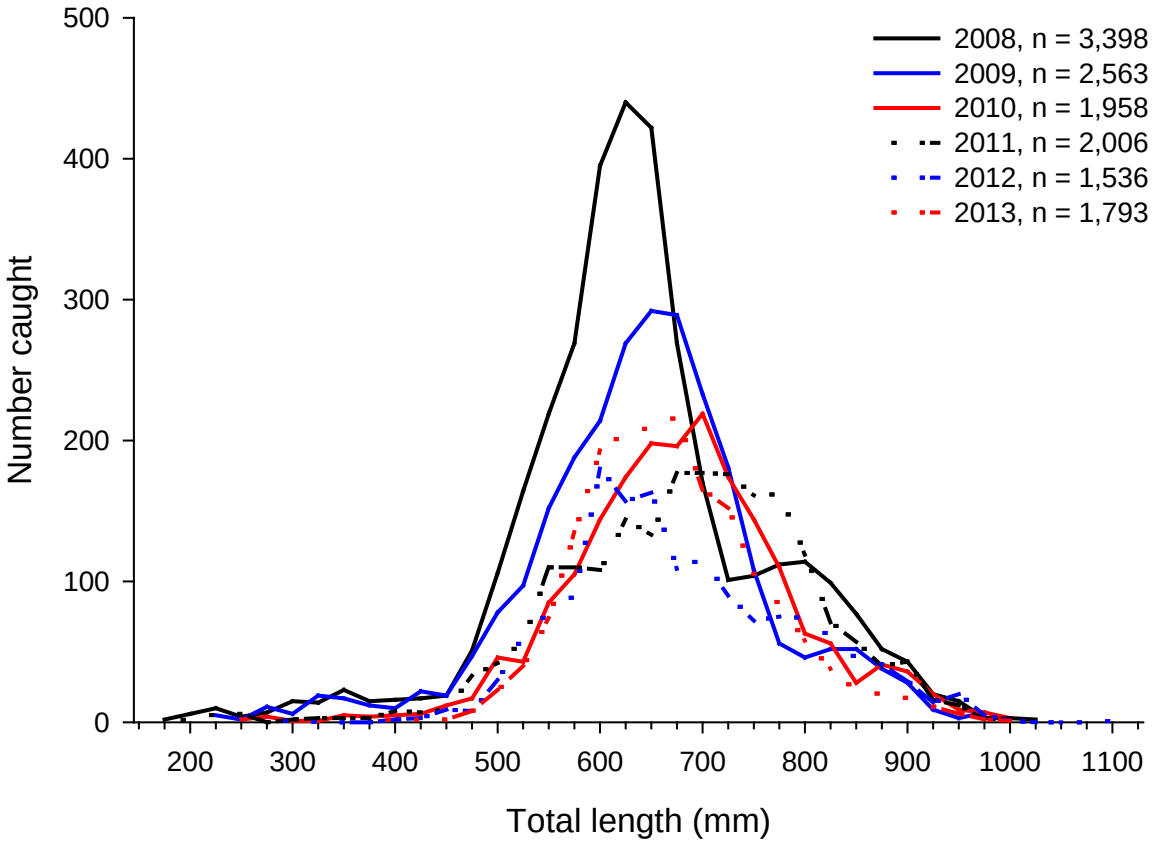

Figure 10. Length-frequency distribution of Lake Trout captured in gillnets at Windy Point, Bernard Beach, and Evans Landing during September and October, 2008-2013 in Lake Pend Oreille.

CHAPTER 3: PREDATOR REMOVAL PROGRAM EVALUATION

ABSTRACT

For more than a decade, Kokanee *Oncorhynchus nerka* restoration in Lake Pend Oreille has been limited by predation, primarily from Lake Trout *Salvelinus namaycush*. To address this issue, the Idaho Department of Fish and Game (IDFG) implemented an aggressive predator removal program intended to reduce Lake Trout. This program included unlimited harvest regulations and a $15 reward for each Lake Trout harvested as part of the Angler Incentive Program. Additionally, IDFG contracted with Hickey Brothers Research, LLC to remove Lake Trout from Lake Pend Oreille using gill nets and deepwater trap nets. During 2013, the contract netters removed 10,402 Lake Trout with gill nets and an additional 359 Lake Trout with trap nets. The contract netters had an incidental catch of 1,838 Bull Trout *S. confluentus* with 539 direct mortalities (29%). Anglers turned in an additional 3,537 Lake Trout heads. Total Lake Trout biomass removed in 2013 was 14,619 kg (0.44 kg/ha). Since the predator removal program began in 2006, 165,492 Lake Trout have been removed from Lake Pend Oreille. Standardized trap net catch of mature Lake Trout was 1.0 Lake Trout per net-night (0.5-1.6 = 95% CI), and standardized gill net catch of juvenile Lake Trout was 4.0 Lake Trout per net (2.5-6.3 = 95% CI). Since the removal program began in 2006, catch rates indicate that the mature and juvenile segments of the Lake Trout population have been reduced by 80% and 74%, respectively.

Authors:

Nicholas C. Wahl
Senior Fishery Research Biologist

Andrew M. Dux
Principal Fishery Research Biologist

INTRODUCTION

Population modeling conducted in 2006 indicated that the Lake Pend Oreille (Figure 1, Appendix A) Kokanee *Oncorhynchus nerka* population had a 65% chance of collapse due to predation, and exploitation rates of Lake Trout *Salvelinus namaycush* and Rainbow Trout *O. mykiss* at that time were not sufficient to reduce the risk to Kokanee (Hansen et al. 2010). Additionally, modeling suggested the Lake Trout population was doubling every 1.6 years and was projected to reach 131,000 adults by 2010 without management intervention (Hansen et al. 2008). With those conditions, the expanding Lake Trout population posed a threat to federally-threatened Bull Trout *S. confluentus* through predation and competition (Fredenberg 2002; Martinez et al. 2009; Guy et al. 2011). To protect Bull Trout and restore Kokanee, the Idaho Department of Fish and Game (IDFG) initiated a two-tiered predator removal program in 2006 aimed at collapsing the Lake Trout population and reducing Rainbow Trout predation. First, IDFG liberalized the angling regulations for Lake Trout and Rainbow Trout on Lake Pend Oreille (removed creel limits and allowed anglers to fish with an unlimited number of rods) and initiated an angler incentive program (AIP) which offered $15 rewards per Lake Trout or Rainbow Trout harvested. Because the program did not decrease Rainbow Trout abundance, the AIP for Rainbow Trout was discontinued after 2012, and harvest regulations were reestablished to rebuild the trophy fishery (Wahl et al. 2015). Additionally, IDFG contracted a commercial fishing operation with prior Lake Trout netting experience in the Great Lakes (Hickey Brothers Research, LLC) to remove Lake Trout with gill nets and deepwater trap nets in Lake Pend Oreille. Although unintentional, commercial overharvest has led to collapse of various Lake Trout populations throughout their native range (Keleher 1972; Healey 1978; Hansen 1999). A combination of gill nets, trap nets, and angling was necessary to maximize the likelihood of exerting high enough annual mortality to sufficiently reduce the Lake Trout population and prevent Kokanee extirpation (Hansen et al. 2010). In 2013, we continued to monitor the implementation of the predator removal program.

METHODS

Hickey Brothers Research, LLC was contracted to remove Lake Trout from Lake Pend Oreille using gill nets and deepwater trap nets during 15 weeks during the winter/spring netting season (January14-April 26) and 15 weeks during the fall netting season (September 4-December 13) in 2013. Gill nets contained stretch mesh of 4.4-12.7 cm. The contract netters set primarily 4.4-7.6 cm mesh in the winter/spring and late fall to target juvenile Lake Trout and 11.4-12.7 cm mesh in the early fall to target adult Lake Trout at spawning sites. Methods for setting gill nets and calculating catch rates are described in Chapter 2. Four trap nets (described in detail by Peterson and Maiolie 2005) were set during the fall netting season at locations standardized in previous years to compare catch rates across years. Trap nets were set on September 4 and lifted weekly until they were removed on November 4. On each lift, fish were removed from the trap nets, identified to species, enumerated, and measured for total length. Catch rates were calculated as the number of fish captured in a trap net divided by the number of nights that net was set (per net-night). All Lake Trout captured were subsequently donated to local food banks.

The IDFG placed freezers around the lake for anglers to turn in the heads of Lake Trout caught from Lake Pend Oreille. Heads were collected from freezers weekly, thawed, identified to species, and measured from the tip of the snout to the posterior edge of the operculum. Previously developed head-length to total-length relationships for Lake Trout in Lake Pend Oreille (Wahl et al. 2013) were used to extrapolate total length.

To evaluate the influence of removals, we used the combined catch rate of Lake Trout in trap nets to index trends in mature Lake Trout abundance. We also used catch rates of Lake Trout caught in small mesh (5.1, 6.4, and 7.6 cm) gill nets set in the north end of the lake during four weeks in October and November to index trends in juvenile Lake Trout abundance.

RESULTS

During the winter/spring 2013 netting season, Hickey Brothers Research, LLC set 1,627 gill nets and captured 5,258 Lake Trout and 542 Bull Trout (Table 8). Of the bull trout captured, 127 were direct mortalities (23%). Weekly catch rates ranged from 1.1 Lake Trout per net (0.7-1.6 = 95% CI) during April 22-25 to 4.6 Lake Trout per net (1.8-10.2 = 95% CI) during February 25-March 1. Captured Lake Trout ranged in total length from 184-942 mm, but because primarily small mesh nets were set to target small Lake Trout, 87% of fish caught were <350 mm (Figure 11). Based on the length-weight relationship developed for Lake Trout in Lake Pend Oreille (Wahl et al. 2011b), 1,716 kg of Lake Trout biomass were removed during winter/spring gill netting.

During the fall 2013 netting season, Hickey Brothers Research, LLC set 1,116 gill nets and captured 5,165 Lake Trout and 1,206 Bull Trout (Table 8). Of the bull trout captured, 387 were direct mortalities (32%). Additionally, 5,144 of the lake trout captured were removed; the remaining 21 Lake Trout were released for the telemetry study (Chapter 2). From September 10 to October 22, when only spawning sites were targeted, mean catch rate was 4.2 Lake Trout per net (3.4-5.1 = 95% CI). After spawning, netting targeted small Lake Trout, and mean catch rate was 3.7 Lake Trout per net (2.8-4.8 = 95% CI). Captured Lake Trout ranged in total length from 190-1007 mm (Figure 11). Based on the length-weight relationship (Wahl et al. 2011b), 6,811 kg of Lake Trout biomass were removed during fall gill netting.

Also during the fall, four trap nets captured 364 Lake Trout and 90 Bull Trout with 25 direct Bull Tout mortalities (28%). Of the Lake Trout captured, 359 were removed, and the remaining five Lake Trout were released as part of the telemetry study. Lake Trout captured in trap nets ranged in total length from 420-918 mm. Based on the length-weight relationship (Wahl et al. 2011b), the trap nets removed 854 kg of Lake Trout biomass during the fall.

The catch rate of the standardized trap nets during the fall was 1.0 Lake Trout per net-night (0.5-1.6 = 95% CI; Figure 12). The catch rate of the small mesh gill nets used to target juvenile Lake Trout was 4.0 Lake Trout per net (2.5-6.3 = 95% CI; Figure 13).

During 2013, anglers turned in 3,537 Lake Trout heads to the AIP (Table 9). Based on head length to total length (Wahl et al. 2013) and length-weight (Wahl et al. 2011b) relationships developed for Lake Trout in Lake Pend Oreille, anglers removed 5,238 kg of Lake Trout biomass.

DISCUSSION

Since the predator removal program began in 2006, 165,492 Lake Trout have been removed from Lake Pend Oreille (Table 9) for a total of 160 metric tonnes of biomass or 4.88 kg/ha. Total angler catch and trap net catch rate have declined as larger Lake Trout have been removed from the population. In 2006, 72% of the Lake Trout were removed by angling (Table

9), which is selective for Lake Trout primarily age-5 to age-9 (Hansen et al. 2010). By 2009, only 30% of Lake Trout were removed by angling. The proportion has decreased further to 25% of Lake Trout removed by anglers in 2013. Similarly, trap nets, which effectively target Lake Trout ≥age-8, have showed an 80% decrease in catch rate since 2006. Gill net total catch and catch rates have also declined, despite increases in gill net effort, shifting netting to target highest catch areas, and using mesh sizes that select for even smaller fish. The shift in contribution of each capture method over time demonstrates the importance of using multiple capture methods in a suppression program to exploit all sizes of Lake Trout (Hansen et al. 2010).

The catch rate of the standardized trap nets decreased 82% from 2006 to 2009, but has remained consistent since then. However, the consistent catch rates since 2009 may be misleading. Lake Trout telemetry data show high use of habitats between Sheepherder Point and Pearl Island where trap nets are located. Trap net catch rates may be artificially high compared to Lake Trout abundance if this portion of the lake is a preferred habitat. Regardless, standardized trap net catch rates have value for trend monitoring as a reasonable index to abundance (Wahl et al. 2015), despite the potential bias from their locations overlapping high-use Lake Trout habitat. Overall, the Lake Trout catch rates in standardized trap nets show that the population has been dramatically reduced since 2006 and, at a minimum, is being held at a low abundance.

High densities of juvenile Lake Trout (≤450 mm) were discovered in the relatively shallow (45-90 m) northern basin of the lake during 2008. This area is now the focal point of juvenile netting efforts in the lake. Since 2008, the mean catch rate of juvenile Lake Trout in standardized fall juvenile gill nets has declined 74% from a high of 15.0 Lake Trout per net (10.4-21.8 = 95% CI). With an exponentially growing population through 2006, and not exploiting Lake Trout at spawning sites until 2008, strong year classes likely were being produced until fairly recently. Based on the decreasing catch rate, recruitment overfishing appears to be occurring. With progressively fewer spawning adults since 2008, juvenile Lake Trout production is likely to decline. Additionally, targeted netting for the juveniles should limit recruitment to maturity and further reduce spawning potential. In the coming years, we expect combined netting of adults and juveniles to result in fewer fish reaching maturity (~650 mm, Wahl et al. 2015) and fewer juvenile fish recruiting to the gear (~250 mm).

We are unsure how much the reduced angler catch of Lake Trout in 2013 was related to lower Lake Trout abundance and how much was related to a decline in angler effort. With the Rainbow Trout AIP program ending in 2013, some casual anglers may have spent less time on Lake Pend Oreille. However, many of the dedicated Lake Trout anglers turned in fewer fish and expressed more difficulty finding fish than in the past, which is consistent with other metrics describing reduced Lake Trout abundance since 2012.

RECOMMENDATIONS

1. Continue the use of gill nets to remove mature Lake Trout from spawning sites in the fall and immature Lake Trout during other times of year.

2. Continue use of the AIP to reduce Lake Trout abundance in Lake Pend Oreille.

3. Continue to set trap nets at standardized locations and use trap net catch rates as an index for adult Lake Trout abundance.

Table 8. Effort, catch, and catch rates (number per gill net) of gill nets set during winter/spring and fall netting seasons.

Netting season	Effort (number of gill nets)	Lake trout caught	Bull trout caught	Bull trout mortalities	Lake trout catch rate (95% CI)	Bull trout catch rate (95% CI)
Winter/spring	1,627	5,258	542	127	2.8 (2.7-2.9)	0.3 (0.3-0.4)
Fall	1,116	5,165	1,206	387	4.1 (3.4-4.8)	1.1 (1.0-1.3)

Table 9. Number of Lake Trout removed from Lake Pend Oreille, Idaho by different gear types each year.

Gear	Angling	Gill nets	Trap nets	Total
2006	11,041	2,774	1,500	15,315
2007	17,665	4,169	1,335	23,169
2008	13,020	10,252	1,509	24,781
2009	7,366	17,186	410	24,962
2010	8,740	17,334	400	26,474
2011	7,324	11,384	150	18,858
2012	7,813	9,500	322	17,635
2013	3,537	10,402	359	14,298
TOTAL	76,506	83,001	5,985	165,492

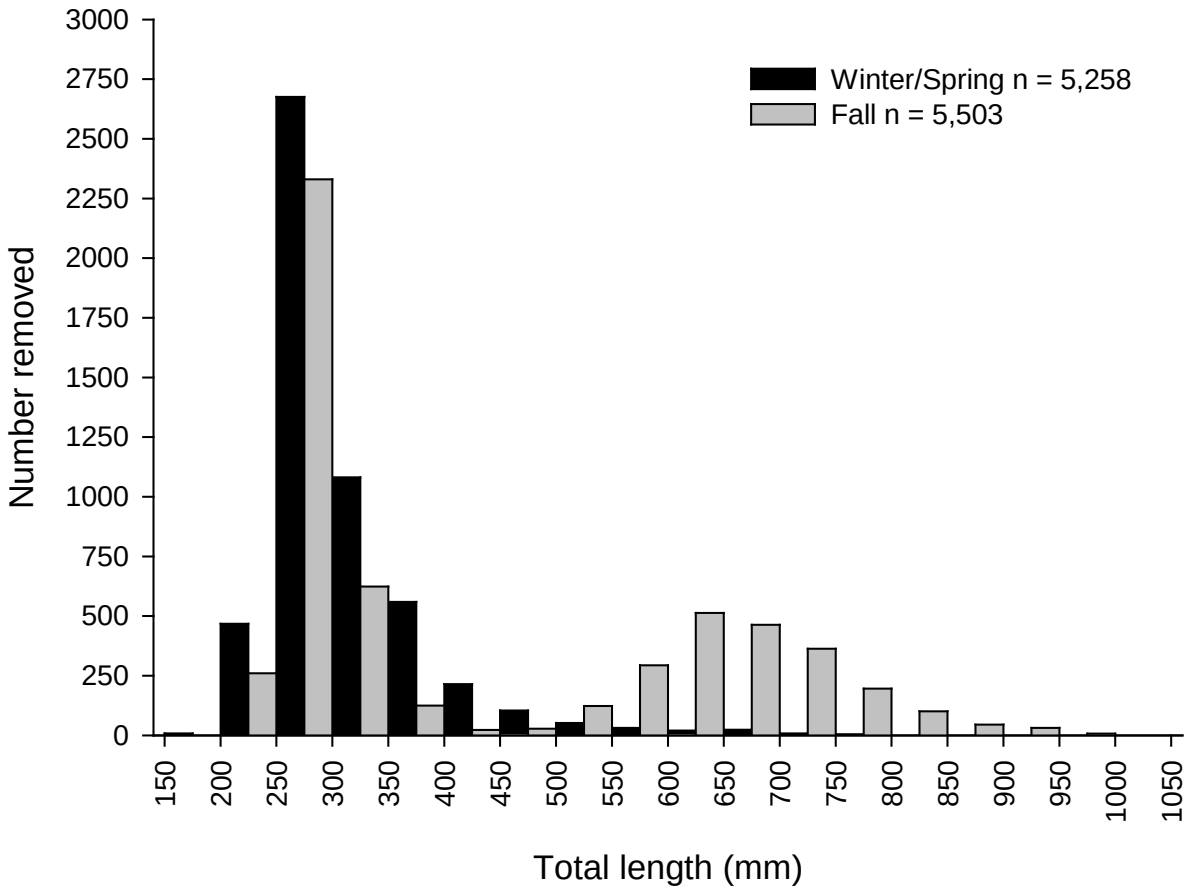

Figure 11. Length-frequency histogram for Lake Trout removed with gill and trap nets during the winter/spring and fall 2013 netting seasons in Lake Pend Oreille.

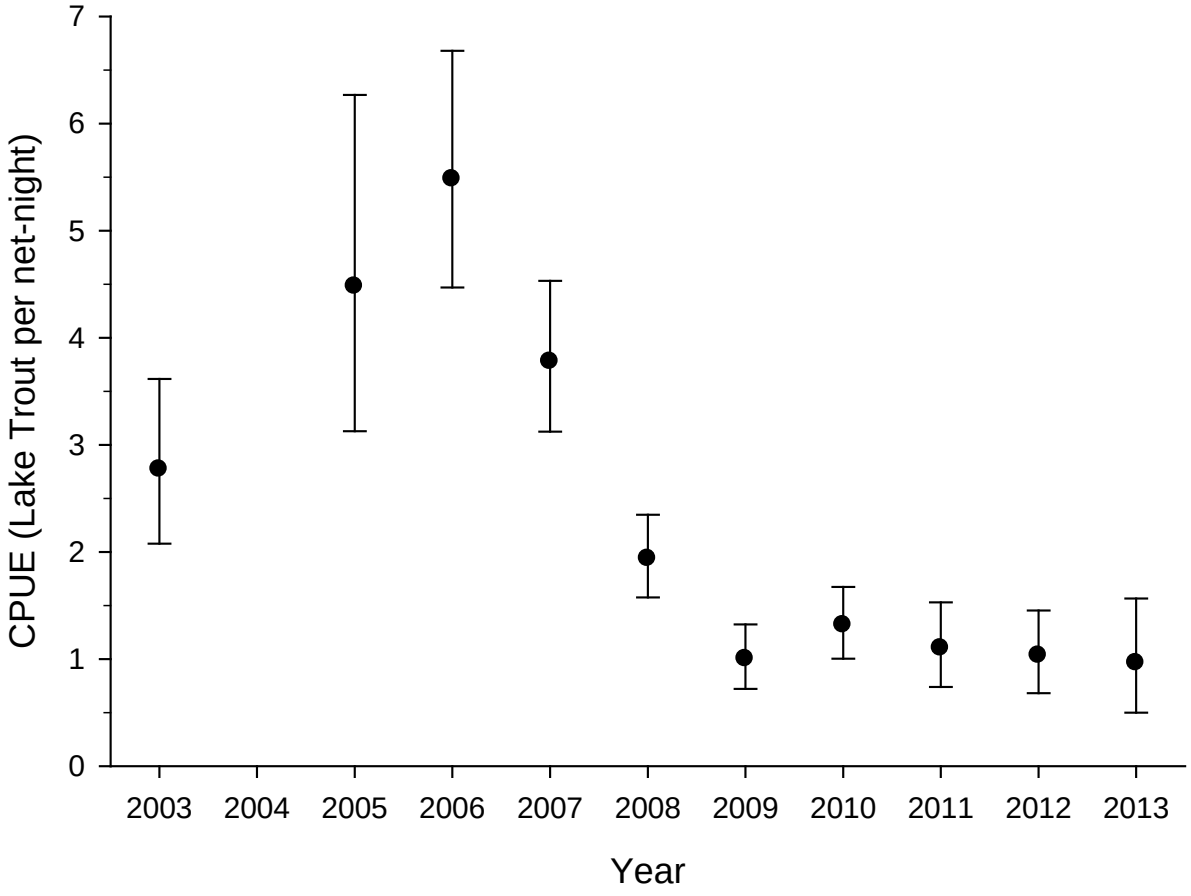

Figure 12. Mean Lake Trout catch rate with 95% confidence intervals for standardized trap nets set during fall in Lake Pend Oreille, Idaho.

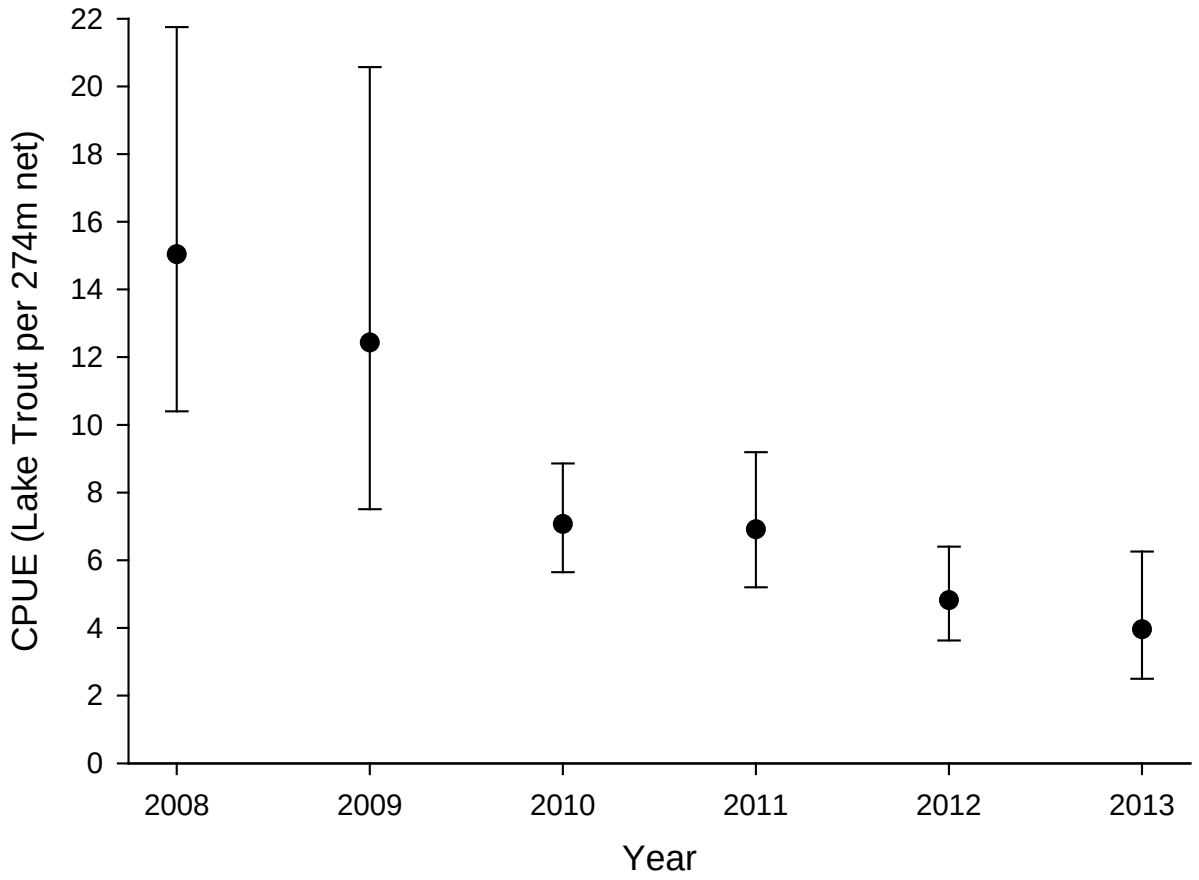

Figure 13. Mean Lake Trout catch rate and 95% confidence intervals for standardized small-mesh gill nets set during the fall in the northern portion of Lake Pend Oreille.

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Appendix A. Detailed maps of tributaries and shoreline areas around Lake Pend Oreille.

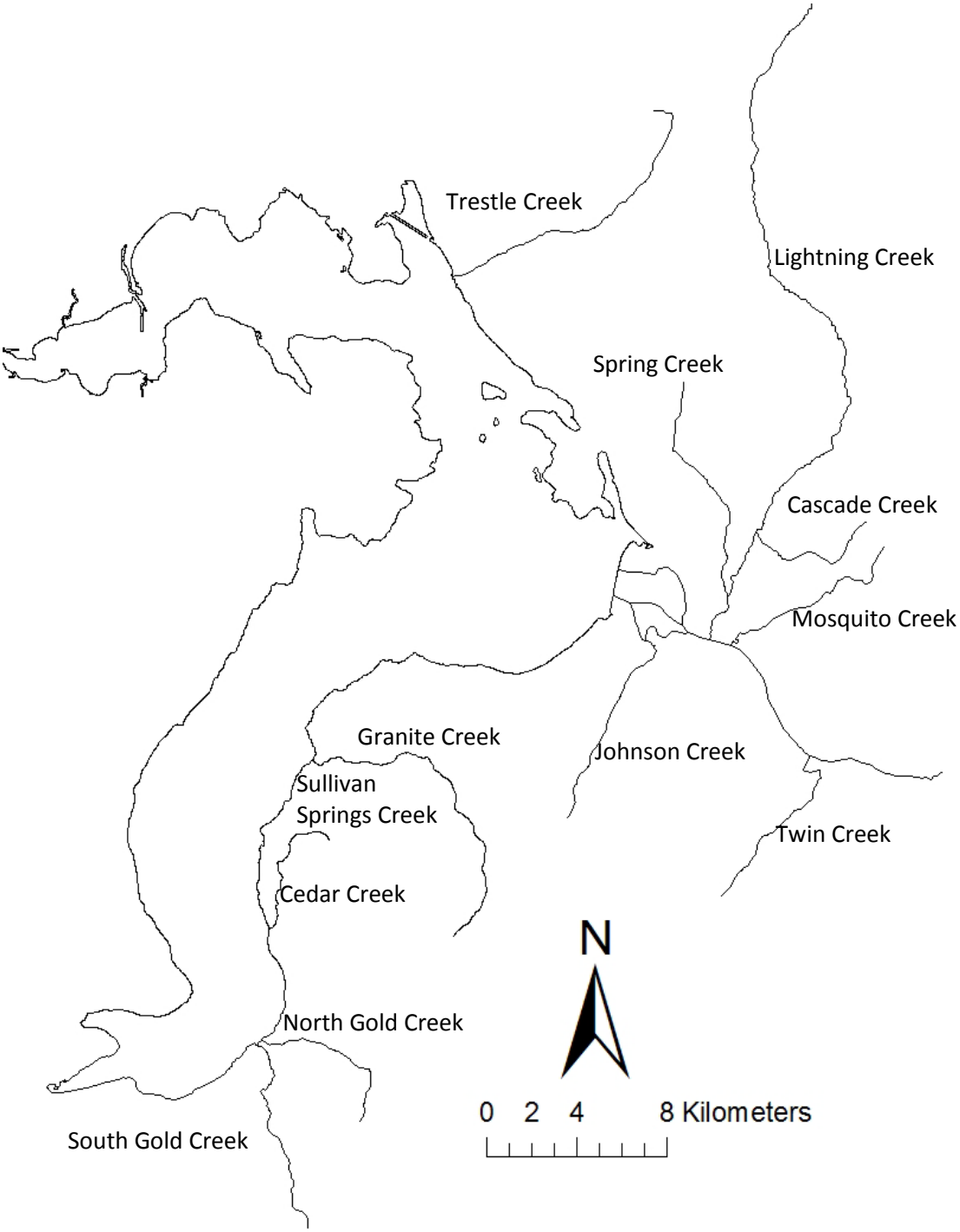

Figure A1. Map of Lake Pend Oreille showing tributaries.

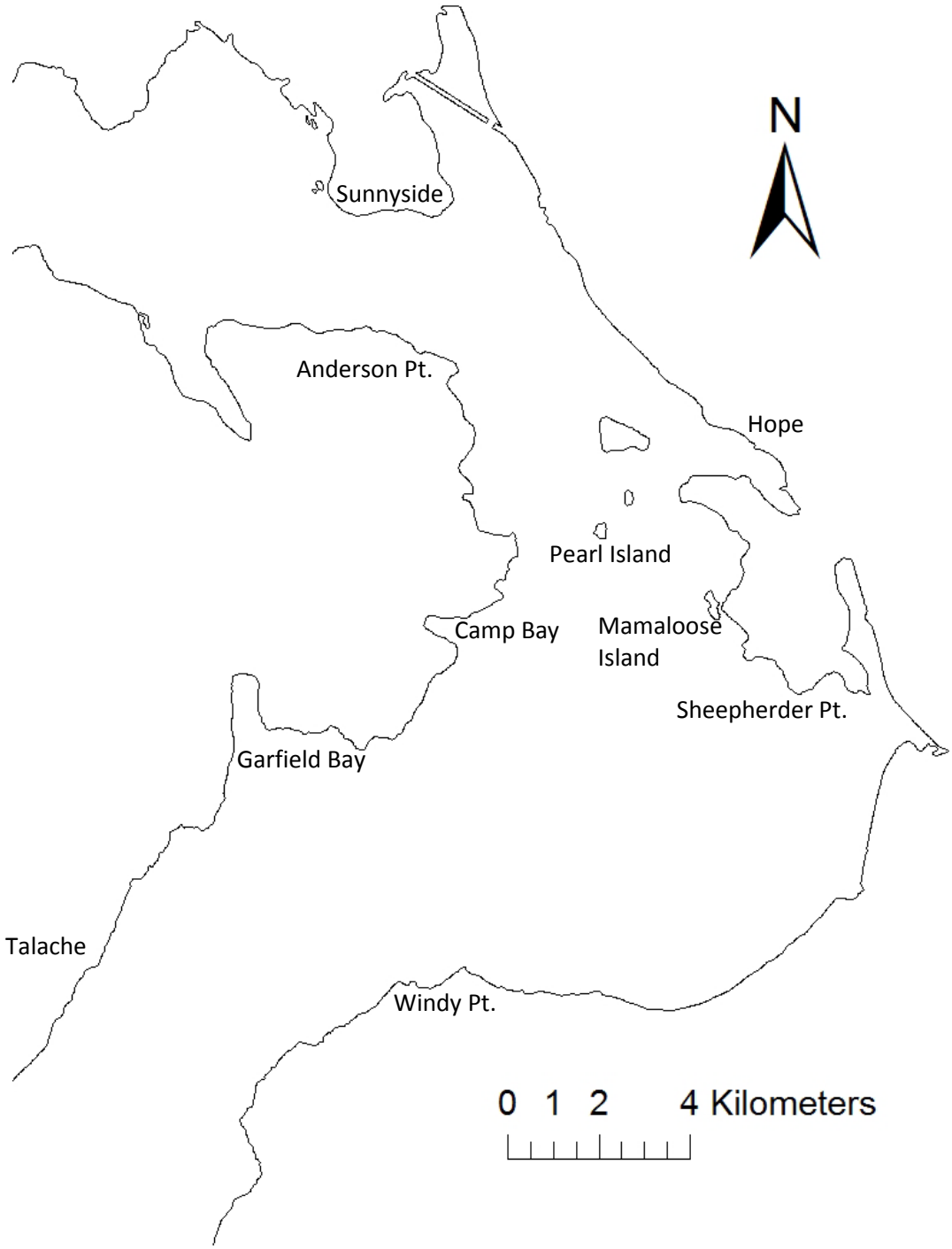

Figure A2. Map of the north half of Lake Pend Oreille showing major landmarks on the lake.

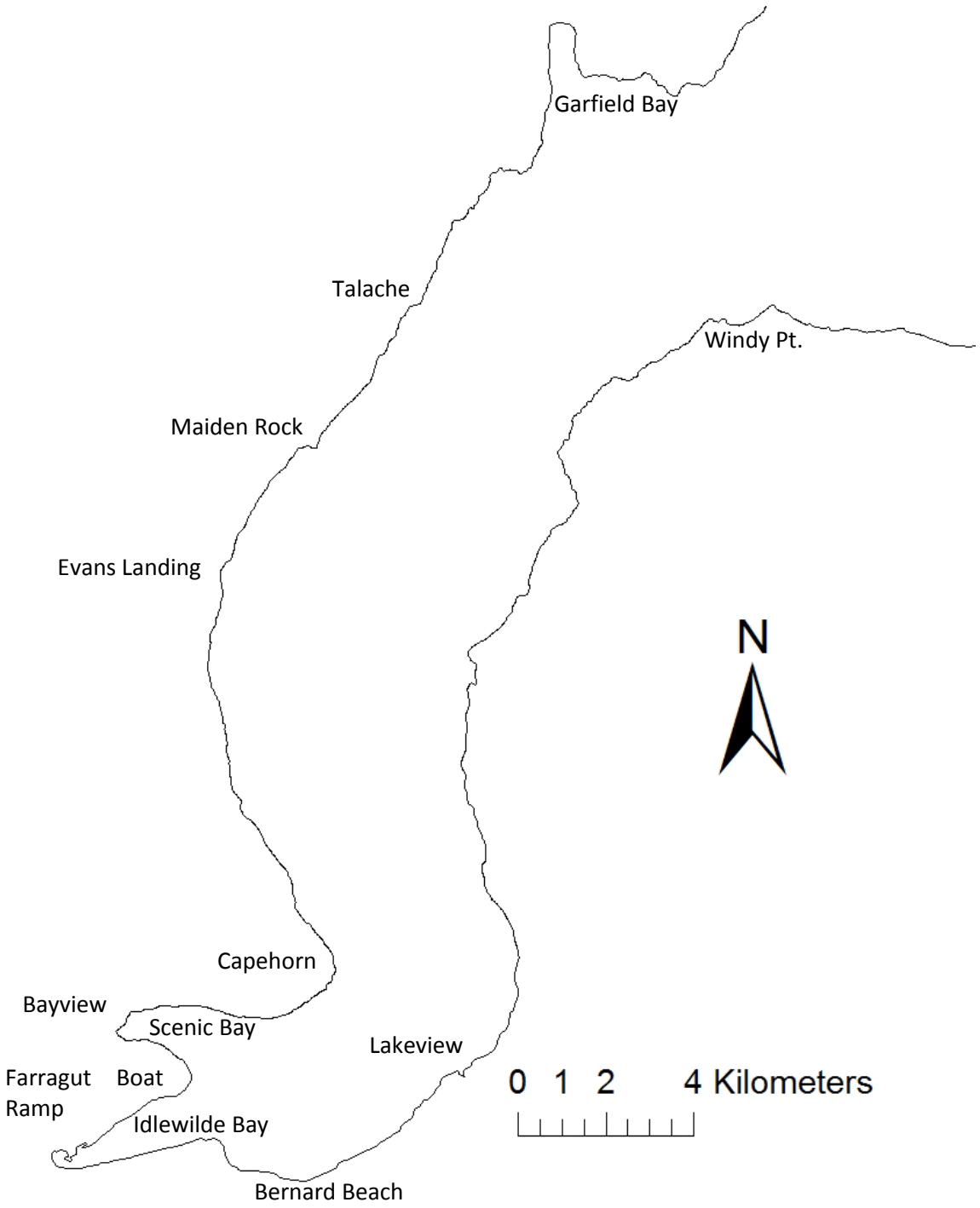

Figure A3. Map of the south half of Lake Pend Oreille showing major landmarks on the lake.

Appendix B. Tag ID, tag date, capture location, size and sex of lake trout with acoustic transmitters in Lake Pend Oreille, Idaho at-large during the 2013 contract period. Fate of fish was as of the end of February 2014; harvested fish were removed by either anglers (A) or the netters (N).

Tag ID	Date tagged	Capture method	Capture location	Total length (mm)	Sex	Number of locations via mobile tracking	Fate of fish	Date of last record (tracked, detected, or harvested)
49000	10/17/2012	Gill Net	Windy Point	851	M	5	At-Large	10/9/2013
49100	10/19/2012	Gill Net	Windy Point	705	M	4	Harvested (N)	10/2/2013
49200	10/17/2012	Gill Net	Windy Point	960	F	6	At-Large	10/7/2013
49300	10/19/2012	Trap Net	Sheepherder Point	591	M	3	At-Large	10/3/2013
49400	10/17/2012	Gill Net	Windy Point	781	M	7	At-Large	10/9/2013
49500	10/12/2012	Gill Net	Evans Landing	829	F	6	At-Large	10/9/2013
49600	10/19/2012	Gill Net	Windy Point	874	F	4	At-Large	10/9/2013
49700	10/17/2012	Gill Net	Windy Point	916	F	2	Dead	9/10/2013
49800	10/12/2012	Gill Net	Evans Landing	792	F	3	At-Large	10/7/2013
49900	10/10/2012	Gill Net	Bernard Beach	877	F	0	No Records	N/A
50000	10/10/2012	Gill Net	Bernard Beach	913	F	5	At-Large	10/7/2013
50100	10/17/2012	Gill Net	Windy Point	928	F	1	Unknown	12/13/2012
50200	10/19/2012	Gill Net	Windy Point	951	F	3	At-Large	10/3/2013
50300	10/10/2012	Gill Net	Bernard Beach	876	F	1	Dead	9/9/2013
50400	10/12/2012	Gill Net	Evans Landing	756	M	4	At-Large	10/9/2013
50500	10/12/2012	Gill Net	Evans Landing	748	F	1	At-Large	10/30/2013
50600	10/10/2012	Gill Net	Bernard Beach	642	F	8	At-Large	10/9/2013
50700	10/12/2012	Gill Net	Evans Landing	837	F	1	Unknown	12/12/2012
50800	10/19/2012	Gill Net	Windy Point	720	M	5	At-Large	10/7/2013
50900	10/17/2012	Gill Net	Windy Point	661	M	2	Harvested (N)	9/9/2013
51000	10/10/2012	Gill Net	Bernard Beach	944	F	3	At-Large	10/9/2013
51100	10/12/2012	Gill Net	Evans Landing	841	M	9	At-Large	10/9/2013
51200	10/19/2012	Gill Net	Windy Point	606	M	2	Harvested (N)	9/10/2013
51300	10/10/2012	Gill Net	Bernard Beach	629	M	6	At-Large	10/7/2013
51400	10/19/2012	Gill Net	Windy Point	855	M	2	At-Large	10/3/2013
51500	10/12/2012	Gill Net	Evans Landing	883	M	8	At-Large	10/9/2013
51600	10/17/2012	Gill Net	Windy Point	627	M	4	At-Large	10/9/2013
51700	10/12/2012	Gill Net	Evans Landing	757	M	6	At-Large	10/9/2013
51800	10/17/2012	Gill Net	Windy Point	887	F	7	At-Large	10/9/2013
51900	10/12/2012	Gill Net	Evans Landing	850	M	2	Harvested (N)	9/10/2013
52000	10/19/2012	Trap Net	Sheepherder Point	696	F	0	No Records	N/A
52100	10/12/2012	Gill Net	Evans Landing	651	M	0	Unknown	10/24/2012
52200	10/19/2012	Trap Net	Mamaloose Island	772	F	8	At-Large	10/9/2013
52300	10/17/2013	Gill Net	Evans Landing	700	M	0	At-Large	N/A
52500	10/16/2013	Gill Net	Bernard Beach	741	M	0	Tag Found*	2/28/2014
52700	10/16/2013	Gill Net	Bernard Beach	733	M	0	At-Large	N/A
52800	10/16/2013	Gill Net	Bernard Beach	907	M	0	At-Large	N/A
52900	10/16/2013	Gill Net	Bernard Beach	721	M	0	At-Large	N/A
53000	10/17/2013	Gill Net	Evans Landing	717	M	0	At-Large	N/A
53100	10/17/2013	Gill Net	Evans Landing	701	M	0	At-Large	N/A

Appendix B. Continued.

Tag ID	Date tagged	Capture method	Capture location	Total length (mm)	Sex	Number of locations via mobile tracking	Fate of fish	Date of last record (tracked, detected, or harvested)
53200	10/16/2013	Gill Net	Bernard Beach	651	M	0	At-Large	N/A
53300	10/16/2013	Gill Net	Bernard Beach	661	M	0	At-Large	N/A
53400	10/18/2013	Gill Net	Windy Point	526	M	0	At-Large	N/A
53500	10/17/2013	Gill Net	Evans Landing	653	M	0	At-Large	N/A
53600	10/17/2013	Gill Net	Evans Landing	660	M	0	At-Large	N/A
54300	10/16/2013	Gill Net	Bernard Beach	696	M	0	At-Large	N/A
54400	10/21/2013	Trap Net	Pearl Island	662	U	0	At-Large	N/A
59700	10/17/2013	Gill Net	Evans Landing	615	M	0	At-Large	N/A
59800	10/17/2013	Gill Net	Evans Landing	778	M	0	At-Large	N/A
60000	10/18/2013	Gill Net	Windy Point	656	F	0	At-Large	N/A
60100	10/18/2013	Gill Net	Windy Point	696	F	0	At-Large	N/A
60200	10/18/2013	Gill Net	Windy Point	676	M	0	At-Large	N/A
60300	10/17/2013	Gill Net	Evans Landing	674	M	0	At-Large	N/A
60500	10/17/2013	Gill Net	Evans Landing	762	M	0	At-Large	N/A
60600	10/21/2013	Trap Net	Pearl Island	691	U	0	At-Large	N/A
60700	10/16/2013	Gill Net	Bernard Beach	655	M	0	At-Large	N/A
60800	10/21/2013	Trap Net	Pearl Island	694	U	0	At-Large	N/A
60900	10/21/2013	Trap Net	Pearl Island	595	U	0	At-Large	N/A
61000	10/21/2013	Trap Net	Pearl Island	616	U	0	At-Large	N/A

* This tag was found along the shoreline, but no fish carcass was present.

Prepared by:

Nicholas C. Wahl
Senior Fishery Research Biologist

Andrew M. Dux
Principal Fishery Research Biologist

William J. Ament
Senior Fishery Technician

William H. Harryman
Senior Fishery Technician

Approved by:

IDAHO DEPARTMENT OF FISH AND GAME

_____
Daniel J. Schill
Fisheries Research Manager

_____
James P. Fredericks, Chief
Bureau of Fisheries