FISHERY RESEARCH

LAKE PEND OREILLE RESEARCH, 2009

LAKE PEND OREILLE FISHERY RECOVERY PROJECT

ANNUAL PROGRESS REPORT

March 1, 2009—February 28, 2010

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LAKE PEND OREILLE FISHERY RECOVERY BACKGROUND

INTRODUCTION

Lake Pend Oreille once provided the largest kokanee *Oncorhynchus nerka* fishery in the state of Idaho. Between 1952 and 1966, harvests of kokanee averaged 1 million kokanee/yr with up to 523,000 angler hours of fishing pressure (Jeppson 1953; Maiolie and Elam 1993). 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). In 2000, Idaho Department of Fish and Game (IDFG) closed the kokanee fishery because of low adult kokanee abundance. Fall and winter drawdowns of the lake for flood control and power production led to much of the early kokanee decline (Maiolie and Elam 1993). High predation on the kokanee stocks led to continued kokanee declines after 2000 mainly due to an increase in the lake trout *Salvelinus namaycush* population (Maiolie et al. 2002; Maiolie et al. 2006a).

Two primary strategies have been implemented to recover the kokanee population. Since 1996, the U.S. Army Corps of Engineers has 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. In an attempt to reduce predation on kokanee, IDFG changed regulations to reduce predator abundance. In 2000, IDFG removed all bag limits on lake trout, followed by the removal of rainbow trout *O. mykiss* limits in 2006. In addition to the regulation changes, IDFG implemented an Angler Incentive Program (AIP), which pays anglers to harvest lake trout and rainbow trout. To further reduce lake trout abundance, IDFG has contracted with Hickey Brothers, LLC (Bailey's Harbor, Wisconsin) since 2006 to target lake trout with gill and trap nets in Lake Pend Oreille.

During 2009, research focused on evaluating the effects of recovery actions. We examined kokanee population responses to both lake level manipulations and predator removals. We also examined changes in kokanee spawning due to lake level manipulations. We conducted take trout research to determine the influence that removals from angling and netting have had on the population and to help improve the efficiency of lake trout netting operations. We also initiated a rainbow trout study to determine if angler harvest was effectively reducing the population.

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, is the largest tributary to the lake, and outflow from the lake forms the Pend Oreille River, located on the northwest shore. 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 lake level high and stable at 628.7 m above MSL during summer (June-September), followed by lower lake levels of 626.4 m to 625.1 m during fall and winter. Littoral areas are limited and most shorelines areas have steep slopes.

A diverse assemblage of fish species is present in Lake Pend Oreille. Native game fish include bull trout *Salvelinus confluentus*, westslope cutthroat trout *O. clarkii lewisi*, and mountain whitefish *Prosopium williamsoni.* Native nongame fishes include pygmy whitefish *P. coulterii*, slimy sculpin *Cottus cognatus*, five cyprinid species, and two catostomid species. The most abundant nonnative game fish present are kokanee, rainbow trout, lake trout, lake whitefish *Coregonus clupeaformis*, and smallmouth bass *Micropterus dolomieu*. Less abundant introduced sport fishes include northern pike *Esox lucius*, brown trout *Salmo trutta*, largemouth bass *M. salmoides*, and walleye *Sander vitreus* (Hoelscher 1992).

Historically, bull trout and northern pikeminnow *Ptychocheilus oregonensis* were the top native predatory fish 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 predatory species are lake trout, rainbow trout, bull trout, and northern pikeminnow.

PROJECT OBJECTIVES

1. Recover 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. Once a kokanee fishery is re-established, indefinitely provide a rainbow trout fishery with overall catch rates of 30 hours per fish and an annual harvest of 3,000 fish greater than 610 mm and 3% (90 fish) over 9 kg.

3. Restore a bull trout harvest fishery of at least 200 fish annually by 2015 while meeting Federal Recovery Plan criteria.

4. Reduce the lake trout population to less than 1,000 fish (>406 mm) by 2013 and prevent abundance from exceeding this threshold indefinitely.

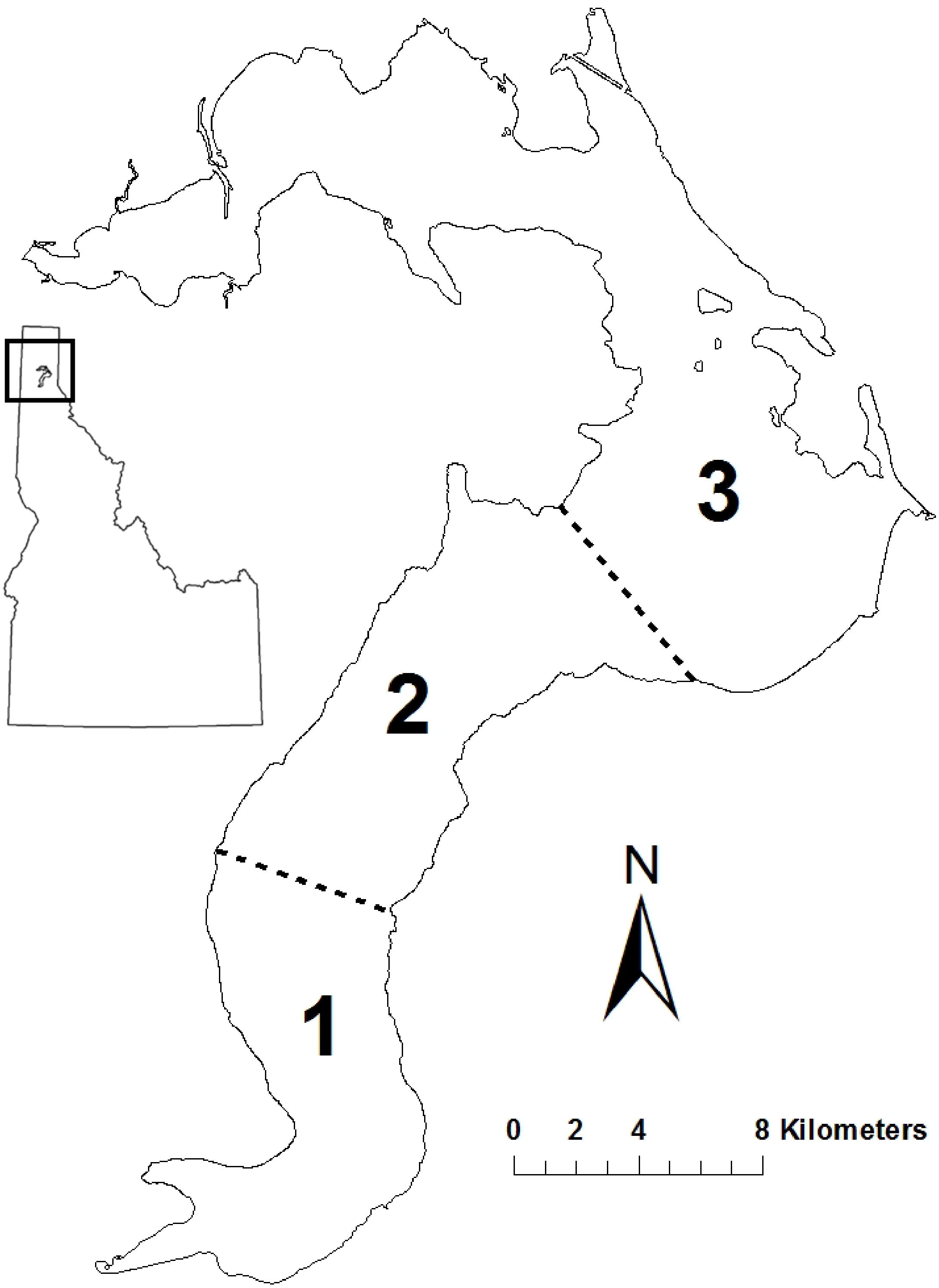

Figure 1. Map of Lake Pend Oreille, Idaho showing the three lake sections, separated by dashed lines.

CHAPTER 1: KOKANEE RESEARCH

ABSTRACT

During 2009, we examined the response of kokanee *Oncorhynchus nerka* to a winter water level management strategy designed to improve spawning and egg incubation success for wild kokanee and to a large-scale predator reduction program aimed at reducing predation by lake trout *Salvelinus namaycush* and rainbow trout *Oncorhynchus mykiss*. We conducted hydroacoustic surveys and trawling during August 2009 to assess the kokanee population and determine the impacts of these recovery actions. Total kokanee abundance was 7.9 million (347 kokanee/ha), including 1.8 million wild fry and 3.5 hatchery fry. Kokanee biomass was 146 metric tonnes (t), with annual kokanee production at 175 t, resulting in a production to biomass ratio of 1.2:1. Survival from age-1 to age-2 was 69%, and egg-to-fry survival was 21%. Substrate monitoring indicated the full drawdown over the winter of 2008-09 increased gravel composition for wild shoreline-spawning kokanee. Peak visual index counts of wild-spawning kokanee were 2,687 fish on the shoreline, 3,237 early-run tributary spawners, and 1,903 late-run tributary spawners. The counts of shoreline and late-run tributary kokanee spawners were the highest recorded since 1999 and 2005, respectively. The return of early-run tributary spawning kokanee was among the highest on record. Kokanee abundance, biomass, and survival rates improved for the second consecutive year, following a near population collapse in 2007. A major reason kokanee have persisted despite low numbers has been due to high production to biomass ratios. While improved survival suggests that kokanee are responding favorably to predator reduction efforts, weak cohorts produced from record-low spawner returns in 2006 through 2008 still exist and will need to be overcome before bigger gains in adult abundance occur.

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INTRODUCTION

Numerous factors have contributed to the dramatic decline of kokanee *Oncorhynchus nerka* from their historical levels of abundance. However, the extent and timing of winter lake drawdowns has been implicated as most detrimental (Maiolie and Elam 1993). In the 1990s, a strategy was developed to address the problems associated with lake levels. Since 1996, the winter lake level of Lake Pend Oreille has been manipulated to test the ability of a higher winter level to improve kokanee spawning and egg incubation success. With rare exceptions, the U.S. Army Corps of Engineers has set the winter lake elevation at either 625.1 or 626.4 m above mean sea level (MSL). The lower lake level has allowed wave action to sort gravels and improve kokanee spawning habitat (Maiolie et al. 2004), and kokanee egg-to-fry survival has been over 150% higher under the higher winter lake level (see Maiolie et al. 2002).

Following the closure of the kokanee fishery in 2000, kokanee abundance increased for two years, which was attributed to winter lake level manipulations (Maiolie et al. 2004). However, kokanee have not yet fully benefited from winter lake level changes due to a record flood in 1997 followed by high predation beginning around 2004 (Maiolie et al. 2006b). Lake level management, which had been the limiting factor for kokanee, became secondary to predation as the limiting factor. Predation has been implicated as the cause for kokanee declines to record low levels during 2004-07. Recent increases in kokanee biomass may have resulted from the predator reduction program (Wahl et al. 2010). Although predation currently appears to be the kokanee population's immediate threat, proper lake level management is necessary for full kokanee recovery.

The winter water level of Lake Pend Oreille ranged between 625.6 and 626.4 MSL from 2005 through 2008. During the winter of 2007-08, the winter water level of Lake Pend Oreille was lowered to 626.4 MSL with the last full drawdown to 625.1 MSL occurring in 2003 (Figure 2). We monitored the kokanee population to evaluate their response to this experiment. We also examined the quality of potential spawning areas using substrate core sampling to see how lake level changes affected spawning habitat. Additionally, we estimated abundance of the nonnative, zooplanktivorous *Mysis* shrimp *Mysis diluviana* to continue expanding the long-term data set and to monitor for potential effects they have on the kokanee population.

METHODS

Kokanee Abundance and Survival

We conducted a lakewide hydroacoustic survey on Lake Pend Oreille to estimate the abundance of kokanee. Surveys were performed at night between August 10 and 14, 2009. We used a Simrad EK60 portable scientific echo sounder equipped with a 120 kHz split-beam transducer mounted on a pole located 0.54 m below the surface, off the port side of a 7.3 m boat, with the transducer pointing downward and set to ping at 0.6 s intervals. Prior to the surveys, we calibrated the echo sounder for signal attenuation to the sides of the acoustic axis using Simrad's EK60 software. Calibration settings for the echo sounder are listed in Appendix A.

We used a stratified, systematic sampling design for our hydroacoustic survey. A uniformly spaced, zigzag pattern of transects was followed while traveling from shoreline to shoreline, as described by MacLennan and Simmonds (1992). The starting point of the first transect in each section was chosen randomly. We sampled 21 transects in the lake with eight in the southern section, six in the middle section, and seven in the northern section (Figure 1).

Transect lengths ranged from 3.6 to 7.7 km and were located using a global positioning system (GPS). For all transects, we maintained a speed of approximately 1.3 m/s (boat speed did not affect fish density calculations). Analysis of hydroacoustic data to derive kokanee density estimates and associated confidence intervals followed the protocol described in Wahl et al. (2010).

To partition out hydroacoustics data based on kokanee age class (age-1 thru age-4), we sampled fish in Lake Pend Oreille using midwater trawling from August 19 to 22, 2009. These dates were during the dark phase of the moon, which optimized the capture efficiency of the trawl (Bowler et al. 1979). We randomly selected 12 locations within each section and made hauls in a predetermined, random direction from the selected point.

Rieman (1992) described in detail the sampling procedures for midwater trawling; however, the net used in our study differed. We used a fixed-frame net, measuring 10.5 m long with a 3.0 m tall x 2.2 m wide mouth. This net had a rigid steel frame that kept the mouth of the net open and, therefore, did not have otter boards preceding the net mouth. Mesh sizes (stretch measure) graduated from 32 mm towards the mouth of the net through 25, 19, and 13 mm meshes in the body of the net and finally to 6 mm in the cod end. We determined the vertical distribution of kokanee by using a Furuno Model FCV-585 depth sounder with a 10° hull-mounted transducer. We towed the net through the water at a speed of 1.58 m/s using an 8.8 m boat and used a stepwise oblique tow along each transect to sample the entire vertical distribution of kokanee. Each tow consisted of three to six steps, with each step being three minutes in duration and representing a 3 m deep portion of the depth zone occupied by kokanee.

We collected kokanee from each trawl transect and placed them on ice until morning when they were processed. We counted fish from each transect, recorded total length (mm) and weight (g), and checked all kokanee over 180 mm for sexual maturity. Two independent readers aged fish using scales collected from 10 to 15 fish in each 10 mm size interval. We used the proportion of age-1 through age-4 kokanee captured by trawling in each section to partition the hydroacoustics survey into age classes and estimate lake-wide kokanee abundances. From these proportions, we calculated annual survival between age classes.

To sample kokanee fry more effectively, we also conducted a survey using a smaller mesh trawl net. Sampling with the fry net began on Lake Pend Oreille in 1999 and has continued annually thereafter. We made eight net hauls per lake section during August 16-17, 2009 (the same new moon period as that year’s midwater trawling) using a similar methodology to that of the midwater trawl. The fry net was 1.27 m high by 1.57 m wide across the mouth (2 m^2) and 5.5 m in length. Bar mesh size for the net was 0.8 mm by 1.6 mm. The sampling bucket, on the cod end of the net, contained panels of 1 mm mesh. All kokanee caught in the fry net were immediately frozen on dry ice. Upon return to the dock, the fry were stored in a freezer until processed. Fish were later thawed and measured for length and weight, and otoliths were removed.

Hatchery and Wild Kokanee Abundance

All kokanee produced at the Cabinet Gorge Fish Hatchery since 1997 have been marked by “thermal mass-marking” techniques (or cold branding) described by Volk et al. (1990). Therefore, hatchery kokanee of all ages contain distinct thermal marks. Hatchery personnel initiated thermal treatments five to ten days after fry entered their respective raceways and sacrificed ten fry from each raceway to verify the thermal marking. To determine hatchery and wild kokanee abundance, we sent otoliths from kokanee captured during the midwater and fry trawl surveys to the Washington Department of Fish and Wildlife (WDFW) Otolith Laboratory where personnel examined otoliths for cold-brand hatchery marks. Methodologies for checking cold-brand marks are described in Wahl et al. (2010).

We calculated the percentage of wild and hatchery kokanee within each 10 mm length group to estimate the percent of wild and hatchery fry in the lake. We then multiplied the percent of wild fish by the hydroacoustic population estimate for each length group. Finally, we summed these values to estimate the abundance of wild fish in the lake.

Kokanee Egg to Fry Survival

We used hydroacoustic data to estimate the potential egg deposition (PED) of wild-spawning kokanee. The acoustic estimate of ages 1-4 kokanee (-45.9 dB to –33 dB) in each lake section was multiplied by the percentage of mature kokanee caught in the midwater trawl in that section. We then divided this number by two (assuming a 1:1 ratio of males to females as determined in past years) to obtain the number of females. To obtain the number of wild spawners, we subtracted the number of mature female kokanee collected at the Sullivan Springs Creek fish trap (return point for all hatchery kokanee) from the population estimate of mature female kokanee. To estimate PED by wild kokanee, we multiplied the wild spawner estimate by mean kokanee fecundity, determined by dissecting 53 female kokanee at Sullivan Springs Creek throughout the duration of the spawning run. Finally, to estimate wild kokanee egg-to-fry survival we divided the estimated number of wild kokanee fry by the previous year's PED.

Historical Trawling Comparisons

In addition to hydroacoustic abundance estimates, we calculated kokanee abundance based on the catch from the midwater trawl sample. These estimates were conducted strictly for comparisons with historic data (kokanee abundance was estimated using trawling alone until 1995). Kokanee abundance was calculated by dividing age-specific catch per trawl haul by the volume of water filtered by the net (while in the kokanee layer) to obtain density of kokanee at each trawl site. We expanded the age-specific density estimates for each section to a whole-lake population estimate and calculated 90% confidence intervals using standard formulas for stratified sampling designs (Scheaffer et al. 1979), described previously for hydroacoustic estimates. Kokanee abundance was estimated using geometric [log (x+1)] means. We calculated the area of the two southern sections along the 91.5 m depth contour and the northern section along the 36.6 m depth contour because of shallower maximum water depth. The 91.5 m contour represents the pelagic area of the lake containing kokanee during late summer (Bowler 1978). For consistency, we have used these same areas (totaling 22,646 ha) each year since 1978.

Kokanee Biomass, Production, and Mortality by Weight

We calculated the biomass, production, and mortality by weight of the kokanee population in Lake Pend Oreille to determine the effects of predation. We used hydroacoustic population estimates and kokanee weights from the trawl catch for these calculations. 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 year class by the mean weight of kokanee in that year class. Finally, we summed the year class weights to obtain total kokanee biomass in the lake.

Production is 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 subtracted the mean weight of kokanee in each year class of the previous year from the current year's mean weight of the same cohort (to get the increase in weight of each year class). Next, we averaged the population estimates between the two years. Lastly, we multiplied the increase in mean weight by the average population estimate for each age class. We then summed the results for all of the year classes to determine the production for the entire population. These calculations assumed linear rates of growth and mortality throughout the year. Hayes et al. (2007) provides additional details on this summation method 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 determine annual mortality by weight for each age class, we calculated the mean weight per fish between the current and previous year. We then subtracted the population estimate of the current year from the previous year (for each age class) to determine the number of fish that died. Finally, we multiplied the mean weight by the number that died to estimate the mortality by weight for each age class. Results were summed across all age classes to estimate total mortality by weight for the kokanee population. Again, calculations assumed linear rates of growth and mortality throughout the year.

We plotted production against kokanee biomass to examine potential compensation in this population using data from 1996 through 2009. The production to biomass curve was forced through the origin. However, we excluded the flood year of 1997 since significant kokanee mortality (i.e., entrainment) occurred that was likely not due to predation.

Kokanee Spawner Counts

We counted spawning kokanee in standard tributaries and shoreline areas (Appendix B) to continue time-series data dating back to 1972. All areas surveyed are historic spawning sites (Jeppson 1960). Tributary streams were surveyed by walking upstream, from their mouth to the highest point utilized by kokanee. Surveys for early-run kokanee occurred on September 22 and 24, 2009 in Trestle Creek, South Gold Creek, North Gold Creek, and Cedar Creek. In addition, surveys for late-run kokanee occurred approximately once per week during November 16-December 18, 2009 in the same four tributaries as well as Johnson Creek, Twin Creek, and Spring Creek. Shoreline counts for late-run kokanee occurred approximately once per week during November 9-December 5, 2009. For all counts, we counted all kokanee, either alive or dead.

Additionally, we removed otoliths from early- and late-run kokanee carcasses in tributaries along the east shore during spawner counts to determine hatchery and wild proportions as well as the age of the hatchery fish. Methodologies for otolith removal, preparation, and reading were similar to those described previously. We removed 40 otoliths from early-run kokanee (South Gold Creek 10, North Gold Creek 12, Sullivan Springs Creek 18) and 56 from late-run kokanee (all Sullivan Springs Creek).

Kokanee Spawning Habitat

We have sampled six standardized sites annually since 2004 to assess changes in kokanee spawning substrate composition and assess the effectiveness of the winter-pool management strategy. These sites include Twin Creek, Green Bay, Ellisport Bay, Kilroy Bay, south of Evans Landing, and the south side of Ellisport Bay. In July 2009, divers collected six randomly located samples from a gravel band between elevations 624.8 and 625.8 MSL at each site. Divers scooped approximately two liters of substrate into a container and sealed it underwater to eliminate the loss of fine material during transport to the surface. We air dried samples before screening each through a series of soil sieves (sizes 31.5 mm, 6.3 mm, 4.0 mm, and 2.0 mm). We weighed the substrate retained on each sieve and the substrate that fell through the finest screen and calculated a percent of the weight of the total sample. We defined "cobble" as substrates that were 31.5 mm and larger, "gravel" as substrates between 31.5 and 4.0 mm, and "fines" as the substrate smaller than 4.0 mm. We modified these size breaks from several other studies (Chapman and McLeod 1987; Cochnauer and Horton 1979; Irving and Bjornn 1984). Differences in the percent of each substrate class were detected using a general linear model (ANOVA).

***Mysis* Shrimp Abundance**

We sampled *Mysis* shrimp on June 22 and 23, 2009 to estimate their density within Lake Pend Oreille. All sampling occurred at night during the dark phase of the moon. The new moon during June has been the standard sampling date for most of the previous work on *Mysis* shrimp and for all of our sampling since 1997. Sampling intensity has varied over time. From 1997-2003, ten random sites were sampled from each of the three lake sections; in 2004-2006, the number of sample sites increased to 15. To minimize time needed to conduct this work, we have only sampled eight sites in each section since 2007. We determined this level of sampling was reasonable for the purposes of maintaining the long-term data set.

We collected *Mysis* shrimp using a 1 m hoop net equipped with a Kahl Scientific pygmy flow meter with an anti-reversing counter. Net mesh and collection bucket mesh measured 1,000 μm and 500 μm, respectively. Using an electric winch, we lowered the net to a depth of 45.7 m, allowed it to settle for 10-15 seconds, and raised it to the surface at a rate of 0.5 m/s. Collected *Mysis* shrimp were preserved in 50% denatured ethanol until laboratory analysis was performed. This methodology has been standard since 1997.

During laboratory analysis, *Mysis* shrimp were classified as either young-of-the-year (YOY) or adult and counted in each sample. Seven samples were randomly selected to determine sex and length-frequency distributions. We examined *Mysis* shrimp under a dissecting scope to determine sex, and measured total length from the tip of the rostrum to the end of the telson, excluding setae. *Mysis* shrimp were then classified into five categories according to sexual characteristics: YOY, immature male, immature female, mature male, and mature female (Pennak 1978). We based density estimates on the number of *Mysis* shrimp collected in each sample and the volume of water filtered as determined by the flow meter. We calculated the arithmetic means and 90% confidence intervals for the immature and adult portion of the *Mysis* shrimp population and for the YOY portion.

RESULTS

Kokanee Abundance and Survival

In 2009, we estimated 7.9 million kokanee (6.5-9.6 million, 90% CI) or 347 fish/ha in Lake Pend Oreille, based on our standard nighttime hydroacoustic survey. This included 5.3 million kokanee fry (4.3- 6.6 million, 90% CI; Table 1), 1.2 million age-1, 892,000 age-2, 393,000 age-3 kokanee, and 8,000 age-4 kokanee (Table 2).

We estimated kokanee survival at 26% from fry to age-1, 69% from age-1 to age-2, 52% from age-2 to age-3, and 7% from age-3 to age-4 (Table 3). Survival for fry to age-1 and age-1 to age-2 since 2006 are displayed in Figure 3.

Hatchery and Wild Abundance

During the spring of 2009, Cabinet Gorge Fish Hatchery released 4.8 million thermally marked kokanee fry into Lake Pend Oreille. Out of this total, 3.8 million late-run fry were stocked into Sullivan Springs Creek, and 1.0 million early-run fry were stocked into Spring Creek and the Clark Fork River (about half in each).. The next two days alternated cold and warm, followed by the final day of cold water.

We sent 61 pairs of otoliths from fry captured in the fry trawl to the WDFW Otolith Laboratory. Additionally, otoliths from 82 kokanee fry and 128 kokanee between ages 1-4 captured in the midwater trawl were sent to the WDFW Otolith Laboratory.

Wild kokanee fry made up 60%, 33%, and 18% 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 1.8 million (Table 1). Further, we estimated that wild kokanee comprised 9%, 63%, 54%, and 0% of age-1, age-2, age-3, and age-4 abundance estimates, respectively (Table 2). Late-run hatchery kokanee were more prevalent than the early-run strain, and all age-4 kokanee were late-run hatchery fish (Table 2).

Kokanee Egg to Fry Survival

During 2009, 11%, 0%, and 1% of the trawl catch were mature in the southern, middle, and northern sections, respectively. Using these percentages to estimate mature kokanee abundance yields an estimate of 76,085 mature kokanee or 38,042 mature female kokanee, assuming a 50:50 ratio of males to females. Hatchery personnel collected 23,563 mature female kokanee at the spawning station at Sullivan Springs Creek. We estimated fecundity of adult female kokanee to be 420 eggs/female. Based on this fecundity estimate, 14,479 naturally spawning adult female kokanee deposited 6.1 million eggs in Lake Pend Oreille and its tributaries. This estimate of potential egg deposition will be used to calculate egg-to-fry survival in 2010.

During 2008, we estimated that wild kokanee deposited 8.8 million eggs in tributaries and along the shoreline of Lake Pend Oreille. Using our estimate of 1.8 million wild kokanee fry, we calculated wild kokanee egg-to-fry survival to be 21% in 2009.

Historical Trawling Comparisons

Total kokanee abundance based on geometric means of trawl samples was 4.5 million fish (3.3 to 5.6 million, 90% CI) with a density of 197 fish/ha (Table 4). This included 2.3 million kokanee fry, 1.0 million age-1 kokanee, 741,000 age-2 kokanee, 360,000 age-3 kokanee, and 8,000 age-4 kokanee (Figure 4). The total standing stock of kokanee was 5.3 kg/ha (Table 4). Kokanee captured by midwater trawling varied in length from 31-283 mm and weight from 0.2-164 g (Table 4; Figure 5).

Kokanee Biomass, Production, and Mortality by Weight

We calculated estimates of kokanee biomass, production, and mortality by weight based on the hydroacoustic estimates of kokanee abundance. Kokanee biomass was 146 metric tonnes (t) and production was 175 t (Table 5) for a production to biomass ratio of 1.2:1. Total mortality by weight was 124 t (Table 5).

Production in 2009 was 51 t higher than mortality by weight. This marks the second consecutive year that production exceeded mortality by weight and that biomass increased. Production in 2009 was roughly 38 tonnes below the curve generated from 1996 through 2008 production estimates, but this variation was not beyond what would be expected (Figure 6).

Kokanee Spawner Counts

In 2009, we observed a peak of 2,687 kokanee spawning on the lake's shorelines. The majority of these fish (98%; 2,635) were on the shoreline around Bayview in Scenic Bay (Table 6). We observed a peak of 1,903 late-run kokanee spawning in tributaries of Lake Pend Oreille, 1,257 of which were in South Gold Creek (Table 7). Additionally, peak abundance of early-run kokanee was 3,237 with 362 in Trestle Creek and 2,231 in South Gold Creek (Table 8).

Early-run kokanee were almost exclusively (98%) of hatchery origin. The age structure of these hatchery fish was 21% age-2 and 79% age-3. Hatchery fish comprised 57% of late-run kokanee in tributaries and their age structure was 9% age-2, 78% age-3, and 13% age-4.

Kokanee Spawning Habitat

Following the last drawdown to 625.1 MSL during the winter of 2003-04, the mean percent gravel at the sites steadily decreased, and in 2008 there was no difference (ANOVA; $F_{1,11}$=1.14, p=0.310) between the mean percent gravel (52% ±19%, 90% CI) and the mean percent cobble (37% ±22%, 90% CI; Figure 7). Following the full drawdown during the winter of 2008-09, the mean percent gravel (62% ±11%, 90% CI) was significantly higher (ANOVA; $F_{1,11}$=13.73, p=0.004) than the mean percent cobble (25% ±17%, 90% CI; Figure 7). The mean percent fines in 2009 (13% ±7%, 90% CI) was similar to all other years (Figure 7).

Mysis Shrimp Abundance

For the analysis of *Mysis* shrimp densities, we excluded one site as an outlier because it was over three times higher than any other site. We estimated a total mean density of 897 *Mysis* shrimp/m^2 during June 2009 (Table 9; Figure 8). This included 377 immature and adult *Mysis* shrimp/m^2 (90% CI of ± 41%; Table 9; Figure 9) and 520 YOY *Mysis* shrimp/m^2 (90% CI of ± 48%; Table 9; Figure 9).

DISCUSSION

Kokanee Population Dynamics

In the past year, total kokanee abundance increased 12%, and age 1-4 abundance increased 15%. The primary driving factors for the higher abundance was a 3.5-fold increase in age-3 kokanee. Additionally, age-2 kokanee abundance increased 19% due to the highest age-1 to age-2 survival we have recorded since 1996. Further, survival for age-1 to age-2 reached the desired range of about 60-80% for the first time since 1996. Higher kokanee survival rates should allow for further population increases; however, increases will be limited by weak year classes of juveniles produced during the record-low spawning escapements from 2006-2008. If higher survival rates can be sustained, these weak year classes will be followed by stronger cohorts, and bigger annual increases in abundance should occur.

Egg-to-fry survival was exceptionally high for the second consecutive year. Our estimate of 21% was twice as high as the average since 1998 (10%), and 2008 is the only year we observed higher survival (36%). During 2008, we based PED on only five mature kokanee caught in the midwater trawl (2008 PED is used to generate 2009 egg-to-fry survival rate), which may have led to error in our estimate as sample size governs the power of our PED estimates. While this potential bias likely influenced the magnitude of the egg-to-fry survival increase, a higher rate was not unexpected (even following a lower winter lake level) given the low numbers of mature kokanee during 2008. Winter lake elevation has less influence on egg-to-fry survival when mature kokanee numbers are low because spawning habitat is not limiting. Further, survival is often higher at low density because fish may preferentially spawn in the highest quality habitat (Shirvell and Dungey 1983) and larger fish produce larger eggs (Rieman and Myers 1992).

We have been concerned since 1999 that predation could lead to the extirpation of the already impaired kokanee population in Lake Pend Oreille (Maiolie et al 2002). The kokanee population has improved since 2007, but the abundance of older age classes remained low enough that the population was still at risk of collapse. By comparing current trawling data to previous years, we have established that survival to older age classes continues to limit the kokanee population's ability to recover. From 1980 to 1998, mean age-3 abundance (687,000) was 21% of mean fry abundance three years earlier (3.25 million; Figure 4). However, from 1999 to 2009, mean age-3 abundance (159,000) was only 4% of mean fry abundance three years earlier (4.42 million; Figure 4), likely due to high predation rates. In order for the kokanee population to recover, survival to older age classes must once again approach 20%. This goal should be met through manipulation of the predator population.

Kokanee biomass increased for the second consecutive year to the highest value since 2005. Biomass had not increased for two consecutive years since 2001-2003. Pronounced increases in the production to biomass ratio were vital to slowing the decline of the kokanee population (Wahl et al. 2010), and were critical the past two years in increasing kokanee biomass. The kokanee population has compensated for low densities with a production to biomass ratio of over 1.5:1 when biomass is below 150 t. This ratio drops to near 1:1 at a biomass of 250 t. Mortality by weight for 2009 was the lowest value recorded in the 14-year history of this metric and has been reduced 55% since 2006, possibly indicating a decreased consumptive demand of the predator populations on kokanee. With kokanee biomass at only 146 t, any increase in mortality by weight would likely result in sharp decrease in biomass despite high production values. Continued implementation of the predator reduction program should further reduce kokanee mortality by weight and, given the high production to biomass ratios, lead to increases in kokanee biomass.

Spawner counts provide only an index to spawner abundance, but do provide a useful way to coarsely monitor trends and corroborate abundance estimates derived by hydroacoustics and midwater trawling. The recent trend has been encouraging, as both shoreline and tributary spawner counts have increased annually since 2007. Shoreline spawner counts showed particular improvement in 2009 and were the highest recorded since 1999. Despite the increased abundance of shorelines spawners, the distribution of these fish during spawning remains a concern. Since nearly all (~98% of fish counted) shoreline spawning takes place within a small portion of Scenic Bay, disturbance to spawning habitat or incubating eggs poses a risk to the long-term survival of the wild kokanee population. This is of particular concern because kokanee spawning in Scenic Bay occurs in a heavily developed shoreline area with high anthropogenic activity.

For the second consecutive year, early-run kokanee returned to Granite, Cedar, and North and South Gold creeks where they historically have been uncommon. Recent returns of early-run kokanee to these tributaries have consisted of strays of early-run fry stocked in Sullivan Springs Creek during 2004-07 to bolster record low kokanee abundance. Stronger returns of early-run kokanee to these streams might appear promising, but despite what appears to be a faster growth rate for early run kokanee, we believe they are unlikely to substantially contribute towards recovery goals for two primary reasons. First, late-run kokanee and bull trout *Salvelinus confluentus* may superimpose redds on top of early-run kokanee redds and reduce egg survival (Chebanov 1991; Weeber et al. 2010). Second, tributaries are vulnerable to dynamic flow conditions during egg incubation that can result in higher mortality than would be expected in the lake environment. Early-run kokanee were stocked in Trestle Creek during the early 1970s and have persisted at fairly low abundance ever since, presumably because natural reproduction suffers from the problems mentioned above. Because high levels of natural reproduction are unlikely to occur over the long-term, early-run kokanee abundance is likely to remain low unless stocking continues.

Gravel Sampling

Prior to 2009, the amount of shoreline gravel had decreased since the last drawdown to 625.1 MSL during the winter of 2003-04. The full drawdown during the winter of 2008-09 allowed wave action to re-sort gravels along the shoreline, which led to the increased amount of gravel (in relation to cobble) observed in 2009. Previously, we recommended that the lake should be drawn down to a winter elevation of 625.1 MSL once every four years to allow wave action to improve spawning habitat (Maiolie et al. 2002). This recommendation still appears valid and is important to follow if kokanee abundance continues to increase in response to predator removal efforts.

***Mysis* Shrimp Abundance**

Mysis shrimp in Lake Pend Oreille have gone through a cycle of expansion and then decline. *Mysis* shrimp were introduced in 1966, became fully established by the mid-1970s, and rapidly expanded until 1980. Since 1980, they declined from their peak abundance. A similar pattern of expansion followed by decline occurred in other western lakes after *Mysis* shrimp introductions (Richards et al. 1991; Beattie and Clancey 1991). Immature and adult *Mysis* shrimp (the segments of the population most likely to compete with kokanee) densities remained relatively stable from 1997 to 2008, but we noted a substantial increase in 2009 (Figure 9). However, total density of *Mysis* shrimp in Lake Pend Oreille remained consistent between 2008 (893 *Mysis* shrimp/m^2) and 2009 (897 *Mysis* shrimp/m^2; Figure 8). The reason for the increase in immature and adult *Mysis* shrimp is unclear. We have documented extreme fluctuations in YOY *Mysis* shrimp densities in past years that were not correlated with higher immature and adult *Mysis* shrimp densities. Thus, the increase observed in 2009 is likely a result of periodic population cycling, possibly being driven by environmental conditions and not a cause for concern at this time.

While it is unclear what limits the *Mysis* shrimp population in Lake Pend Oreille, it does not appear that *Mysis* shrimp are limiting kokanee recovery. Total *Mysis* shrimp densities have generally stabilized and kokanee survival has continued to fluctuate over the past several years. Maiolie et al. (2002) did not find a correlation between *Mysis* shrimp densities and survival rates of kokanee between the egg and fry stages. This was also the case in 2009. We recommend continued monitoring of the *Mysis* shrimp population given the potential they have to influence both the kokanee and lake trout *Salvelinus namaycush* populations.

RECOMMENDATIONS

1. Continue to monitor kokanee population response to lake level management and reductions in predation.

2. Coordinate with the U.S. Army Corps of Engineers, Bonneville Power Administration, and other agencies to set a winter lake level that benefits kokanee spawning to the extent possible.

3. Continue to reduce predator abundance in an effort to increase kokanee survival.

Table 1. Population estimates of kokanee fry (millions) based on hydroacoustic surveys of Lake Pend Oreille, Idaho in 2009. Percentage of wild, early-run hatchery (KE), and late-run hatchery (KL) fry was based on the proportions of fry caught using a fry net.

	Southern	Middle	Northern	Lakewide Total	90% CI
Total kokanee fry abundance estimate	1.3	1.9	2.1	5.3	4.3 to 6.6
Percent wild fry in fry trawl	60.0	33.3	18.2	—	
Percent KE in fry trawl	6.7	0	9.1	—	
Percent KL in fry trawl	33.3	66.7	72.7	—	
Wild fry abundance estimate	0.77	0.65	0.39	1.80	

Table 2. Population estimates for kokanee age classes 1 through 4 in Lake Pend Oreille, Idaho 2009. Estimates were generated from hydroacoustic data that were partitioned into age classes based on the percent of each age class sampled by midwater trawling. Percentage of wild, early-run hatchery (KE), and late-run hatchery (KL) were based on the proportions of each caught in the trawl net.

Area	Age-1	Age-2	Age-3	Age-4	Total
Southern Section					
Percent of age class by trawling	10.0	51.1	38.5	1.4	
Population estimate (millions)	0.053	0.301	0.227	0.008	0.590
Middle Section					
Percent of age class by trawling	55.8	35.4	8.8	0	
Population estimate (millions)	0.396	0.251	0.062	0	0.709
Northern Section					
Percent of age class by trawling	63.5	27.9	8.6	0	
Population estimate (millions)	0.772	0.339	0.104	0	1.215
Total population estimate for lake (millions)	1.221	0.892	0.393	0.008	2.514
90% confidence interval (millions)					1.969-3.208
Percent wild	9.0	63.8	56.7	0	
Percent KE	8.5	6.5	0	0	
Percent KL	82.6	29.6	43.3	100	

Table 3. Survival rates (%) between kokanee year classes estimated by hydroacoustics, 1996-2009. Year refers to the year the older age class in the survival estimate was collected.

	Age Class			
Year	**Fry to 1**	**1 to 2**	**2 to 3**	**3 to 4**
2009[a]	26	69	52	7
2008[a]	14	32	40	84
2007[a]	20	10	—[b]	—[b]
2006[a]	23	13	—[b]	—[b]
2005[a]	46	15	26	28
2004[a]	21	33	28	18
2003[a]	35	55	65	—[b]
2002[a]	30	43	—[b]	—[b]
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

[a] Data from 2002 to 2008 were based on geometric means transformed by log(x+1).
[b] Too few kokanee caught to provide a reliable estimate of survival.

Table 4. Kokanee population statistics based on geometric ($\log_{10}$ transformed; log[x+1]) means of midwater trawl catches on Lake Pend Oreille, Idaho during August 2009.

	Fry	**Age-1**	**Age-2**	**Age-3**	**Age-4**	**Total (90% CI)**
Population estimate (millions)	2.34	0.99	0.74	0.36	0.01	4.5 (3.3 to 5.6)
Density (fish/ha)	104.2	43.7	32.7	15.9	0.4	196.8
Standing stock (kg/ha)	0.17	1.45	2.17	1.45	0.06	5.3
Mean weight (g)	1.7	33.2	66.5	91.2	164.0	-
Mean length (mm)	58.9	159.7	201.4	221.7	283	-
Length range (mm)	31-126	101-201	165-244	204-267	283	-
Number measured	85	52	43	28	1	

Table 5. Biomass, production, and mortality by weight (metric tonnes) of kokanee in Lake Pend Oreille, Idaho from 1996-2009.

Year	Biomass	Production	Mortality by Weight
2009	146	175	124
2008	91	179	165
2007	74	182	221
2006	100	206	276
2005	156	231	247
2004	158	218	329
2003	258	236	173
2002	182	237	209
2001	145	240	267
2000	162	174	222
1999	198	217	245
1998	216	201	179
1997	191	196	322
1996	308	254	260
1995	344	NA	NA

Table 6. Counts of kokanee spawning along the shorelines of Lake Pend Oreille, Idaho. The numbers shown indicate the highest weekly count and should be interpreted as an index rather than a total estimate of spawner abundance.

Year	Bayview	Farragut Ramp	Idlewilde Bay	Lakeview	Hope	Trestle Cr. Area	Sunnyside	Garfield Bay	Camp Bay	Anderson Point	Total
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 7. Counts of late-run kokanee spawning in tributaries of Lake Pend Oreille, Idaho. The numbers shown indicate the highest weekly count and should be interpreted as an index rather than a total estimate of spawner abundance.

Year	S. Gold	N. Gold	Cedar	Johnson	Twin	Mosquito	Lightning	Spring	Cascade	Trestle	Total
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 spawners from the hatchery ladder to Spring Creek.

Table 8. Counts of early-run kokanee spawning in tributaries of Lake Pend Oreille, Idaho. The numbers shown indicate the highest weekly count and should be interpreted as an index rather than a total estimate of spawner abundance. Monitoring early-run kokanee began in 2008; prior to this, only Trestle Creek was counted.

Year	S. Gold	N. Gold	Cedar	Trestle	Total
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 9. Densities of *Mysis* shrimp (per m^2), by life stage (young of year [YOY], and immature and adult), in Lake Pend Oreille, Idaho June 22-23, 2009.

Section	YOY/m^2	Immature & Adults/m^2	Total *Mysis* Shrimp/m^2
Section 1	387.8	263.9	651.7
Section 2	675.3	479.4	1154.7
Section 3	477.4	368.4	845.8
Whole lake means	520.3	376.6	897.3

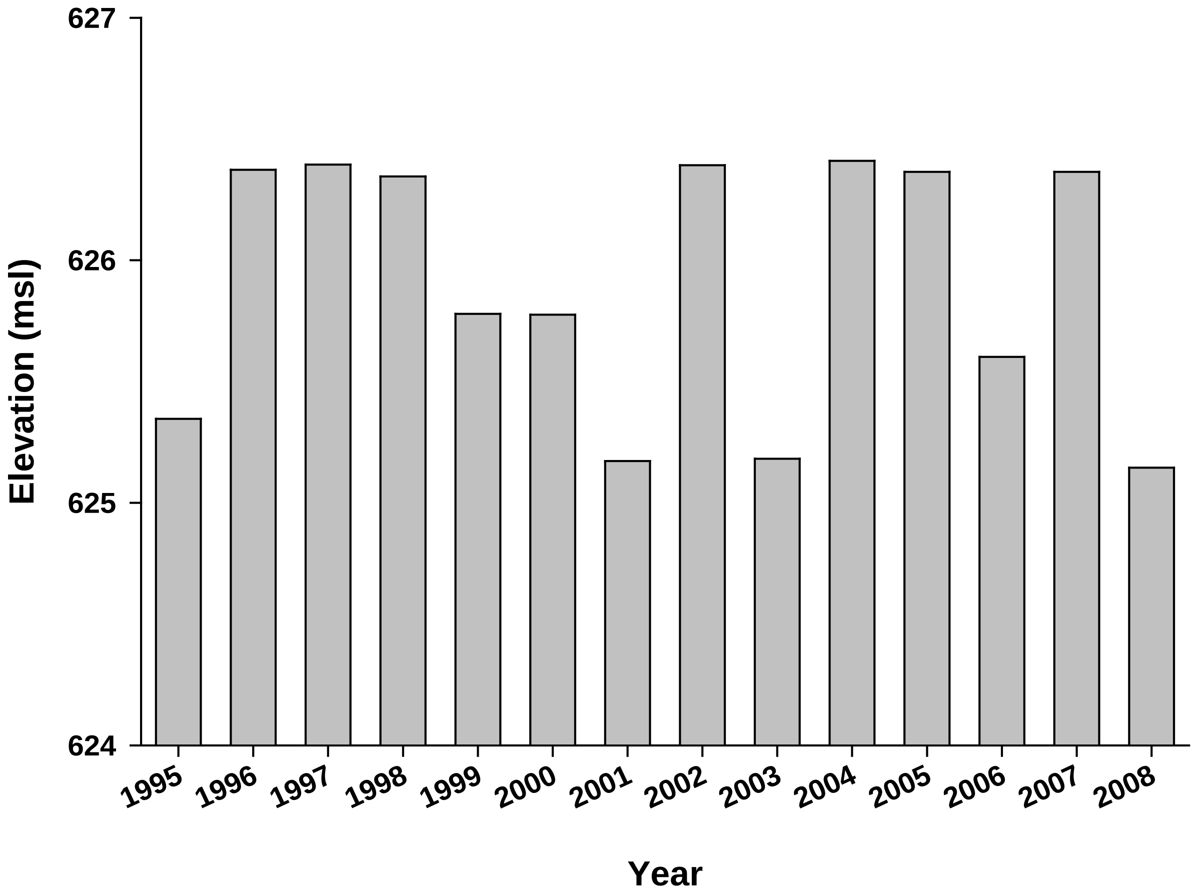

Figure 2. Winter pool surface elevation in meters above mean sea level (MSL) during years of lake level experiment in Lake Pend Oreille, Idaho. Year shown represents the year the lake was drawn down (i.e., 1995 for winter of 1995-1996).

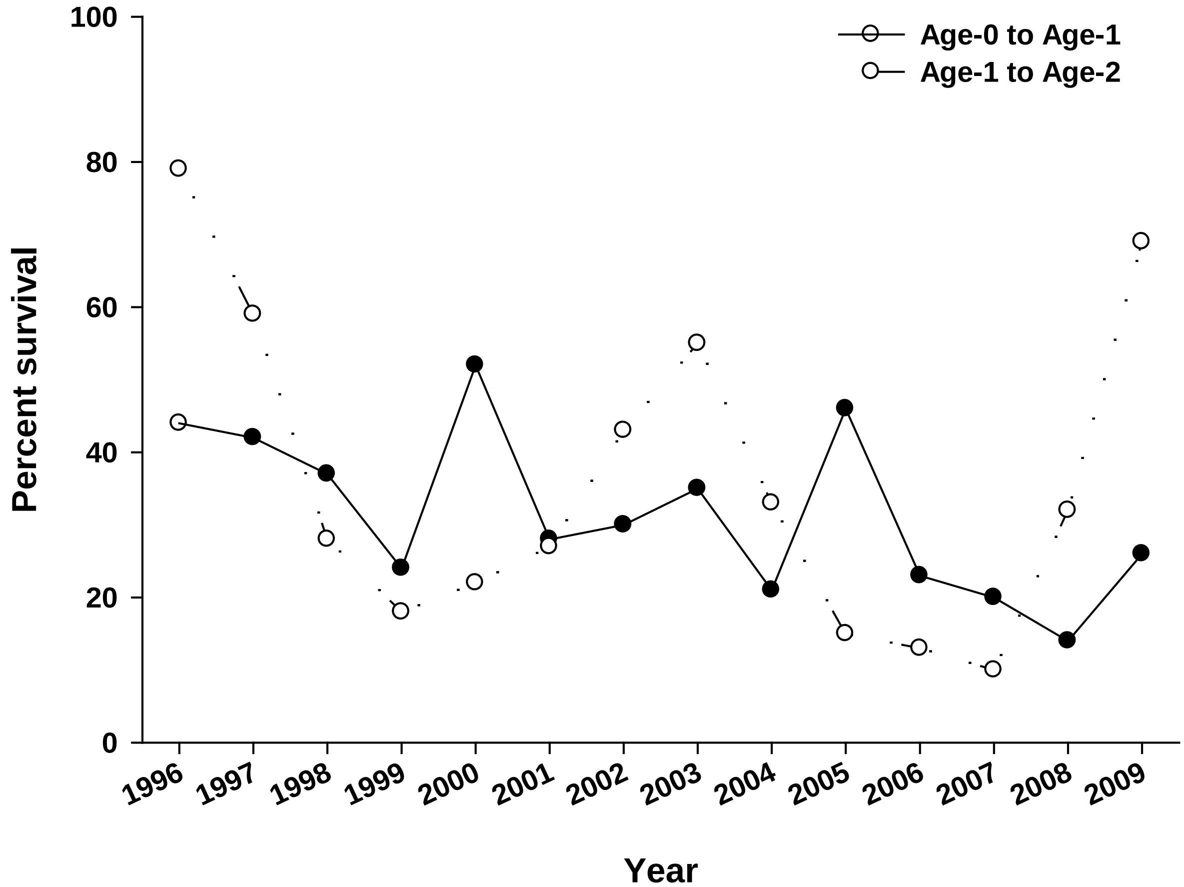

Figure 3. Survival rates of kokanee from age-0 to age-1 (black circles and solid line) and age-1 to age-2 (open circles and dashed line) in Lake Pend Oreille, Idaho. Estimates were generated from hydroacoustic surveys conducted between 1996 and 2009.

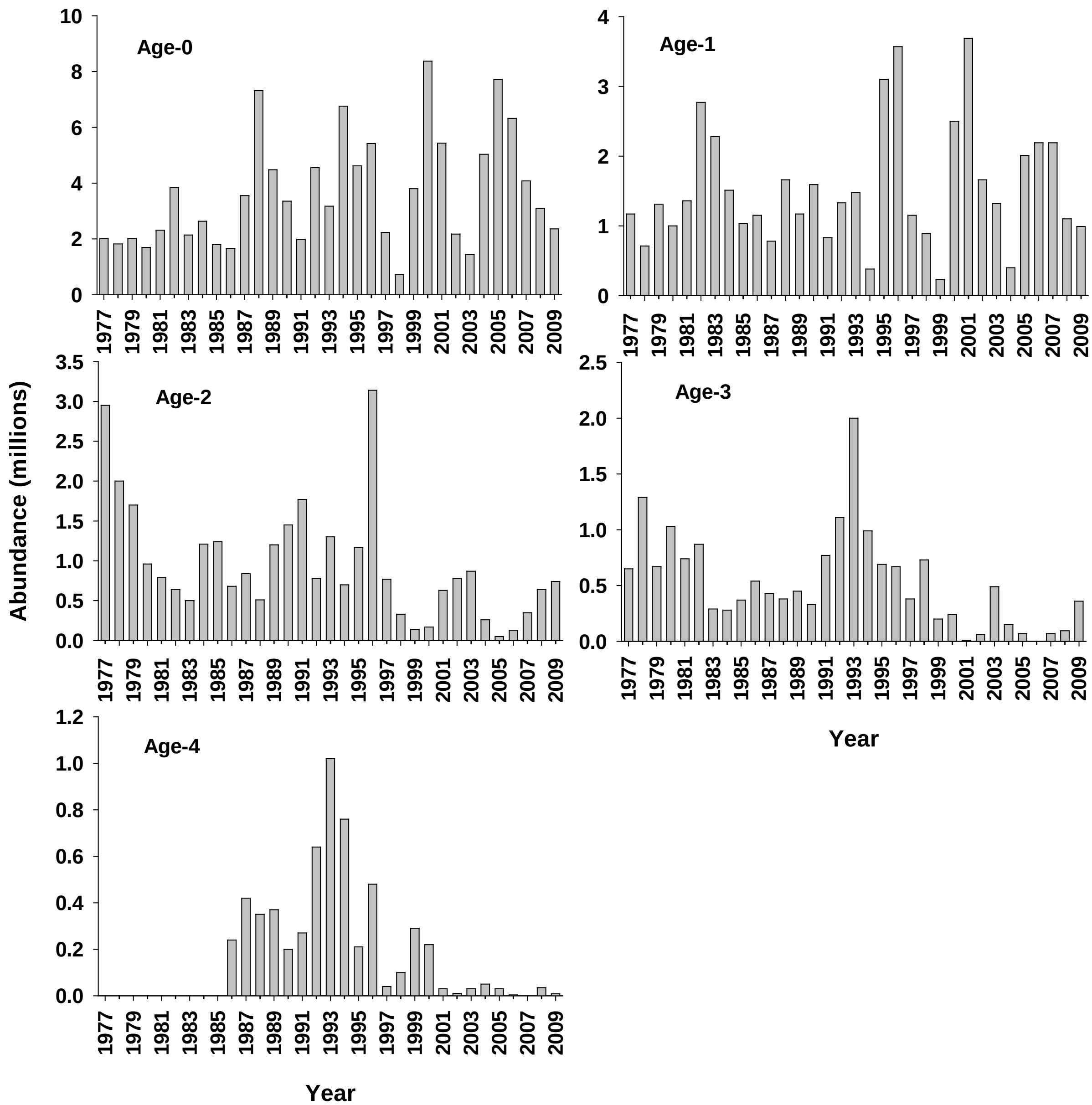

Figure 4. Kokanee age-specific population estimates based on midwater trawling between 1978 and 2009. Age-3 and -4 kokanee were not separated prior to 1986.

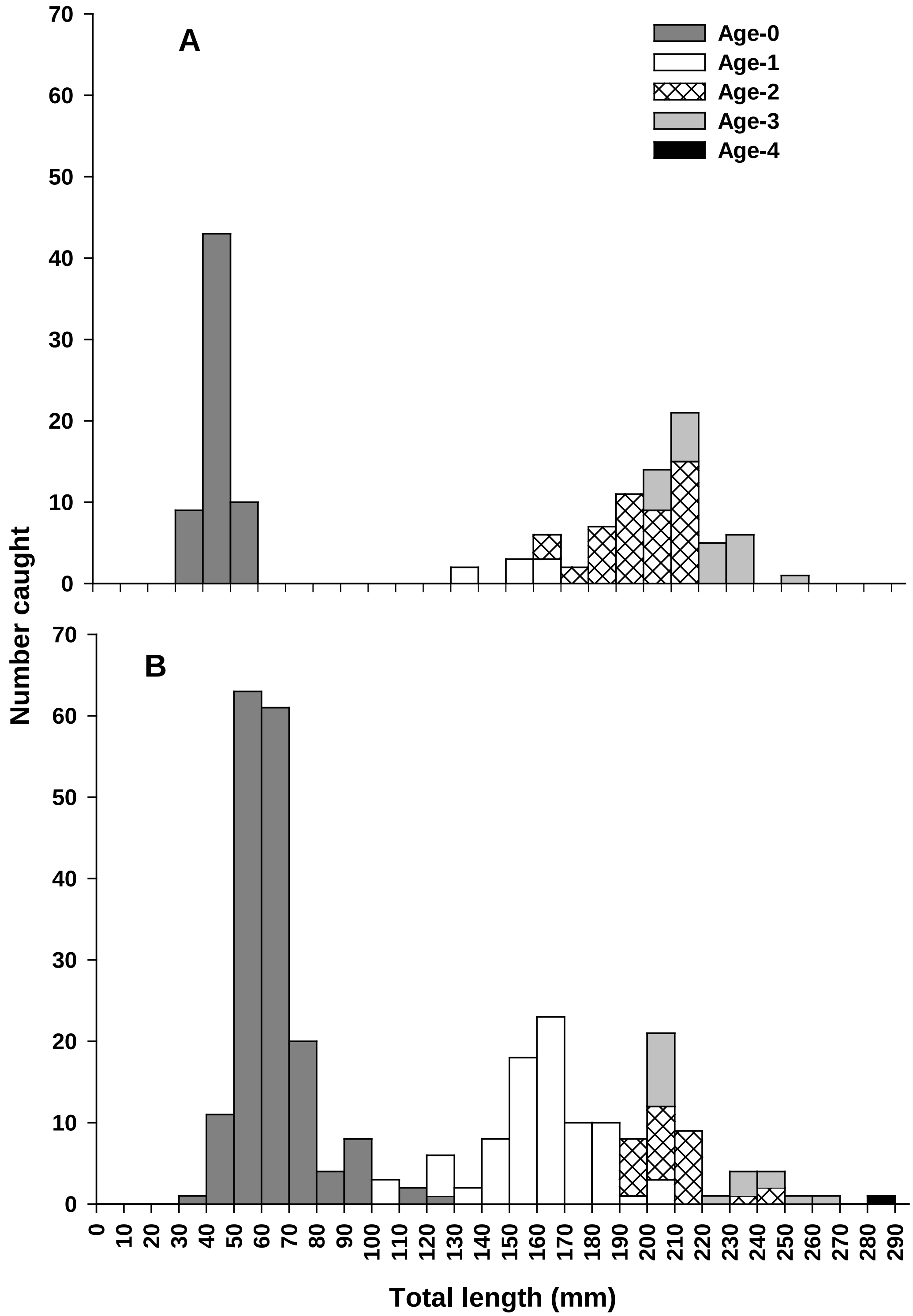

Figure 5. Length-frequency distribution of individual age classes of wild (A) and hatchery (B) kokanee caught by midwater trawling in Lake Pend Oreille, Idaho during August 2009.

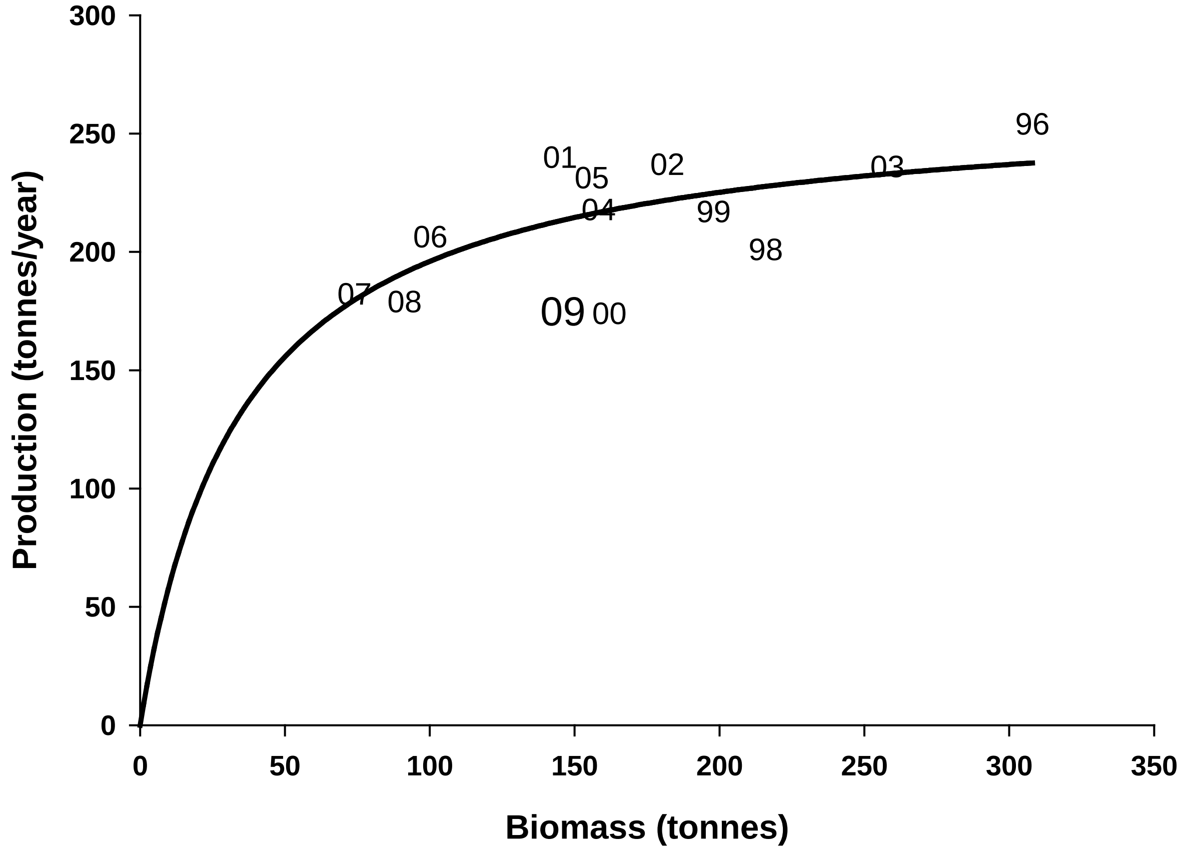

Figure 6. Kokanee biomass and production relationship (metric tonnes) in Lake Pend Oreille, Idaho from 1996-2009, excluding 1997 due to 100-year flood. Kokanee biomass was measured at the start of the year. The solid black line represents the production curve from 1996-2008.

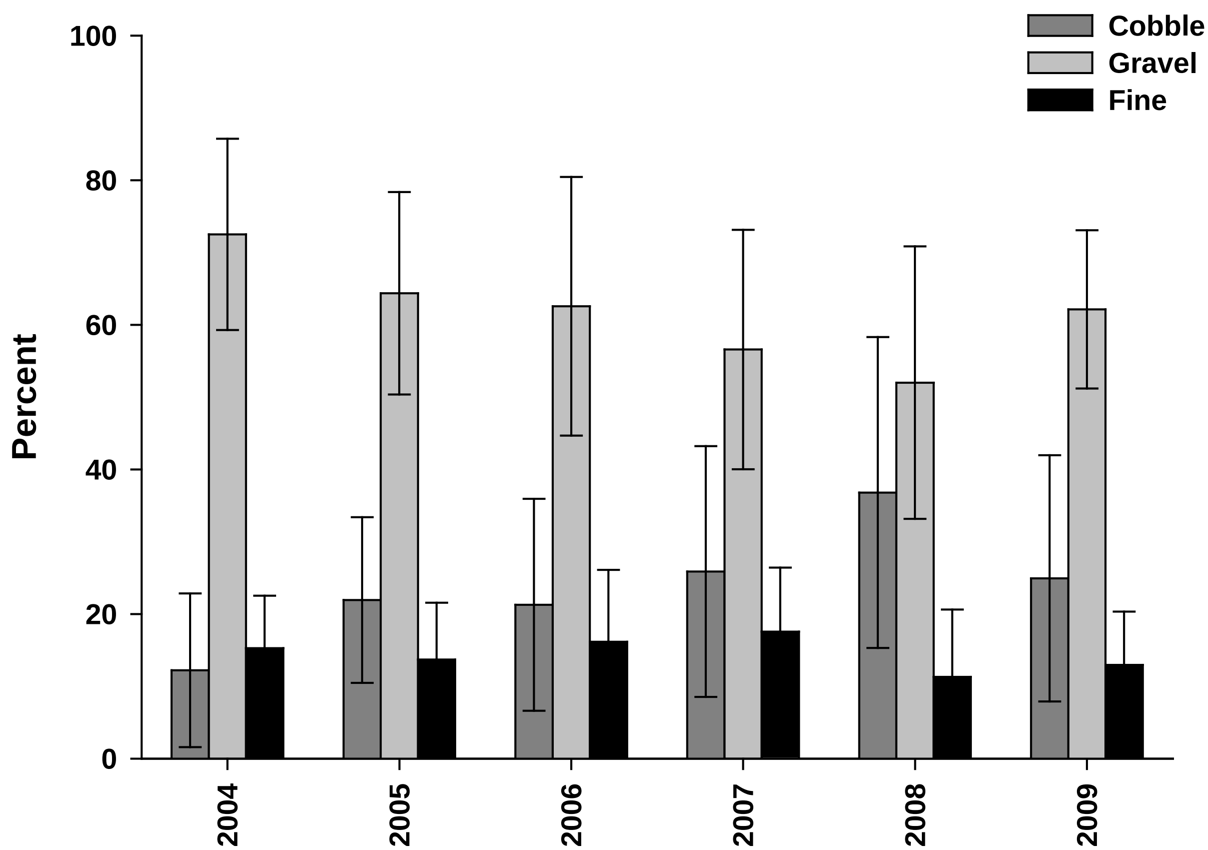

Figure 7. Mean substrate composition (± 90% CI) in Lake Pend Oreille, Idaho during summer 2004-2009. Full winter drawdowns to 625.1 msl took place during the winters of 2003-04 and 2008-09. Winter pool remained above 626.6 msl during all other winters.

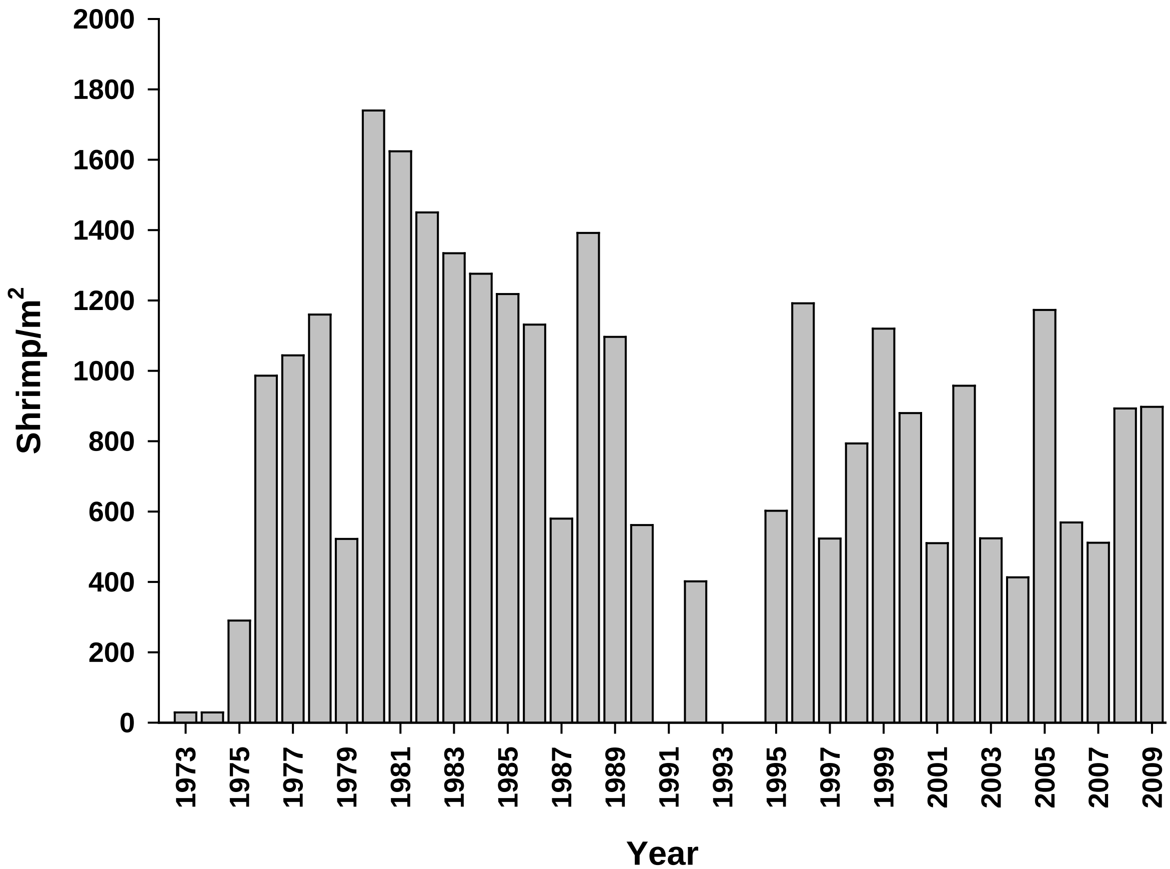

Figure 8. Annual mean density of *Mysis* shrimp in Lake Pend Oreille, Idaho from 1973-2009. Data collected before 1989 were obtained from Bowles et al. (1991), and data from 1995 and 1996 were from Chipps (1997). *Mysis* shrimp densities from 1992 and earlier were converted from Miller sampler estimates to vertical tow estimates by using the equation y = 0.5814x (Maiolie et al. 2002). Gaps in the histogram indicate no data were collected that year. *Mysis* shrimp were first introduced in 1966.

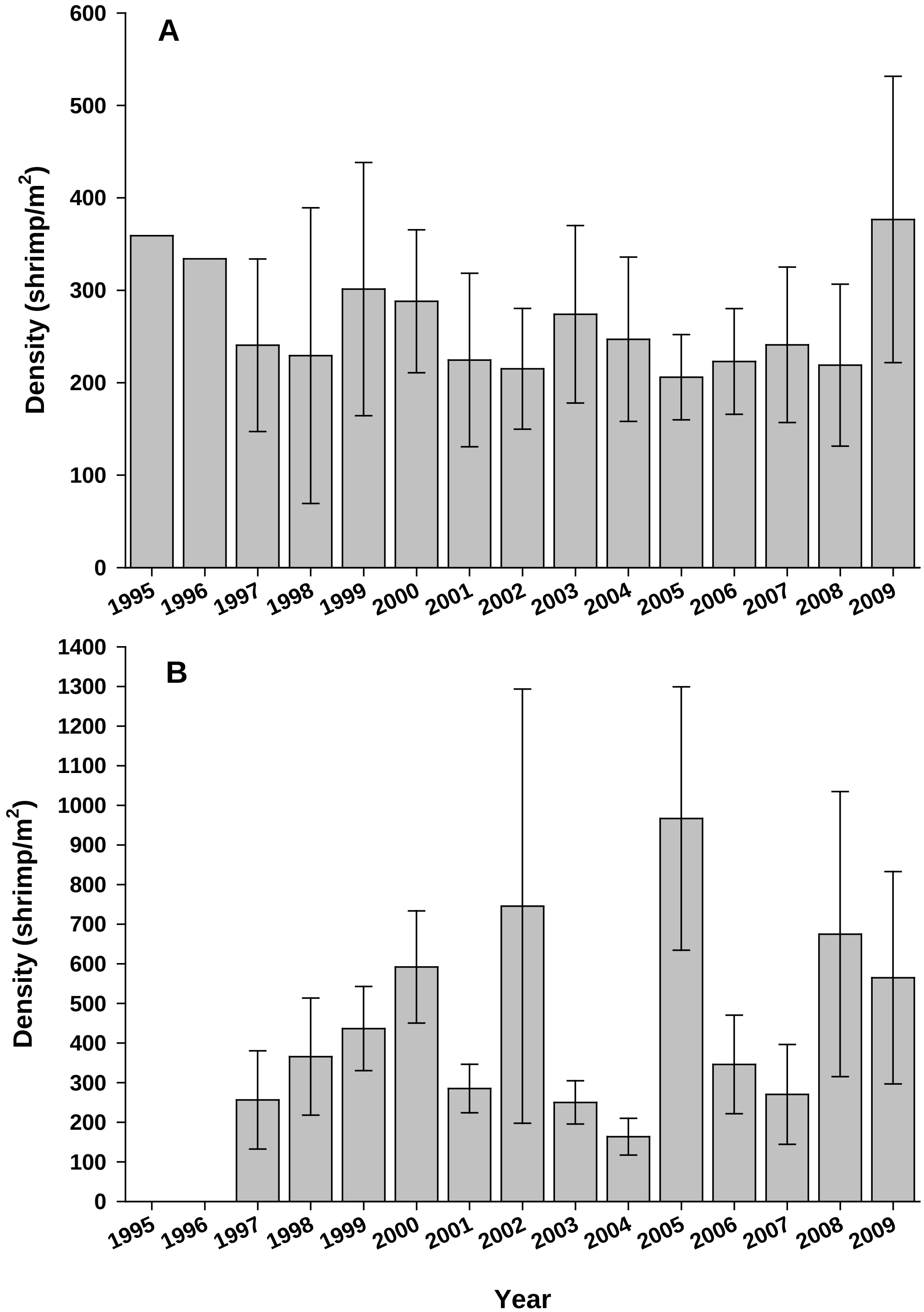

Figure 9. Density estimates of immature and adult (A) and young-of-the-year (B) *Mysis* shrimp in Lake Pend Oreille, Idaho 1995-2009. Error bounds identify 90% confidence intervals around the estimate. Immature and adult densities from 1995 and 1996 were obtained from Chipps (1997).

CHAPTER 2: LAKE TROUT RESEARCH EFFORTS

ABSTRACT

The kokanee *Oncorhynchus nerka* population in Lake Pend Oreille is currently at a record low. To increase kokanee survival in Lake Pend Oreille, we have implemented extensive predator (lake trout *Salvelinus namaycush* and rainbow trout *O. mykiss*) removal efforts, including commercial fishing and angler incentive programs. To improve lake trout removal efforts and efficiency, we used acoustic transmitters, some equipped with depth and temperature sensors, to follow mature lake trout to spawning sites. During 2009, we tagged 47 adult lake trout ranging from 590-912 mm total length (x = 689 mm) and weighing from 1.7-7.7 kg (x = 3.3 kg). From May to December, we tracked tagged lake trout at least once per month, and increased tracking frequency to at least once per week during the spawning period (September and October). We relocated each individual an average of seven times during the year. Spawning occurred from mid-September to mid-October when lake trout aggregated at the same two shoreline areas documented during the two previous years. Tagged lake trout were recorded predominately at depths around 30 m on spawning areas dominated by cobble and rubble substrates. We examined 1,869 lake trout caught in gill nets at the two spawning areas and found 1,634 (87%) were mature, confirming spawning at these two locations. Additionally, through telemetry, we determined subadult lake trout habitat use made them highly vulnerable to netting, while subadult lake trout habitat use made them vulnerable to angling. Age and growth data from lake trout captured in gill nets during the fall suggested these fish had a rapid growth rate in Lake Pend Oreille, with the oldest fish we aged at 20 years. The information gathered from these studies has helped the lake trout netting efforts, which removed 17,602 fish (14,071 kg of biomass) in 2009.

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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 in 1925. Lake trout present a threat to native and non-native salmonids, including bull trout *S. confluentus* and kokanee *Oncorhynchus nerka*. Bull trout are particularly susceptible to negative interactions with lake trout, and bull trout populations cannot be sustained after lake trout introduction without human intervention (Donald and Alger 1993; Fredenberg 2002). Nearby Priest and Flathead lakes both 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 lake trout introduction (Bowles et al. 1991; Stafford et al. 2002). Other western United States lakes have experienced similar detrimental effects to native fish populations following lake trout introductions (Martinez et al. 2009). Lake trout population modeling conducted in 2006 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. 2006). This modeling suggested that changes similar to those seen in Flathead and Priest lakes were eminent without immediate management action. This led IDFG to initiate aggressive predator removal efforts (netting and 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 lake trout populations throughout their native range, including the Great Lakes and Great Slave Lake (Keleher 1972; Healey 1978; Hansen 1999).

The goal of this study was to identify patterns in lake trout distribution that could be used to guide netting efforts. Telemetry research conducted in 2007 and 2008 identified two lake trout spawning sites in Lake Pend Oreille. Netting at these sites in 2008 yielded high numbers of mature lake trout and substantially increased the annual mortality rate on the reproductive segment of the population. We continued telemetry research in 2009 to further validate that only two lakewide spawning sites exist and to evaluate whether lake trout spawning distribution changed in response to netting. Further, telemetry research provided real-time data to guide netting during the spawning period. Additional telemetry research was conducted to assess distribution patterns of juvenile and subadult lake trout, which are targeted by netting operations but have not been part of previous telemetry studies. While telemetry was the focus of this study, we also examined lake trout population characteristics to evaluate the population response to suppression.

METHODS

Lake Trout Telemetry

Mature Lake Trout

To evaluate lake trout spawning distribution, we tracked mature lake trout using acoustic telemetry equipment. We surgically implanted acoustic transmitters (MA-16-25 and MA-TP16-25), 10 of which were equipped with depth and temperature sensors (MA-TP16-25, Lotek Wireless Inc., Newmarket, Ontario), into the abdomen of mature lake trout (see Wahl and Dux 2010 for surgical procedures). Depth sensors were able to detect depths up to 100 m. Tags measured 56 mm in length, 16 mm in diameter, and weighed 23 g in air, with an expected battery life of approximately one year. The acoustic signal operated at a frequency of 76.8 kHz.

Lake trout were captured for tag insertion during the spring using trap and gill nets operated by Hickey Brothers, LLC and by angling. To ensure sexual maturity, we tagged only lake trout greater than 600 mm (IDFG, unpublished data). We recorded total length, wet weight, and sex for each fish. We determined sex using external characteristics (i.e., head shape, vent size and shape). After surgery, we immediately released lake trout back into the lake.

We used paired, boat-mounted, omnidirectional hydrophones and a MAP 600RT P2 receiver to mobile-track tagged lake trout (Lotek Wireless Inc., Newmarket, Ontario). This system incorporated MAPHOST software, which allowed simultaneous decoding of multiple signals and used stereo hydrophones to provide direction of arrival of the transmitters' acoustic signal. The route used for tracking consisted of a path 0.4 km off the shore around the lake where water depths were at least 20 m deep, as well as a loop around the islands on the north end of the lake. We only searched shoreline areas during daylight hours because no diel differences occurred during 2007 (Schoby et al. 2009). A complete perimeter survey typically required three, 8-hour days with a boat speed of 9.5 km/hr. Additionally, a grid survey was conducted on June 10-11 to detect any fish that were located offshore. Once each tagged fish was located, we recorded transmitter code, date, time, latitude and longitude, fish depth, transmitter temperature, lake depth under fish, and lake surface temperature.

Subadult and Juvenile Lake Trout

While all ages of lake trout in Lake Pend Oreille are targeted for removal, previous telemetry research has focused on spawning adults. To better understand the distribution of juvenile and subadult lake trout and improve the removal efficiency, we surgically implanted acoustic transmitters in smaller lake trout during the spring of 2009. Lake trout were separated into juvenile (<450 mm) and subadult (450-550 mm) size classes. All subadults and five of the juvenile lake trout received the same transmitters (MA-TP16-25) used for mature lake trout. Remaining juvenile lake trout received smaller tags (MA-TP11-25) that measured 61 mm in length, 11 mm in diameter, and weighed 1 g in air, with an expected battery life of approximately seven months. All tags contained the same sensors described previously and operated at a frequency of 76.8 kHz. We used gill nets operated by Hickey Brothers, LLC to capture juvenile lake trout and angling to capture subadult lake trout for tag insertion during the spring. Surgeries and tracking events were the same as those described above.

Lake Trout Spawning Assessment

To validate suspected spawning sites identified by telemetry aggregations, gill nets set by Hickey Brothers, LLC as a part of the removal effort were also used to document the presence of ripe fish. Gill nets used to capture lake trout were 274 m long, 1.8 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 long gang that was set in a serpentine pattern that paralleled shore. Gill nets were set around dawn and pulled 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 stage of sexual maturity (i.e., ripe) were determined for a subsample of lake trout captured throughout the spawning period.

Lake Trout Population Characteristics

To evaluate age structure of the lake trout population, we removed otoliths from 10 fish in each 50 mm length class during fall netting. We imbedded otoliths in epoxy then sectioned each one across the transverse plane. For accuracy, two independent readers examined each otolith and settled differences by re-examination. To describe lake trout growth rate, we applied the von Bertalanffy growth model:

where L_t = length at time t, L_∞ = the theoretical maximum length, K = the growth coefficient, t = age in years, and t_0 = the time when length theoretically equals 0 mm.

To estimate lake trout fecundity, we removed ovaries from a subsample of female lake trout captured at the spawning sites during the fall. We only removed ovaries from females that had not yet released any eggs. To calculate fecundity for each individual, we weighed the entire ovary, weighed three samples of the ovary, and counted the number of eggs in the samples. We then calculated the number of eggs per gram for the samples and extrapolated to the entire ovary. A similar approach to estimating fecundity has previously proven effective (Trippel 1993; Murua et al. 2003; Cox 2010).

Additionally, we used recaptures of acoustic-tagged lake trout to approximate the exploitation rate of the mature segment of the lake trout population. For this analysis, we omitted lake trout that died following tagging and those with unknown dispositions at the end of February 2010.

Lake Trout Removal

IDFG contracted with Hickey Brothers, LLC to remove lake trout from Lake Pend Oreille using gill nets and deepwater trap nets during 26 weeks (14 weeks in the spring and 12 weeks in the fall) in 2009. Gill nets, described above, contained stretch mesh of 5.1-12.7 cm. The netters set primarily mesh 5.1-7.6 cm in the spring (March-June) to target juvenile lake trout and mesh 10.2-12.7 cm in the fall (August-November) to target large lake trout at spawning sites. Methodologies for setting gill nets are described above. Gill nets were either set around dawn and pulled several hours later or were set in the afternoon and pulled the following morning. Trap nets (described in detail by Peterson and Maiolie 2005) were set at locations standardized in previous years. Hickey Brothers, LLC set the trap nets during the first week of spring and fall netting and lifted the nets at least weekly.

RESULTS

Lake Trout Telemetry

Mature Lake Trout

We tagged 47 mature lake trout from March 20 to June 16, 2009, with 27 captured in the northern section and 20 captured in the southern section of Lake Pend Oreille (Figure 10). We captured and tagged 20 lake trout by trap nets, 8 by gill nets, and 19 by angling. Tagged mature lake trout averaged 689 mm total length (SE = 13, range = 590-912 mm; Figure 11) and 3.3 kg in mass (SE = 0.2, range = 1.7–7.7 kg). We tagged two lake trout <600 mm (590 and 591 mm) later in the spring because of low catch rates for larger lake trout. A complete list of tagged mature lake trout is compiled in Appendix C.

Lake trout were tracked monthly during May-August, weekly during September-October, and monthly during November-December. Lake trout were tracked for 0-272 days (median =

206 d), depending on the fate of individual fish. Two tagged lake trout either shed their tags or died by early August, as no movement occurred after August. Anglers harvested one fish in April, one in early June, and one in early July. We were unable to locate four fish after tagging, although three of these fish were eventually caught and removed at the spawning sites by the contract netters. Additionally, we were unable to locate one fish after May and two fish after early October. The contract netters harvested six acoustic-tagged fish during the spawning period. Through mobile tracking, we relocated tagged lake trout an average of seven times per individual (SE = 0.7, range = 0-16). In the fall of 2009, we tracked 32 of the remaining 37 at-large lake trout to potential spawning locations.

We successfully relocated an average of 59% of at-large lake trout per week (SE = 4, range = 38-90%). Tagged lake trout migrated away from spring capture and tagging locations by July 13-15 (Figure 12). Some lake trout arrived at the Windy Point and Bernard Beach spawning areas by mid-August (August 10-12); however, most lake trout (n = 11; 77%) were still dispersed throughout the lake. By the end of August (August 24-September 1), 18 of the 40 at-large lake trout (45%) were observed at the either the Windy Point or Bernard Beach areas in tight aggregations (Figure 13). This week marked the peak density of tagged lake trout at the Windy Point spawning area (n = 12; Figure 13), although density remained similar through September 8 (Figure 14). Afterwards, the number of tagged lake trout decreased at the Windy Point spawning area, but increased at the Bernard Beach spawning area to a peak of nine fish on September 21. By October 5-7, lake trout began to disperse throughout the lake, as 7 out of 19 relocated fish (37%) were away from the spawning sites. By October 19-21, only 3 out of 19 relocated fish (16%) remained at the spawning sites (Figure 15). Only one fish was relocated near the spawning sites in November and December (Figure 16). See Appendix D for complete weekly tracking maps. Six at-large lake trout were never relocated at a potential spawning site between September 8 and October 6 (peak spawning period); one of these fish was not relocated during the spawning period.

Across all seasons, mature lake trout carrying acoustic tags equipped with sensors used a mean water depth of 25.8 m (SE = 1.6, range = 2.0-100 m, sensor maximum; Table 10) and a mean water temperature of 7.9°C (SE = 0.3, range = 2.8-14.8°C; Table 11). Prior to spawning (May 6 to September 1), depth use averaged 21.1 m (SE = 2.7, range = 2.0-34.7 m). During spawning (September 8 to October 15), depth of tagged lake trout at Windy Point and Bernard Beach averaged 25.2 m (SE = 2.5, mode = 24.5 m) and 30.6 m (SE = 2.0, mode = 22.4), respectively (Table 10). Temperature use averaged 8.3°C (SE = 0.6) at Windy Point and 7.7°C (SE = 0.5) at Bernard Beach during spawning (Table 11). Depth and temperature use varied greatly after fish departed spawning sites (Tables 10 and 11).

Subadult and Juvenile Lake Trout

We tagged 20 juvenile lake trout from April 9-15, 2009. Ten fish were captured in the northern section (near Warren Island), and another 10 were captured in the southern section (Scenic and Idlewilde bays) of Lake Pend Oreille. Additionally, we tagged 12 subadult lake trout from May 1-22, 2009 that were captured from the pelagic zone throughout the lake. Juvenile lake trout averaged 388 mm total length (SE = 6.6, range = 350-450 mm; Figure 11) and 0.6 kg in mass (SE = 0.03, range = 0.4–0.9 kg). Subadult lake trout averaged 491 mm total length (SE = 8.3, range = 451-541 mm; Figure 11) and 0.9 kg in mass (SE = 0.06, range = 0.7-1.3 kg). Complete lists of tagged subadult and juvenile lake trout can be found in Appendix E and Appendix F, respectively.

Subadult and juvenile lake trout were tracked for 0–252 days (median = 208 d), depending on the fate of individual fish. Fourteen tagged lake trout (12 juveniles and 2 subadults) either shed their tags or died by early August, as no movement occurred after August. Anglers harvested three subadults and two juveniles from May through October. One juvenile was never relocated after release, and another was not relocated after June.

We successfully relocated an average of 59% of at-large subadult and juvenile lake trout per week (SE = 6, range = 40-100%). Subadult lake trout exhibited distribution patterns similar to the mature lake trout, but the immature individuals were dispersed more throughout the lake. Additionally, five of the eight subadult lake trout at-large at the beginning of the spawning period visited one of the two spawning sites at least once, but these fish did not show any tendency to visit the spawning site nearest to their original capture location. We relocated most juvenile fish within 4 km of their tagging location, but we did relocate some fish >15 km away from their original capture location. The largest juvenile we tagged (450 mm) visited the Bernard Beach spawning area during August, but we do not believe this individual spawned.

Across all seasons, subadult lake trout were primarily pelagic and used a mean water depth of 25.1 m (SE = 2.4, range = 2.0 to 100.0 m). These fish were often not associated with the bottom as lake depths averaged 104 m (SE = 10.0, range = 20-300 m) under these fish. Mean water depth used was similar among seasons (spring and summer = 26.8 m, SE = 4.8; spawning period = 25.7 m, SE = 2.4; late fall = 20.9 m, SE = 1.7). Mean water temperature used varied seasonally (7.3°C, 6.0°C, and 4.8°C for summer, spawning period, and post-spawn, respectively) and depended on the water temperature at 20-25 m depths. Juvenile lake trout were commonly associated with the bottom and used a mean water depth of 37.2 m (SE = 3.2, range = 4.1 to 100.0 m). Mean water depth used increased from the summer (30.0 m, SE = 3.8) through the spawning period (39.7 m, SE = 6.1) and into the late fall (46.9 m, SE = 6.8). Similarly, mean water temperature used decreased from 7.8°C (SE = 0.68) in summer to 6.3°C (SE = 0. 74) during the spawning period to 5.3°C (SE = 0.55) in the late fall.

Lake Trout Spawning Assessment

During 24 days of the lake trout spawning period (September 4-October 23), a total of 59,436 m of gill net (216.67 individual nets) were set at the Windy Point spawning site. We captured 1,335 lake trout (4.2 lake trout per 274-m net; 3.5-5.0 95% CI) and examined 1,025 for sexual maturity. Of those fish, 357 were mature females (mean TL: 717 mm, SE = 4.6, range = 517-992 mm) and 578 were mature males (mean TL: 675 mm, SE = 3.9, range = 317-1040 mm). This resulted in a sex ratio of 1.6 mature males per mature female. Length-frequency distributions of fish caught at the Windy Point spawning site are presented in Figure 17.

Additionally, during 22 days of the lake trout spawning period, a total of 33,650 m of gill net (123 individual nets) were set at the Bernard Beach spawning site. We captured 844 lake trout (4.8 lake trout per 274-m net; 3.9-5.9 95% CI) and examined 768 for sexual maturity. Of those fish, 305 were mature females (mean TL: 706 mm, SE = 4.6, range = 495-982 mm) and 394 were mature males (mean TL: 667 mm, SE = 4.1, range = 390-932 mm). This resulted in a sex ratio of 1.3 mature males per mature female. Length-frequency distributions of fish caught at the Bernard Beach spawning site are also presented in Figure 17.

Combined telemetry and netting data allowed us to better assess spawning duration. Based on mean weekly gill net catch rates and locations of acoustic-tagged lake trout, the peak of spawning activity spanned a three-week period from September 21 to October 11. During this period, catch rates of lake trout at the spawning sites were high (5-7 lake trout per net), and few acoustic-tagged lake trout were located elsewhere in the lake. Catch rates of ripe or spent females (n = 138) also peaked during this period. Although gill nets captured ripe female lake trout as early as the first week in September, catch rates were low and tagged lake trout remained distributed throughout much of the lake. Weekly catch rate of lake trout exceeded seven fish per net (274 m) from September 14 to October 4 at the Bernard Beach spawning site and six fish per net (274 m) from September 21 to October 25 at the Windy Point spawning site. A rapid emigration of lake trout away from the two spawning sites in mid- to late October signaled the end of the peak spawning period.

Lake Trout Population Characteristics

We aged 157 lake trout (226-1040 mm) that ranged in age from three to 20 years. Lake trout grew from a starting age of t_0 = 1.02 years toward their asymptotic length of L_∞ = 1177 mm at an instantaneous rate of K = 0.099/year (Figure 18).

We estimated fecundity of 107 female lake trout ranging in total length from 470 to 997 mm (= 738 mm; SE = 11.0). Median fecundity per female was 4,993 eggs (range = 1,110-19,414). The fecundity-length relationship was exponential such that fecundity roughly doubled for every 130 mm increase in total length (Figure 19).

Of the 47 mature lake trout tagged in the spring, 41 were either at-large or recaptured at the end of February 2010. Fifteen of those were recaptured (13 by the contract netters, 2 by anglers) for an exploitation rate of 37%.

Lake Trout Removal

During the spring portion of the 2009 netting effort, from March 1 to June 6, Hickey Brothers, LLC set a total of 254,843 m of gill net (929 individual nets) and captured 10,673 lake trout (6.6 lake trout per 274-m net; 6.0-7.3 95% CI). Of the lake trout caught, 10,641 were removed. Weekly catch rates ranged from 4.3 lake trout per net (2.9-6.1 95% CI) during May 12-16 to 19.8 lake trout per net (14.9-26.3 95% CI) during March 3-6. Captured lake trout ranged in size from 190-925 mm, but because the netters set primarily small mesh nets to target small lake trout, 93% of fish caught were <450 mm (Figure 20). Based on a length-weight regression developed for lake trout in Lake Pend Oreille (IDFG, unpublished data), the lake trout biomass removed during spring gill netting was 4,973 kg. From March 1 to May 30, Hickey Brothers, LLC captured 329 lake trout in trap nets (0.5 lake trout/net-night; 0.4-0.6 95% CI) of which 43 were removed. Captured lake trout ranged in size from 355-930 mm, but because trap nets capture primarily large fish, 94% were >500 mm. Based on the same length-weight regression, trap nets removed 90 kg of lake trout biomass during the spring.

In the fall portion of the 2009 netting effort, from August 31 to November 15, Hickey Brothers, LLC set a total of 135,161 m of gill net (558 individual 274-m nets) and captured 6,551 lake trout (5.6 lake trout per net 5.0-6.3 95% CI). Of the lake trout caught, 6,456 were removed. Weekly catch rates ranged from 1.9 lake trout per net (1.4-2.5 95% CI) from August 31 to September 4 to 24.1 lake trout per net (20.7-28.1 95% CI) during October 26-November 1. From September 7 to October 18, when the netters were only fishing at spawning sites, weekly catch rates ranged from 3.4 (2.2-5.1 95% CI) to 7.0 (5.2-9.3 95% CI) lake trout per net. After this point, netting targeted small lake trout, and catch rates ranged from 16.2 lake trout per net (13.3-19.6 95% CI) to 24.1 lake trout per net (20.7 to 28.7 95% CI). Captured lake trout ranged in size from 226-1040 mm (Figure 20). Based on the length-weight regression, the lake trout biomass removed during fall gill netting was 8,260 kg. Also during the fall (August 24 to

November 8), Hickey Brothers, LLC captured and removed 367 lake trout in trap nets (1.0 lake trout/net-night; 0.8-1.3 95% CI). Captured lake trout ranged in size from 322-875 mm. Based on the length-weight regression, the trap nets removed 848 kg of lake trout biomass during the fall.

DISCUSSION

Lake Trout Telemetry

Mature Lake Trout

During 2009, we observed lake trout using the spawning sites that have been identified in previous studies of lake trout behavior in Lake Pend Oreille (Schoby et al. 2009; Wahl and Dux 2010). The high proportion of acoustic-tagged lake trout that used one of these sites (86%) suggests that use of other sites is minimal. Further supporting this, no additional spawning sites were identified despite having a larger group of tagged fish with a broader capture distribution than in past years. Several tagged fish visited both spawning sites (sometimes only days apart), which suggests that lake trout can easily locate and migrate between spawning sites. Since acoustic-tagged lake trout did not aggregate in other locations, given their ability to easily visit multiple sites, this gives us more confidence that only two primary spawning sites exist. While aggregations occurred in the same locations as the past two years, they have become progressively less distinct. Gill nets set over aggregations of tagged fish likely caused fish to disperse, and continued intensive netting effort may have prevented new aggregations from forming. During 2008, aggregations would break up the day nets were set on them then slowly reform over the week if effort was moved (IDFG unpublished data). Some tagged lake trout left the spawning areas shortly after arriving, possibly due to the disturbance from the gill nets. These gill net disturbances may have acted as a deterrent to fish attempting to spawn or negatively influenced spawning success by fish that were not captured in gill nets. This distribution pattern does highlight the importance of continuing telemetry research. Determining where lake trout are most concentrated within each spawning site will be important for identifying the most productive place to set gill nets as fish shift their distribution during the spawning period. Further, it will allow us to monitor whether disturbance from netting causes fish to seek out new spawning areas.

Subadult and Juvenile Lake Trout

We had poor survival with the smaller lake trout we surgically implanted with acoustic tags. Survival of these lake trout may have been lower because of stress induced during capture (deep-water gill netting), or they may not have the ability to easily recover from the carbon dioxide used to anesthetize fish during tagging as well as the mature lake trout. Although our telemetry research of juvenile lake trout was limited, we were able to draw some conclusions from their telemetry data. Juvenile lake trout (<450 mm) were closely associated with the bottom and did not move far from their original tagging locations. Gill netting has identified areas of the lake that have high concentrations of juvenile lake trout, but we were unsure how much these fish move. Given the localized distribution of telemetered juveniles, gill netting should be able to effectively target these fish once concentrations are found. If we are able to improve survival of tagged juvenile lake trout, telemetry information from these fish may further increase our netting efficiency. Subadult lake trout (450-550 mm), which are underrepresented in both gill and trap net catches, are exploited more effectively by anglers. Telemetry data suggest these fish are mobile and occupy both pelagic and nearshore habitats, which likely makes them vulnerable to the troll fishery that comprises most angler effort on the lake. Further, subadult and mature lake trout tagged in pelagic areas of Lake Pend Oreille did not remain offshore, suggesting there is no distinct offshore population, and they should be vulnerable to nearshore netting.

Lake Trout Spawning Assessment

Although we were confident the areas in which lake trout aggregated during the past two years were spawning areas, we had limited data to confirm spawning (Schoby et al. 2009; Wahl and Dux 2010). However, the combination of three years of telemetry data and two years of intense netting at these potential spawning sites seems adequate to validate that spawning actually occurred at these sites. Further, no female lake trout captured elsewhere in the lake (i.e., trap nets in the northern portion of the lake) have ever been ripe.

In other lakes, lake trout spawning occurs over a 5-20 day period (DeRoche 1969; Gunn 1995); however, in 2007 tagged lake trout in Lake Pend Oreille remained at potential spawning sites for up to two months (Schoby et al 2009). We observed a similar pattern during 2008 (Wahl and Dux 2010) and 2009, but netting data determined the duration of active spawning lasts less than three weeks as is commonly reported (DeRoche 1969; Gunn 1995). During 2009, we documented kokanee in the stomachs of most lake trout captured at the spawning sites prior to mid-September (IDFG unpublished data). After this point, most lake trout had empty stomachs, which coincided with ripe fish first being caught. Therefore, the time lake trout spent at potential spawning sites prior to mid-September was likely related to prespawn staging.

Based on depth data from acoustic transmitters and the depth at which gill nets captured lake trout, it appears lake trout in Lake Pend Oreille spawn deeper than commonly reported for this species. During 2009, lake trout again used depths near 30 m deep. Most studies have suggested lake trout spawn in water <10 m deep (e.g., DeRoche 1969, MacLean et al. 1990, Flavelle et al. 2002). However, the results of our study are similar to those seen in Seneca Lake, New York, where spawning was observed at up to 30 m (Storr 1962), and may take place at depths of up to 44 m (Sly and Widmer 1984). In addition, Dux (2005) determined the mean depth of lake trout spawning in Lake McDonald, Montana to be 18 m. Lake Pend Oreille, although much larger, has similar bathymetry to Seneca Lake and Lake McDonald (i.e., steeply sloping shorelines). Steep shoreline slope may provide suitable substrate (i.e., free of fine sediment) at greater depth than would be expected in lakes with lesser shoreline slope.

Lake trout in Lake Pend Oreille spawned in water temperatures slightly cooler than reported elsewhere (Gunn 1995). This was similar to the mean temperature lake trout used during the previous two years. Surface water temperatures during much of the spawning period in Lake Pend Oreille (mid-September to mid-October) were higher than the 8-14°C commonly used by lake trout (Gunn 1995). Surface water temperatures in Lake Pend Oreille were above 14°C until October 14 and did not reach 8°C until December (after lake trout had vacated the two spawning sites). With water temperatures reaching the optimal range for lake trout spawning by mid-October, surface water temperatures should not have prevented lake trout from spawning in shallower water, albeit later than we estimate spawning occurred. The availability of suitable temperatures across a range of depths suggests that some other factor, such as substrate presence or quality, influences depth selection for spawning more than temperature.

Lake trout most often spawn along areas that face into the prevailing winds (Scott and Crossman 1973). However, the prevailing winds on Lake Pend Oreille come from the south, and both of the potential spawning locations were at the bottom of steep, north-facing slopes that were >750 m high. Therefore, the shoreline topography protected the lake trout spawning locations on Lake Pend Oreille from the prevailing wind. Subsurface water currents may provide cool, well-oxygenated water at the depths where spawning occurs. Additionally, many of these slopes are associated with talus slides (e.g., avalanche chutes) that provide cobble, rubble, and boulder substrates, an important characteristic of lake trout spawning habitat (Martin 1957, Scott and Crossman 1973). The spawning sites appear to be at the base of the two shoreline areas in Lake Pend Oreille with the most potential for recruitment of large substrate into the lake. As such, it is possible that substrate availability plays a larger role than fetch distance in the selection of spawning sites by lake trout in Lake Pend Oreille. In contrast, prevailing winds may not be an important site selection characteristic because spawning occurs at greater depths than in other lakes.

Despite attempts to track during only calm weather, lake conditions and fish movement patterns sometimes decreased tag detection distances and limited our success in relocating lake trout. Further, Lake Pend Oreille has a large pelagic zone, and fish are difficult to relocate if they are located offshore. A more sensitive acoustic telemetry receiver may improve relocation success and should be explored in the future. Despite some difficulties, our relocation success was high during the three years of this study, especially during spawning when fish frequent shoreline habitats.

Lake Trout Population Characteristics

Lake trout age and growth data suggested this population was made up of young individuals (<20 years). The growth rate of fish in this population has not changed since 2003-2004 (Hansen 2007). It is unlikely, despite the high-intensity of the removal efforts, to see any changes in the growth curve of long-lived fish in such a short time period. This is especially true given that the lake trout population abundance was growing exponentially until recently (Hansen 2007), and the individual growth rate we documented in 2009 was among the highest recorded for exploited lake trout populations (Healey 1978). Because individual growth is already rapid, lake trout should have less potential for a compensatory growth response as density decreases. Surprisingly, lake trout in Lake Pend Oreille have relatively low fecundity compared to other exploited systems (Healey 1978) and nearby Swan Lake, Montana (Cox 2010). We are unsure as to the reason for the lower fecundity, but should continue to monitor it for any changes as removal efforts continue.

Based on the recapture rate of mature lake trout with acoustic tags, exploitation of the mature segment of the population was lower during 2009 than during the same time period in 2008 (60%; IDFG unpublished data). However, if natural mortality of lake trout was ≥13% in 2009, (which was the case in 2006, Hansen 2007), total annual mortality (A = 50%) would be sufficient to reduce lake trout abundance (Healy 1978). With the reduced exploitation rate of mature lake trout and their broader distribution within the spawning sites, continued telemetry work is essential to guide netting, maximize exploitation of mature lake trout, and maximize the likelihood of population collapse.

Lake Trout Removal

Since the predator removal program began in 2006, 88,560 lake trout have been removed from Lake Pend Oreille. However, there has been a dramatic shift in the capture method, potentially indicative of changing lake trout age- and size-structure. In 2006, 72% of the lake trout removed were by angling, which is selective for lake trout primarily age-6 to age-9 (Hansen 2007). By 2009, this relationship had flipped to 70% of lake trout removed by netting.

Trap nets, which have proven most selective for adult lake trout (Hansen 2007), set at the same locations over the past three years have experienced a 62% and 73% reduction in catch rates in the spring and fall, respectively. This decline in catch rate suggests a decrease in the mature segment of the lake trout population. With decreased catches for angling and trap nets, gill nets, which effectively capture all lake trout ≥age-4 (Hansen 2007), have become a more important tool in the lake trout removal efforts. Gill nets have proven especially effective at capturing lake trout ≤450 mm, which were mostly unexploited until recently. Although the removal of these juvenile lake trout is important to reduce predation, a combination of gill nets, trap nets, and angling to exploit all sizes of lake trout is better than any single method at ensuring population collapse (Hansen 2007).

RECOMMENDATIONS

1. Use gillnets to remove spawning lake trout from the areas identified in 2009.

2. Maintain a lake trout exploitation rate high enough that total annual mortality is ≥50%.

3. Tag adult lake trout captured at spawning sites during the fall to better be able to determine sex, explore spawning site fidelity, and quantify alternate year spawning.

4. Continue to monitor lake trout population dynamics, especially growth, fecundity, and age structure, to determine what effects the removal efforts are having.

Table 10. Summary of depth use by season for acoustic-tagged mature lake trout in Lake Pend Oreille, 2009. Sensor maximum was 100 m.

	Depth (m)					
Season	**Mean**	**SE**	**Mode**	**Min**	**Max**	**# of records**
All (5/6–12/18)	25.8	1.6	20.4	2.0	100	77
Summer/Prespawn (5/6–9/1)	21.1	2.7	20.4	2.0	100	34
Spawning (9/8–10/15)						
Windy Pt	25.2	2.5	24.5	16.3	34.7	6
Bernard Beach	30.6	2.0	22.4	10.2	42.8	18
Nonspawning Sites	23.8	3.4	20.4	20.4	30.6	3
Winter/Post-Spawn (10/19–12/18)	27.5	2.6	32.6	12.2	44.9	15

Table 11. Summary of seasonal temperature use by acoustic-tagged mature lake trout in Lake Pend Oreille, 2009.

	Temperature (°C)					
Season	**Mean**	**SE**	**Mode**	**Min**	**Max**	**# of records**
All (5/6–12/18)	7.9	0.3	10.0	2.8	13.2	77
Summer/Prespawn (5/6–9/1)	8.7	0.4	6.8	2.8	13.2	34
Spawning (9/8–10/15)						
Windy Pt	8.3	0.6	7.6	6.8	10.0	6
Bernard Beach	7.7	0.5	6.0	4.4	11.6	19
Nonspawning Sites	7.3	1.6	N/A	4.4	10	3
Winter/Post-Spawn (10/19–12/18)	6.2	0.5	4.4	3.6	9.2	15

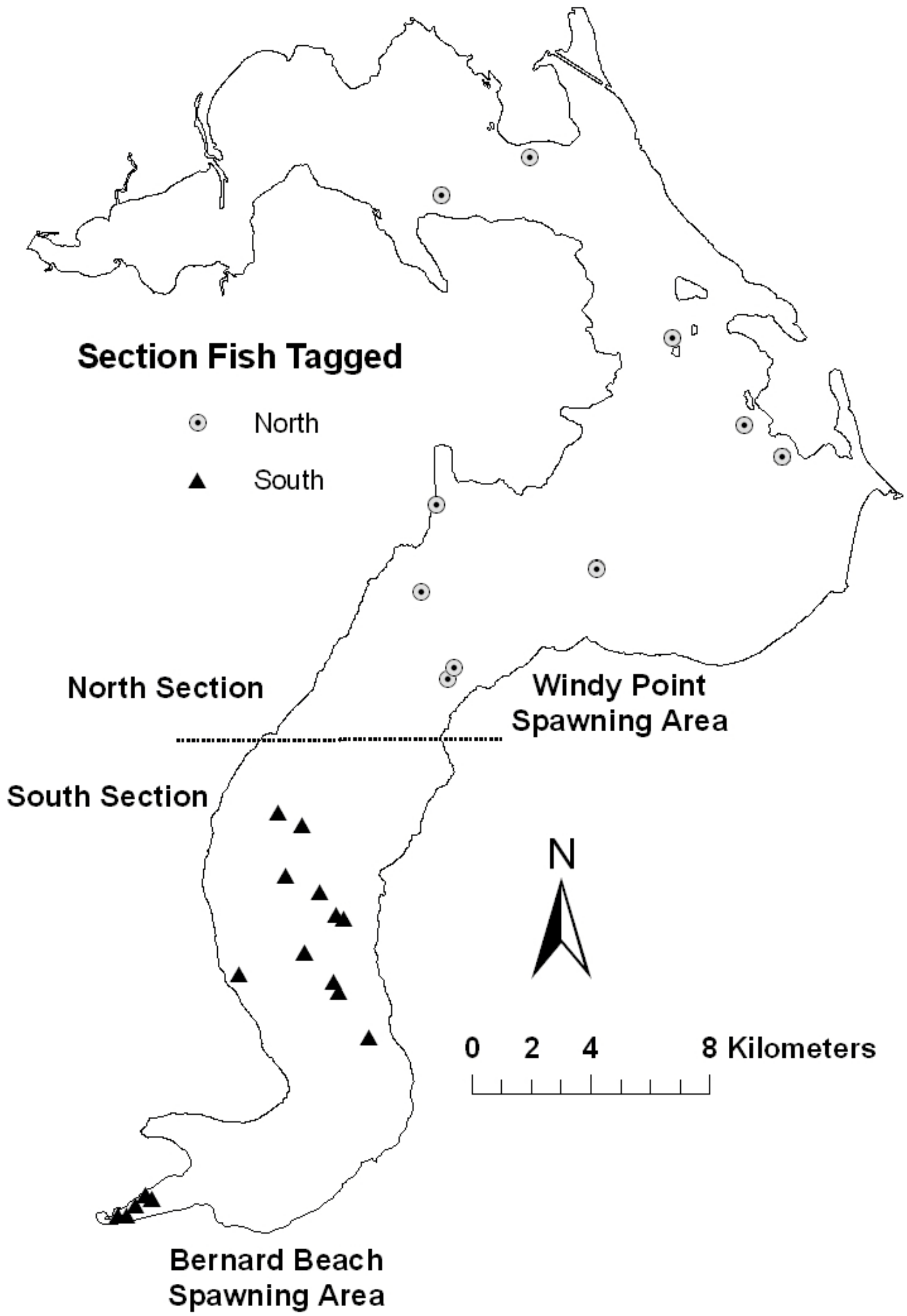

Figure 10. Location of capture and tagging of 47 mature lake trout implanted with acoustic transmitters in Lake Pend Oreille during 2009. The dotted line represents the separation between north and south portions of the lake, and the spawning sites documented in 2007 and 2008 are shown.

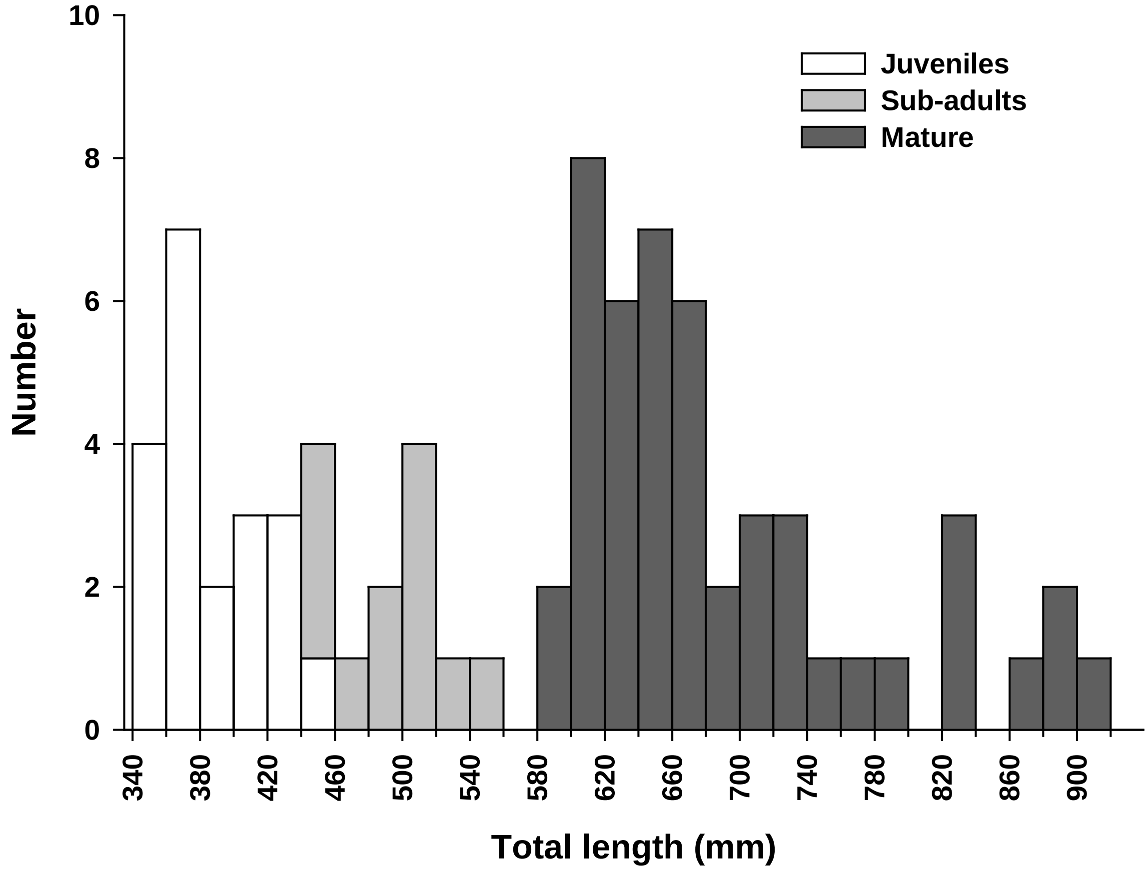

Figure 11. Length frequency of the three size classes of lake trout captured and implanted with acoustic transmitters in Lake Pend Oreille during 2009.

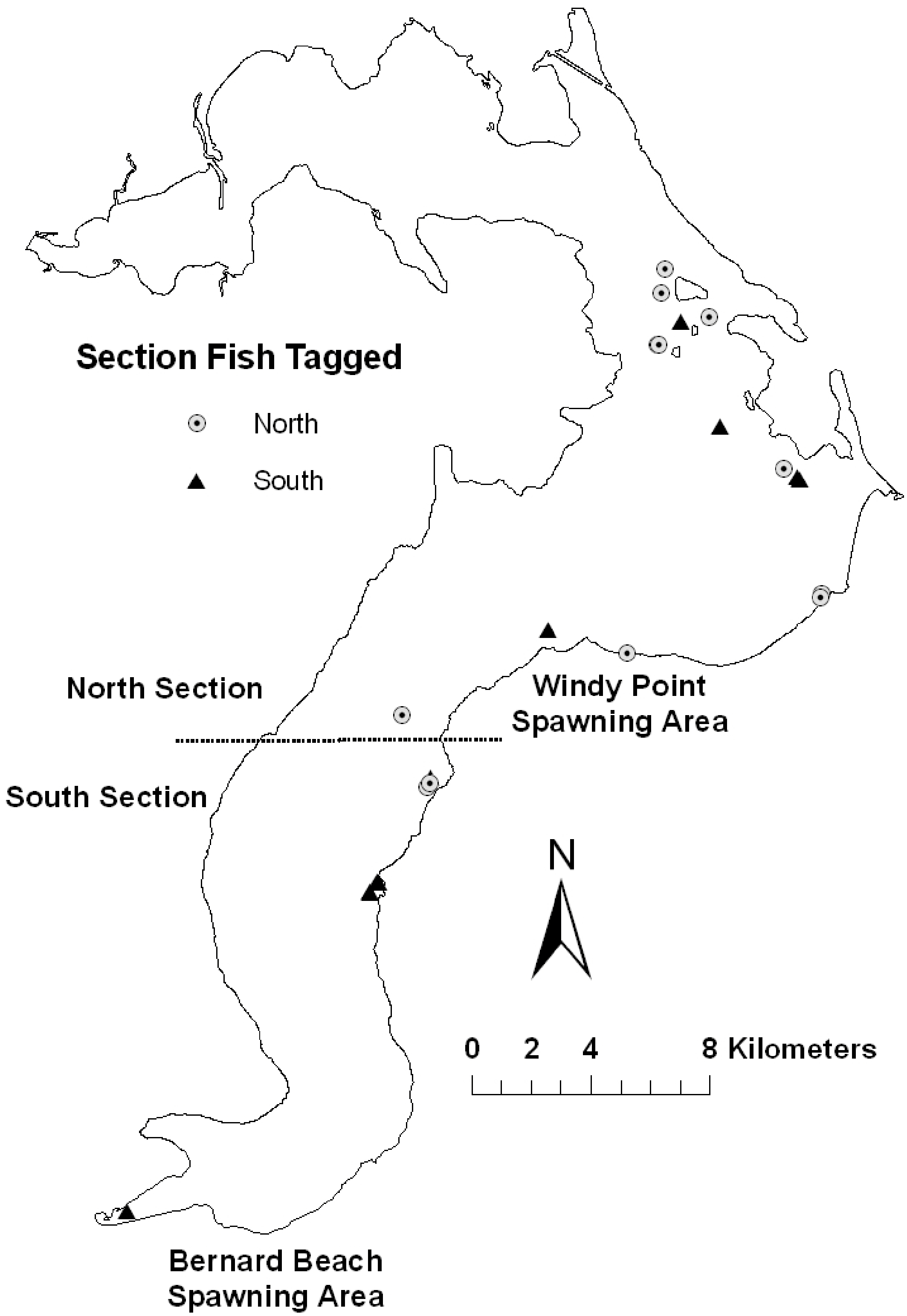

Figure 12. Location of tagged mature lake trout (n = 23) during July 13-15, 2009 in Lake Pend Oreille, Idaho.

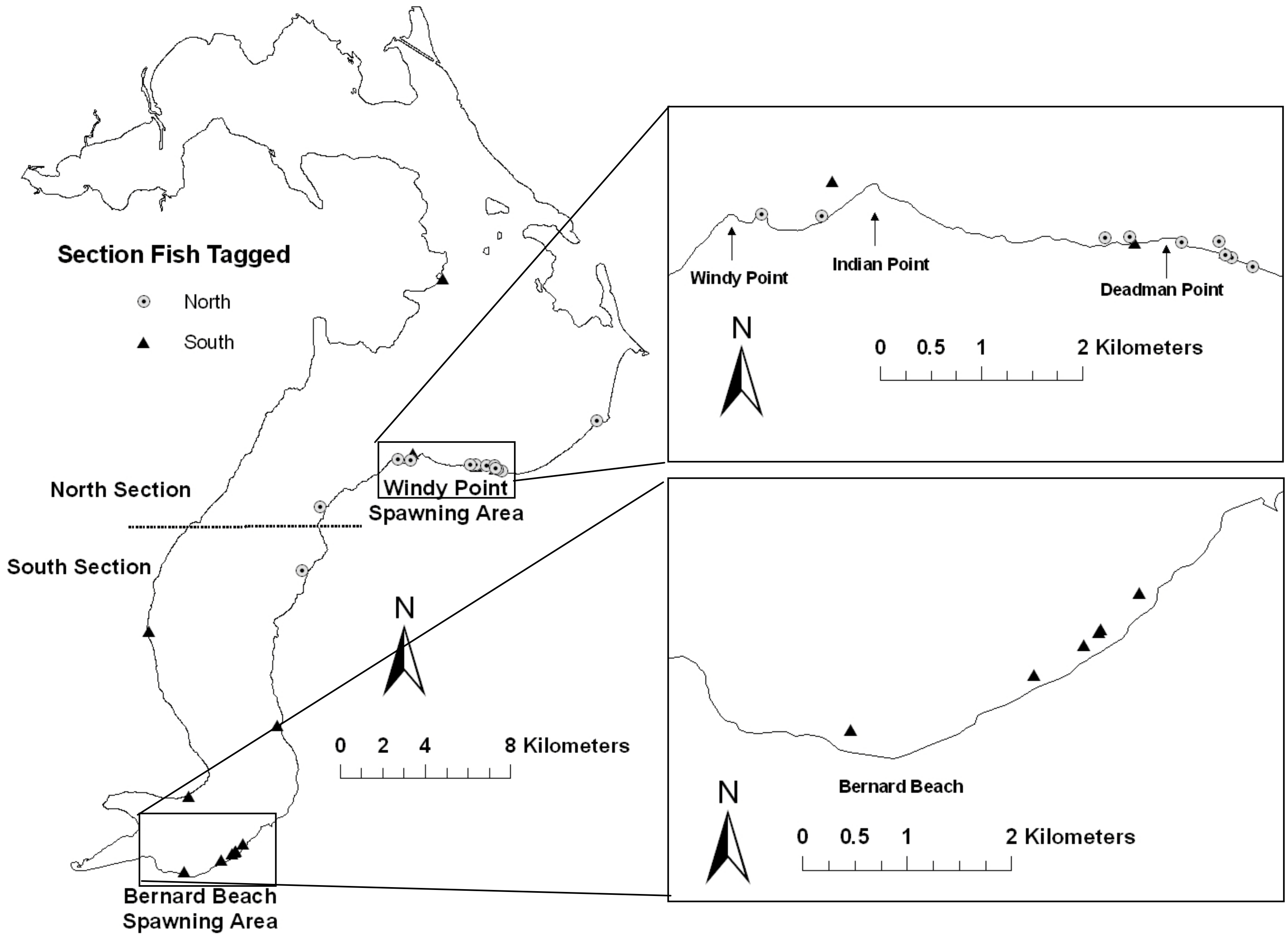

Figure 13. Location of tagged lake trout (n = 25) during August 24-September 1, 2009 in Lake Pend Oreille, Idaho.

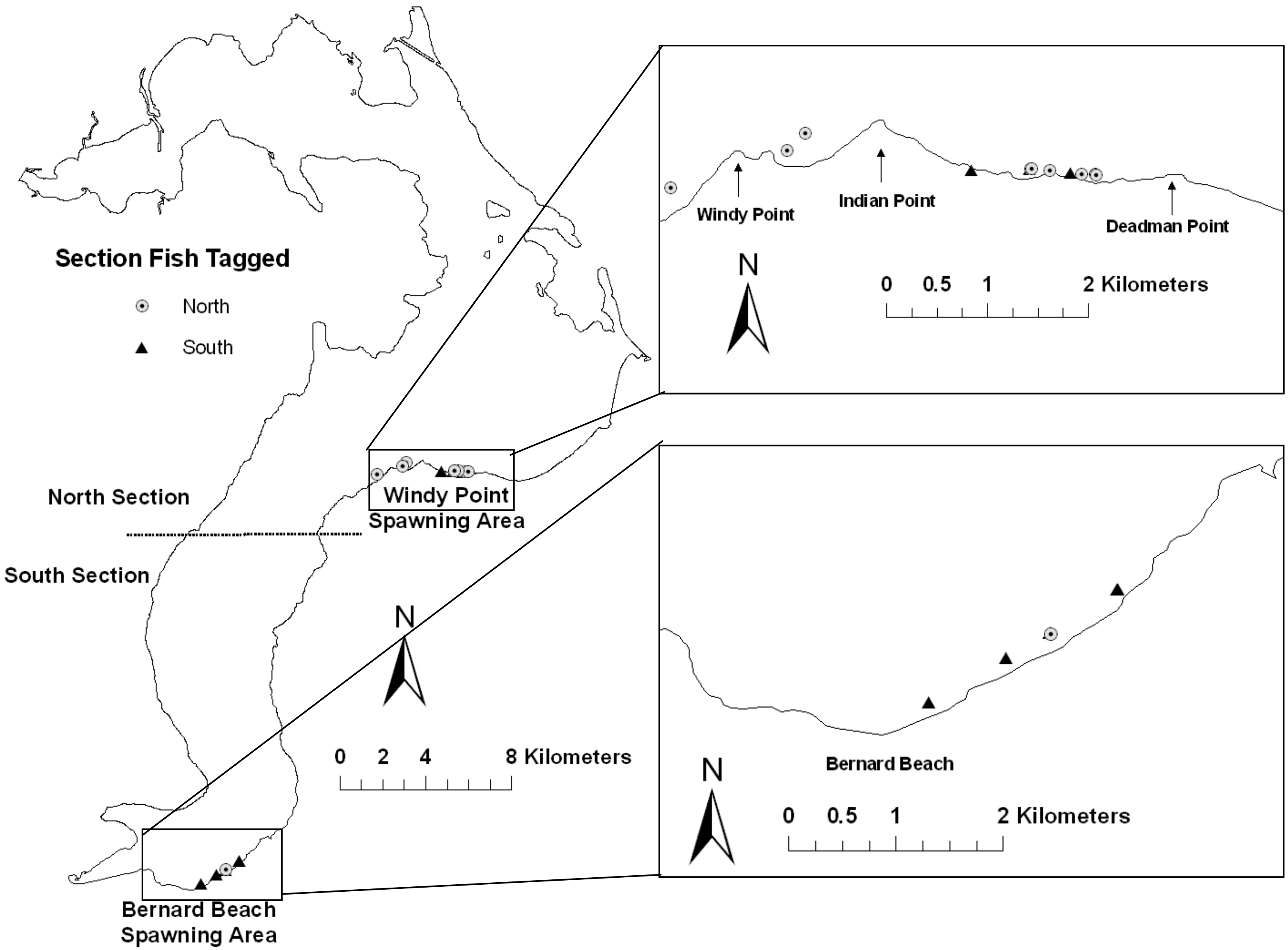

Figure 14. Location of tagged lake trout (n = 18) during September 8, 2009 in Lake Pend Oreille, Idaho.

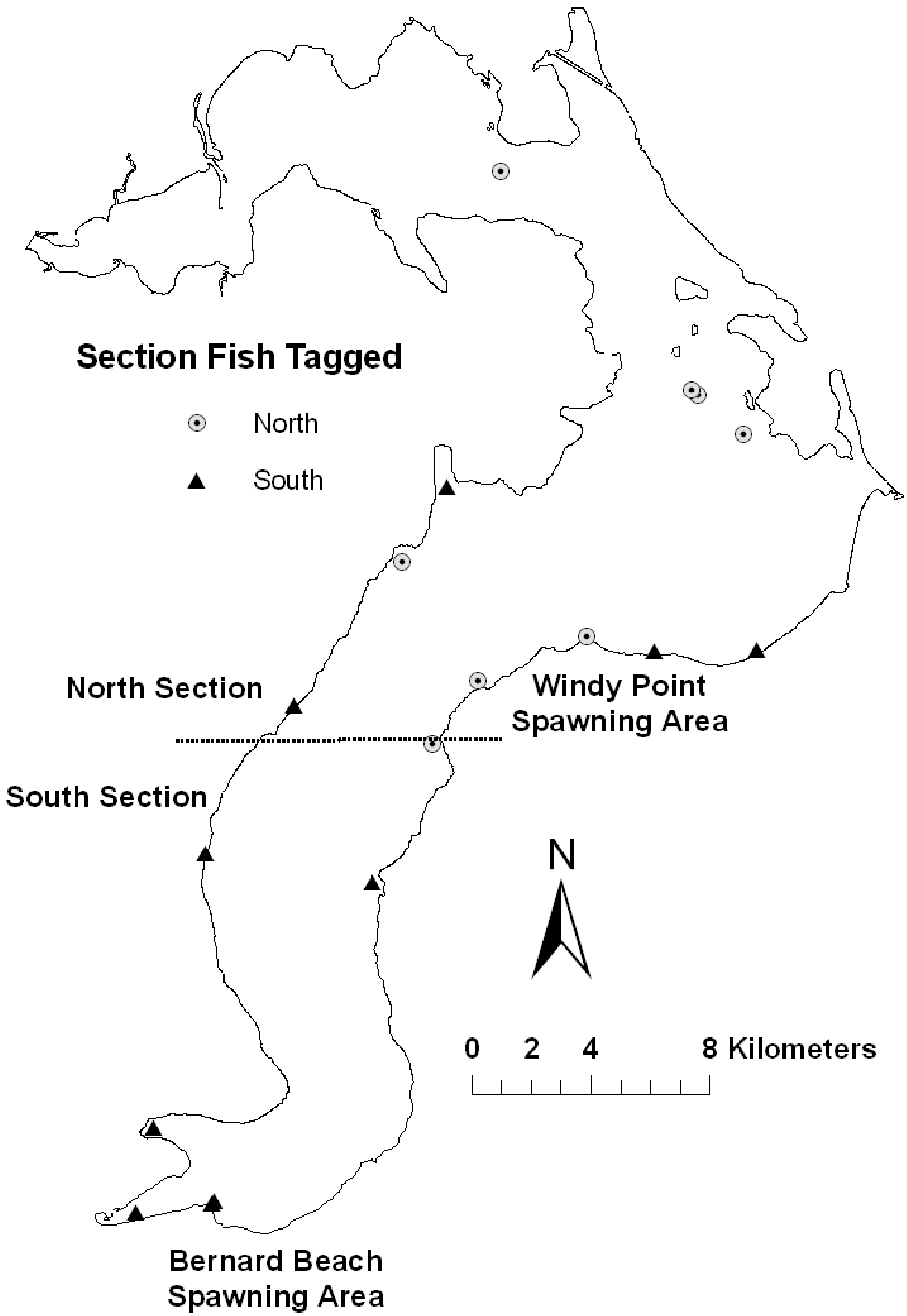

Figure 15. Location of tagged lake trout (n = 18) during October 19-21, 2009 in Lake Pend Oreille, Idaho.

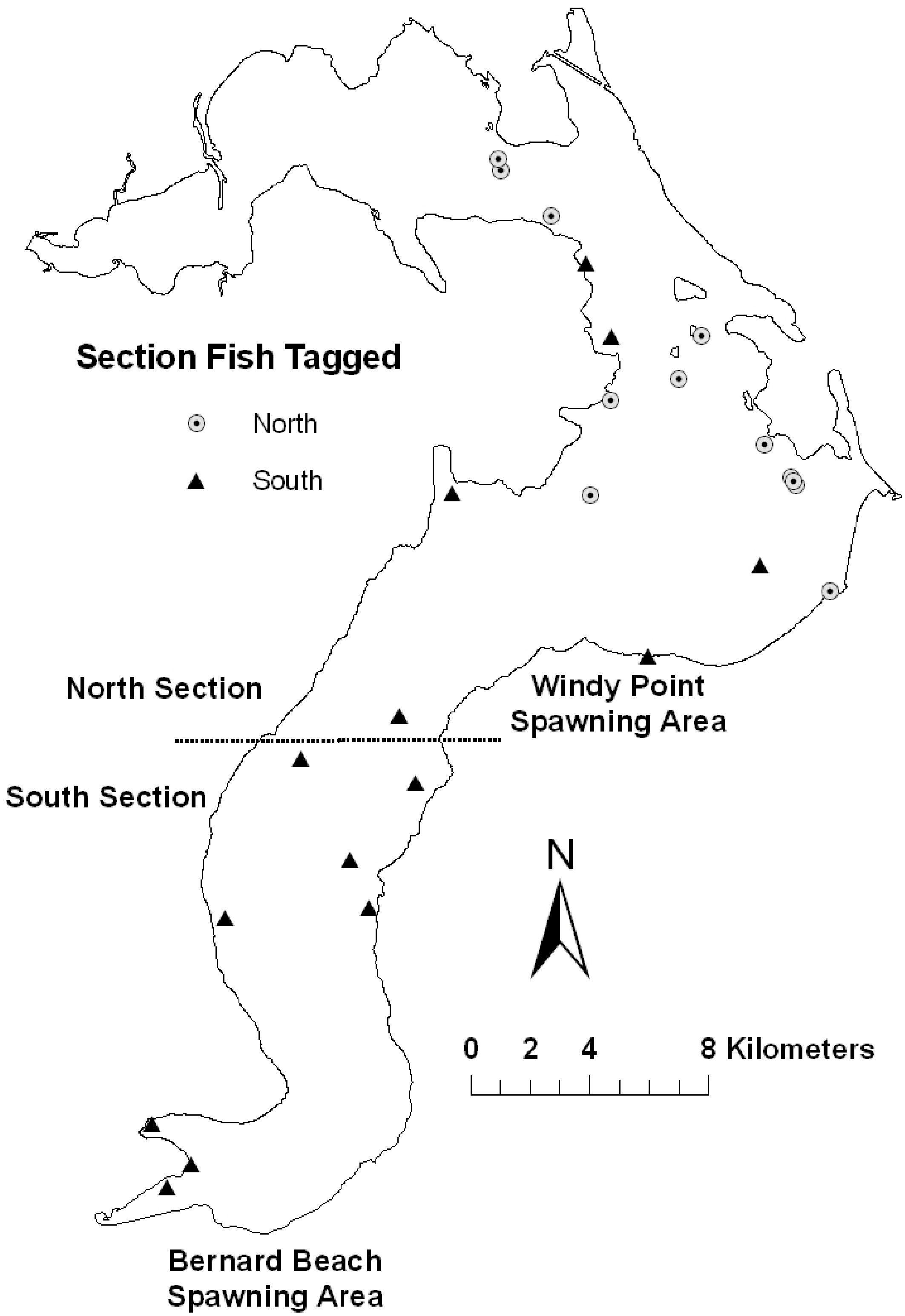

Figure 16. Location of tagged mature lake trout (n = 28) during December 16-18, 2009 in Lake Pend Oreille, Idaho.

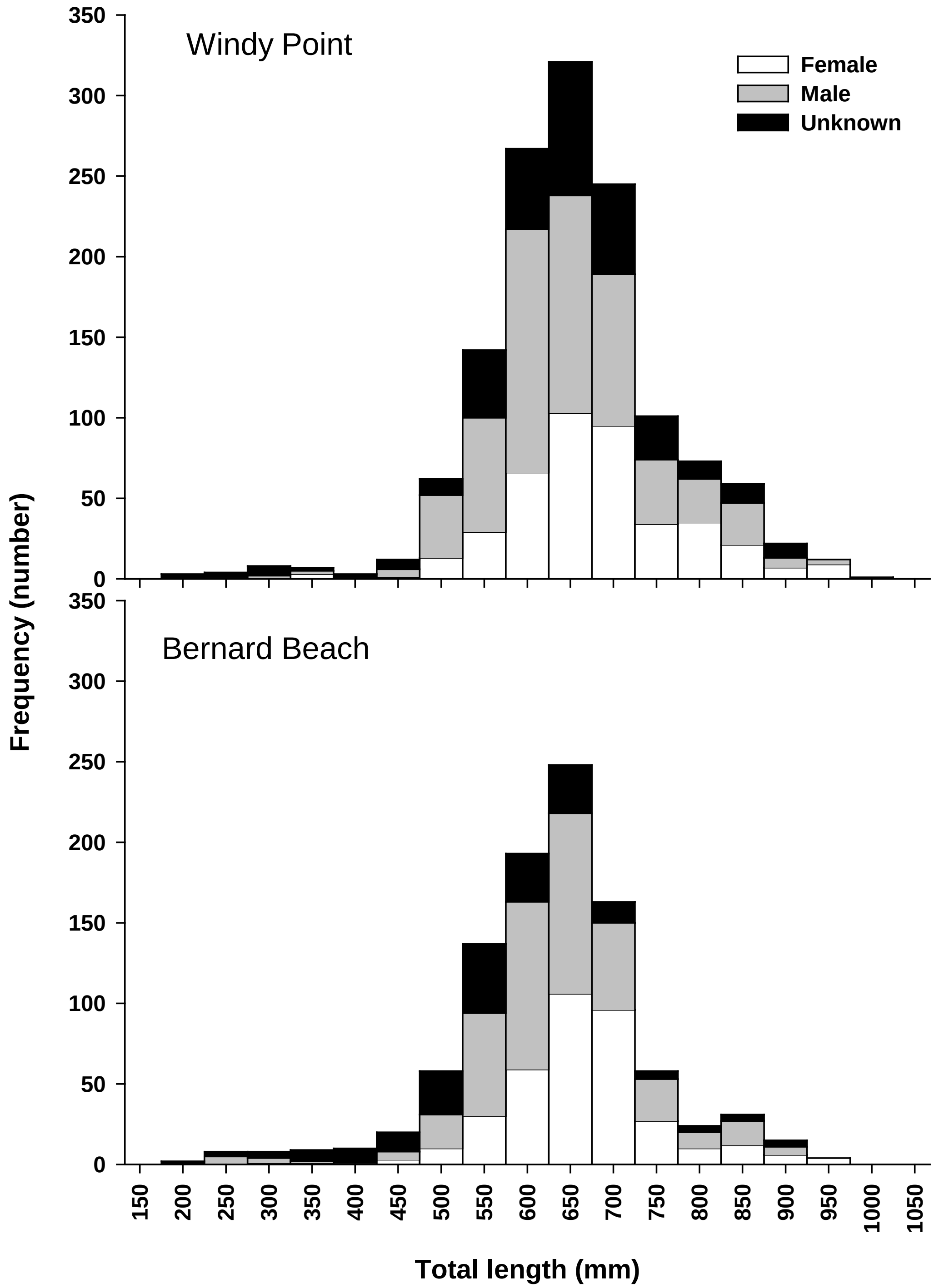

Figure 17. Length frequency histogram of lake trout captured in gillnets at Windy Point and Bernard Beach during September 4 to October 23, 2009 in Lake Pend Oreille. "Unknown" fish were not examined for sex.

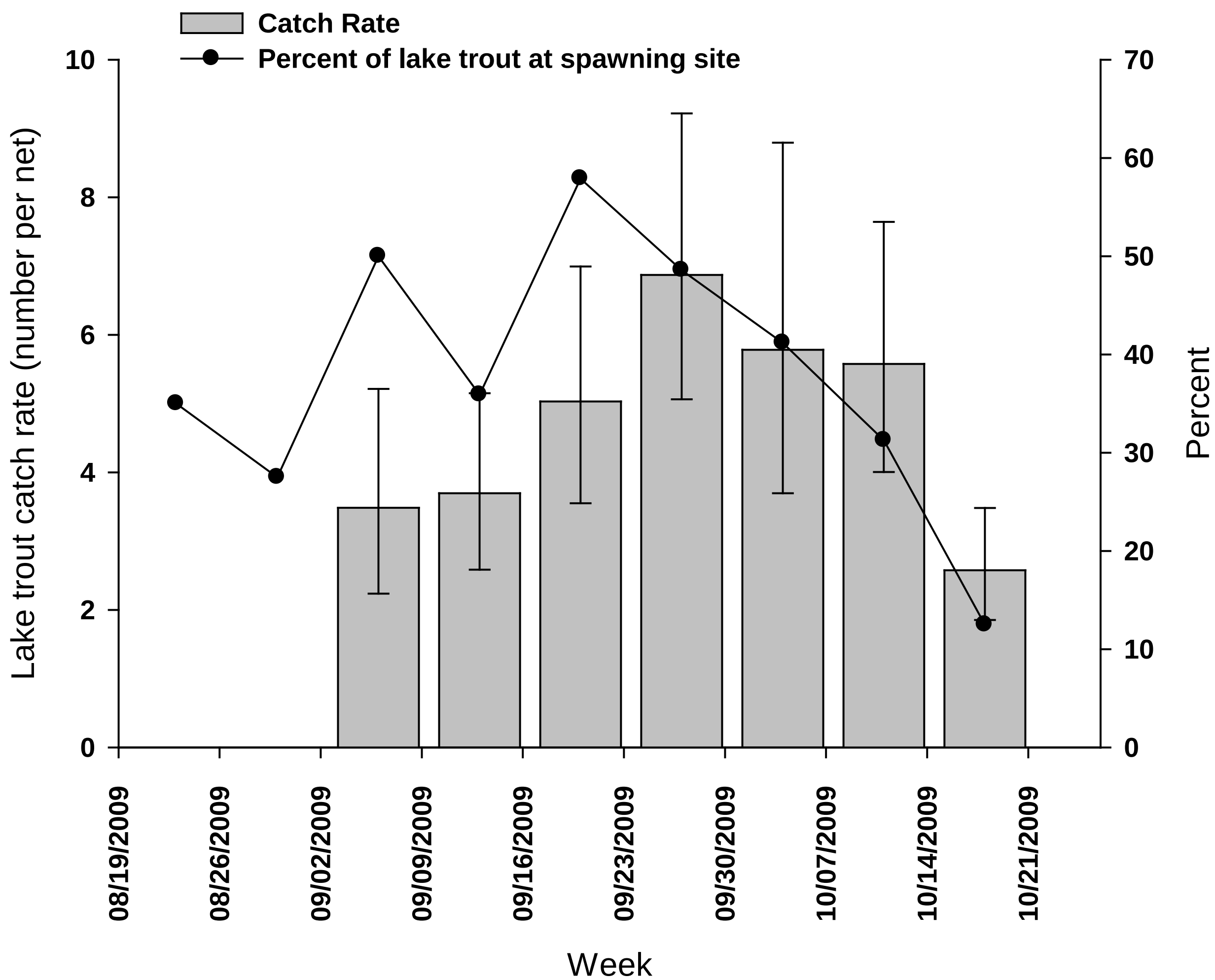

Figure 18. Mean lake trout catch rate and percent of acoustic-tagged lake trout at the spawning sites each week during fall 2009 in Lake Pend Oreille, Idaho.

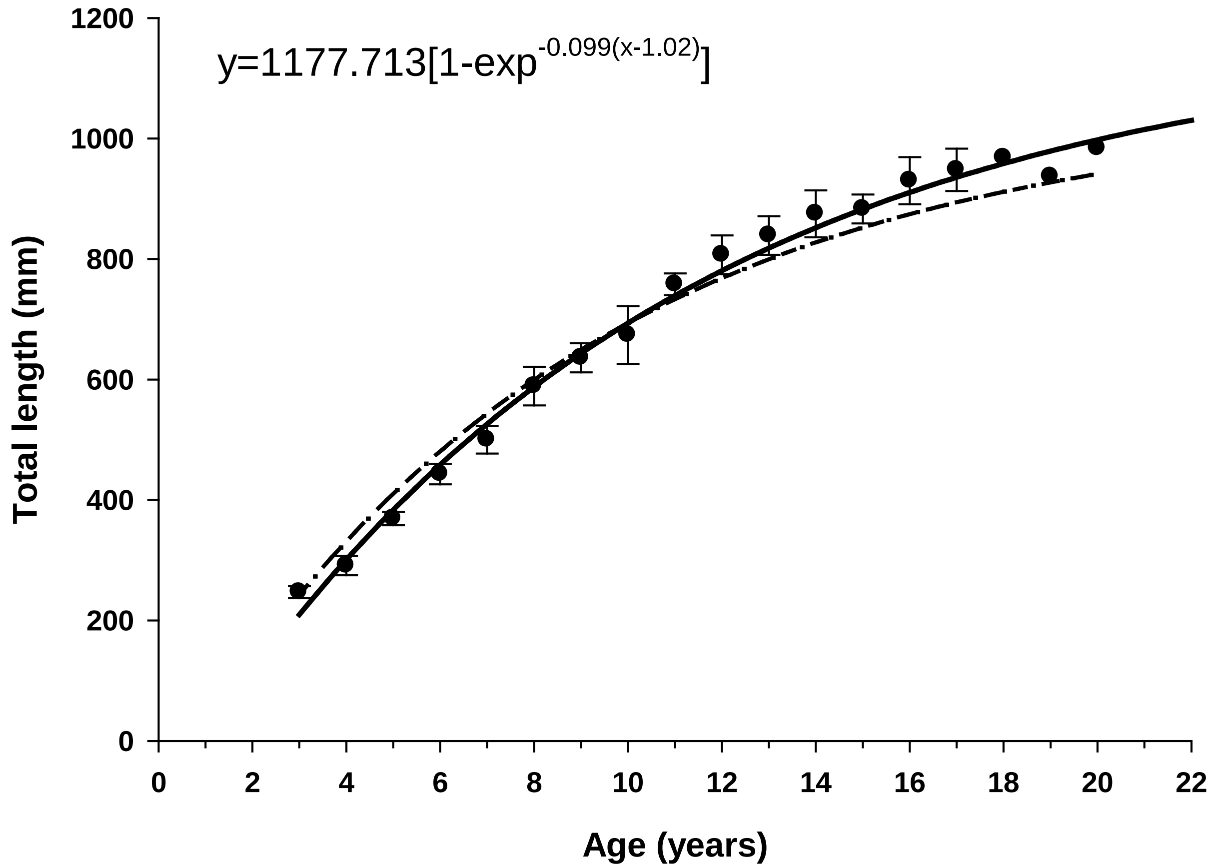

Figure 19. Mean total length-at-age with 95% confidence intervals for lake trout captured during the fall of 2009 in Lake Pend Oreille. Confidence intervals were not calculated for fish ≥18 years old because of low sample size. Growth of these fish is described by the fitted von Bertalanffy growth model (solid line), where l_t = total length at time *t*, and *t* = age in years. The dashed line represents the lake trout growth curve developed in 2004.

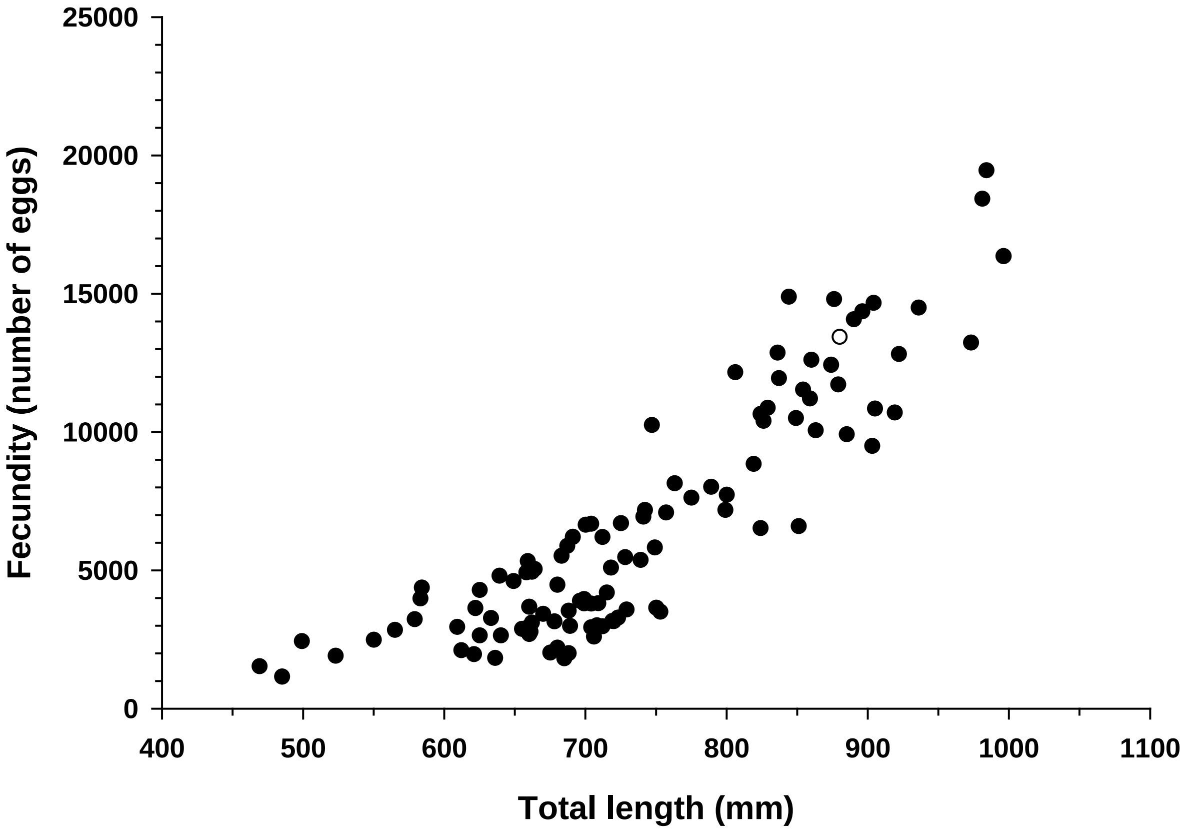

Figure 20. Fecundity-total length relationship of female lake trout captured during the fall of 2009 in Lake Pend Oreille (n = 107). These data fit a curvilinear relationship of y = $0.0000001x^{3.7237}$ (R^2 = 0.76).

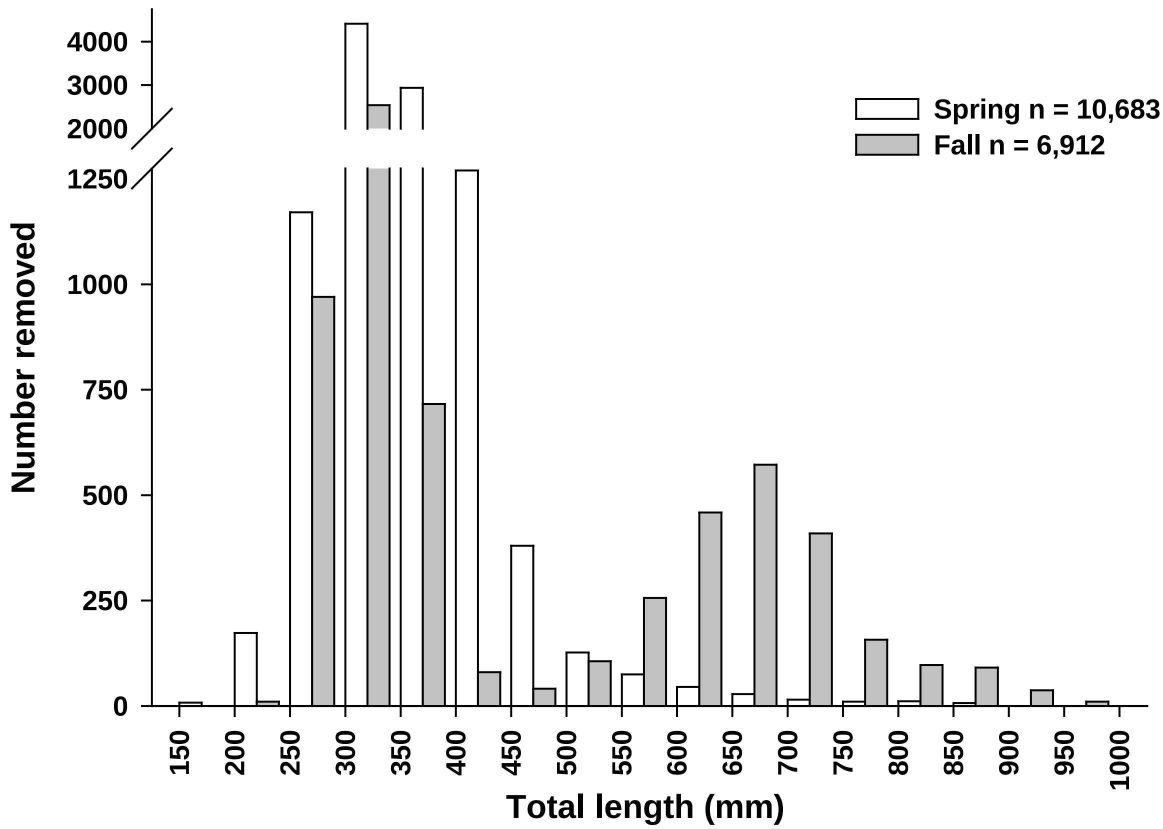

Figure 21. Length frequency histogram of lake trout removed during the spring and fall of 2009 in Lake Pend Oreille.

CHAPTER 3: RAINBOW TROUT RESEARCH

ABSTRACT

Currently, kokanee *Oncorhynchus nerka* recovery in Lake Pend Oreille is limited by predation from lake trout *Salvelinus namaycush* and rainbow trout *O. mykiss*. Population estimates conducted in 1999 and 2006 suggest the number of rainbow trout ≥406 mm was not decreasing, so Idaho Department of Fish and Game implemented a new management strategy aimed at reducing rainbow trout abundance. Unlimited harvest regulations and a $15 reward for each rainbow trout harvested were instituted as part of the Angler Incentive Program. In 2009, we initiated a study to evaluate the response of the rainbow trout population to this incentive program. During the spring, we tagged 97 rainbow trout ≥406 mm with passive integrated transponder tags to estimate population size and exploitation. These estimates will be provided in the 2010 report, after the one-year recapture period has been completed.

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INTRODUCTION

In 1999, the rainbow trout *Oncorhynchus mykiss* population, estimated at 14,607 fish ≥406 mm, consumed an estimated 125 metric tonnes (t) of kokanee *O. nerka* biomass annually (Vidergar 2000). Other salmonid predators (e.g., lake trout *Salvelinus namaycush*, bull trout *S. confluentus*) only consumed an estimated 25 t of kokanee biomass (Vidergar 2000). By 2006, the rainbow trout population had grown to 19,157 fish ≥406 mm (Maiolie et al. 2008). Although the lake trout population had also grown substantially since 1999, rainbow trout predation still threatened the kokanee population, and therefore needed to be reduced to prevent kokanee population collapse (Hansen 2007). Modeling by Hansen (2007) suggested exploitation rates in 2006 were not sufficient to reduce rainbow trout abundance. Therefore, IDFG removed all creel limits for rainbow trout, allowed anglers to fish with up to four rods, and initiated an Angler Incentive Program (AIP) that offered anglers a $15 reward per rainbow trout harvested. No monitoring of the rainbow trout population to evaluate response to these management actions has been done. As such, we conducted this research to estimate abundance and exploitation rate of rainbow trout ≥406 mm.

METHODS

To estimate rainbow trout abundance and angler exploitation in Lake Pend Oreille, a mark-recapture study was initiated during the spring of 2009. Rainbow trout received two passive integrated transponder (PIT) tags, one in each operculum. We collected and tagged rainbow trout from Lake Pend Oreille using angling during the spring of 2009. One PIT tag was implanted into the opercle musculature on each side of the fish. We only marked fish ≥406 mm; smaller fish did not appear to have sufficient opercle musculature to accommodate a PIT tag. Further, past population estimates were for rainbow trout ≥406 mm since these fish are known to primarily eat kokanee (Vidergar 2000).

To encourage harvest of rainbow trout, each fish had a dollar amount ranging from $50 to $1,000 assigned to its PIT tags (on top of the general AIP reward of $15). In order to receive payment, anglers were required to remove the head from the fish and place it into one of the AIP collection freezers, located around the lake. Heads turned in to the AIP were used as the recapture portion of the estimate. Total length was derived from a head length to total length regression from rainbow trout captured during the spring of 2006 (Maiolie et al. 2008).

The rainbow trout tagging efforts continued until June 9; therefore, any heads turned in prior to this time were excluded from the population estimate. Rainbow trout population estimates were calculated for each month after all head returns were processed and summarized.

RESULTS

A total of 97 rainbow trout were tagged between May 13 and June 9, 2009. Average size of tagged rainbow trout was 547 mm total length (SE = 9.5, range = 406-780; Figure 21). Because the one-year recapture period was not complete as of the end of this contract period (February 28, 2010), a complete analysis and discussion of these data will appear in the 2010 report. A complete list of tagged rainbow trout is compiled in Appendix G.

RECOMMENDATIONS

1. Calculate population abundance and exploitation estimates after completion of the one-year recapture period.

2. Tag rainbow trout during the spring of 2010 to estimate the abundance and exploitation rate of fish ≥406 mm and fish ≥305 mm.

ACKNOWLEDGMENTS

Many people contributed to making this study possible. Fisheries technicians Mark Duclos and Jake Hughes assisted with many of the field and laboratory activities and the maintenance of equipment. We would also like to thank the ten anglers who graciously allowed us to tag and release rainbow trout they caught. The U.S. Army Corps of Engineers made the necessary lake level changes, and the Bonneville Power Administration provided funding for this study. We wish to thank Cecilia Brown for her help in administering our BPA contract and Greg Schoby and Jim Fredericks who edited drafts of this report. The help from these people and agencies was greatly appreciated.

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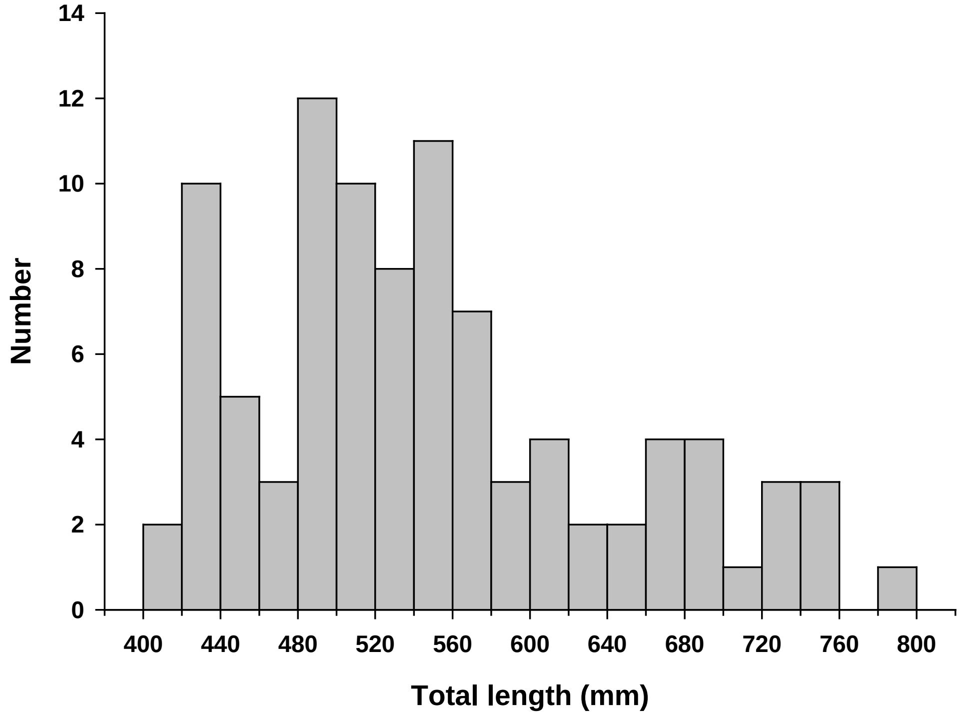


Figure 22. Length-frequency of rainbow trout tagged in Lake Pend Oreille, Idaho, during the spring of 2009 (n = 95).

APPENDICES

Appendix A. Transceiver settings for the Simrad EK 60 echo sounder used for hydroacoustic survey on Lake Pend Oreille, Idaho during 2009.

Setting	Value
Transducer: Simrad	Split Beam 120-7C
Absorption Coefficient (dB/m)	.005200
Sound Speed (m/s)	1431.5
Transmitted Power (w)	200
Two-way Beam Angle (dB re: 1 steradian)	-20.20
Transducer Gain (dB)	27.36
SA Correction (dB)	-0.60
Transmitted Pulse Length(ms)	0.256
Frequency (kHz)	120 kHz
Minor-Axis Angle Offset (degrees along)	0.00
Major- axis Angle Offset (degrees Athwart)	-0.03
Major Axis 3 dB Angle (degrees)	6.48
Minor Axis 3 dB Angle (degrees)	6.50
Athwart Angle Sensitivity	23.00
Along Angle Sensitivity	23.00
Depth of Calibration Sphere (m)	25 m
Depth of Transducer (m)	0.52
Receiver Band (kHz)	8.71
Water Temp at Mid-depth (°C)	6.2°

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

Scenic Bay

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

Farragut State Park

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

Lakeview

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

Hope/East Hope

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

Trestle Creek Area

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

Sunnyside

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

Garfield Bay

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

Camp Bay

- Entire area within confines of Camp Bay.

Fisherman's Island

- Entire Island Shoreline - not surveyed since 1978.

Anderson Point

- Not surveyed since 1978.

Appendix C. Tag number, tag date, capture location, size, and sex of mature lake trout captured and tagged with combined acoustic transmitters in Lake Pend Oreille, Idaho in 2009. Fate of fish were as of December 2009. Harvested fish were removed by either anglers (A) or the netters (N).

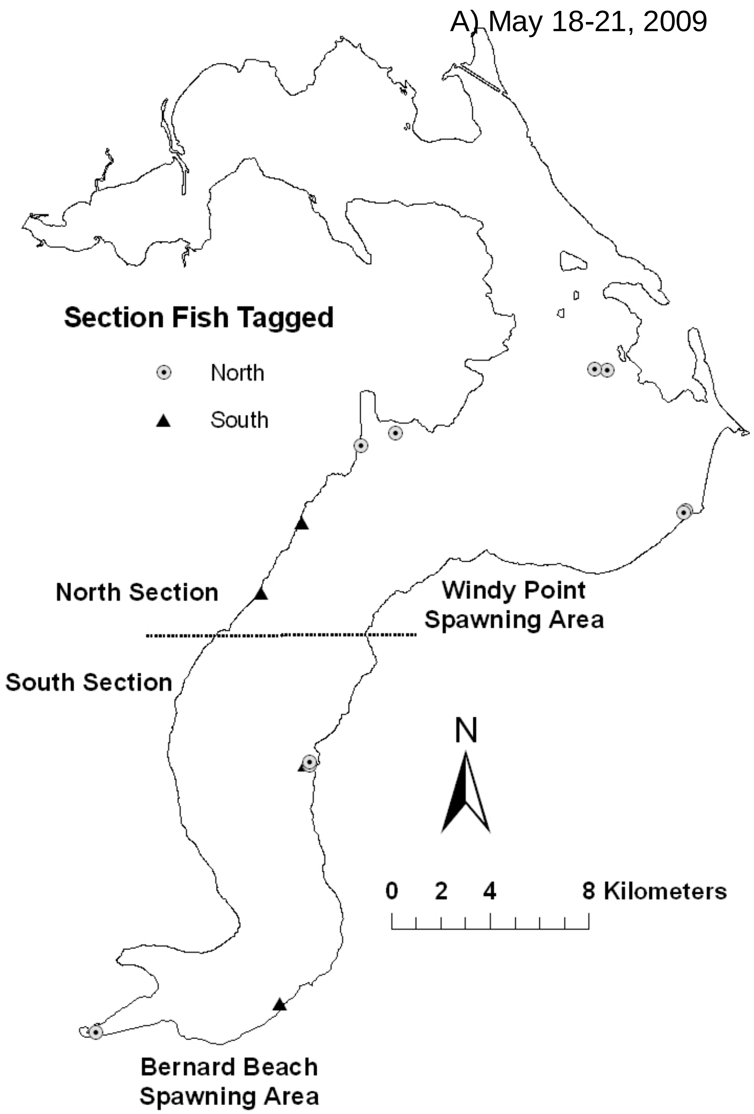
Tag ID	Date Tagged	Capture Method	Capture Location	Lake Section	Total Length (mm)	Weight (kg)	Sex	Number of Locations	Fate of Fish	Date of Last Record
1	5/13/2009	Gill Net	Idlewilde Bay	South	720	3.96	U	11	At-Large	12/16/2009
3	5/27/2009	Angling	Navy Wigwam	South	630	1.88	U	12	At-Large	12/16/2009
4	6/16/2009	Angling	Idlewilde Bay	South	665	2.95	F	9	Harvested (N)	9/28/2009
6	4/15/2009	Gill Net	Idlewilde Bay	South	625	2.70	U	11	Harvested (N)	9/23/2009
7	6/16/2009	Angling	Idlewilde Bay	South	622	2.14	U	12	At-Large	12/16/2009
8	5/26/2009	Angling	Off Cedar Creek	South	718	4.57	F	8	At-Large	12/18/2009
10	5/22/2009	Angling	Off Cedar Creek	South	738	3.5	M	0	Unknown	N/A
11	5/6/2009	Gill Net	Idlewilde Bay	South	642	2.74	M	14	At-Large	12/16/2009
12	6/3/2009	Angling	South of Garfield Bay	North	610	2.10	M	0	Harvested (N)	N/A
13	6/4/2009	Angling	Off Kilroy Bay	North	677	2.90	M	0	Harvested (N)	N/A
14	5/21/2009	Angling	North of Indian Point	North	621	2.45	U	10	At-Large	12/17/2009
15	5/27/2009	Angling	Off Evan's Landing	South	626	2.26	U	4	At-Large	12/17/2009
16	6/3/2009	Angling	Off Kilroy	North	590	1.72	M	3	Harvested (N)	9/8/2009
17	5/21/2009	Angling	North of Indian Point	North	640	2.17	U	7	At-Large	12/17/2009
18	5/21/2009	Angling	South of Whiskey Rock	South	613	2.2	U	8	At-Large	12/17/2009
19	3/27/2009	Trap Net	Sunnyside	North	821	5.48	M	1	Harvested (A)	4/1/2009
19[A]	5/4/2009	Trap Net	Sheepherder Point	North	610	1.9	M	0	Harvested (N)	N/A
20	5/22/2009	Angling	Maiden Rock	South	825	6.05	F	4	At-Large	12/18/2009
21	4/30/2009	Gill Net	Garfield Bay	North	647	2.38	U	1	Harvested (A)	5/21/2009
23	5/21/2009	Angling	South of Whiskey Rock	South	605	1.9	U	4	At-Large	12/16/2009
24	4/1/2009	Trap Net	Sheepherder Point	North	882	7.52	F	11	At-Large	12/17/2009
25	4/1/2009	Trap Net	Bottle Bay	North	779	4.98	M	5	At-Large	12/17/2009
26	3/27/2009	Trap Net	Pearl Island	North	866	7.10	F	15	At-Large	12/17/2009
27	3/27/2009	Trap Net	Bottle Bay	North	750	3.70	U	4	Unknown	10/7/2009
28	3/27/2009	Trap Net	Pearl Island	North	718	3.68	F	6	Harvested (N)	10/5/2009
29	3/27/2009	Trap Net	Sheepherder Point	North	882	5.80	F	13	At-Large	12/17/2009
30	3/27/2009	Trap Net	Mamaloose Island	North	912	7.65	F	12	At-Large	12/17/2009
31	3/20/2009	Trap Net	Pearl Island	North	673	3.22	F	16	At-Large	12/17/2009
32	3/20/2009	Trap Net	Bottle Bay	North	659	2.72	F	8	At-Large	12/17/2009
33	3/27/2009	Trap Net	Sheepherder Point	North	705	3.10	F	8	At-Large	12/17/2009
34	3.27/2009	Trap Net	Sheepherder Point	North	618	2.26	F	3	Unknown	5/20/2009
35	3/27/2009	Trap Net	Thompson Point	North	685	2.56	M	7	At-Large	12/16/2009
37	3/27/2009	Trap Net	Sheepherder Point	North	645	2.32	U	12	At-Large	12/17/2009
38	3/20/2009	Trap Net	Thompson Point	North	658	2.14	M	2	Dead	5/20/2009
39	3/20/2009	Trap Net	Bottle Bay	North	685	3.38	F	15	At-Large	12/17/2009
40	5/29/2009	Angling	Off Maiden Rock	South	677	2.77	M	5	At-Large	12/16/2009

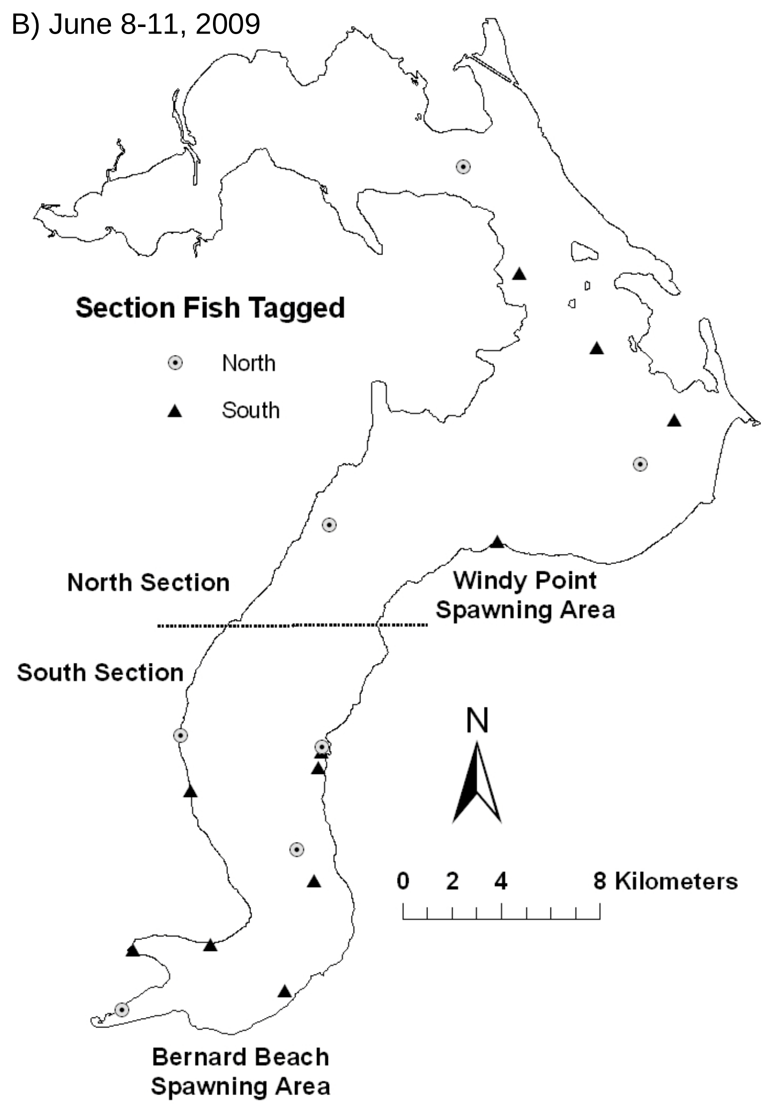
Appendix C. Continue.

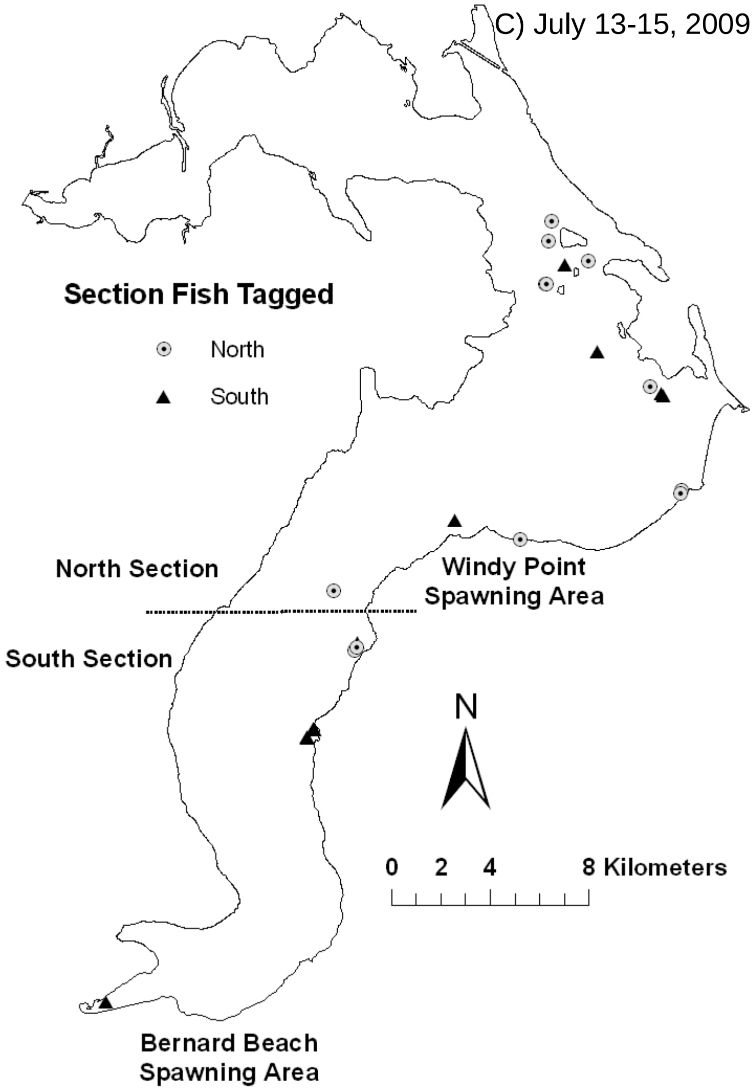
Tag ID	Date Tagged	Capture Method	Capture Location	Lake Section	Total Length (mm)	Weight (kg)	Sex	Number of Locations	Fate of Fish	Date of Last Record
38200	5/4/2009	Trap Net	Bottle Bay	North	830	5.84	U	7	Unknown	10/6/2009
38800	4/30/2009	Gill Net	Garfield Bay	North	678	3.08	U	0	Dead	N/A
38900	5/13/2009	Angling	South of Whiskey Rock	South	615	2.15	M	7	Harvested (N)	9/14/2009
39200	5/20/2009	Angling	South of Whiskey Rock	South	591	1.8	M	7	Harvested (N)	9/23/2009
39400	5/20/2009	Angling	South of Whiskey Rock	South	625	2.2	U	13	At-Large	12/18/2009
39600	4/14/2009	Gill Net	Idlewilde Bay	South	675	3.14	U	8	At-Large	12/16/2009
39800	5/4/2009	Trap Net	Mamaloose Island	North	722	3.34	U	9	At-Large	12/17/2009
40300	5/4/2009	Trap Net	Sheepherder Point	North	600	2.06	U	6	At-Large	12/16/2009
40400	5/6/2009	Gill Net	Idlewilde Bay	South	780	4.40	M	1	Harvested (A)	5/20/2009
40400[A]	6/9/2009	Angling	Off Cedar Creek	South	648	2.23	M	7	At-Large	12/16/2009
40500	5/6/2009	Gill Net	Idlewilde Bay	South	600	2.00	M	16	At-Large	12/17/2009

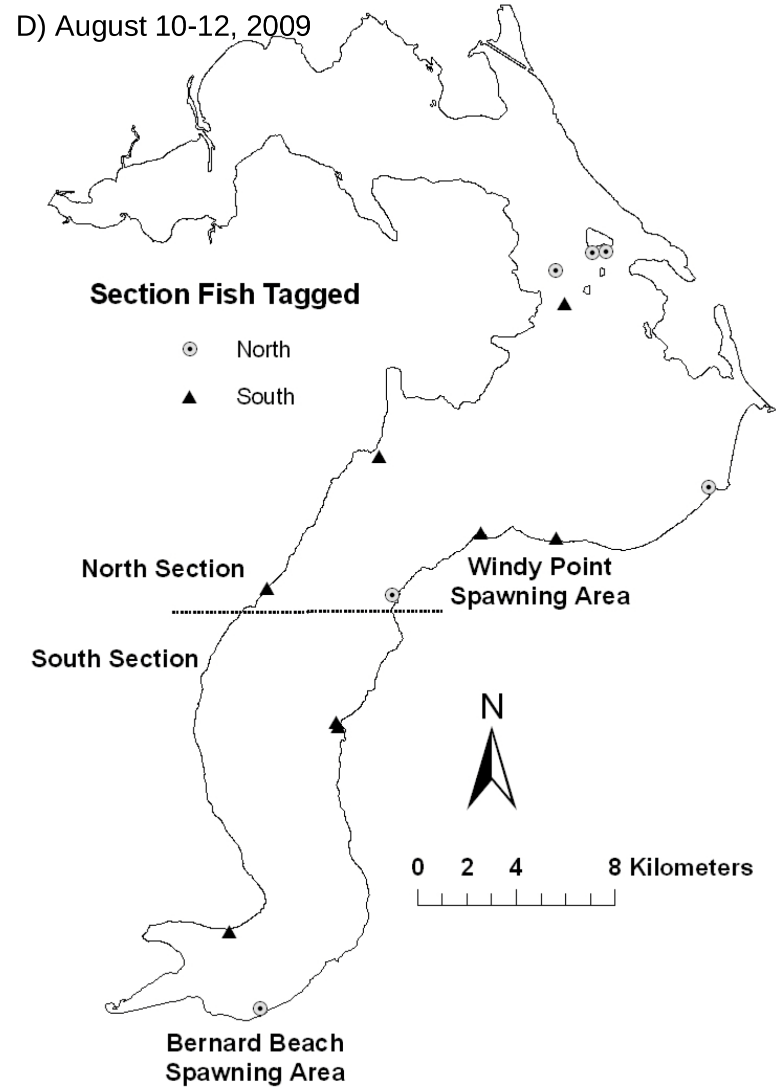
[A] This tag was used in a new fish after the original fish was harvested by an angler.

Appendix D. Telemetry locations of mature lake trout from May 18 to December 18, 2009 in Lake Pend Oreille. Only one location is shown for each fish during a tracking event.

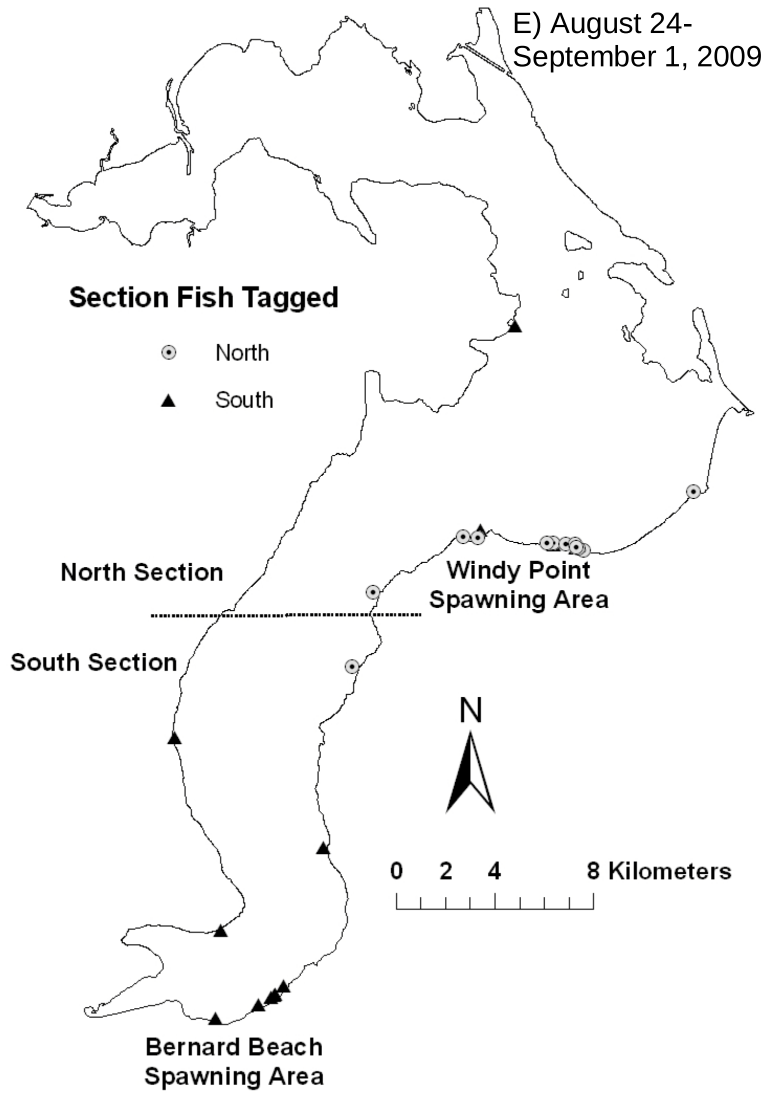


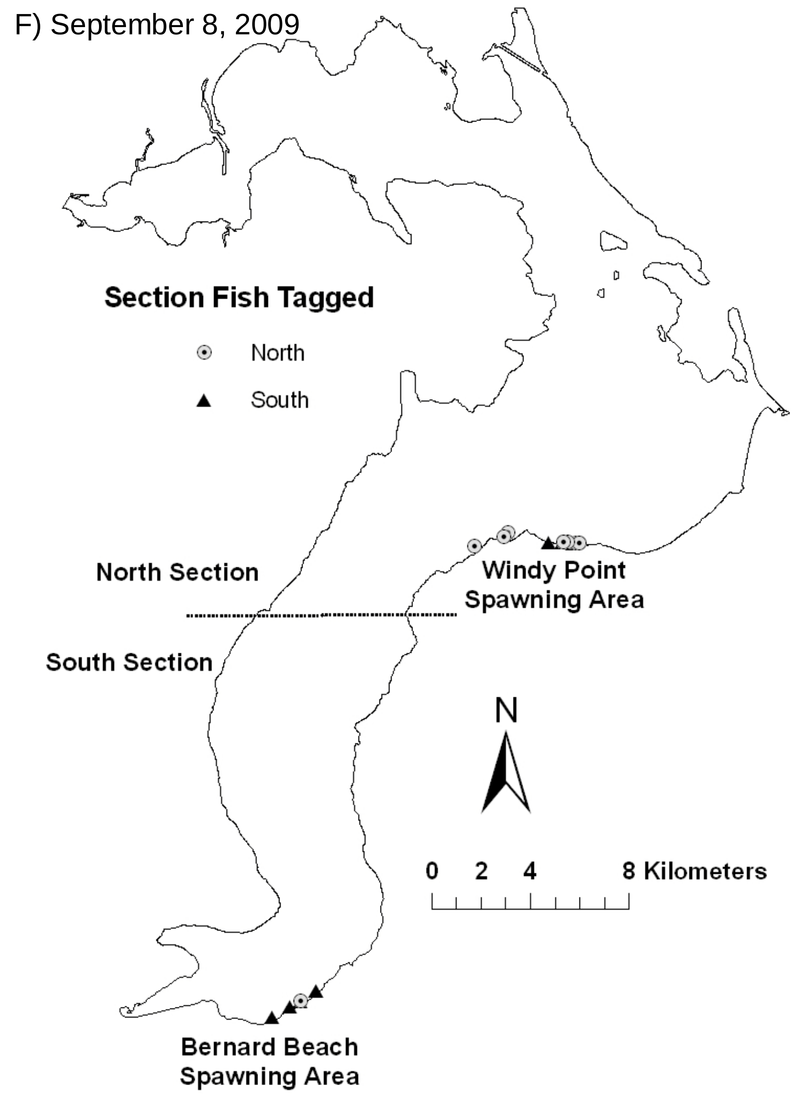


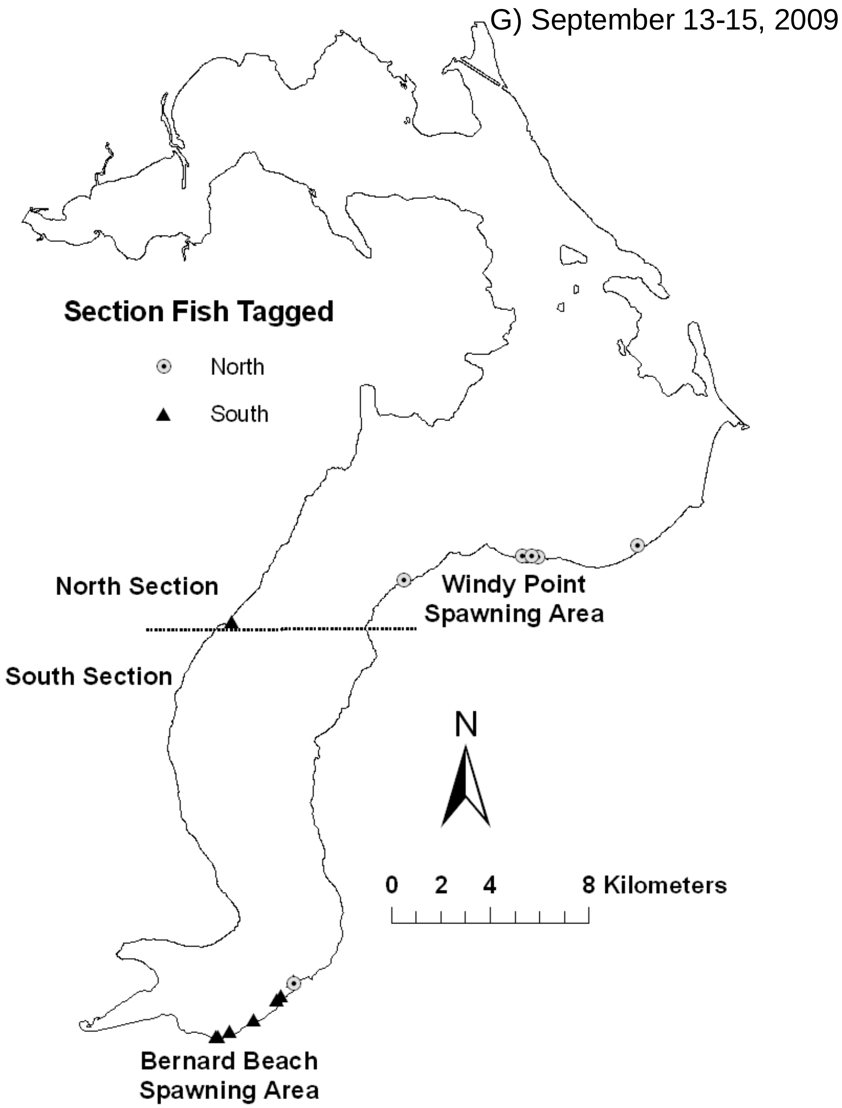

C) July 13-15, 2009
Section Fish Tagged
North
South
North Section
South Section
Windy Point
Spawning Area
N
0 2 4 8 Kilometers
Bernard Beach
Spawning Area

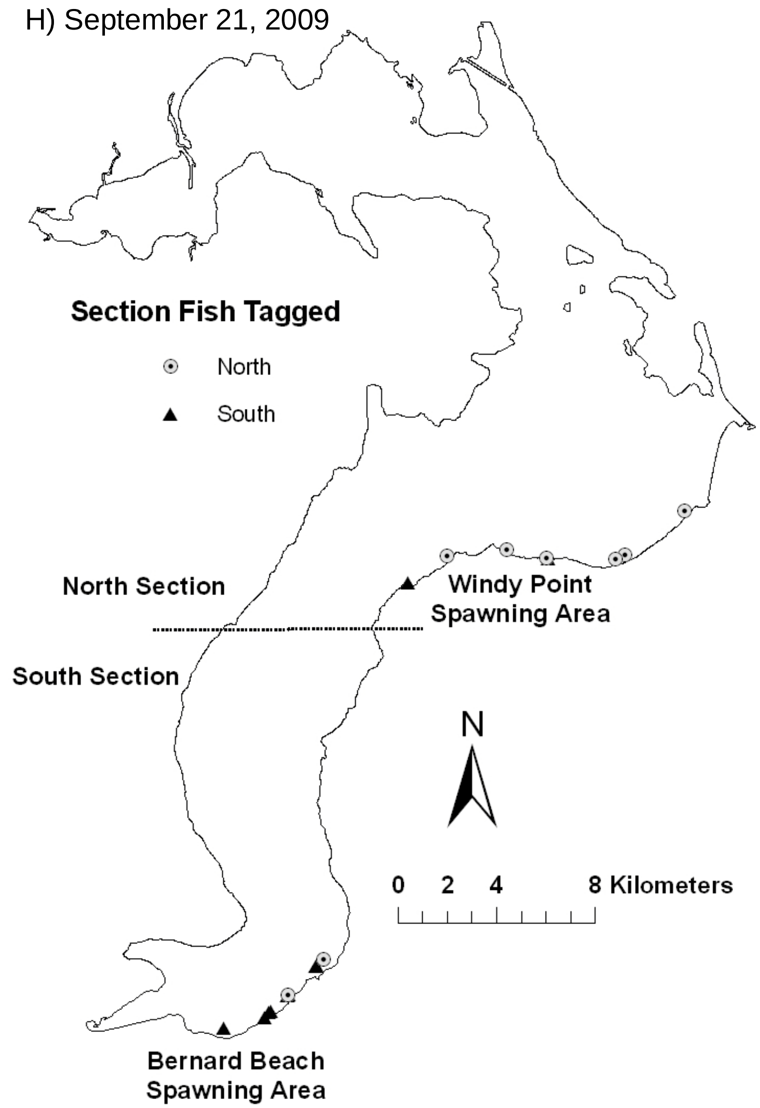

D) August 10-12, 2009
Section Fish Tagged
North
South
North Section
South Section
Windy Point
Spawning Area
N
0 2 4 8 Kilometers
Bernard Beach
Spawning Area

Appendix D. Continued.

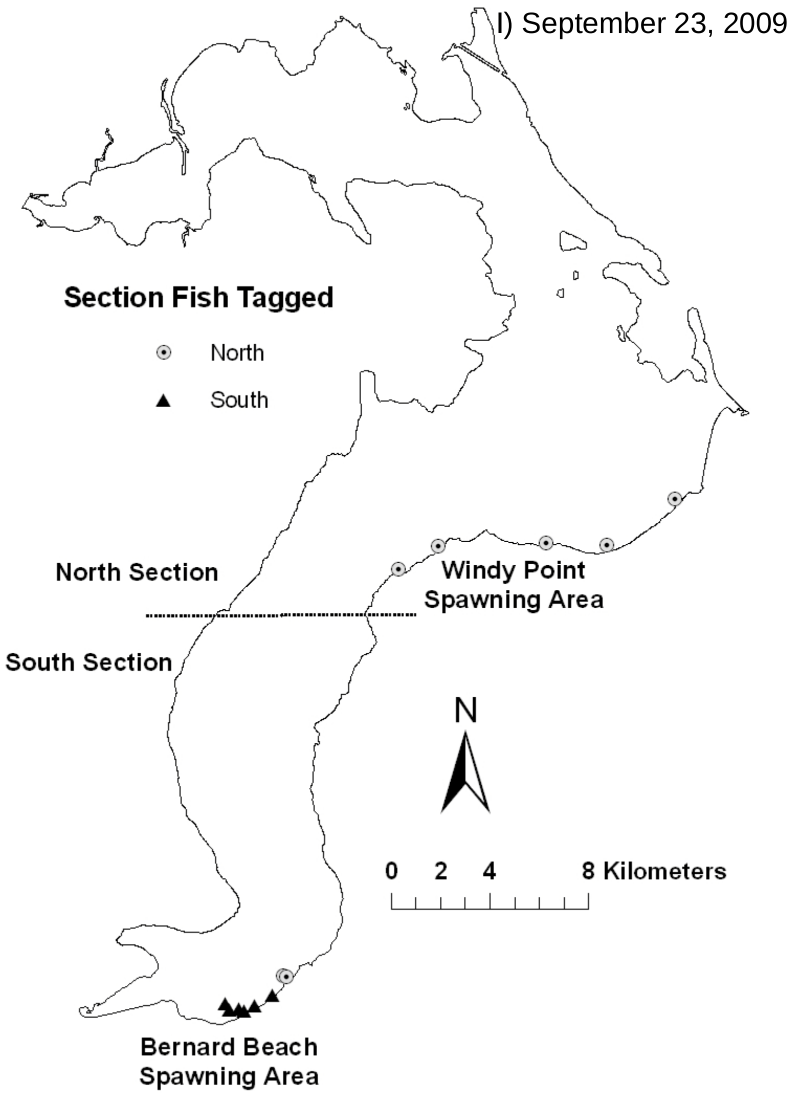


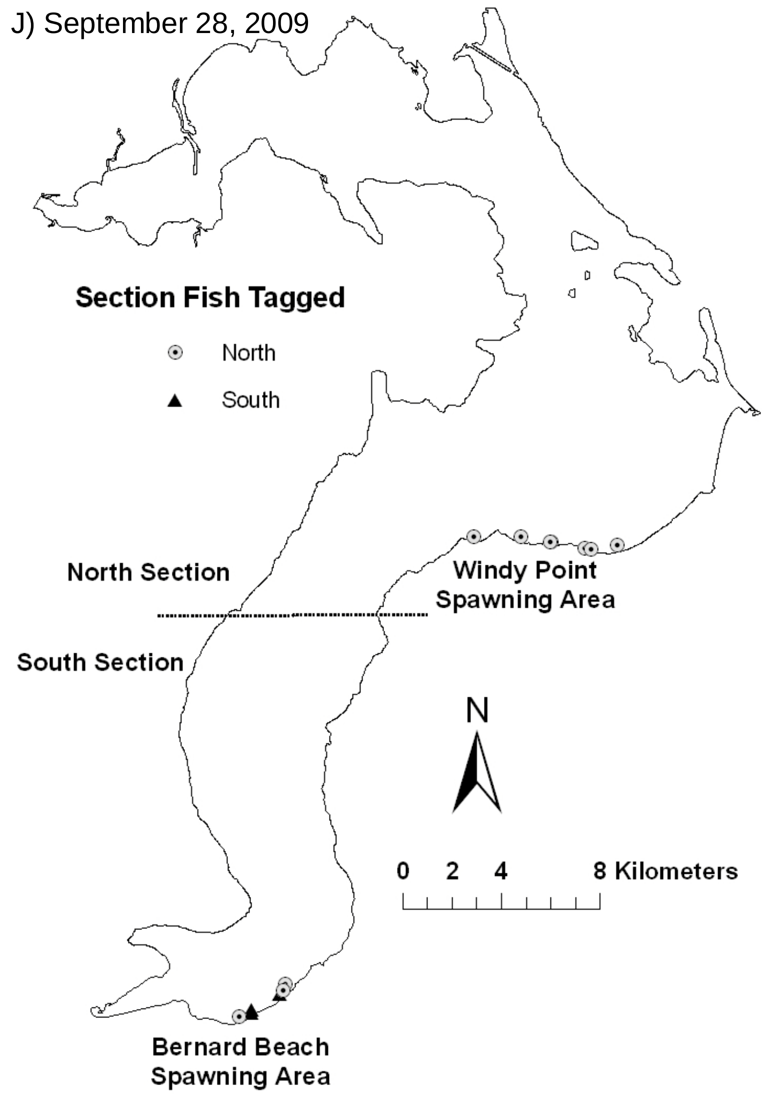



G) September 13-15, 2009
Section Fish Tagged
North
South
North Section
South Section
Windy Point
Spawning Area
N
0 2 4 8 Kilometers
Bernard Beach
Spawning Area


H) September 21, 2009
Section Fish Tagged
North
South
North Section
South Section
Windy Point
Spawning Area
N
0 2 4 8 Kilometers
Bernard Beach
Spawning Area

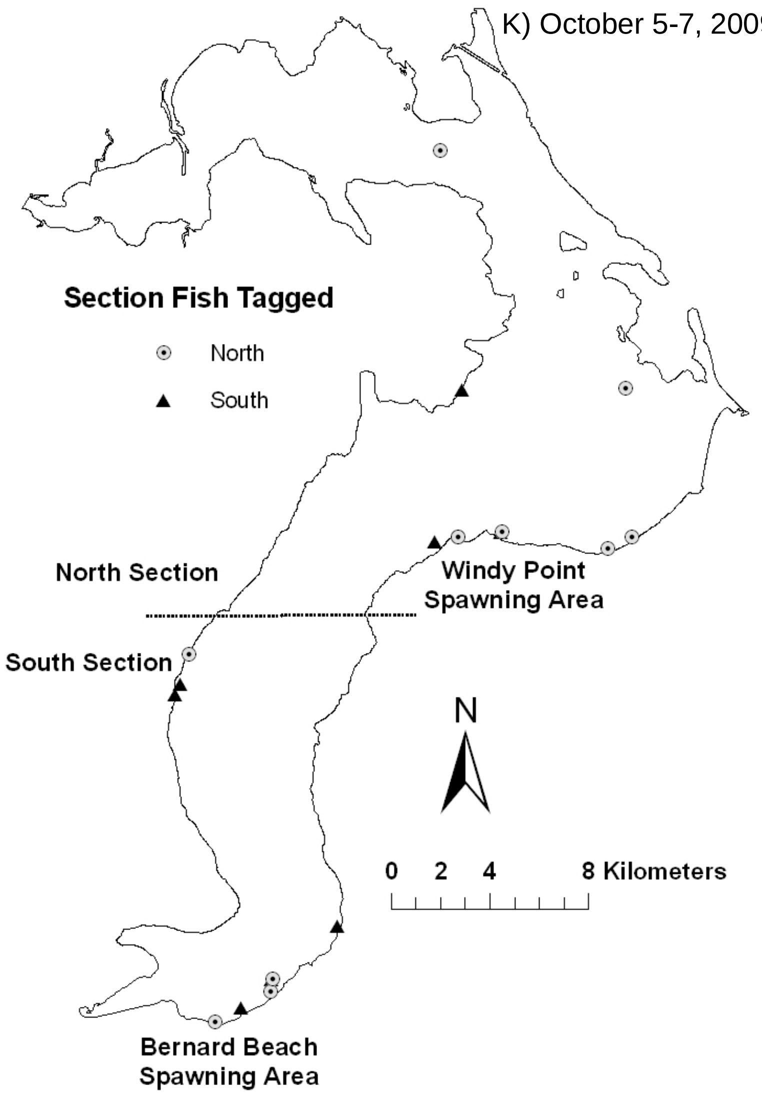
Appendix D. Continued.



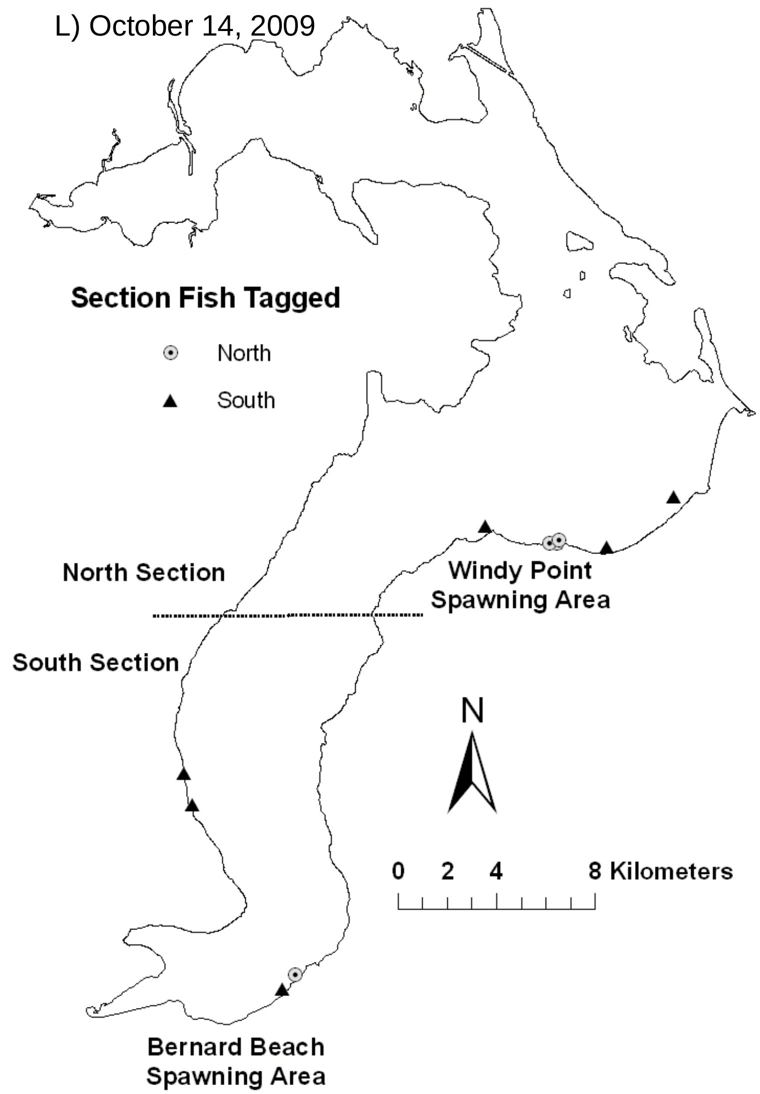


Appendix D. Continued.

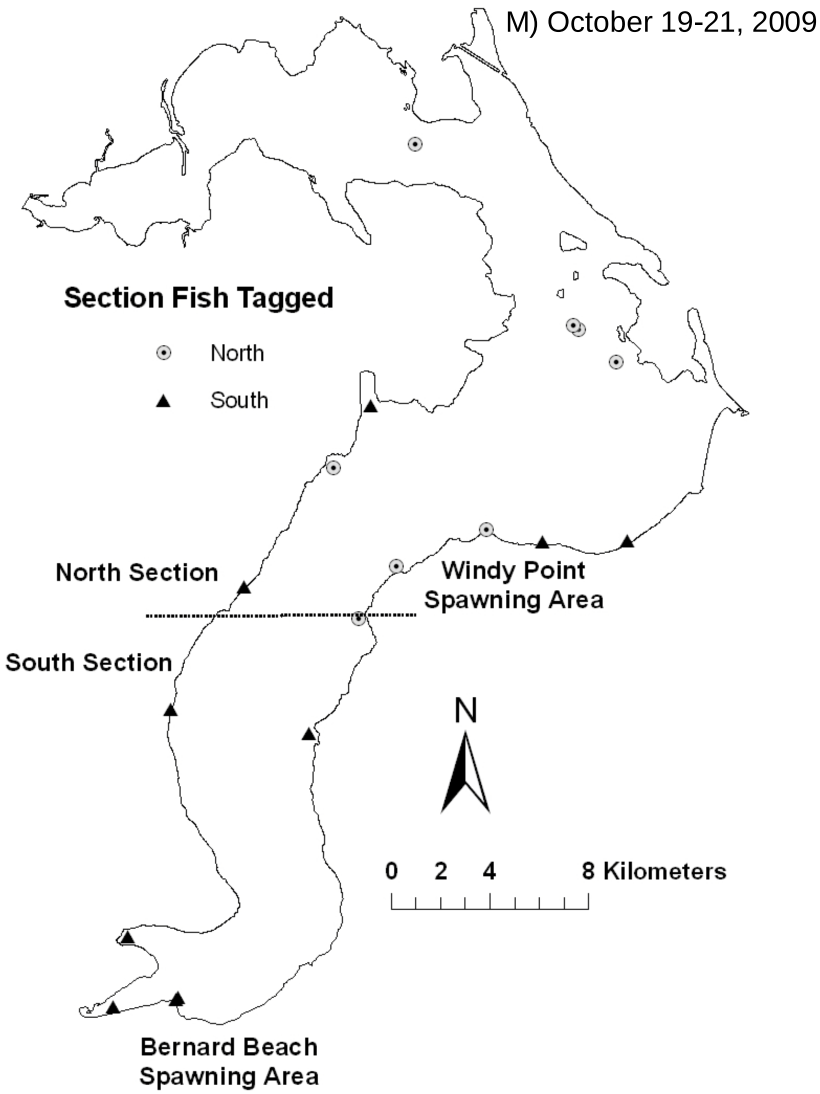
K) October 5-7, 2009

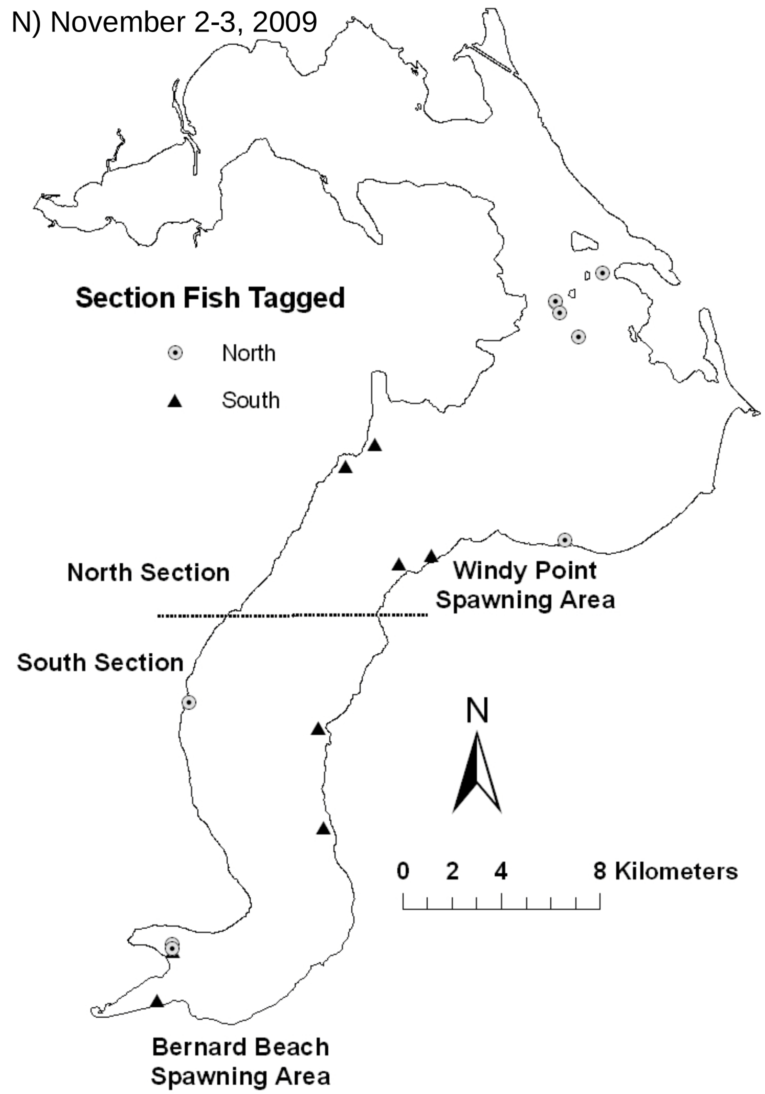


L) October 14, 2009

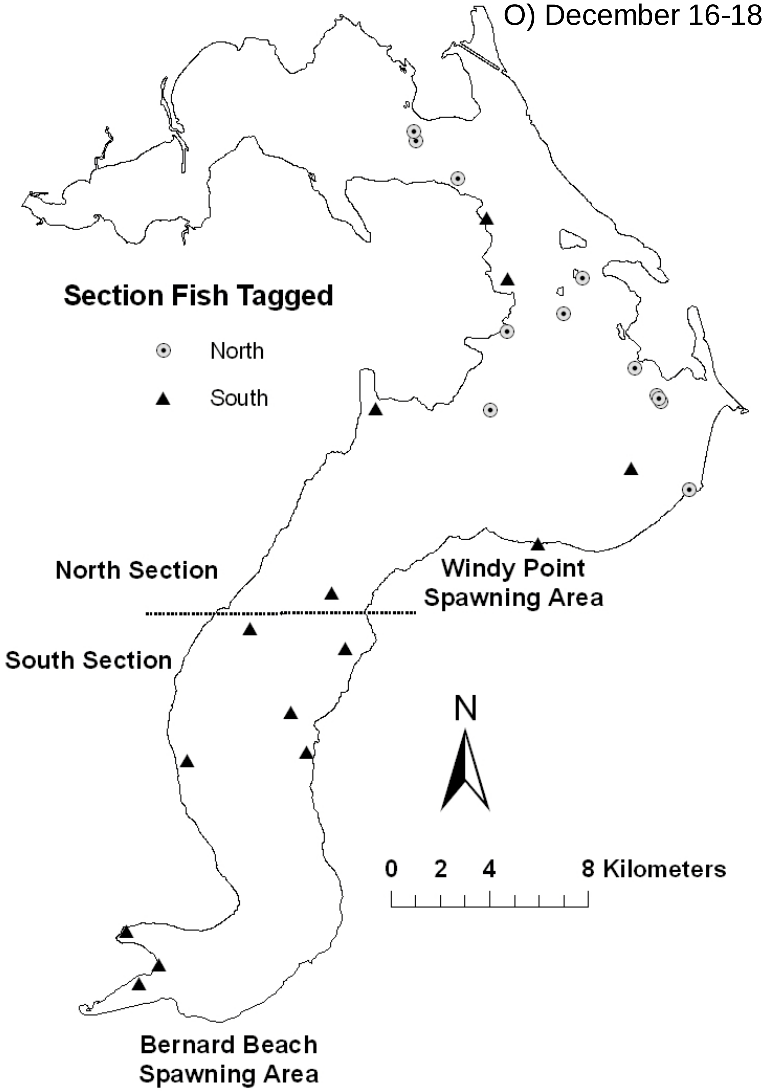


Appendix D. Continued.





O) December 16-18, 2009



Appendix E. Tag number, tag date, capture location, size, and sex of subadult (450-550 mm) lake trout captured and tagged with combined acoustic in Lake Pend Oreille, Idaho in 2009. Fate of fish were as of December 2009; harvested fish were removed by anglers (A).

Tag ID	Date Tagged	Capture Method	Capture Location	Total Length (mm)	Weight (kg)	Sex	Number of Locations	Fate of Fish	Date of Last Record
38100	5/21/2009	Angling	Off Windy Point	480	0.91	U	0	Dead	N/A
38400	5/22/2009	Angling	Off Maiden Rock	470	0.78	U	5	At-Large	11/2/2009
38500	5/22/2009	Angling	Off Whiskey Rock	451	0.82	U	11	At-Large	12/16/2009
38600	5/21/2009	Angling	Off Windy Point	525	1.30	U	10	At-Large	12/16/2009
38700	5/14/2009	Angling	South of Capehorn	503	0.87	U	2	Harvested (A)	8/25/2009
39000	5/14/2009	Angling	Off Garfield Bay	488	0.86	U	11	At-Large	12/17/2009
39300	5/21/2009	Angling	Off Kilroy Bay	512	1.05	U	9	At-Large	12/17/2009
39500	5/14/2009	Angling	Off Kilroy Bay	458	0.71	U	0	Dead	N/A
39700	5/22/2009	Angling	Off Garfield Bay	455	0.72	U	3	Harvested (A)	7/21/2009
39900	5/22/2009	Angling	Off Evan’s Landing	506	1.03	U	5	At-Large	12/16/2009
40000	5/22/2009	Angling	Off Deadman Point	541	1.25	U	4	At-Large	12/17/2009
40200	5/22/2009	Angling	Off Maiden Rock	503	1.00	U	11	At-Large	12/16/2009

Appendix F. Tag number, tag date, capture location, size and sex of juvenile (<450 mm) lake trout captured and tagged with combined acoustic in Lake Pend Oreille, Idaho in 2009. Fate of fish were as of December 2009; harvested fish were removed by anglers (A).

Tag ID	Date Tagged	Capture Method	Capture Location	Lake Section	Total Length (mm)	Weight (kg)	Sex	Number of Locations	Fate of Fish	Date of Last Record
36600	4/9/2009	Gill Net	Warren Island	North	378	0.60	U	0	Dead	N/A
36700	4/9/2009	Gill Net	Warren Island	North	398	0.62	U	3	At-Large	12/17/2009
36800	4/9/2009	Gill Net	Warren Island	North	369	0.54	U	0	Unknown	N/A
36900	4/10/2009	Gill Net	Warren Island	North	402	0.52	U	0	Dead	N/A
37000	4/9/2009	Gill Net	Warren Island	North	425	0.66	U	0	Dead	N/A
37100	4/10/2009	Gill Net	Warren Island	North	350	--	U	1	Dead	5/1/2009
37200	4/9/2009	Gill Net	Warren Island	North	370	0.48	U	2	Unknown	6/10/2009
37300	4/10/2009	Gill Net	Warren Island	North	359	0.42	U	0	Dead	N/A
37400	4/9/2009	Gill Net	Warren Island	North	378	0.46	U	0	Dead	N/A
37500	4/9/2009	Gill Net	Warren Island	North	364	0.44	U	0	Dead	N/A
37600	4/14/2009	Gill Net	Idlewilde Bay	South	366	0.56	U	2	Harvested (A)	5/20/2009
37700	4/15/2009	Gill Net	Idlewilde Bay	South	372	0.54	U	3	Dead	7/13/2009
37800	4/14/2009	Gill Net	Idlewilde Bay	South	399	0.78	U	9	At-Large	12/16/2009
37900	4/14/2009	Gill Net	Scenic Bay	South	354	0.50	U	0	Dead	N/A
38000	4/15/2009	Gill Net	Idlewilde Bay	South	358	0.46	U	1	Dead	5/20/2009
38300	4/15/2009	Gill Net	Idlewilde Bay	South	450	0.88	U	13	At-Large	12/16/2009
39100	4/14/2009	Gill Net	Idlewilde Bay	South	427	0.78	U	0	Dead	N/A
40100	4/15/2009	Gill Net	Idlewilde Bay	South	410	0.76	U	12	At-Large	12/16/2009
40600	4/14/2009	Gill Net	Idlewilde Bay	South	429	0.80	U	0	Dead	N/A
40700	4/14/2009	Gill Net	Idlewilde Bay	South	410	0.74	U	3	Harvested (A)	7/13/2009

Appendix G. Tagging data for rainbow trout implanted with passive integrated transponder tags in Lake Pend Oreille, Idaho during 2009 and the prize money awarded to anglers for recapturing that fish. Fish for which capture location or total lengths were not recorded are marked as unknown (Unk).

Capture/Tagging date	Total Length (mm)	Capture Location	Prize money
5/13/2008	661	Garfield Bay	$50
5/11/2009	400	Near Talache Landing	$500
5/11/2009	520	Unk	$100
5/11/2009	660	South of Cape Horn	$50
5/11/2009	518	Between Granite Bay & Evans Landing	$100
5/11/2009	423	Maiden Rock	$50
5/11/2009	474	South of Navy Wigwam	$50
5/11/2009	542	South of Navy Weather Barge	$500
5/11/2009	615	North of Cape Horn	$50
5/11/2009	643	Cape Horn	$100
5/11/2009	410	North of Cape Horn	$50
5/11/2009	628	South of Navy Wigwam	$100
5/13/2009	576	South of Granite Bay	$100
5/13/2009	725	Windy Point	$100
5/13/2009	430	Camp Bay	$50
5/13/2009	537	North of Green Monarch Mountains	$100
5/13/2009	501	Section 2	$100
5/13/2009	480	Garfield Bay	$50
5/14/2009	487	Kilroy Bay	$50
5/14/2009	500	Unk	$500
5/14/2009	490	Unk	$500
5/14/2009	530	Unk	$500
5/14/2009	680	North of Cape Horn	$500
5/15/2009	423	Mouth of Scenic Bay	$100
5/15/2009	430	Evans Landing	$500
5/15/2009	530	Between Navy shore facilities	$50
5/15/2009	510	Between Navy shore facilities	$100
5/18/2009	730	Granite Bay	$100
5/18/2009	525	Navy Wigwam	$100
5/20/2009	565	East of Cape Horn	$50
5/20/2009	740	East of Navy Wigwam	$50
5/20/2009	735	Off Falls Creek	$100
5/20/2009	517	Between Whiskey Rock & Evans Landing	$50
5/20/2009	605	Whiskey Rock	$50
5/21/2009	515	Unk	$100
5/21/2009	445	Unk	$100
5/21/2009	685	Unk	$1,000
5/21/2009	590	Unk	$50
5/21/2009	565	Unk	$1,000
5/21/2009	483	Unk	$50
5/22/2009	673	Off Cedar Creek	$100
5/22/2009	438	Whiskey Rock	$100
5/22/2009	421	Evans Landing	$50
5/22/2009	573	Maiden Rock	$50
5/22/2009	615	Maiden Rock	$500
5/22/2009	551	Garfield Bay	$50
5/22/2009	628	Garfield Bay	$500
5/22/2009	546	Garfield Bay	$50

Appendix G, continued

Capture/Tagging date	Total Length (mm)	Capture Location	Prize money
5/22/2009	494	Garfield Bay	$500
5/22/2009	667	Evans Landing	$100
5/22/2009	553	Evans Landing	$50
5/22/2009	505	Garfield Bay	$100
5/22/2009	704	Mineral Point	$50
5/22/2009	541	Kilroy Bay	$50
5/22/2009	483	South of Navy Weather Barge	$100
5/22/2009	690	South of Navy Weather Barge	$100
5/26/2009	685	Section 2	$100
5/26/2009	510	Section 2	$50
5/26/2009	750	Section 1	$50
5/26/2009	542	Section 1	$50
5/26/2009	465	Section 1	$1,000
5/26/2009	581	Section 1	$50
5/27/2009	480	Echo Bay	$100
5/27/2009	425	Section 2	$1,000
5/27/2009	536	Section 2	$100
5/28/2009	430	Unk	$500
5/28/2009	482	Unk	$50
5/28/2009	562	Unk	$100
5/28/2009	780	Unk	$100
5/28/2009	Unk	Unk	$500
5/28/2009	508	Unk	$100
5/29/2009	651	Unk	$50
5/29/2009	750	Garfield Bay	$50
5/29/2009	578	Garfield Bay	$50
5/29/2009	540	Garfield Bay	$100
5/29/2009	447	South of Evans Landing	$50
5/29/2009	535	Talache Landing	$50
5/29/2009	503	Talache Landing	$50
5/29/2009	591	West of Navy Weather barge	$50
6/1/2009	570	South of Cedar Creek	$50
6/1/2009	488	Kilroy Bay	$500
6/1/2009	527	Granite Point	$500
6/1/2009	437	South of Cedar Creek	$50
6/2/2009	611	Idlewilde Bay	$50
6/3/2009	541	Windy Point to Kilroy Bay	$100
6/3/2009	540	Windy Point to Kilroy Bay	$100
6/3/2009	448	Windy Point to Kilroy Bay	$100
6/3/2009	475	Windy Point to Kilroy Bay	$100
6/3/2009	440	Kilroy Bay	$50
6/3/2009	550	Windy Point	$50
6/3/2009	550	Windy Point	$1,000
6/3/2009	455	Kilroy Bay	$500
6/3/2009	437	Kilroy Bay	$100
6/4/2009	485	Unk	$100
6/4/2009	483	Unk	$50
6/4/2009	488	Unk	$100
6/9/2009	Unk	Unk	$50

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