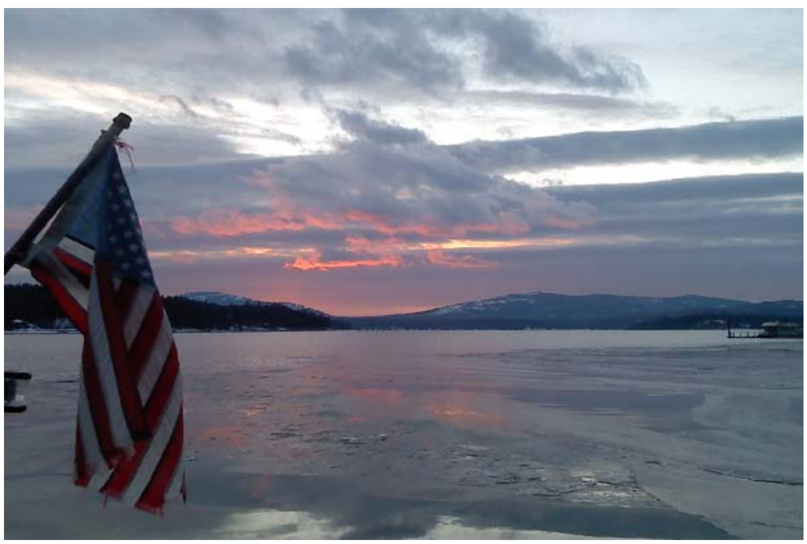
FISHERY RESEARCH

LAKE PEND OREILLE RESEARCH, 2010

LAKE PEND OREILLE FISHERY RECOVERY PROJECT

ANNUAL PROGRESS REPORT
March 1, 2010—February 28, 2011



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Annual Progress Report

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TABLE OF CONTENTS

Page

Table of Contents, continued.

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 were responsible for 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 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 fish gill and trap nets in Lake Pend Oreille.

During 2010, research focused on evaluating the effects of recovery actions. We examined kokanee population responses to both lake level manipulations and predator removals. We also assessed changes in kokanee spawning habitat due to lake level manipulations. Lake trout research was conducted 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 completed the first year of a two-year rainbow trout study to better determine whether angler harvest is effectively reducing the population. Additionally, a study was completed to better understand the role of *Mysis diluviana* (mysids hereafter) in the Lake Pend Oreille food web.

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. Outflow from the lake forms the Pend Oreille River, 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 shoreline areas have steep slopes.

A diverse assemblage of fish species is present in Lake Pend Oreille. Native game fish include bull trout *S. 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*, yellow perch *Perca flavescens*, and walleye *Sander vitreus* (Hoelscher 1992).

Historically, bull trout and northern pikeminnow *Ptychocheilus oregonensis* were the primary 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. Provide kokanee with adequate spawning habitat to allow for population recovery.

3. Reduce the lake trout population to pre-1999 abundance and ensure long-term suppression keeps the population below this level. Below this abundance threshold, negative influences of lake trout on the kokanee and bull trout populations are expected to be minimal.

4. Reduce the rainbow trout population to decrease predation on kokanee until predation no longer limits kokanee recovery.

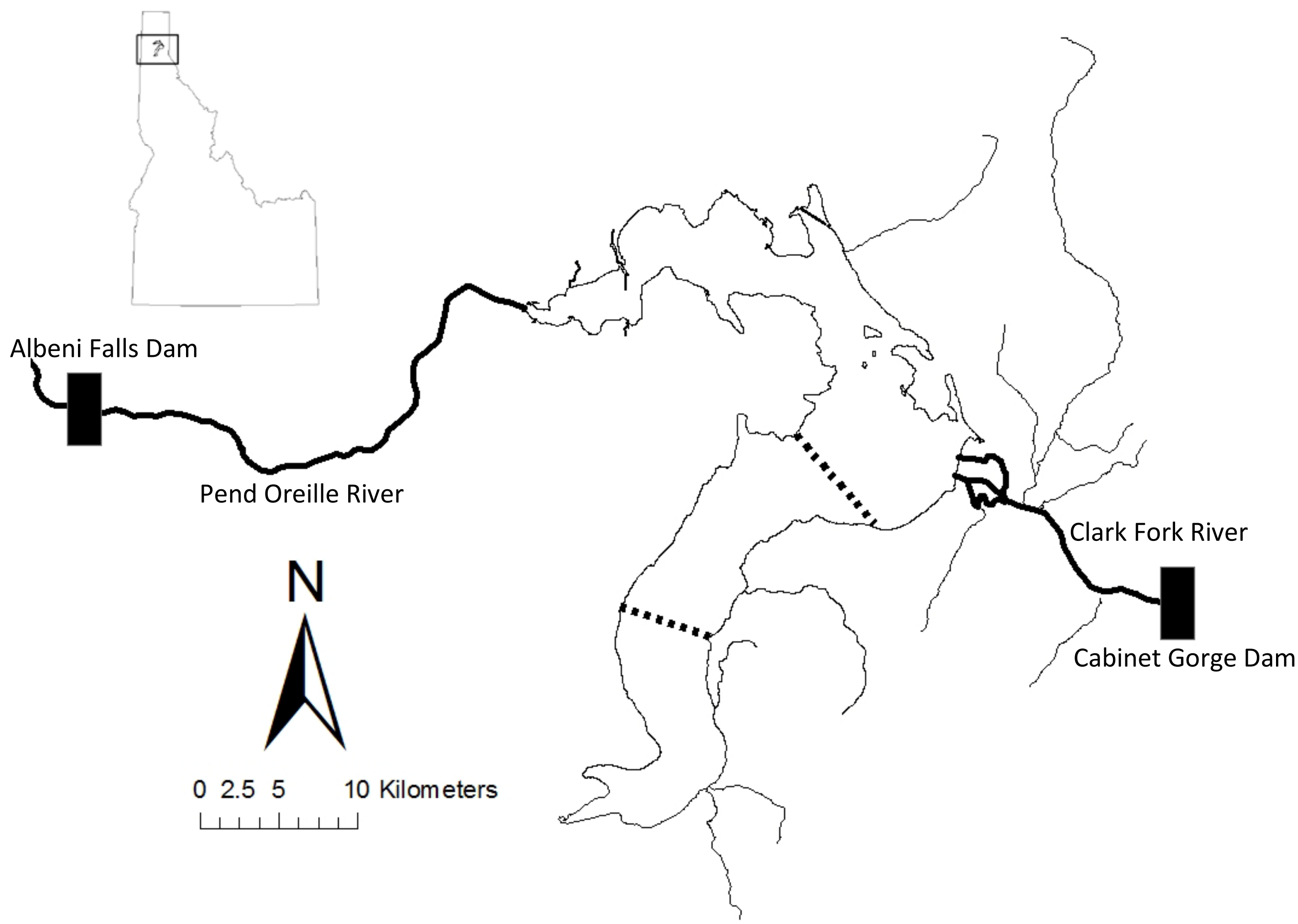

Figure 1. Map of Lake Pend Oreille, Idaho showing the three lake sections (separated by dashed lines) and primary kokanee spawning tributaries. The main inflow and outflow rivers (Clark Fork River and Pend Oreille River) and dams (Cabinet Gorge Dam and Albeni Falls Dam) are shown.

CHAPTER 1: KOKANEE RESEARCH

ABSTRACT

During 2010, 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 and September 2010 to assess the kokanee population and determine the impacts of these recovery actions. Total kokanee abundance was 12.5 million (551 kokanee/ha), including 3.9 million wild fry and 6.2 million hatchery fry. Kokanee biomass was 130 metric tonnes (t), with annual kokanee production at 174 t, resulting in a production to biomass ratio of 1.3:1. Survival from age-1 to age-2 was 35%, and egg-to-fry survival was 65%. Substrate monitoring indicated the full drawdown over the winter of 2009-10 resulted in no change in gravel composition for wild shoreline-spawning kokanee. Peak visual index counts of wild-spawning kokanee were 8,478 fish on the shoreline, 13,578 early-run tributary spawners, and 7,849 late-run tributary spawners. The counts of shoreline and late-run tributary kokanee were the highest recorded since 1975 and 2004, respectively. The return of early-run kokanee was the highest on record since 1975. Despite the increase in kokanee abundance, biomass and survival rates declined for the first time since 2007. A major reason kokanee have persisted despite low abundance is that production to biomass ratios have been high. While improved kokanee abundance is promising, most of the increase is from fry, and weak cohorts produced from record-low spawner returns in 2006 through 2008 still exist and will need to be overcome for bigger gains in biomass and abundance to occur.

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INTRODUCTION

Numerous factors have contributed to the dramatic decline of kokanee *Oncorhynchus nerka* from their historical abundance levels. 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 drawdowns. 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; Figure 2).

Benefits from lake level manipulations have been documented, including habitat improvement (substrate redistribution) during winters at 625.1 MSL (Maiolie et al. 2004) and higher kokanee egg-to-fry survival during winters at 626.4 MSL (Maiolie et al. 2002). However, conditions have not yet allowed the expected full benefits of lake level manipulations to occur. The need for additional spawning habitat provided by a higher (626.4 m) winter elevation increases in importance as mature kokanee density increases. Since starting experimental manipulations, mature kokanee density has been low. Initially, kokanee suffered major mortality from a record flood in 1997 (Maiolie 2006b). By the early 2000s, high predation levels created by a rapidly expanding lake trout *Salvelinus namaycush* population surpassed spawning habitat (i.e., winter lake level) as the primary limiting factor for kokanee (Maiolie et al. 2006b). These unanticipated occurrences have slowed progress towards kokanee recovery goals and necessitated a longer time period to evaluate the effects of lake level manipulations.

Since reaching a record low abundance in 2007, kokanee abundance and biomass have increased in response to predator reduction (Wahl et al. 2010; Wahl et al. 2011). Continued success of predator reduction efforts will allow for increased kokanee abundance and the opportunity for lake level manipulations to provide greater benefit to kokanee.

The amount and quality of spawning habitat and increased predation from lake trout are the two primary factors limiting kokanee recovery. However, the food web and nutrient dynamics in Lake Pend Oreille have changed over time, especially since the introduction of mysids, and it is necessary to better understand these changes to consider additional strategies that may benefit kokanee recovery. For instance, increased nutrient levels from either direct nutrient addition or mysid removal may improve kokanee growth and survival. Mysid research has been conducted in the past, but questions remain given their prominent role in the lakewide food web.

During the 2010-11 contract period, we evaluated the response of the kokanee population to both lake level manipulations and predator reduction. We also completed a retrospective analysis of kokanee egg-to-fry survival estimates to further assess the influence of winter lake level on spawning and incubation success. Additionally, we examined the quality of kokanee spawning habitat with respect to the winter lake level. Finally, we conducted research designed to better understand the role that mysids play in the Lake Pend Oreille food web, especially with respect to nutrient transfer. Similarly, we estimated mysid abundance to determine whether there was a population response to predator reduction and changes in kokanee abundance.

METHODS

Kokanee Population Dynamics

Abundance and Survival

We conducted a lakewide hydroacoustic survey on Lake Pend Oreille to estimate the abundance and survival rate of kokanee. Surveys were performed at night between August 24 and 27, 2010 following the same protocol described in detail by Wahl et al. (2011). Prior to the surveys, we calibrated the echo sounder for signal attenuation to the sides of the acoustic axis using Simrad's EK60 software. Analysis of hydroacoustic data to derive kokanee density estimates and associated confidence intervals followed the protocol described in Wahl et al. (2010).

We were able to partition out kokanee fry from older age classes during the analysis. However, to partition out hydroacoustics data based on older kokanee age classes (age-1 thru age-5), we sampled kokanee using midwater trawling from September 4 to 10, 2010. These dates were during the dark phase of the moon, which optimized the capture efficiency of the trawl (Bowler et al. 1979). Details of the sampling procedures for midwater trawling have been described in previous reports (Rieman 1992; Wahl et al. 2011).

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 10-15 fish in each 10 mm size interval. We used the proportion of age-1 thru age-4 kokanee captured by trawling in each section of the lake to partition hydroacoustics data and generate lakewide age-specific abundance estimates. From these estimates, we calculated annual survival between age classes.

To sample kokanee fry for assessing origin (hatchery or wild), we also conducted a midwater trawl survey using a smaller mesh trawl net. Sampling with the fry net began in 1999 and detailed methods have been previously described (Wahl et al. 2011). 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, length and weight were measured, and otoliths were removed.

Hatchery and Wild Abundance

All kokanee produced at the Cabinet Gorge Fish Hatchery since 1997 have been marked using thermal mass-marking techniques (or cold branding) described by Volk et al. (1990). Therefore, 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 trawl surveys (10-15 per 10 mm size interval) to the Washington Department of Fish and Wildlife (WDFW) Otolith Laboratory where personnel checked them for hatchery thermal marks. Methodologies for checking thermal marks are described in Wahl et al. (2010).

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

Egg-to-Fry Survival Estimate

We used hydroacoustic data to estimate the potential egg deposition (PED) of wild-spawning kokanee. The acoustic estimate of ages 1-5 kokanee 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 using a total length-fecundity relationship developed in past years (IDFG, unpublished data). Finally, to estimate wild kokanee egg-to-fry survival we divided the estimated number of wild kokanee fry by the previous year's PED.

Egg-to-Fry Survival Analysis

We worked with Dr. E. O. Garton, a population ecologist with the University of Idaho, to evaluate egg-to-fry survival estimates from 1995 through 2009. The goal was to model and statistically test the effects of winter lake level on egg-to-fry survival rate. A variety of methods were considered and ultimately a model building approach using information theoretic tools, in this case Akaike's Information Criterion (AICc, corrected for small sample size, Burnham and Anderson 2002), was selected. Linear models were used and based on a number of available predictors in a mixed model framework where the response (survival) was assumed to be measured with normally distributed errors. And, where the predictors were a mixture of fixed effects (e.g., lake level of 625.1 or 626.4 MSL) and random effects (e.g., number of hatchery females returning to Sullivan Springs trap) assumed to have minimal measurement error.

A series of models were evaluated that included four predictors of egg-to-fry survival. These predictors were lake elevation (LE), lake elevation change from previous year (LEchange), the number of mature wild female kokanee (WildKok) estimated from lakewide surveys, and the number of mature hatchery females returning to the spawning trap (HatchKok). The data set spanned from 1995 to 2009, but several years were excluded (1997, 2000, 2001, 2007) because of atypical scenarios that either influenced survival estimates or the winter lake level. High fry mortality occurred following a major flood in 1997, the winter lake elevation was set at an intermediate winter level in 2000 and 2001, and a survival estimate could not be obtained in 2007 because of record low kokanee density. The predictive ability of the full model with all four predictors was compared to a variety of reduced models (Table 1). The reduced models contained one to three of the predictors appropriately selected using the standard AICc and by the proportion of the variation explained by the predictors (r^2). Statistical significance of models was tested using an alpha level of 0.10.

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). Details regarding the calculation of these estimates can be found in Wahl et al. (2011).

Biomass, Production, and Mortality by Weight

We calculated the biomass, production, and mortality by weight of the kokanee population in Lake Pend Oreille to assess the effects of predation. Biomass was the total weight of kokanee within Lake Pend Oreille at the time of our population estimate, calculated by multiplying the population estimate of each kokanee 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). 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). Hayes et al. (2007) and Wahl et al. (2011) provide additional details on methods for estimating production and mortality by weight.

Spawner Counts

We counted spawning kokanee in standard tributaries and shoreline areas (Appendix A) 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 in September in Trestle Creek, South Gold Creek, North Gold Creek, and Cedar Creek. In addition, surveys for late-run kokanee occurred in November in the same four tributaries as well as Johnson Creek, Twin Creek, and Spring Creek. Shoreline counts for late-run kokanee occurred at nine standardized sites approximately once per week in November and December. For all counts, we counted all kokanee, either alive or dead.

We removed otoliths from early- and late-run kokanee carcasses to determine hatchery and wild proportions of the run, as well as the age of hatchery fish. Methods for otolith removal, preparation, and reading were similar to those described previously. We removed 96 otoliths from early-run kokanee (South Gold Creek 26, Granite Creek 30, Sullivan Springs Creek 10, Cabinet Gorge Hatchery ladder 30) and 96 from late-run kokanee (Sullivan Springs Creek 58, North Gold Creek 18, Scenic Bay 20).

Kokanee Spawning Habitat Quality

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 included Twin Creek, Green Bay, Ellisport Bay, Kilroy Bay, south of Evans Landing, and the south side of Ellisport Bay. In August 2010, divers collected six randomly located samples from a gravel band between elevations 624.8 and 625.8 MSL at each site. 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). Finally, we weighed the substrate from each sieve and the substrate that fell through the finest sieve. 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).

Mysid Research

Role of Mysids in Nutrient and Food Web Dynamics

We subcontracted the University of Idaho to conduct research aimed at better understanding the role mysids play in the Lake Pend Oreille food web. Specifically, this research was designed to quantify vertical nutrient transport by mysids to determine whether they represent a nutrient sink that may negatively influence kokanee. To accomplish this work, a Master's project was initiated in January 2009 and was completed in January 2011. Detailed methods can be found in Wilhelm and Caldwell (2011).

Mysid Abundance

We sampled mysids on June 14 and 15, 2010 to estimate their density within Lake Pend Oreille. All sampling occurred at night during the dark phase of the moon. We collected mysids at eight sites per lake section using a 1 m hoop net. Further details can be found in Wahl et al. (2011).

During laboratory analysis, mysids were classified as either young-of-the-year (YOY) or immature and adults and counted for each sample. We based density estimates on the number of mysids collected in each sample and the volume of water filtered. We calculated the arithmetic means and 90% confidence intervals for the immature and adult portion of the mysid population and for the YOY portion.

RESULTS

Kokanee Population Dynamics

Abundance and Survival

In 2010, we estimated 12.5 million kokanee (11.4-13.6 million, 90% CI) or 551 fish/ha in Lake Pend Oreille, based on our standard hydroacoustic survey. This included 10.1 million kokanee fry (9.3-11.0 million, 90% CI; Table 2), 1.6 million age-1, 430,000 age-2, 200,000 age-3 kokanee, and 70,000 age-4 kokanee (Table 3).

We estimated kokanee survival at 31% from fry to age-1, 35% from age-1 to age-2, 22% from age-2 to age-3, and 17% from age-3 to age-4 (Table 4).

Hatchery and Wild Abundance

During the spring of 2010, Cabinet Gorge Fish Hatchery released 7.4 million thermally marked kokanee fry into Lake Pend Oreille. Out of this total, 7.1 million late-run fry were stocked into Sullivan Springs Creek, and 0.3 million October-run fry (from Lake Mary Ronan, Montana) were stocked into the Clark Fork Fish Hatchery spawning channel.

We sent 100 pairs of otoliths from fry captured in the fry trawl to the WDFW Otolith Laboratory. Additionally, otoliths from 102 kokanee fry and 144 kokanee between ages 1-4 captured in the midwater trawl were sent to the WDFW Otolith Laboratory.

Wild kokanee fry made up 64%, 53%, and 16% of the fry net catch in the southern, middle, and northern sections, respectively (Table 2). Based on these proportions, we estimated the wild fry population at 3.9 million (Table 2). Further, we estimated that wild kokanee comprised 29%, 15%, 52%, and 89% of age-1, age-2, age-3, and age-4 abundance estimates, respectively (Table 3).

Egg-to-Fry Survival Estimate

During 2010, 18%, 3%, and 2% of the kokanee sampled by trawling were mature in the southern, middle, and northern sections, respectively. Applying these proportions to hydroacoustics estimates yielded a lakewide estimate of 117,667 mature kokanee or 58,833 mature female kokanee, assuming a 50:50 ratio of males to females. Hatchery personnel collected 27,253 mature female kokanee at the spawning trap in Sullivan Springs Creek. We estimated fecundity of adult female kokanee to be 381 eggs/female. Based on this fecundity estimate, 31,581 naturally spawning adult female kokanee deposited 12.0 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 2011.

During 2009, we estimated that wild kokanee deposited 6.1 million eggs in tributaries and along the shoreline of Lake Pend Oreille. Using our estimate of 3.9 million wild kokanee fry, we calculated wild kokanee egg-to-fry survival to be 65% in 2010.

Egg-to-Fry Survival Analysis

The full model (four predictors) had the highest predictive ability (r^2 = 72%) of variation in egg-to-fry survival (Table 1). Three of the estimated parameters in this model were significantly different from zero under a hypothesis testing framework at the $\alpha = 0.10$ level. Results of the full model implied that egg-to-fry survival at the 626.4 MSL level is 20% higher than at 625.1 MSL. The information theoretic best model was the model containing only LE as a predictor (Table 1). This model only explained 11% of the variation in egg-to-fry survival, but was the most parsimonious model and predicted a 6.2% higher survival rate at 626.4 MSL compared to 625.1 MSL. The model averaged predictor of change in egg-to-fry survival as a function of increased lake level was estimated by calculating model weights (ΔAICc) and suggested a 6.4% survival increase at 626.4 MSL. All three of the models discussed above produced statistically significant relationships ($P < 0.1$).

Historical Trawling Comparisons

Total kokanee abundance based on geometric means of trawl samples was 5.6 million fish (4.7 to 6.5 million, 90% CI) with a density of 248 fish/ha (Table 5). This included 3.8 million kokanee fry, 1.2 million age-1 kokanee, 370,000 age-2 kokanee, 180,000 age-3 kokanee, and 70,000 age-4 kokanee (Figure 3). The total standing stock of kokanee was 4.3 kg/ha (Table 5). Kokanee captured by midwater trawling varied in length from 24-277 mm and weight from 0.1-158 g (Table 5; Figure 4).

Biomass, Production, and Mortality by Weight

Based on the hydroacoustic estimates of kokanee abundance, kokanee biomass was 130 metric tonnes (t) and production was 174 t (Table 6; Figure 5) for a production to biomass ratio of 1.3:1. Total mortality by weight was 196 t, 22 t higher than production (Table 6; Figure 5).

Spawner Counts

In 2010, we observed a peak of 8,478 kokanee spawning on the lake's shorelines. The majority of these fish (57%; 4,865) were on the shoreline around Bayview in Scenic Bay (Table 7). We observed a peak of 7,849 late-run kokanee spawning in tributaries of Lake Pend Oreille, with 3,115 in South Gold Creek and 3,522 in Spring Creek (Table 8). Additionally, peak abundance of early-run kokanee was 13,578 with 6,240 in South Gold Creek and 3,817 in Trestle Creek (Table 9).

Early-run kokanee were predominately (76%) of hatchery origin. This pattern held true for the Cabinet Gorge Hatchery ladder and Granite and Sullivan Springs creeks where fish were primarily (≥89%) hatchery origin. However, South Gold Creek early-run kokanee were primarily (84%) wild origin. The age structure of these early-run hatchery fish was 14% age-2 and 86% age-3. Hatchery fish comprised 66% of late-run kokanee in North Gold and Sullivan Springs creeks and their age structure was 2% age-2, 82% age-3, and 16% age-4. Late-run kokanee spawning in Scenic Bay were primarily (95%) wild fish.

Kokanee Spawning Habitat Quality

Following the full drawdown during the winter of 2009-10, the mean percent gravel (65% ±12, 90% CI) was significantly higher than the mean percent cobble (18% ±10%, 90% CI; ANOVA; $F_{1,11}$=24.13, p=0.0006) and mean percent fines (18% ±8%, 90% CI; ANOVA; $F_{1,11}$=27.29, p=0.0004; Figure 6). There was no difference in substrate composition between 2009 and 2010 (Figure 6).

Mysid Research

Role of Mysids in Food Web and Nutrient Dynamics

All elements of the University of Idaho graduate research project were completed in 2011. A final report was submitted to IDFG that provides details of this research (Wilhelm and Caldwell 2011).

Mysid Abundance

We estimated a total mean density of 468 mysids/m^2 during June 2010 (Table 10; Figure 7). This included 331 immature and adult mysids/m^2 (90% CI of ± 32%; Table 10; Figure 8) and 137 YOY mysids/m^2 (90% CI of ± 25%; Table 10; Figure 8).

DISCUSSION

Kokanee Population Dynamics

In the past year, total kokanee abundance increased 59%. However, this increase was driven by a nearly two-fold increase in kokanee fry; age 1-4 abundance decreased 7%. Survival from age-1 to age-2, the stage when kokanee are most vulnerable to predation, dropped to 35%. Although age-1 to age-2 survival decreased from 2009, the 2010 estimate was the second highest recorded since 2003. Lower survival was not unexpected as the age-2 cohort was produced during the weakest spawner return on record (2007). Predation, even by a smaller predator population, can have a greater impact on a weaker cohort (Rieman and Myers 1991), which may explain the survival decrease in 2010. During the past two years, survival was better than in preceding years when lake trout were more abundant and suggests that kokanee are responding positively to predator reduction efforts.

During 2010, egg-to-fry survival was over double the highest rate ever recorded previously (36% in 2008). Further, during the past three years, egg-to-fry survival has been two to six times higher than the average from 1998 to 2007 (10%). We believe that two factors may be largely responsible for these higher than expected survival rates. First, sample size governs the power of our PED estimates. The estimated PED, which is used to generate egg-to-fry survival rate the following year, is based on the number of mature kokanee sampled with the midwater trawl. Kokanee densities during the past three years have been the lowest on record, which has resulted in small sample size of mature kokanee and may have led to error in our estimate. Alternatively, survival is often higher at low density because fish may preferentially spawn in the highest quality habitat (McFadden 1977) and larger fish, which occur at lower kokanee density, produce larger eggs (Rieman and Myers 1992). Although our results indicate winter lake elevation influences egg-to-fry survival, it is believed to have minimal influence when kokanee spawner density is low because spawning habitat is adequate even at 625.1 MSL to accommodate limited spawners. Likely, a combination of sampling error and the influence of low spawner density are influencing egg-to-fry survival estimates. Another consideration is whether an increasing density of early-run kokanee is influencing our estimates of PED and wild fry abundance. During the time of hydroacoustic and trawl surveys, all mature early-run kokanee are already staged at tributary mouths or have entered tributaries. No early-run adults were sampled in the trawl, thus these fish did influence the PED estimate. All hatchery stocked early-run fry are thermally marked and can be excluded from the estimate of wild fry abundance; however, naturally produced early-run fry cannot be separated. Sampling spawners from tributaries and determining their origin showed that most early-run spawners are of hatchery origin. South Gold Creek was the only tributary with substantial natural reproduction, but spawner counts suggest that the potential fry production is likely to negligibly affect the lakewide wild fry estimate.

The analysis of egg-to-fry survival data spanning from 1995-2009 showed that higher survival has occurred during 626.4 MSL conditions. The models with the highest predictive ability based on r^2, the most parsimonious model (lowest AIC value), and the model averaged predictor all resulted in significant p-values, indicating that the lake level manipulation strategy has benefitted kokanee recruitment. The 6.2% increase in survival at 626.4 MSL (based on the model averaged predictor) would provide nearly a two-fold increase in kokanee recruitment. Improved survival under higher winter lake level conditions has potential to result in substantially more recruits annually, especially at higher kokanee densities. At low kokanee density the recruitment benefit is reduced. Thus, low densities of kokanee over the past decade resulting from high predation have delayed the opportunity for winter lake level manipulations to benefit kokanee to the extent anticipated. If the upward trend in kokanee abundance observed since 2007 can be sustained in coming years, lake level manipulations will be of increasing importance in improving kokanee recruitment.

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). By comparing trawling data from the past decade to previous decades, we have established that survival to maturity has limited kokanee recovery over the past decade. From 1980 to 1998, an average of 3.2 million kokanee fry produced an average of 690,000 age-3 kokanee resulting in 22% survival. However, from 1999 to 2010, an average of 4.4 million fry produced an average of only 160,000 age-3 kokanee, resulting in 4% survival. For the kokanee population to recover, survival from fry to age-3 must once again approach 20%. The positive responses observed for the kokanee population and continued reduction of lake trout since 2007 both indicate significant progress towards this goal.

From 1996 to 2010, kokanee production remained relatively consistent, ranging from 174 t to 254 t. However, during 2004-2007, kokanee mortality by weight ($\bar{x}$ = 268 t) was consistently higher than production ($\bar{x}$ = 209 t), leading to decreases in kokanee biomass. Pronounced increases in the production to biomass ratio during this period was vital to slowing the decline of the kokanee population (Wahl et al. 2010). Since 2007, both kokanee production and mortality by weight have averaged 177 t, suggesting less imbalance between predator and kokanee populations. While we are unsure whether the increase in mortality by weight from 2009 to 2010 was caused by predation or other factors (e.g., more kokanee reaching maturity before age-4), it remained substantially lower than during 2004-2007 when predation potential was highest. Further, it was within the range of estimates from 1997-1999 when predation was not yet causing low kokanee survival. Continued implementation of the predator reduction program should further reduce kokanee mortality by weight and, with sustained high production to biomass ratios, lead to increased kokanee biomass.

Spawner counts provide only an index to spawner abundance, but do provide a useful way to coarsely monitor trends in spawner escapement. Additionally, it allows the spatial extent of spawning to be evaluated. The recent upward trend in late-run kokanee escapement has been encouraging, as both shoreline and tributary spawner counts have increased annually since 2007. Shoreline spawner counts in 2010 were the highest recorded since 1975, while tributary counts were the highest since 2004. Additionally, 2010 marks the first time since the 1970s that we noted a substantial number of shoreline spawners outside of Scenic Bay. If kokanee density continues to increase, we anticipate the spatial extent of spawning will further expand to historically used spawning habitats. As this occurs, more opportunity will exist for spawning habitat created by winter lake level manipulations to be used by kokanee.

For the third consecutive year, early-run kokanee returned to Granite, Cedar, and North and South Gold creeks where they historically have been uncommon. Most of the early-run kokanee returning to these tributaries have been strays from early-run fry stocked in Sullivan Springs Creek during 2004-09 to bolster the kokanee population when it was at risk of collapse. The only exception was South Gold Creek, where otolith analyses showed that the majority of spawners were of wild origin. Previously we stated that early-run kokanee were unlikely to substantially contribute towards recovery goals (Wahl et al. 2011). Over the long term, we still believe this is the case because redd superimposition by late-run kokanee and bull trout *Salvelinus confluentus* and dynamic flow conditions during egg incubation are threats to sustained fry production. Because stocking of early-run fry was discontinued after 2009, hatchery origin fish will only persist through 2012. Afterwards, early-run kokanee should diminish because natural reproduction appears to be largely limited to South Gold Creek.

Kokanee Spawning Habitat Quality

During the winter of 2008-09, the full drawdown to 625.1 MSL allowed wave action to redistribute substrates along the shoreline, which led to significantly more shoreline gravels and reduced cobble (Wahl et al. 2011). However, the second straight full drawdown during the winter of 2009-10 did not change the composition of shoreline substrates. 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). Current data continue to support the need for periodic drawdown to 625.1 MSL to prevent loss of gravels that are the preferred spawning substrate for kokanee (Maiolie et al. 2004). And, the lack of change following consecutive full winter drawdowns supports the previous recommendation that a single year at 625.1 MSL is sufficient to adequately replenish gravels lost during multiple winters at 626.4 MSL (Maiolie et al. 2002).

Mysid Research

Mysids play a prominent role in the Lake Pend Oreille food web and have altered nutrient transport since their introduction. Research conducted by the University of Idaho was insightful to better understanding food web and nutrient dynamics and will be used to further consider actions that may increase available nutrients and positively affect kokanee production. See Wilhelm and Caldwell (2011) for detailed discussion of research results.

Mysids in Lake Pend Oreille have gone through a cycle of expansion, decline, and stability. Mysids were introduced in 1966, became fully established by the mid-1970s, and rapidly expanded until 1980. Since 1980, they declined from their peak abundance and have remained relatively stable since 1997. A similar pattern of population fluctuation occurred in other western lakes after mysid introductions (Richards et al. 1991; Beattie and Clancey 1991). While immature and adult mysid (the segments of the population most likely to compete with kokanee) densities have been relatively stable since 1997, YOY mysid densities have periodically spiked by up to an order of magnitude. The reason for these increases in YOY densities is unclear, but they have not correlated with immature and adult mysid densities. Additionally, we have not documented any changes in mysid abundance since 2006 that could be linked to lake trout removal efforts. We recommend continued monitoring of mysids given the potential they have to influence both the kokanee and lake trout populations.

RECOMMENDATIONS

1. Continue to assess the kokanee population response to lake level manipulations and predator removal.

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

3. Continue to reduce predator abundance to further increase kokanee survival.

4. Investigate potential modifications to midwater trawling techniques and egg-to-fry survival analysis methods to provide more robust estimates during years of low kokanee density.

5. Further evaluate food web and nutrient dynamics, including potential strategies for increasing available nutrients (i.e., nutrient addition, mysid removal). Additionally, examine zooplankton spatiotemporal distribution and relate to kokanee distribution.

Table 1. Candidate model set (contains 95% of model weight) and model statistics for evaluating egg-to-fry survival (EFS) with respect to winter lake elevation in Lake Pend Oreille, Idaho from 1995-2009. Predictors in the models include lake elevation (LE), lake elevation change from previous year (LEchange), wild female kokanee abundance (WildKok), and hatchery kokanee abundance (HatchKok).

	Model statistic[a]			
Model	r^2	**k**	ΔAIC_c	w_i
EFS = -3198+1.563(LE)	0.11	3	0.0[b]	0.94
EFS = -a+1.93LE+LEchange-WildKok	0.41	5	7.2	0.03
EFS = -a+3.41LE+LEchange-HatchKok	0.58	5	7.4	0.02
EFS = -a+1.71LE-WildKok	0.41	4	9.9	0.01
EFS = -a+2.13LE-HatchKok	0.52	4	10.6	0.00
EFS = a-WildKok	0.29	3	13.7	0.00
EFS = a-HatchKok	0.32	3	15.7	0.00
EFS = -a+4.07LE+LEchange-WildKok-HatchKok	0.72	6	18.9	0.00
EFS = -a+2.33LE-WildKok-HatchKok	0.65	5	22.3	0.00
EFS = -a+LEchange-WildKok-HatchKok	0.48	5	25.3	0.00

[a] Model fit described by coefficient of determination (r^2), the number of parameters (k), the difference in Akaike's Information Criteria corrected for small sample size (ΔAIC_c), and the AIC_c wt (w_i).

[b] AIC_c = 75.3 for best selected model.

Table 2. Population estimates of kokanee fry (millions) based on hydroacoustic surveys of Lake Pend Oreille, Idaho in 2010. Percentage of wild and late-run hatchery (KL-H) 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	2.4	3.2	4.6	10.1	9.3-11.0
Percent wild fry in fry trawl	64	53	16	—	
Percent KL in fry trawl	36	47	84	—	
Wild fry abundance estimate	1.5	1.7	0.7	3.9	

Table 3. Population estimates for kokanee age classes 1 through 4 in Lake Pend Oreille, Idaho 2010. 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-H), and late-run hatchery (KL-H) were based on the proportions of each caught in the trawl net.

Area	Age-1	Age-2	Age-3	Age-4	Total
Southern Section					
Percent of age class by trawling	28.3	40.8	20.8	10.1	
Population estimate (millions)	0.13	0.18	0.09	0.04	0.44
Middle Section					
Percent of age class by trawling	76.5	16.2	5.9	1.4	
Population estimate (millions)	0.40	0.08	0.03	0.01	0.52
Northern Section					
Percent of age class by trawling	81.7	11.7	5.4	1.2	
Population estimate (millions)	1.12	0.16	0.07	0.02	1.37
Total population estimate for lake (millions)	1.64	0.43	0.20	0.07	2.33
90% confidence interval (millions)					1.94-2.81
Percent wild	29	15	52	88	
Percent KE-H	3	8	0	0	
Percent KL-H	68	77	48	12	

Table 4. Survival rates (%) between kokanee year classes estimated by hydroacoustics, 1996-2010. 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
2010[a]	31	35	22	17
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 2010 were based on geometric means transformed by log(x+1).
[b] Too few kokanee caught to estimate survival.

Table 5. Kokanee population statistics based on geometric (log_{10} transformed; log[x+1]) means of midwater trawl catches on Lake Pend Oreille, Idaho during September 2010.

	Fry	Age-1	Age-2	Age-3	Age-4	Total (90% CI)
Population estimate (millions)	3.83	1.15	0.37	0.18	0.07	5.6 (4.7 to 6.5)
Density (fish/ha)	169	51	16	8	3	248
Standing stock (kg/ha)	0.35	1.22	1.46	0.88	0.40	4.32
Mean weight (g)	2.1	24.0	88.6	112.7	134.5	-
Mean length (mm)	63.2	147.8	219.3	237.8	260.0	-
Length range (mm)	24-112	110-184	166-254	215-265	245-277	-
Number measured	104	82	27	19	9	

Table 6. Biomass, production, and mortality by weight (metric tonnes) of kokanee in Lake Pend Oreille, Idaho from 1996-2010.

Year	Biomass	Production	Mortality by Weight
2010	130	174	196
2009	146	175	124
2008	91	179	165
2007	74	182	221
2006	101	209	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

Table 7. 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
2010	4,865	0	0	3,500	0	0	0	113	0	—	8,478
2009	2,635	36	1	0	0	6	0	9	0	—	2,687
2008	663	6	0	0	0	0	0	0	0	—	669
2007	325	0	0	0	0	0	0	0	0	—	325
2006	1,752	0	0	0	17	0	0	12	0	—	1,781
2005	1,565	0	5	1	0	1	0	66	0	—	1,638
2004	2,342	0	100	1	0	0	0	34	0	—	2,477
2003	940	0	0	0	0	20	0	0	0	—	960
2002	968	0	0	0	0	0	0	0	0	—	968
2001	22	0	0	0	0	0	0	0	1	—	23
2000	382	0	0	2	0	0	0	0	0	—	384
1999	2,736	4	7	24	285	209	0	275	0	—	3,540
1998	5,040	2	0	0	22	6	0	34	0	—	5,104
1997	2,509	0	0	0	0	7	2	0	0	—	2,518
1996	42	0	0	4	0	0	0	3	0	—	49
1995	51	0	0	0	0	10	0	13	0	—	74
1994	911	2	0	1	0	114	0	0	0	—	1,028
1993	—	—	—	—	—	—	—	—	—	—	—
1992	1,825	0	0	0	0	0	0	34	0	—	1,859
1991	1,530	0	—	0	100	90	0	12	0	—	1,732
1990	2,036	0	—	75	0	80	0	0	0	—	2,191
1989	875	0	—	0	0	0	0	0	0	—	875
1988	2,100	4	—	0	0	2	0	35	0	—	2,141
1987	1,377	0	—	59	0	2	0	0	0	—	1,438
1986	1,720	10	—	127	0	350	0	6	0	—	2,213
1985	2,915	0	—	4	0	2	0	0	0	—	2,921
1978	798	0	0	0	0	138	0	0	0	0	936
1977	3,390	0	0	25	0	75	0	0	0	0	3,490
1976	1,525	0	0	0	0	115	0	0	0	0	1,640
1975	9,231	0	0	0	0	0	0	0	0	0	9,231
1974	3,588	0	25	18	975	2,250	0	20	0	50	6,926
1973	17,156	0	0	200	436	1,000	25	400	617	0	19,834
1972	2,626	25	13	4	1	0	0	0	0	0	2,669

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

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

Table 9. 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
2010	6,240	2,169	1,352	3,817	13,578
2009	2,231	631	13	362	3,237
2008	592	181	27	50	850
2007	—	—	—	124	124
2006	—	—	—	327	327
2005	—	—	—	427	427
2004	—	—	—	682	682
2003	—	—	—	2,251	2,251
2002	—	—	—	1,412	1,412
2001	—	—	—	301	301
2000	—	—	—	1,230	1,230
1999	—	—	—	1,160	1,160
1998	—	—	—	348	348
1997	—	—	—	615	615
1996	—	—	—	753	753
1995	—	—	—	615	615
1994	—	—	—	170	170
1992	—	—	—	660	660
1991	—	—	—	995	995
1990	—	—	—	525	525
1989	—	—	—	466	466
1988	—	—	—	422	422
1987	—	—	—	410	410
1986	—	—	—	1,034	1,034
1985	—	—	—	208	208
1978	—	—	—	1,589	1,589
1977	—	—	—	865	865
1976	—	—	—	1,486	1,486
1975	—	—	—	14,555	14,555
1974	—	—	—	217	217
1973	—	—	—	1,100	1,100
1972	—	—	—	0	0

Table 10. Densities of mysids (per m^2), by life stage (young of year [YOY], and immature and adult), in Lake Pend Oreille, Idaho June 14-15, 2010.

Section	YOY/m^2	Immature & Adults/m^2	Total mysids/m^2
Section 1	154	359	513
Section 2	163	349	511
Section 3	101	292	393
Whole lake means	138	331	468

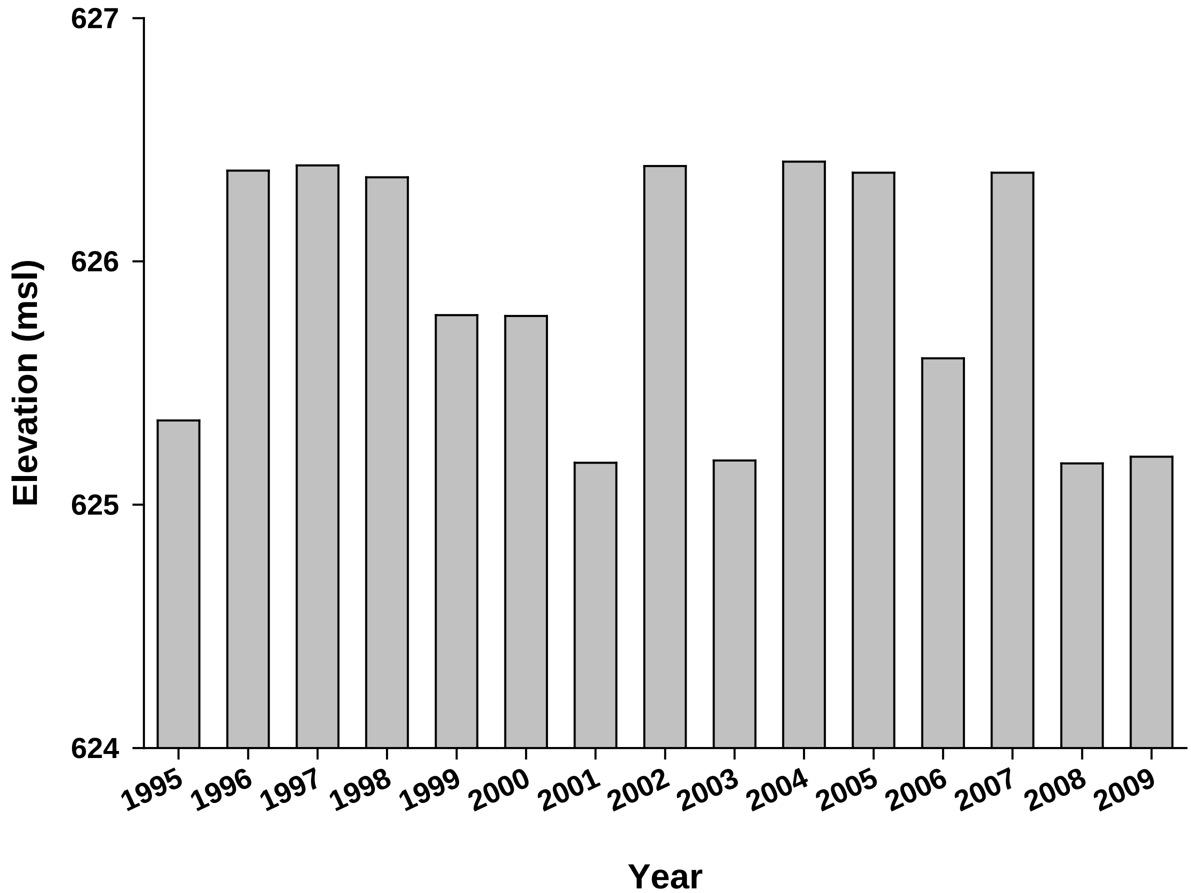

Figure 2. Winter pool surface elevation in meters above mean sea level (MSL) during years of lake level experiment in Lake Pend Oreille, Idaho. Year shown represents the year the lake was drawn down (i.e., 1995 for winter of 1995-1996).

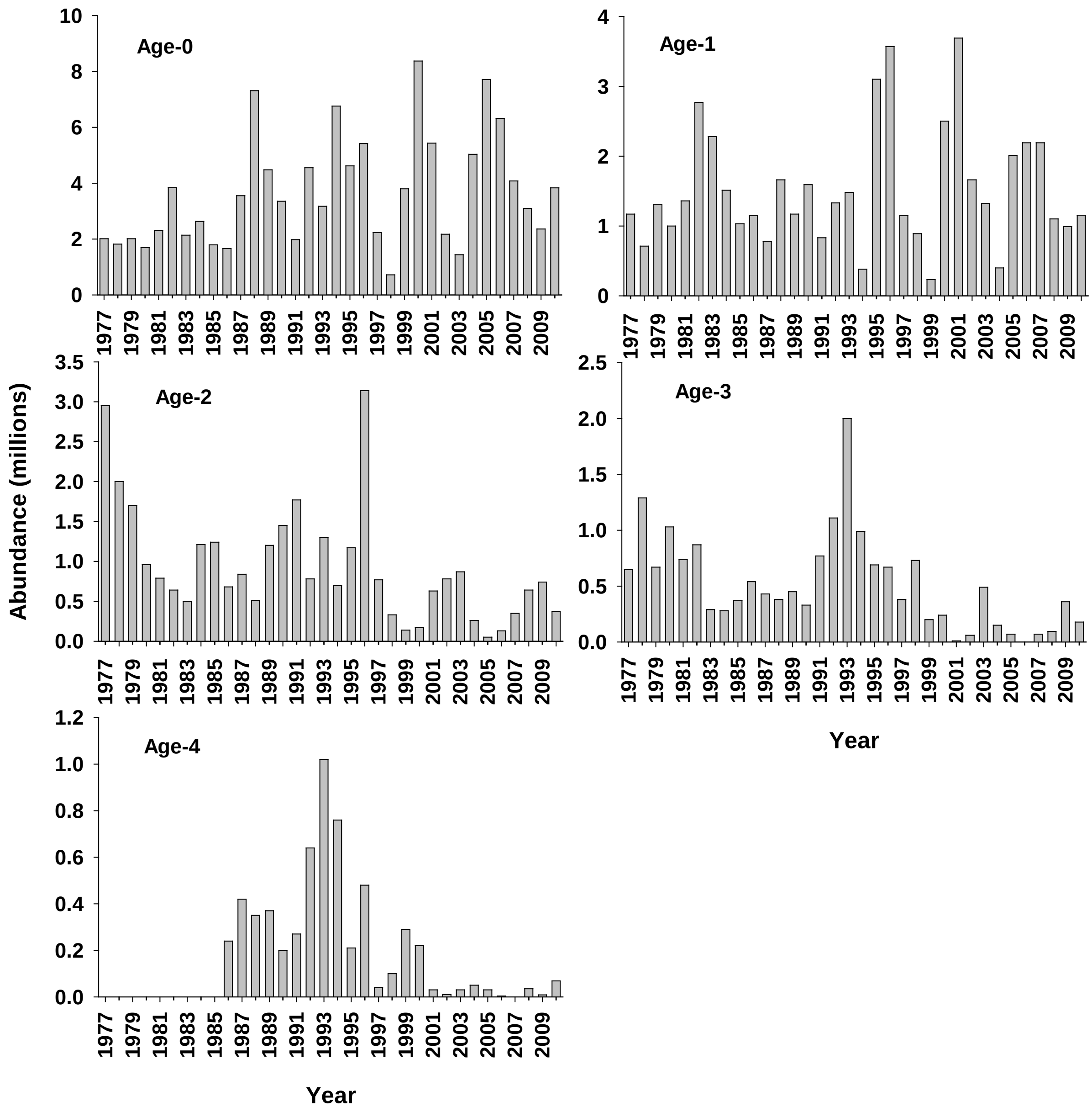

Figure 3. Kokanee age-specific population estimates based on midwater trawling between 1978 and 2010. Age-3 and -4 kokanee were not separated prior to 1986.

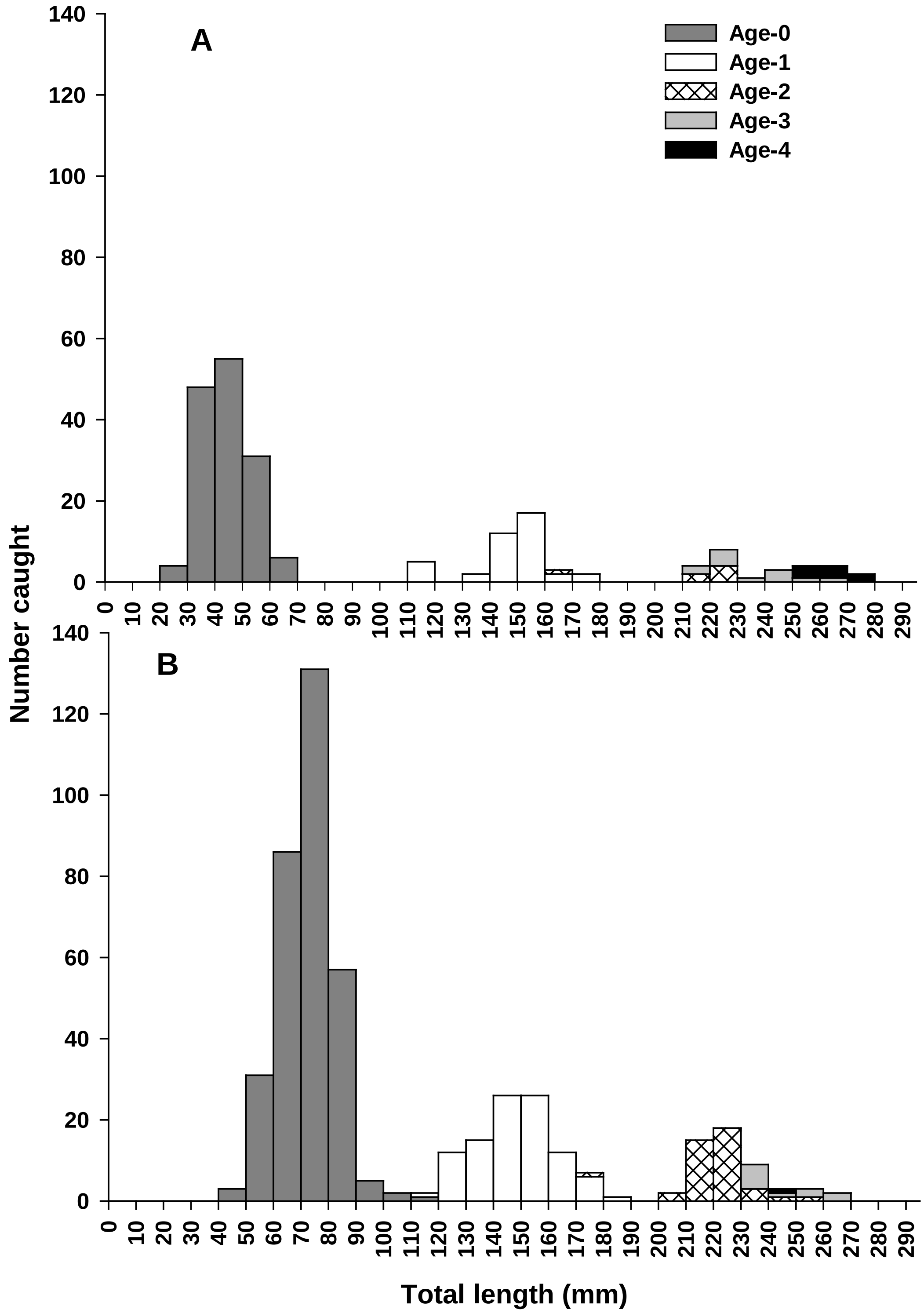

Figure 4. Length-frequency distribution of individual age classes of wild (A) and hatchery (B) kokanee caught by midwater trawling in Lake Pend Oreille, Idaho during September 2010.

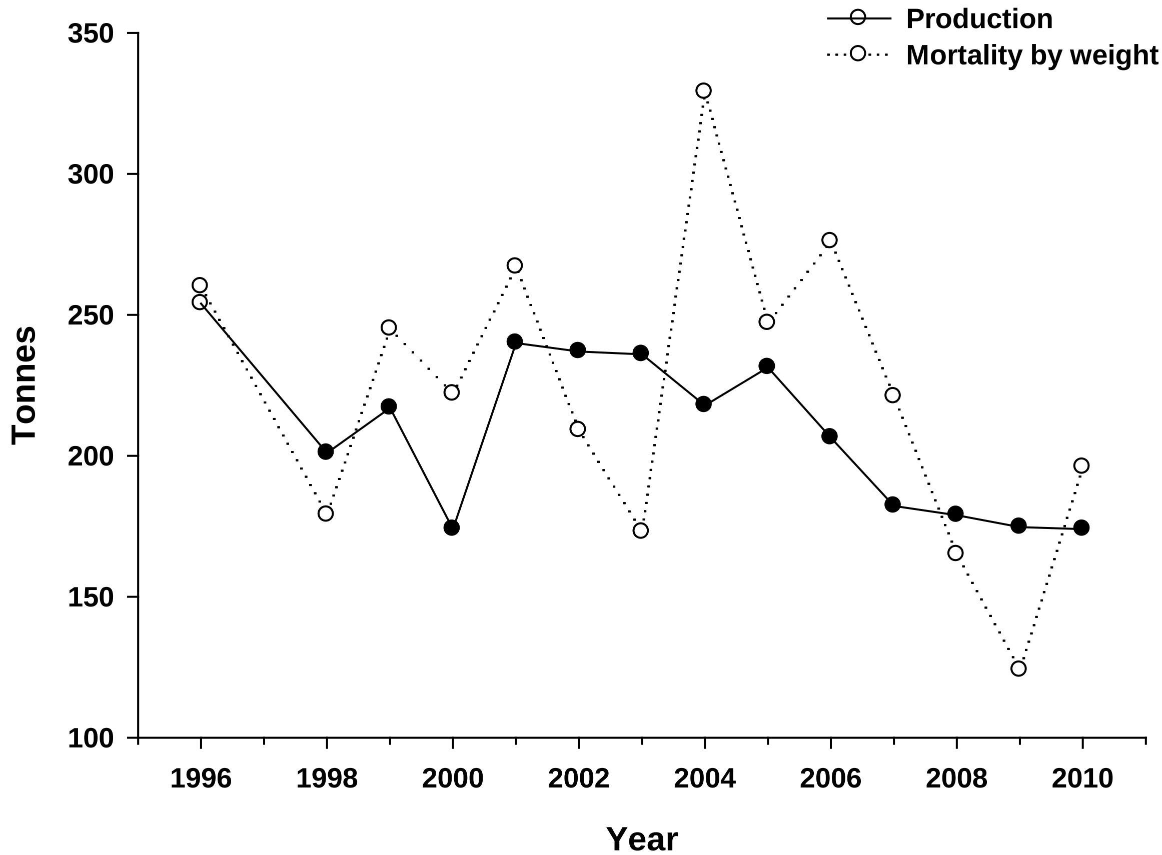

Figure 5. Kokanee production and mortality by weight (metric tonnes) in Lake Pend Oreille, Idaho from 1996-2010, excluding 1997 due to 100-year flood.

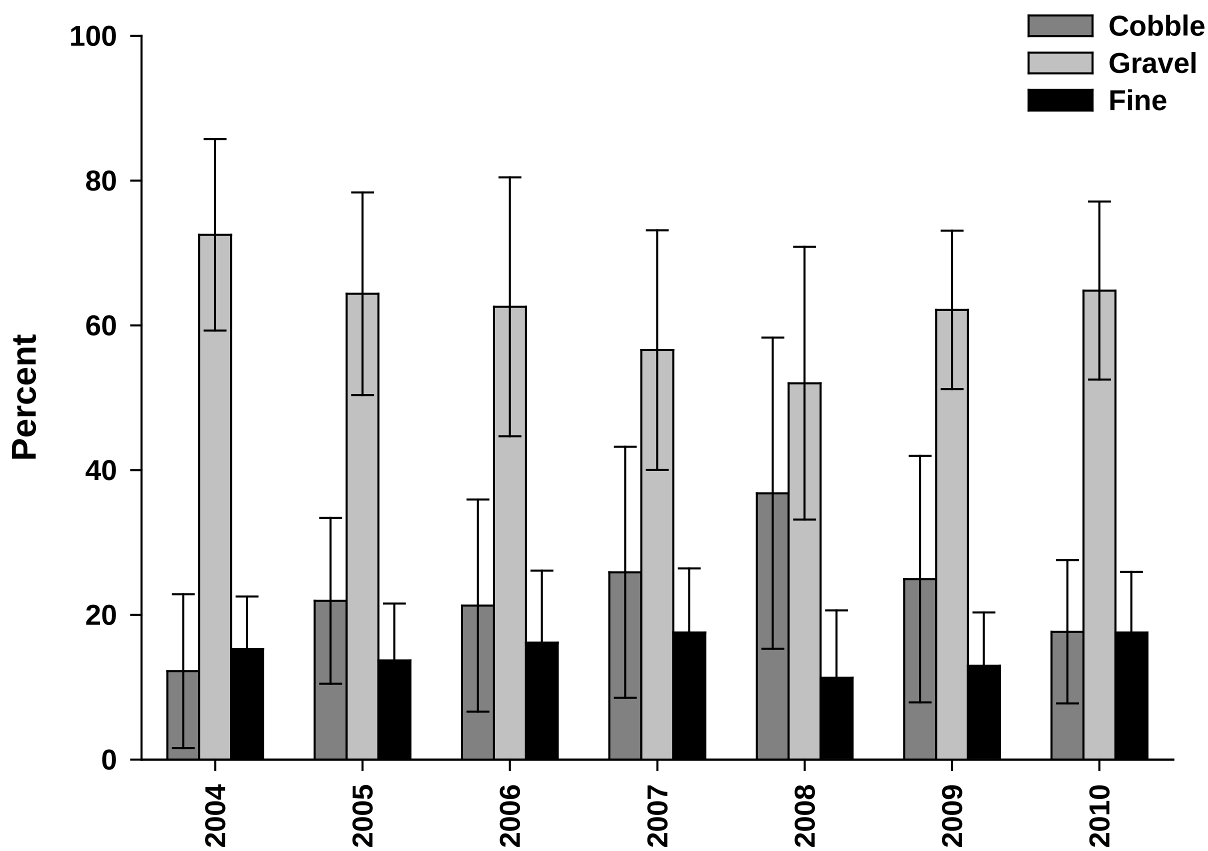

Figure 6. Mean substrate composition (± 90% CI) in Lake Pend Oreille, Idaho during summer 2004-2010. Full winter drawdowns to 625.1 MSL took place during the winters of 2003-04, 2008-09, and 2009-10. Winter pool remained above 626.6 MSL during all other winters.

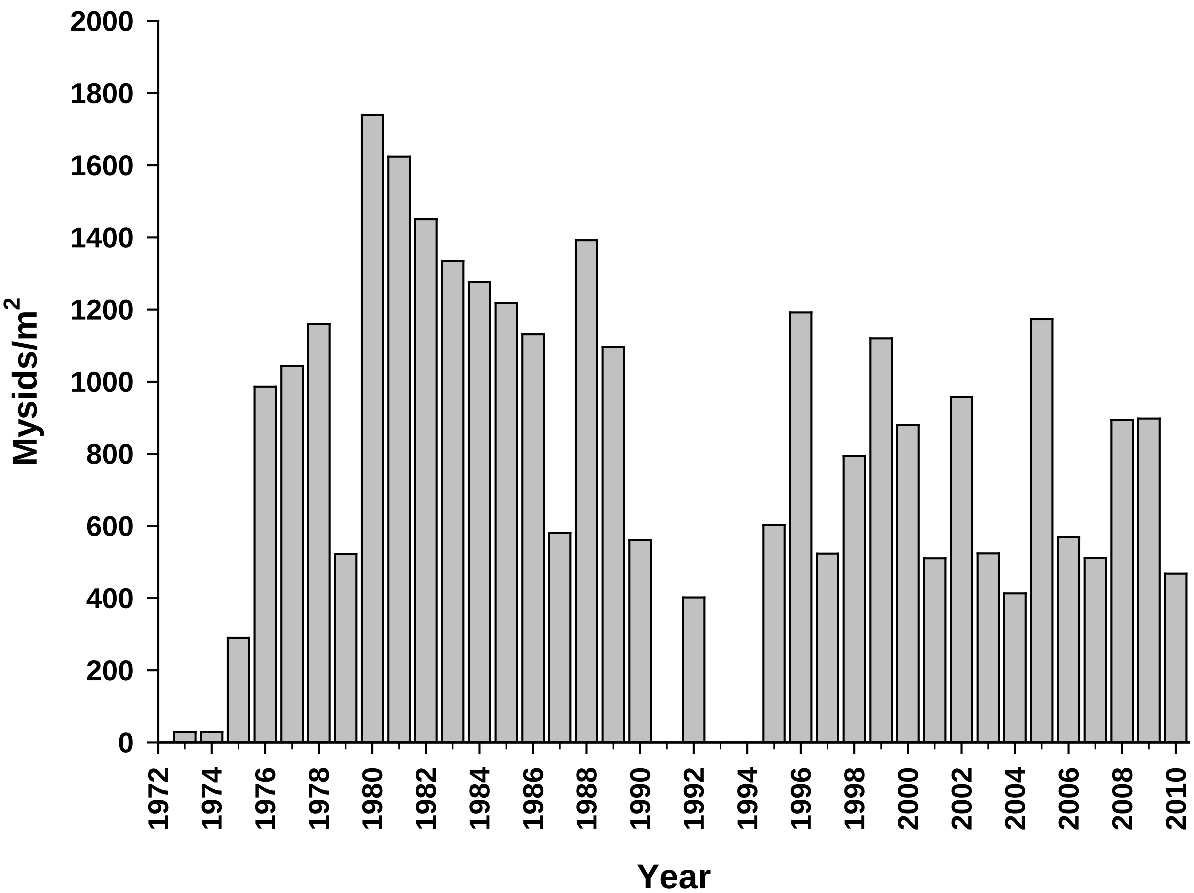

Figure 7. Annual mean density of mysids in Lake Pend Oreille, Idaho from 1973-2010. Data collected before 1989 were obtained from Bowles et al. (1991), and data from 1995 and 1996 were from Chipps (1997). Mysid densities from 1992 and earlier were converted from Miller sampler estimates to vertical tow estimates by using the equation y = 0.5814x (Maiolie et al. 2002). Gaps in the histogram indicate no data were collected that year. Mysids were first introduced in 1966.

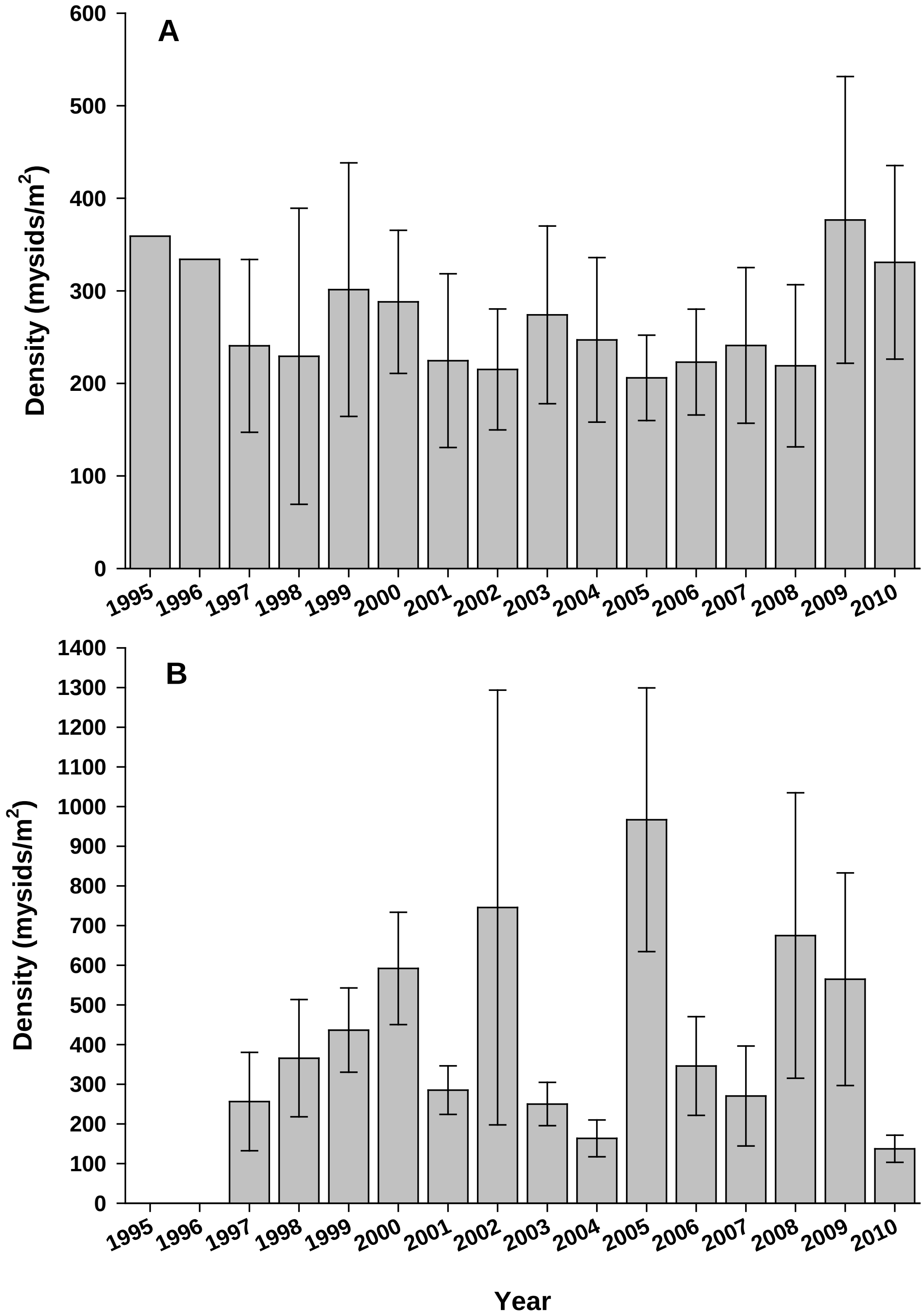

Figure 8. Density estimates of immature and adult (A) and young-of-the-year (B) mysids in Lake Pend Oreille, Idaho 1995-2010. Error bounds identify 90% confidence intervals around the estimate. Immature and adult densities from 1995 and 1996 were obtained from Chipps (1997).

CHAPTER 2: LAKE TROUT RESEARCH

ABSTRACT

The kokanee *Oncorhynchus nerka* population in Lake Pend Oreille has been threatened by high levels of predation over the past decade and was on the verge of total collapse in 2007. To increase kokanee survival, extensive predator (lake trout *Salvelinus namaycush* and rainbow trout *O. mykiss*) removal actions have been implemented, including commercial netting and angler incentive programs. To maximize lake trout removal efficiency, we used acoustic transmitters, some equipped with depth and temperature sensors, to follow mature lake trout to spawning sites. During April and May 2010, we tagged 36 adult lake trout ranging from 595 to 950 mm total length ($\bar{x}$ = 697 mm) and weighing from 1.8 to 9.8 kg ($\bar{x}$ = 3.7 kg). Additionally, during October we tagged 18 adult lake trout at spawning sites that ranged from 627 to 917 mm total length ($\bar{x}$ = 810 mm). From July to December, we conducted lake trout tracking events 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 four times during the year. Spawning occurred from mid-September to mid-October when lake trout aggregated at the same two shoreline areas documented during previous years. However, we also identified a third lake trout spawning site at Evans Landing on the west shore. At all sites, tagged lake trout were recorded predominately in depths around 30 m at spawning areas dominated by cobble and rubble substrates. We examined 1,669 lake trout caught in gill nets from the two spawning areas and found 1,573 were mature, further confirming spawning aggregations occurred at these three locations. Lake trout in Lake Pend Oreille exhibited relatively rapid growth characteristic of an expanding population that is not being regulated by density dependent mechanisms.

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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 salmonids, including kokanee *Oncorhynchus nerka* and bull trout *S. confluentus*. Bull trout are particularly susceptible to negative interactions with lake trout, and bull trout populations cannot be sustained after lake trout introduction (Donald and Alger 1993; Fredenberg 2002) without human intervention. Nearby Priest and Flathead lakes share similar characteristics with Lake Pend Oreille and exemplify the impact lake trout can have on bull trout and kokanee populations. In both of these lakes, bull trout were reduced to a small fraction of their historical abundance and kokanee suffered complete collapse after 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 implement aggressive predator removal actions (netting and incentivized angling) in 2006 in an attempt to substantially reduce or collapse the lake trout population in Lake Pend Oreille (see Wahl and Dux 2010 for details). Although unintentional, commercial overharvest has led to collapse of various lake trout populations throughout their native range, including the Great Lakes and Great Slave Lake (Keleher 1972; Healey 1978; Hansen 1999).

The goal of this study was to identify patterns in lake trout distribution that could be used to guide netting efforts. Telemetry research conducted from 2007 to 2009 identified two lake trout spawning sites in Lake Pend Oreille. Netting at these sites in 2008 and 2009 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 2010 to evaluate whether lake trout spawning distribution changed in response to netting. Telemetry research also provided real-time data to guide netting during the spawning period. Additionally, lake trout implanted with transmitters allowed annual exploitation rate to be estimated (see Chapter 4). 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

To evaluate lake trout spawning distribution, we tracked mature lake trout using acoustic telemetry equipment. We surgically implanted acoustic transmitters (MA-TP16-25, Lotek Wireless Inc., Newmarket, Ontario), equipped with depth and temperature sensors into the abdomen of mature lake trout (see Wahl and Dux 2010 for surgical procedures). Depth sensors were effective to 100 m depths. Lake trout were captured for tag insertion during the spring using 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 mass, and sex (if determined) 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.

Additionally, we tagged a group of lake trout that were caught at spawning sites during the fall. We transitioned towards fall tagging of lake trout to better assess spawning site fidelity between years and to better determine the sex of fish tagged. Further, reduced density of adult lake trout necessitated tagging when fish were aggregated for logistical reasons. Transmitters and tagging procedures were identical to those described above.

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. Further description of field methodologies for telemetry can be found in Wahl et al. (2011). Once each tagged fish was relocated, we recorded transmitter code, date, time, latitude and longitude, fish depth, transmitter temperature, lake depth under fish, and lake surface temperature. We tested differences in mean depth and temperature of tagged lake trout during the spawning period among spawning sites using a general linear model (ANOVA).

Lake Trout Spawning Site 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 calculate the condition factor of the lake trout population, we collected weights of lake trout caught in gill nets during the spring. We calculated relative weight (W_r; Wege and Anderson 1978) of lake trout >280 mm using the equation:

$$W_r = (W/W_s) \times 100$$

where W = the weight of an individual and W_s = the length-specific standard weight predicted by the weight-length regression:

$$log_{10}(W_S) = a' + b \times log_{10}(L)$$

where *a'* is the intercept value and *b* is the slope of the $\log_{10}$(weight)-$\log_{10}$(length) regression and *L* is the total length of the fish. The values for a' and b for lake trout were obtained from Piccolo et al. (1993).

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 the lake trout growth rate, we applied the von Bertalanffy growth model:

$$L_t = L_\infty \left[1 - e^{-K(t-t_0)}\right]$$

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 subsamples of the ovary, and counted the number of eggs in the subsamples. 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).

RESULTS

Lake Trout Telemetry

We tagged 36 mature lake trout from April 7 to May 26, 2010, with 18 captured in the northern section and 18 captured in the southern section of Lake Pend Oreille (Figure 9). We captured and tagged 18 lake trout by gill nets and 18 by angling. These tagged lake trout averaged 697 mm total length (SE = 15, range = 595-950 mm; Figure 10) and 3.7 kg in mass (SE = 0.3, range = 1.8–9.8 kg). We tagged 18 additional lake trout from gill nets during the fall (October 7-14) with six captured at each of the three spawning sites (Bernard Beach, Windy Point, Evans Landing; Figure 9). Tagged lake trout from these sites averaged 810 mm total length (SE = 20, range = 627-917 mm; Figure 10). A complete list of tagged lake trout is compiled in Appendix B.

We tracked lake trout at least once per month from July to December and increased the frequency to at least once per week during September-October. Lake trout were tracked for 0-245 days (median = 173 d), depending on the fate of individual fish. Eight tagged lake trout either shed their tags or died by August, as no movement occurred after this point. An angler harvested one fish in August, and we were unable to locate three fish after tagging. Additionally, we were unable to locate two fish after early October. The contract netters harvested one fish during the spawning period. Through mobile tracking, we relocated tagged lake trout an average of four times per individual (SE = 0.6, range = 0-10). In the fall of 2010, 23 of the remaining 25 at-large lake trout visited at least one of the three spawning sites.

We successfully relocated an average of 51% of at-large lake trout per week (SE = 5, range = 40-64%). Tagged lake trout migrated away from spring capture and tagging locations and were widely dispersed throughout the lake prior to spawning (July 19-September 1; Figure 11). During spawning (September 13-October 20), lake trout were concentrated along the Windy Point and Bernard Beach spawning sites (Figures 12 and 13). Additionally, a concentration of lake trout was located along the west shore near Evans Landing (Figures 12 and 13). Following spawning (October 27-December 9), lake trout migrated away from spawning sites and were again widely dispersed throughout the lake (Figure 14). See Appendix C for complete weekly tracking maps.

Spawning site used was linked to the area of the original capture location. Of the lake trout captured in the northern section of the lake, 64% visited the Windy Point spawning site, and 64% of the lake trout captured in the southern section visited the Bernard Beach spawning site. Four fish visited the spawning site at Evans Landing, two originally tagged from each lake section. Additionally, 32% of tagged lake trout visited multiple sites.

During spawning (September 13 to October 20), depth of tagged lake trout at Windy Point, Bernard Beach, and Evans Landing averaged 34.5 m (SE = 2.2, mode = 30.6 m), 33.8 m (SE = 3.3), and 41.3 m (SE = 8.8, mode = 30.6), respectively (Table 11). We detected no differences in mean depth of lake trout during the spawning period among the three spawning sites ($F_{2, 28}$ = 0.78, p = 0.47). Temperature use averaged 8.1°C (SE = 0.4) at Windy Point, 7.3°C (SE = 0.4) at Bernard Beach, and 7.6°C (SE = 0.5) at Evans Landing during spawning (Table 12). Again, we detected no difference in mean water temperature among sites ($F_{2, 26}$ = 1.26, p = 0.30).

Lake Trout Spawning Site Assessment

During 24 days of the lake trout spawning period, a total of 44,806 m of gill net (163 individual nets) was set at the Windy Point spawning area. We captured 890 lake trout (4.2 lake trout per 274 m net; 3.6-4.8 = 95% CI) and examined 696 for sexual maturity. Of those fish, 336 were mature females (mean TL = 724 mm, SE = 5.0, range = 517-992 mm) and 326 were mature males (mean TL = 670 mm, SE = 5.3, range = 444-965 mm). This resulted in a sex ratio of 1.0 mature male per mature female. Length-frequency distributions of fish caught at the Windy Point spawning site are presented in Figure 15.

On 19 days during lake trout spawning, a total of 45,263 m of gill net (165 individual nets) was set at the Bernard Beach spawning site. We captured 774 lake trout (3.4 lake trout per 274 m net; 3.0-3.9 = 95% CI) and examined 697 for sexual maturity. Of those fish, 275 were mature females (mean TL = 738 mm, SE = 4.7, range = 500-1015 mm) and 380 were mature males (mean TL = 680 mm, SE = 5.0, range = 255-1000 mm). This resulted in a sex ratio of 1.4 mature males per mature female. Length-frequency distributions of fish caught at the Bernard Beach spawning site are presented in Figure 15.

Additionally, on six days during lake trout spawning, a total of 13,259 m of gill net (48 individual nets) was set at the Evans Landing spawning site. We captured 283 lake trout (3.7 lake trout per 274 m net; 2.8-5.0 = 95% CI) and examined 276 for sexual maturity. Of those fish, 88 were mature females (mean TL = 768 mm, SE =11.2, range = 514-1005 mm) and 168 were mature males (mean TL = 698 mm, SE = 8.6, range = 489-986 mm). This resulted in a sex ratio of 1.9 mature males per mature female. Length-frequency distributions of fish caught at the Evans Landing spawning site are presented in Figure 15.

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 19 to October 9. During this period, weekly catch rates of lake trout at the spawning sites were high (averaging 2.8 to 4.2 lake trout per net), and a high percentage of acoustic-tagged lake trout were located at the spawning sites (Figure 16). Catch rates of ripe or spent females also peaked during this period. Although gill nets captured ripe female lake trout as early as the first week in September, the proportion of ripe or spawned out females did not peak until the first week of October. A rapid emigration of lake trout away from the three spawning sites in mid- to late-October signaled the end of the spawning period.

Lake Trout Population Characteristics

We collected weights on 190 lake trout, ranging from 293 to 950 mm and from 0.18 to 9.84 kg. Based on these data, W_r for this population averaged 96 (median = 96, SE = 0.8, range = 70-135; Figure 17). Additionally, mean W_r increased slightly with size across the four size classes and ranged from 94 for stock-quality (300-499 mm) to 104 for memorable-trophy (800-999 mm; Figure 17).

We aged 175 lake trout (210-1005 mm) that ranged in age from 3 to 21 years. Lake trout grew from a starting age of t_0 = 1.42 years toward their asymptotic length of L_∞ = 1119 mm at an instantaneous rate of K = 0.118/year (Figure 18).

We estimated the fecundity of 190 female lake trout ranging from 559 to 997 mm ($\bar{x}$ = 765 mm, SE = 12.5). Median fecundity per female was 5,805 eggs, and egg counts ranged from 993 to 18,051. Fecundity roughly doubled for every 130 mm increase in total length (Figure 19).

DISCUSSION

Lake Trout Telemetry

During 2010, lake trout in Lake Pend Oreille used the same two spawning sites (Windy Point and Bernard Beach) that had been identified in the past (Schoby et al. 2009; Wahl and Dux 2010; Wahl et al. 2011). However, we also identified a third spawning site at Evans Landing. The Evans Landing site is likely not a new site as we had relocated fish near Evans Landing during spawning in previous years, but these relocations were few in number and sporadic. The geographic extent of this spawning site appeared smaller than the other two sites and fewer fish visited this site. Thus, it is likely that the site has been used in past years by a fewer number of lake trout, which required more telemetry data to identify it as a spawning site. Although tagged lake trout did exhibit a preference towards a spawning site near their original capture location, as has been documented in the past (Wahl and Dux 2010), several tagged fish visited two of the three spawning sites (sometimes only days apart), which suggests that lake trout can easily locate and migrate between spawning sites.

Spawning aggregations were again less distinct than in the earlier years of tracking. Gill nets set over at spawning sites may have prevented aggregations from forming by altering fish behavior. However, fish continued to occupy the same shoreline reaches where spawning has occurred in the past, and there was no evidence that fish spawned elsewhere. We do not know whether gill net disturbances negatively influenced spawning success by fish that were not captured and removed. The apparent influence of gill netting on fish distribution highlights the importance of continued telemetry research. Determining where lake trout are most concentrated within each spawning site will be important for identifying the most productive place to set gill nets as fish shift their distribution during the spawning period. More importantly, continued telemetry research is needed to assess whether disturbances from netting cause fish to seek out new spawning areas. Additionally, having telemetry data to guide netting efforts increases confidence that netting is occurring in areas of highest fish density and at times when fish are present, which will become more important as lake trout abundance continues to decline and catch rates become low.

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 (<10 m deep; e.g., DeRoche 1969, MacLean et al. 1990, Flavelle et al. 2002). However, lake trout spawning at similar depths has been reported in some studies (Storr 1962; Sly and Widmer 1984; Dux et al. 2011). Additionally, lake trout in Lake Pend Oreille spawned in water temperatures slightly cooler than reported elsewhere (Gunn 1995), but water temperatures in shallower depths of Lake Pend Oreille are within the range of temperatures used by spawning lake trout elsewhere and should not have necessitated spawning in deeper water. Because depth use at spawning sites has remained consistent across years while temperature use has varied, some other factor, such as substrate type or quality, most likely influences depth selection for spawning more than temperature. Steep shoreline slopes may provide suitable substrate (i.e., free of fine sediment) at greater depth than would be expected in lakes with lesser shoreline slope. To date, we have not evaluated the quality of spawning substrate at lake trout spawning sites.

Lake trout most often spawn along shorelines that receive prevailing winds (Scott and Crossman 1973), but this is not the case on Lake Pend Oreille. Shallow water spawning areas likely need wave action to keep spawning substrate clean of fine sediments. However, all three spawning sites on Lake Pend Oreille are characterized by steep shoreline slopes that contain many talus slides (e.g., avalanche chutes). These slides provide an influx of cobble, rubble, and boulder substrates, an important characteristic of lake trout spawning habitat (Martin 1957, Scott and Crossman 1973). As such, it is possible that substrate availability, especially at depth, plays a larger role than fetch distance in the selection of spawning sites by lake trout in Lake Pend Oreille.

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 offshore. The use of a more sensitive acoustic telemetry receiver did not vastly improve relocation success as was expected. Despite some difficulties, our overall relocation success was high (given such a large lake) during this study, especially during spawning when fish frequent shoreline habitats. We documented lake trout mixing between the three spawning sites, but we have not been able to quantify this movement. The use of stationary receivers placed at the three spawning sites to continuously log lake trout relocations should allow us to quantify how often fish move between sites, how long these movements take, and better understand the influence of gill net disturbances on distribution during spawning. Additionally, by tagging lake trout from spawning sites in the fall, sex determination of all tagged fish will be possible and will allow us to investigate site fidelity and alternate-year spawning in females.

Lake Trout Spawning Assessment

In other lakes, lake trout spawning occurs over a 5-20 day period (DeRoche 1969; Gunn 1995); however, tagged lake trout in Lake Pend Oreille have occupied spawning sites for up to two months (Schoby et al. 2009). We observed a similar pattern during 2008-10 (Wahl and Dux 2010; Wahl et al. 2011), but with the use of netting data, we have determined the duration of peak spawning activity lasts roughly three weeks as is commonly reported (DeRoche 1969; Gunn 1995). Therefore, the time lake trout spent at spawning sites prior to mid-September was likely a staging behavior.

In the past, we have reported that the combination of three years of telemetry data and two years of intense netting at spawning sites sufficiently confirmed that spawning actually occurred at these sites (Wahl et al. 2011). During the past year, we have further demonstrated that these combined techniques can be used to effectively identify a spawning site. Lake trout telemetry relocations occurred at Evans Landing on September 29, and nets set at this locatily on October 1 confirmed the presence of ripe lake trout. However, the use of telemetry alone is not always sufficient to identify a spawning site, especially when few relocations occur in an area. We relocated two lake trout in Camp Bay at roughly 32 m deep on October 5, but nets set in that location the next day caught no ripe or mature lake trout. Because no other aggregations of lake trout have been found in Lake Pend Oreille, we are confident that only three spawning sites exist at this time.

Lake Trout Population Characteristics

The W_r of lake trout in Lake Pend Oreille was high across all sizes, indicating good growth conditions for this population. Further, W_r was above the 50^{th} percentile for all sizes of fish (62^{nd} percentile for the population) when compared to populations throughout their range, which suggests there is sufficient prey for fish across size classes (Hubert et al. 1994). Although not always a good predictor of growth, W_r values have been linked to fat content in fish (McComish et al. 1974) which may influence quantity and quality of eggs and thereby reproductive success (Chambers et al. 1989; Brown and Taylor 1992). We will continue to examine W_r to evaluate changes in growth conditions that may occur with increasing kokanee density.

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 2003-04 (Hansen 2007), providing evidence that lake trout have not had a compensatory growth response to removal efforts. Lake trout abundance was increasing exponentially until recently (Hansen 2007), and the growth rate we documented was among the highest recorded for exploited lake trout populations (Healey 1978). Because growth is already rapid, the lake trout population should have a minimal 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 will continue to monitor fecundity as removal efforts continue.

RECOMMENDATIONS

1. Use gill nets to remove spawning lake trout from the areas identified in 2010.

2. Tag adult lake trout captured at spawning sites during the fall to better determine sex, investigate spawning site fidelity, and quantify alternate year spawning.

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

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

Table 11. Summary of mean depth use of individual acoustic-tagged lake trout by spawning site in Lake Pend Oreille, Idaho from September 13 to October 20, 2010.

	Depth (m)					
Location	**Mean**	**SE**	**Mode**	**Min**	**Max**	**# of fish**
Windy Pt	34.5	2.2	30.6	23.5	52.5	15
Bernard Beach	33.8	3.3	n/a	21.8	55.1	10
Evans Landing	41.3	8.8	30.6	30.6	67.3	4

Table 12. Summary of temperature use of individual acoustic-tagged lake trout by spawning site in Lake Pend Oreille, Idaho from September 13 to October 20, 2010.

	Temperature (°C)					
Location	**Mean**	**SE**	**Mode**	**Min**	**Max**	**# of fish**
Windy Pt	8.1	0.4	9.2	6.0	10.8	14
Bernard Beach	7.3	0.4	7.1	4.4	9.2	10
Evans Landing	7.6	0.5	N/A	6.8	8.4	3

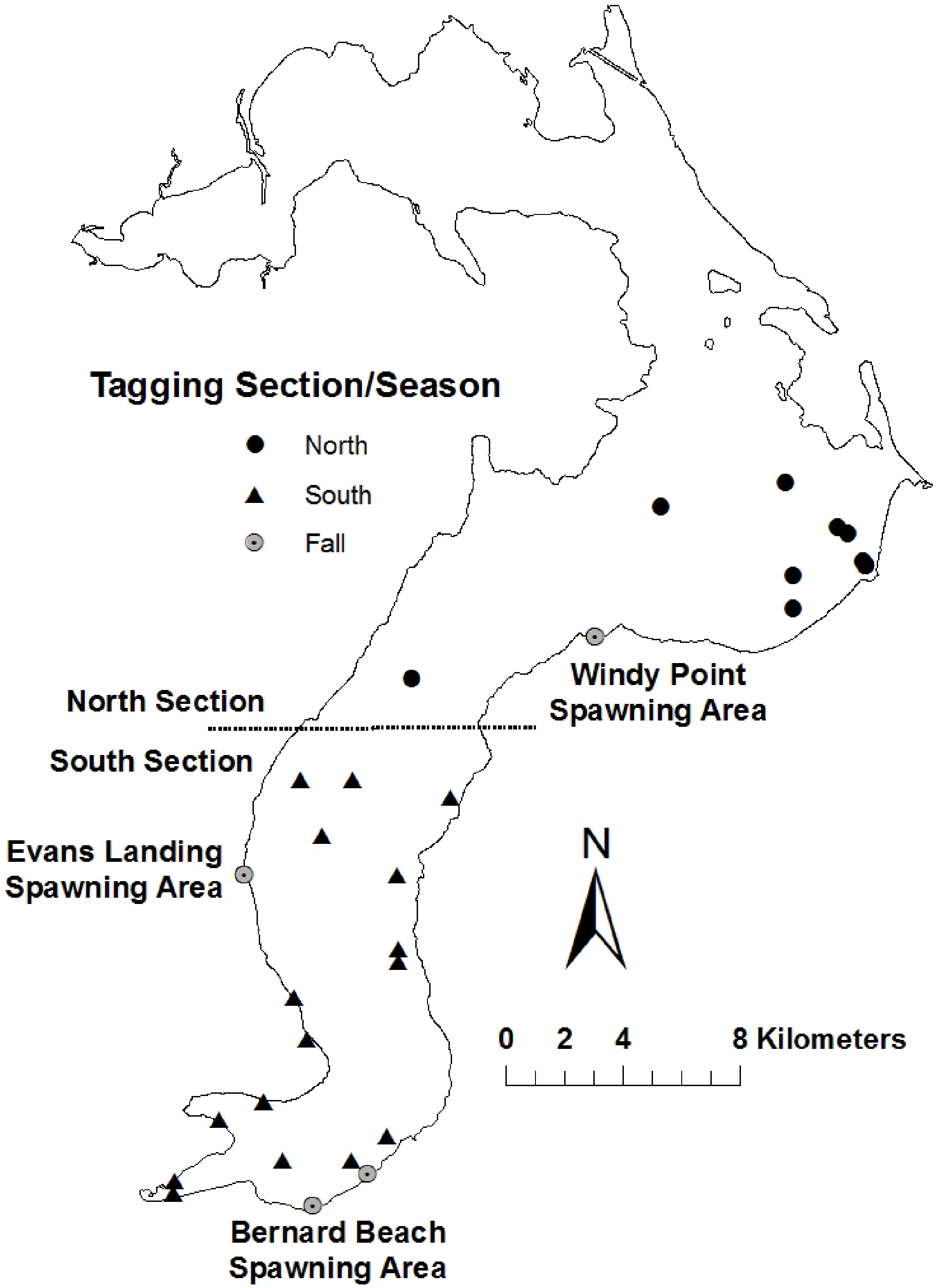

Figure 9. Locations of capture and tagging of 54 lake trout implanted with acoustic transmitters in Lake Pend Oreille during 2010. Lake trout tagged during the spring were separated between the north and south sections of the lake (denoted by the dotted line). Multiple fish were tagged at locations designated by symbols for the fall season. The locations of three spawning sites are shown.

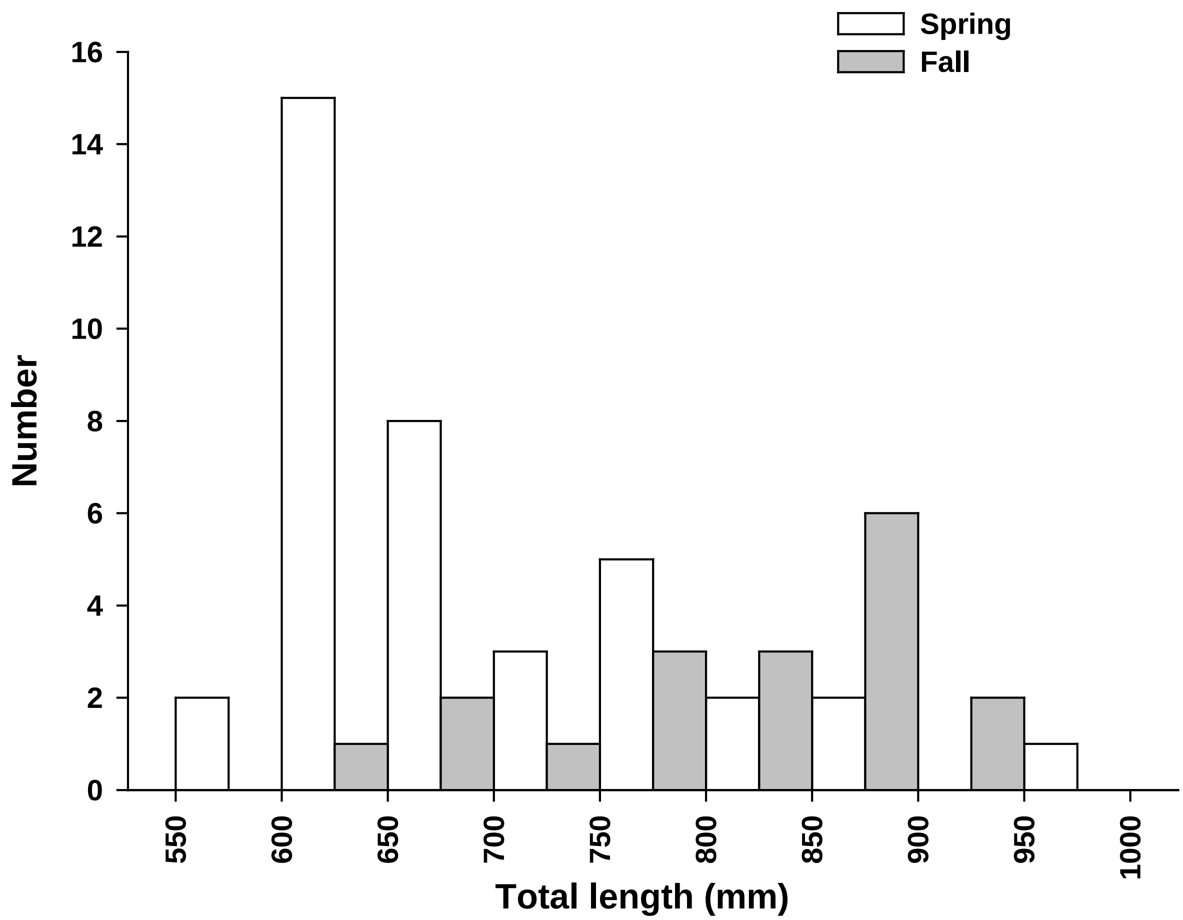

Figure 10. Length frequency of lake trout captured and implanted with acoustic transmitters in Lake Pend Oreille during spring and fall 2010.

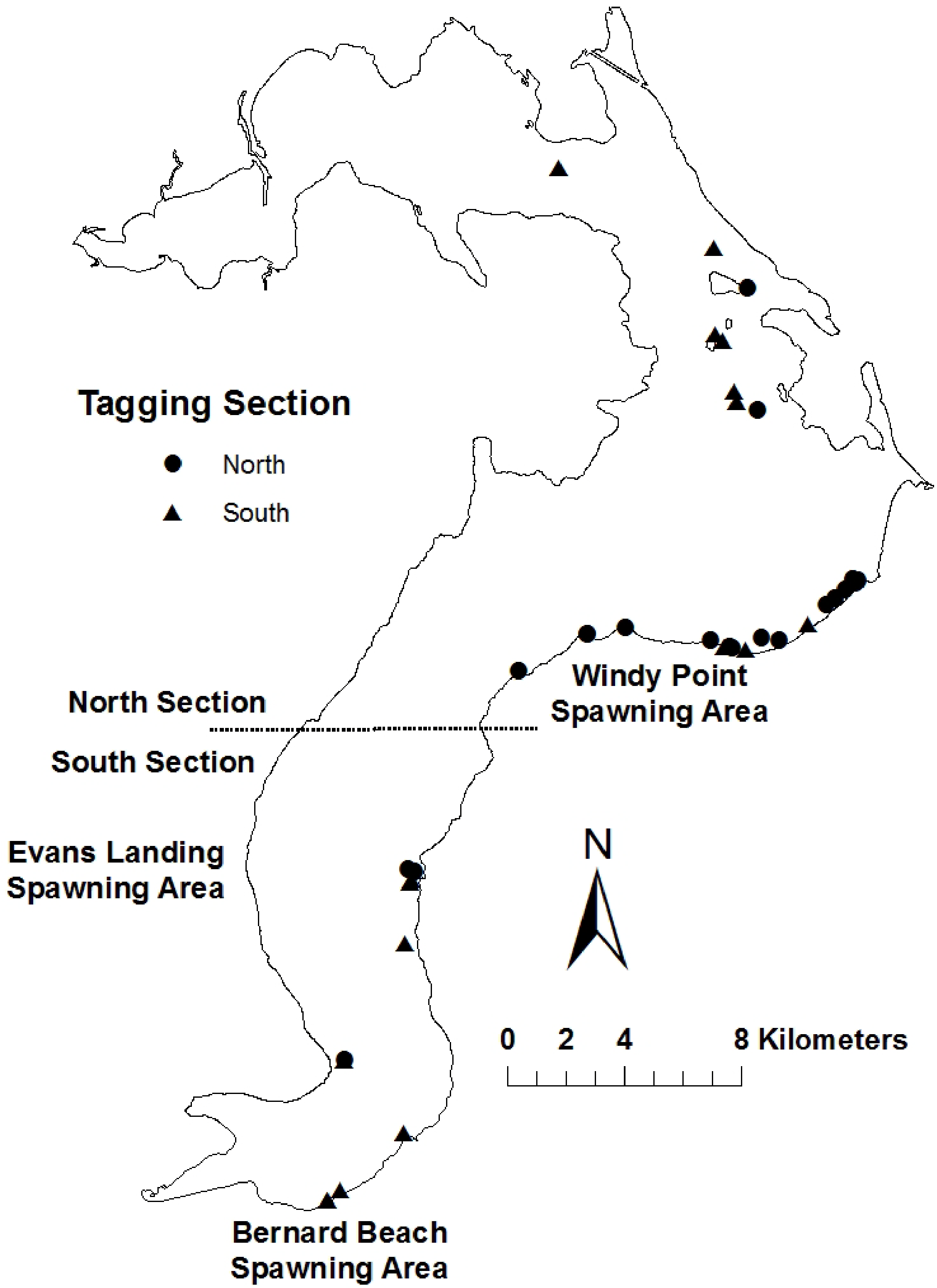

Figure 11. Locations of tagged lake trout prior to spawning (July 19 to September 1, 2010) in Lake Pend Oreille, Idaho.

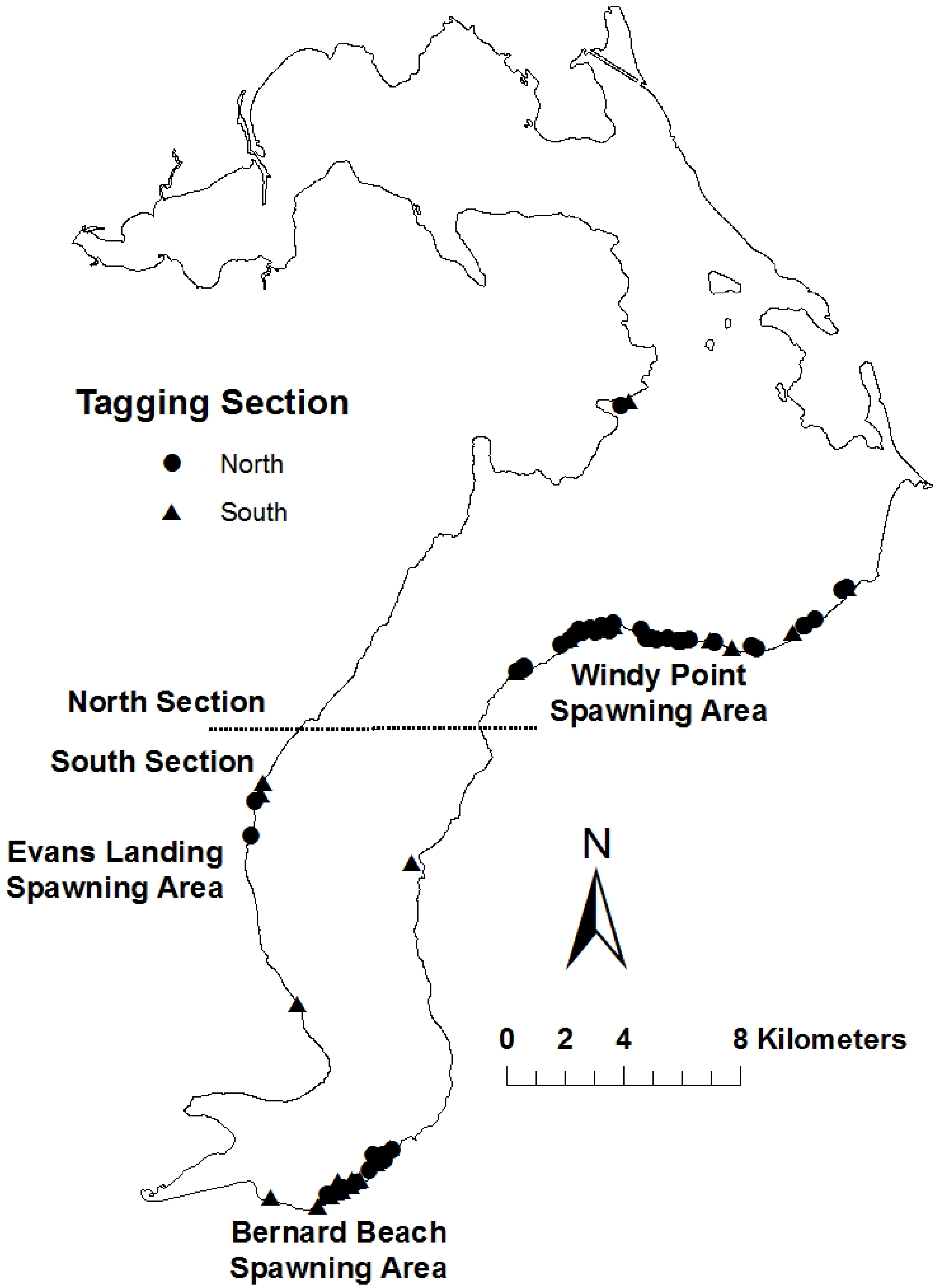

Figure 12. Locations of tagged lake trout during spawning (September 13 to October 20, 2010) in Lake Pend Oreille, Idaho.

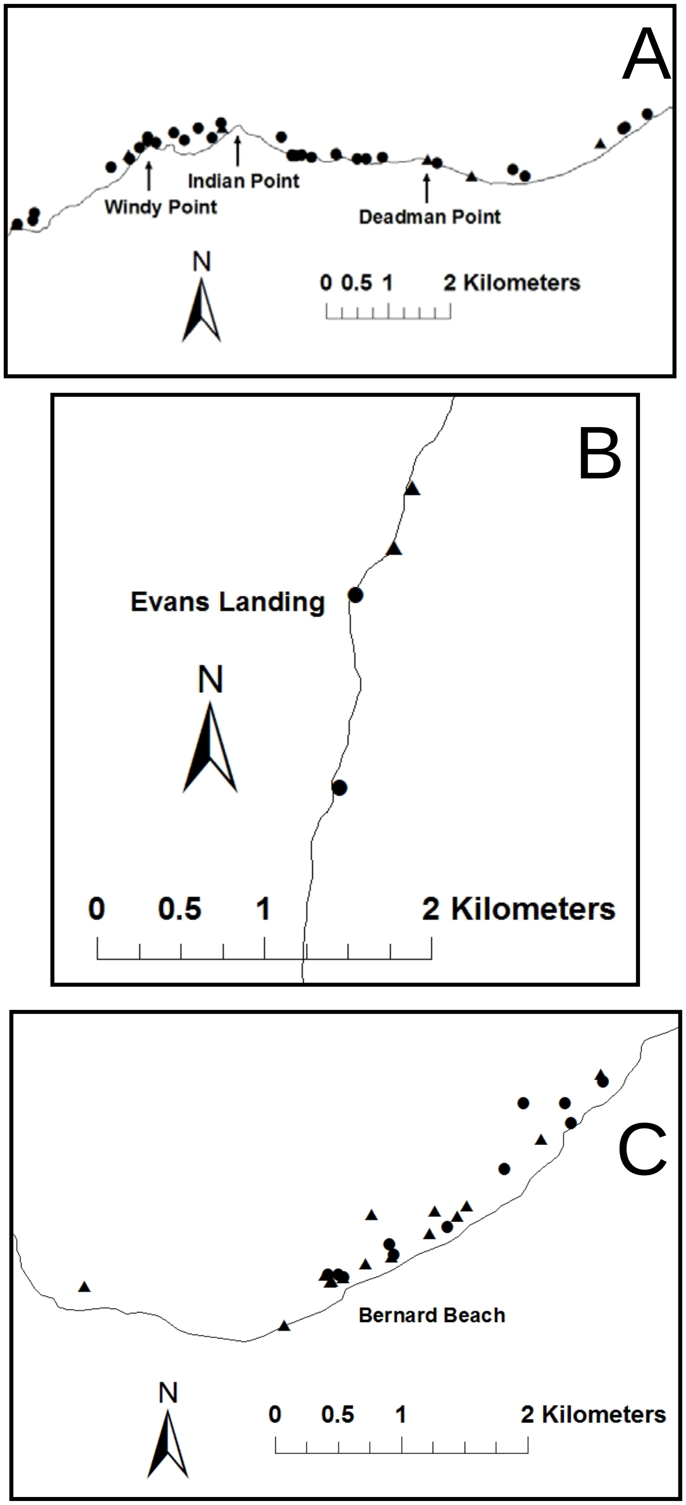

Figure 13. Locations of tagged lake trout at the three spawning sites: Windy Point (A), Evans Landing (B), and Bernard Beach (C) during spawning (September 13 to October 20, 2010) in Lake Pend Oreille, Idaho. Circles and triangles represent lake trout tagged on the north and south sections of the lake, respectively.

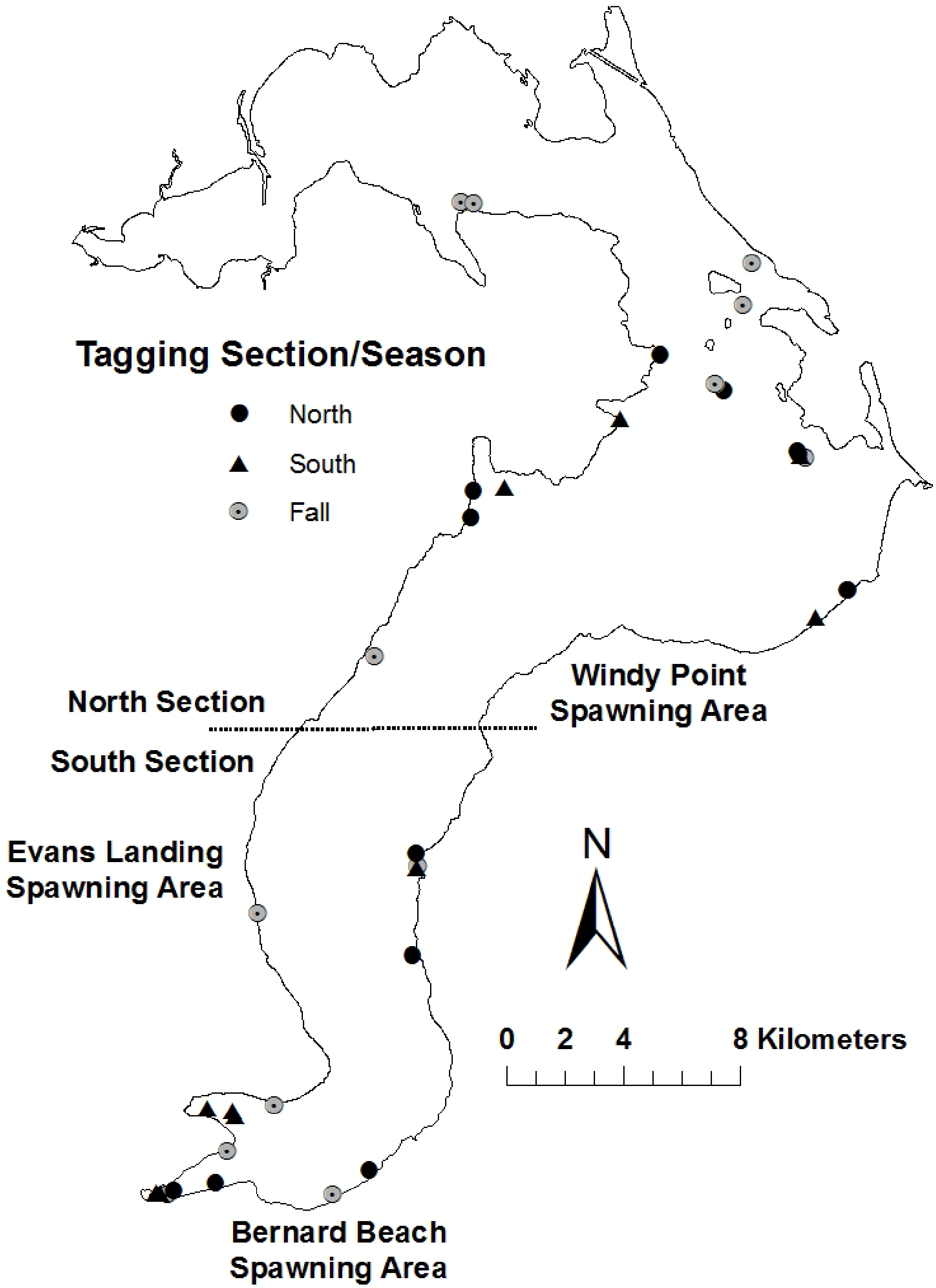

Figure 14. Locations of tagged lake trout after spawning (October 27 to December 9, 2010) in Lake Pend Oreille, Idaho.

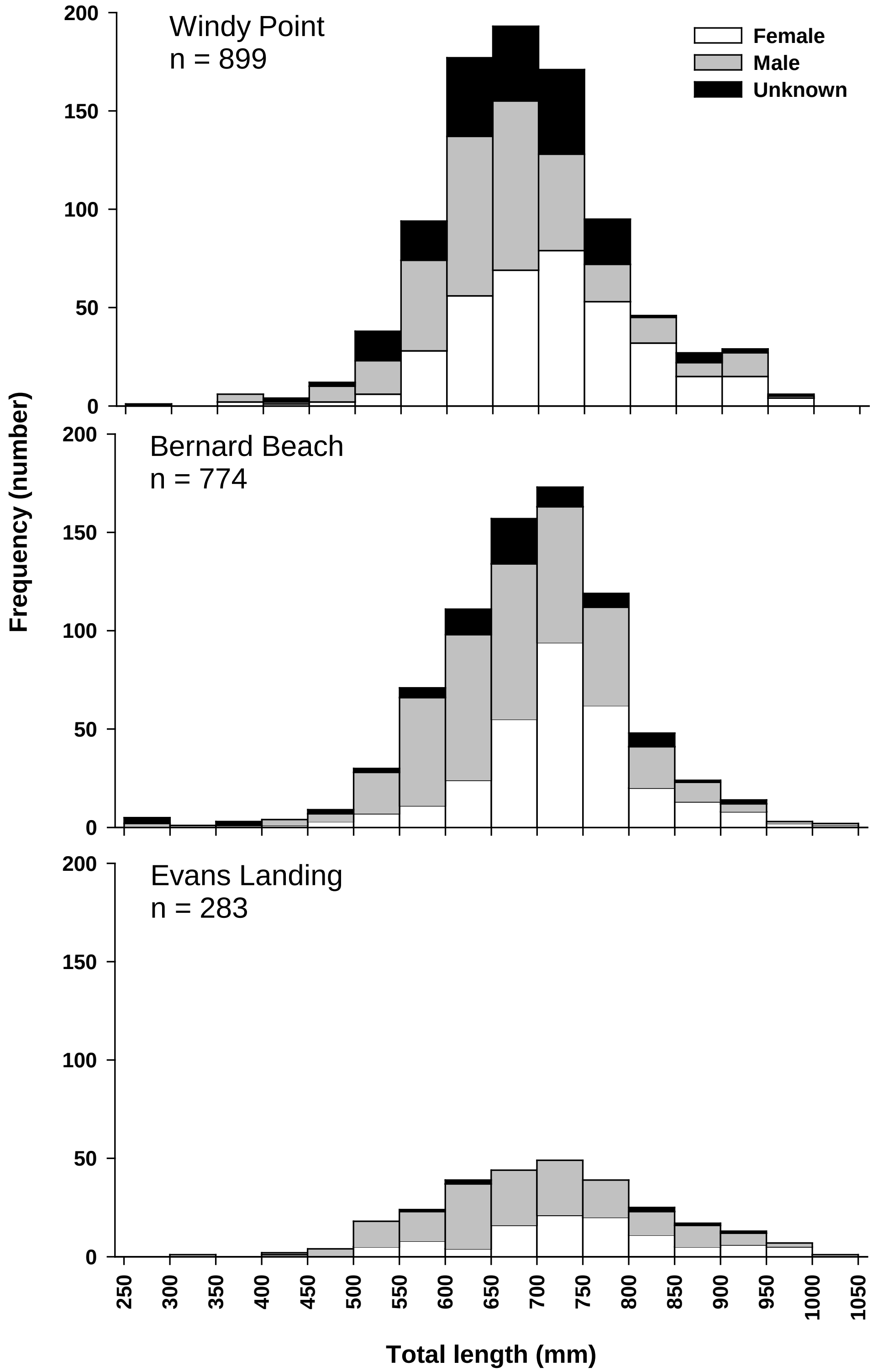

Figure 15. Length frequency histogram of lake trout captured in gillnets at Windy Point, Bernard Beach, and Evans Landing during September 8 to October 20, 2010 in Lake Pend Oreille. "Unknown" fish were not examined for sex.

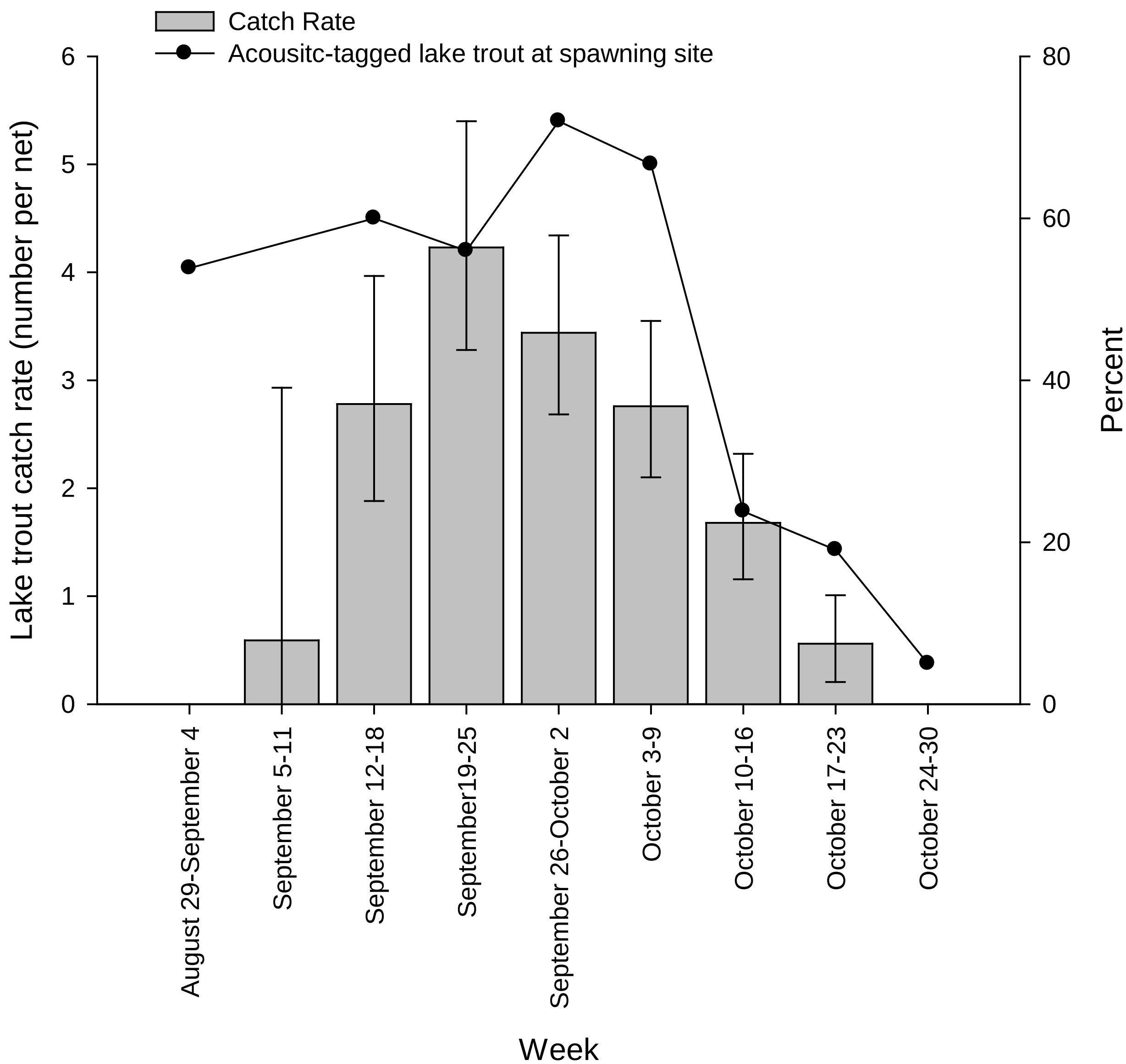

Figure 16. Lake trout catch rate and percent of acoustic-tagged lake trout at the spawning sites each week during fall 2009 in Lake Pend Oreille, Idaho.

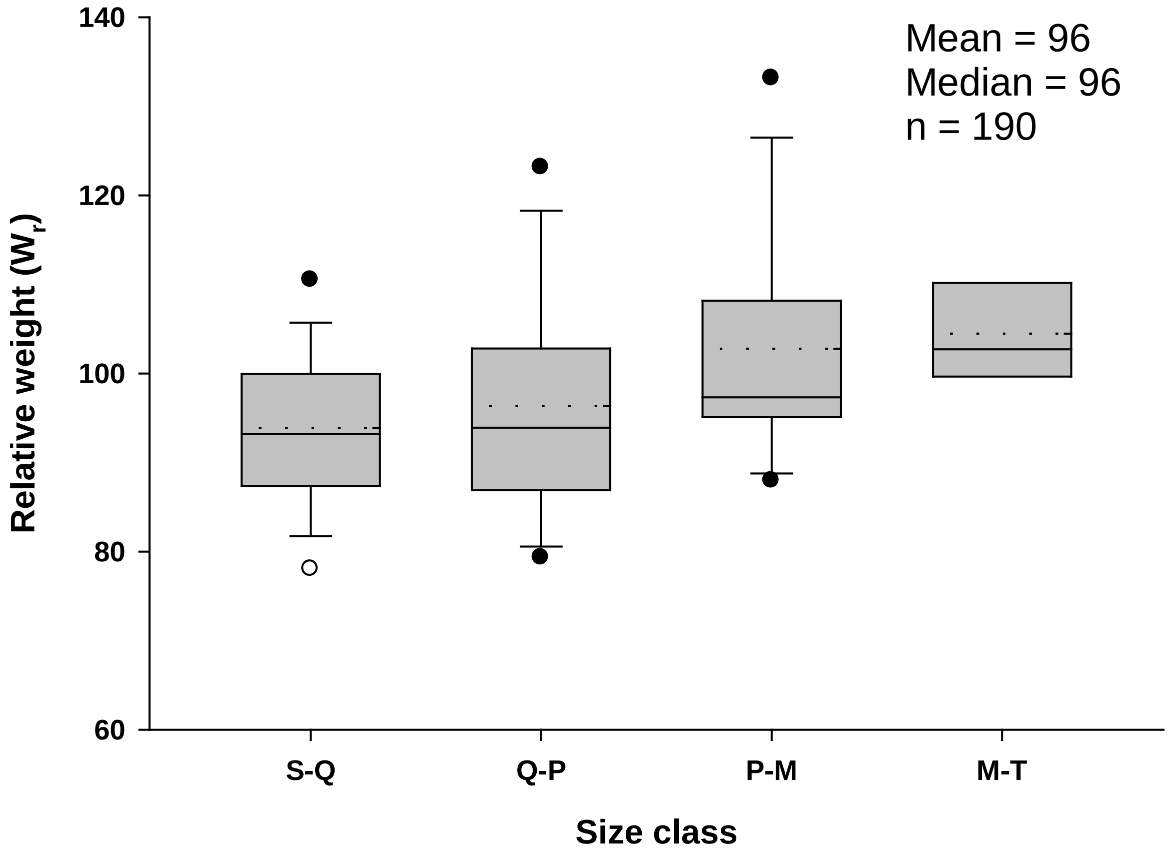

Figure 17. Box and whisker plot of relative weight (W_r) of lake trout caught in gill nets during spring 2011 in Lake Pend Oreille, Idaho for the size categories S-Q (Stock-Quality, 300-499 mm), Q-P (Quality-Preferred, 500-649 mm), P-M (Preferred-Memorable, 650-799 mm), and M-T (Memorable-Trophy, 800-999 mm). Within each box, median is indicated by a solid line, mean is indicated by a dashed line, boxes represent 25^{th} and 75^{th} percentiles, whiskers represent 10^{th} and 90^{th} percentiles, and circles represent 5^{th} and 95^{th} percentiles.

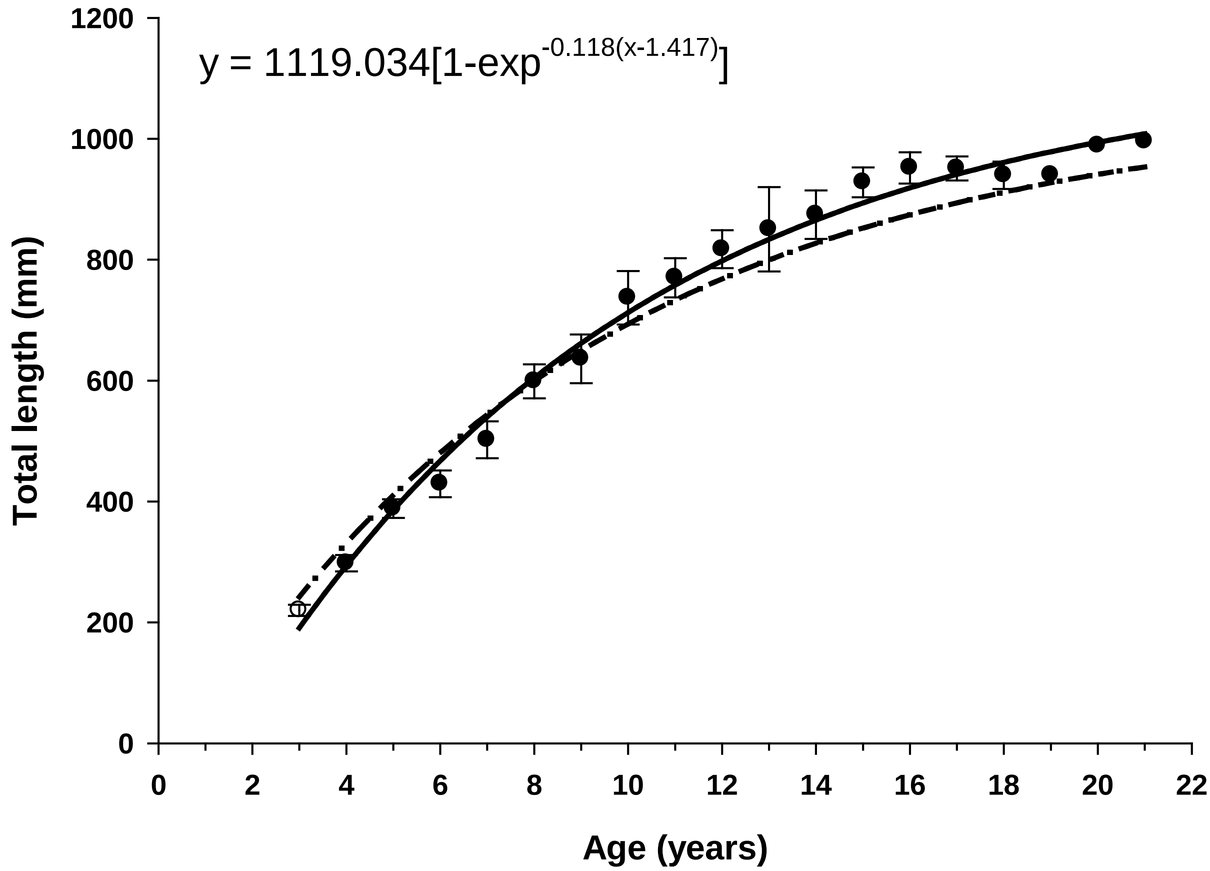

Figure 18. Mean total length-at-age with 95% confidence intervals for lake trout captured during the fall of 2010 in Lake Pend Oreille. Confidence intervals were not calculated for fish ≥19 years old because of low sample size. Growth is described by the fitted von Bertalanffy growth model (solid line), 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.

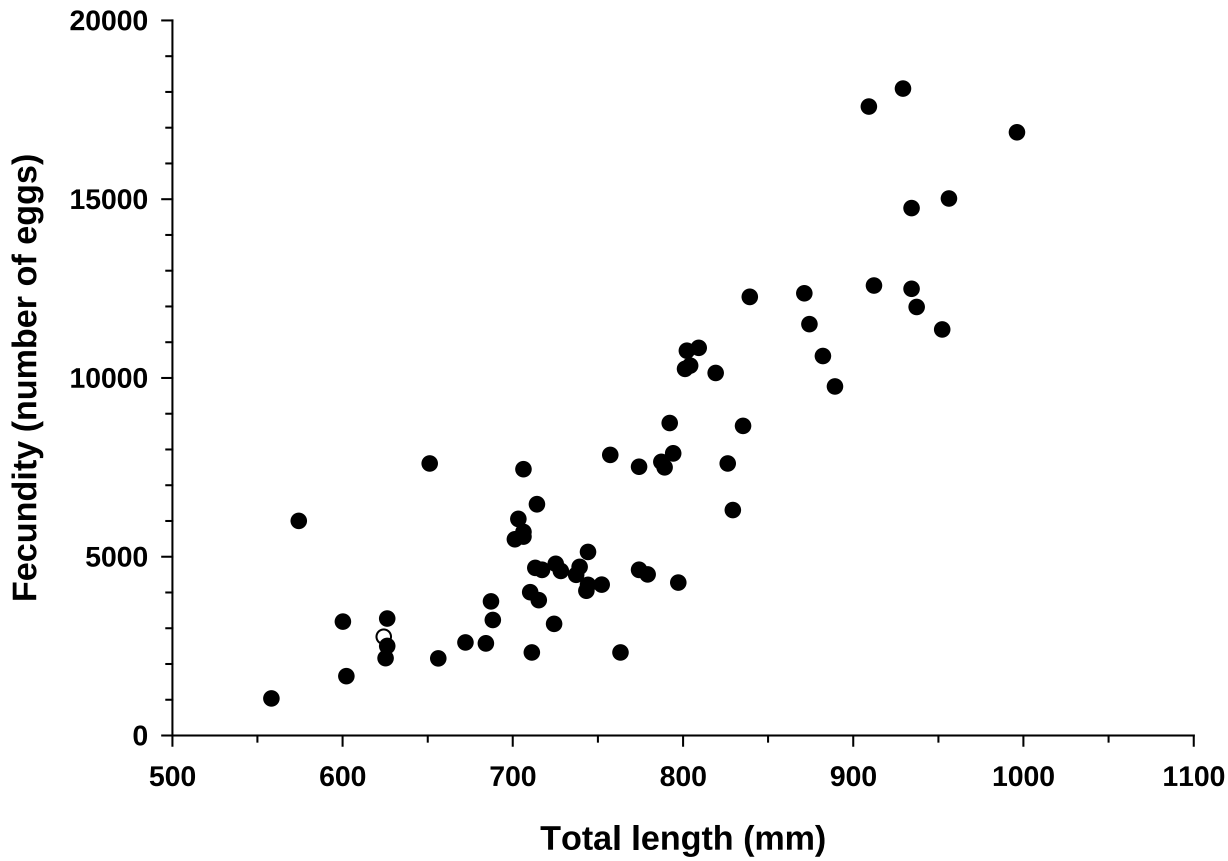

Figure 19. Fecundity-total length relationship of female lake trout captured during the fall of 2010 in Lake Pend Oreille (n = 66). These data fit a curvilinear relationship of $y = 0.00000001x^{4.0557}$ ($r^2 = 0.71$).

CHAPTER 3: RAINBOW TROUT RESEARCH

ABSTRACT

For over a decade, kokanee *Oncorhynchus nerka* recovery in Lake Pend Oreille has been limited by predation, primarily from lake trout *Salvelinus namaycush* and rainbow trout *O. mykiss*. Abundance estimates conducted in 1999 and 2006 for rainbow trout ≥406 mm indicated a stable population, so Idaho Department of Fish and Game implemented an aggressive predator removal 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 spring 2009, we tagged 97 rainbow trout with passive integrated transponder (PIT) tags (inserted in opercle musculature) to estimate population size and exploitation of rainbow trout ≥406 mm. Anglers are required to turn in heads from each fish caught to claim their reward, which allowed tags to be recaptured. Based on a head length to total length relationship we developed for rainbow trout, heads ≥71 mm were from rainbow trout ≥406 mm. Following the recapture period, we estimated 10,251 (6,894-15,932 95% CI) in Lake Pend Oreille with 29% annual exploitation. Additionally, we tagged 290 rainbow trout during spring 2010 with PIT tags, coded wire tags, or both to estimate the abundance and exploitation of all rainbow trout vulnerable to angling (≥300 mm) as well as those fish ≥406 mm. The results of that estimate will be presented in the 2011 report, following the one-year recapture period.

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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 in Lake Pend Oreille (Vidergar 2000). Other salmonid predators combined (e.g., lake trout, bull trout *S. confluentus*) only consumed an estimated 25 t of kokanee biomass (Vidergar 2000). Although the lake trout population grew exponentially since 1999 (Hansen et al. 2006), predation from the rainbow trout population (estimated at 19,157 fish ≥406 mm; Maiolie et al. 2008) still threatened the kokanee population in 2006 (Hansen 2007). Population modeling in 2006 suggested exploitation rates were not sufficient to reduce rainbow trout abundance (Hansen 2007). Therefore, Idaho Department of Fish and Game (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 rainbow trout population assessments had been conducted since 2006 to evaluate responses to these management actions. As such, we conducted this research to estimate abundance and exploitation rate of rainbow trout ≥406 mm.

METHODS

To estimate rainbow trout abundance and angling exploitation in Lake Pend Oreille, a mark-recapture study was initiated during the spring of 2009. Because the one-year recapture period had not yet been completed by the end of our 2009 contract, the results of this study are presented here. Tagging methodologies and details were described in a previous report (Wahl et al. 2011). Anglers turned heads in to the AIP freezers, and these heads were used for the capture and recapture portions of the estimate. We assumed that all rainbow trout harvested were turned in for rewards. In order to estimate abundance of rainbow trout ≥406 mm, we derived total length from a head length to total length regression developed during spring 2010. Estimates of population abundance (*N*) were generated using the Chapman mark-recapture estimate as described by the formula:

$$N = \frac{(M+1) \times (C+1)}{R+1} - 1$$

where *M* is the number of marked fish, *C* is the number of fish sampled, and *R* is the number of fish recaptured. Confidence intervals around the mean were calculated using Poisson distributions of the variable *R* obtained from Ricker (1975). Additionally, we estimated PIT tag retention over the one-year recapture period based on the number of fish that retained both PIT tags.

A similar mark-recapture estimate was initiated during 2010 to estimate all rainbow trout vulnerable to angling in Lake Pend Oreille (>300 mm) as well as rainbow trout ≥406 mm. We implanted coded wire tags (CWT) into the snout of all rainbow trout caught. Additionally, we inserted both a CWT into the snout and a passive integrated transponder (PIT) tags into the opercle musculature of a subsample of rainbow trout. We collected and tagged rainbow trout from Lake Pend Oreille using angling during spring 2010. Again, heads caught by anglers and turned in to the AIP were used for the capture and recapture portions of the estimate. Tagging efforts continued through May; therefore, any heads turned in prior to this time were excluded from the population estimate. Cumulative rainbow trout population estimates were calculated for each month after all head returns were processed and summarized.

RESULTS

During spring 2010, we measured head length and total length of 202 rainbow trout with total lengths ranging from 327 to 808 mm and head lengths ranging from 51 to 160 mm (Figure 20). These data fit the following linear regression (r^2 = 0.9633) where *TL* is fish total length (mm) and *HL* is head length (mm):

$$TL = 4.7167 \times HL + 71.332$$

From June 2009 through May 2010, anglers turned 6,689 rainbow trout heads in to the AIP. Based on the head length to total length relationship, 4,409 of these were ≥406 mm. At the end of May, we estimated 14,902 (10,439-22,050 = 95% CI) rainbow trout ≥406 mm in Lake Pend Oreille with an annual angling exploitation rate of 29%. For comparison with previous population estimates, we also estimated rainbow trout abundance at the end of December. At that point, we estimated 10,251 (6,894-15,932 = 95% CI) rainbow trout ≥406 mm. A summary of the number of heads in the AIP, recaptures, and population estimates by month is presented in Table 13. Of the 28 recaptures, 25 of these retained both PIT tags for an annual retention rate of 89%.

For the 2010-11 population estimates of rainbow trout ≥300 mm and ≥406 mm, a total of 290 rainbow trout were tagged between April 8 and May 28, 2010. Average size of tagged rainbow trout was 454 mm total length (SE = 5.5, range = 327-808; Figure 21). Because the one-year recapture period was not complete at the end of this contract period (February 28, 2011), a complete analysis and discussion of these data will appear in the 2011 report.

DISCUSSION

The rainbow trout population estimate for fish ≥406 mm remained relatively consistent from August 2009 through March 2010 (from 10,041 to 10,468), but during April and May, the population estimate of fish ≥406 mm increased to nearly 15,000. This increase may have represented recruitment of young fish into the lake from tributaries or a skewed R/C ratio during the time when mature rainbow trout are in tributaries to spawn. Because of this and the low number of fish caught from January to March, we believe the population estimate at the end of December most likely represents the true abundance of rainbow trout ≥406 mm (10,251; 6,894-15,932 95% CI). Additionally, the use of this estimate provides consistency with previous estimates (Maiolie et al. 2008).

Based on the population estimate of rainbow trout ≥406 mm generated in 2009, this population has been reduced 46% since 2006 (19,157; Maiolie et al. 2008). Additionally, the 2009 estimate is 30% lower than the one calculated in 1999 (14,607; Vidergar 2000). Therefore, it appears as though the AIP may have reduced the number of rainbow trout that would potentially feed on kokanee. However, annual angling exploitation rates calculated in 2006-07 (19%) and 2009-10 (29%) were lower than is likely necessary to drastically reduce the rainbow trout population. Average annual exploitation of 33% was not sufficient to reduce stream-dwelling trout over a nine year period (Gard and Seegrist 1972), but 62% exploitation did lead to overharvest of age-4 to age-7 cutthroat trout (Moore and Schill 1984). Additionally, population modeling of rainbow trout in Lake Pend Oreille suggested only a minimal reduction in population abundance with annual fishing exploitation rates of up to 26% (Hansen 2007). Other factors, such as a flood event in the Lightning Creek drainage (which contains some of the major rainbow trout spawning tributaries) during fall 2006 or record low kokanee abundance may have more strongly influenced rainbow trout abundance than the AIP.

The retention rate of PIT tags in the opercle musculature of rainbow trout that we estimated in Lake Pend Oreille was very similar to the 82% retention rate for Yellowstone cutthroat trout *O. clarkii bouvieri* (High et al. 2011) and 89% retention rate for bull trout (Baxter et al. 2001). However, we marked all rainbow trout with a PIT tag in each operculum, and it is possible that both tags may have been lost in some fish. We will be able to assess PIT tag retention in rainbow trout during 2010-11 because many of the tagged rainbow trout also received a CWT in the snout, which has a nearly 100% retention rate (Hale and Gray 1998).

RECOMMENDATIONS

1. Calculate 2010-11 population abundance and exploitation estimates of fish ≥406 mm and fish ≥305 mm after completion of the one-year recapture period.

2. Conduct periodic population and exploitation estimates in future years to evaluate the response of rainbow trout to the AIP program.

3. Examine rainbow trout age structure and growth rates to assess population response to the AIP program and changes in kokanee abundance.

Table 13. Monthly summary of rainbow trout heads ≥71 mm collected from Lake Pend Oreille, Idaho through the AIP, the number of recaptures, and cumulative population estimates of rainbow trout ≥406 mm with 95% confidence intervals. Period covered includes June 2009-May 2010.

	Number of heads in AIP	Number of Recaptures	Cumulative estimate of rainbow trout ≥406 mm	95% Confidence Interval	
				Lower Limit	Upper Limit
June	245	0	24,107	5,129	24,108
July	239	3	11,882	4,850	29,706
August	249	3	10,275	5,102	22,479
September	296	3	10,093	5,577	20,188
October	712	7	10,041	6,323	16,737
November	633	6	10,119	6,806	15,726
December	31	0	10,251	6,894	15,932
January	27	0	10,366	6,972	16,110
February	24	0	10,468	7,041	16,269
March	103	1	10,452	7,087	16,082
April	820	0	13,801	9,357	21,233
May	1030	5	14,902	10,439	22,050

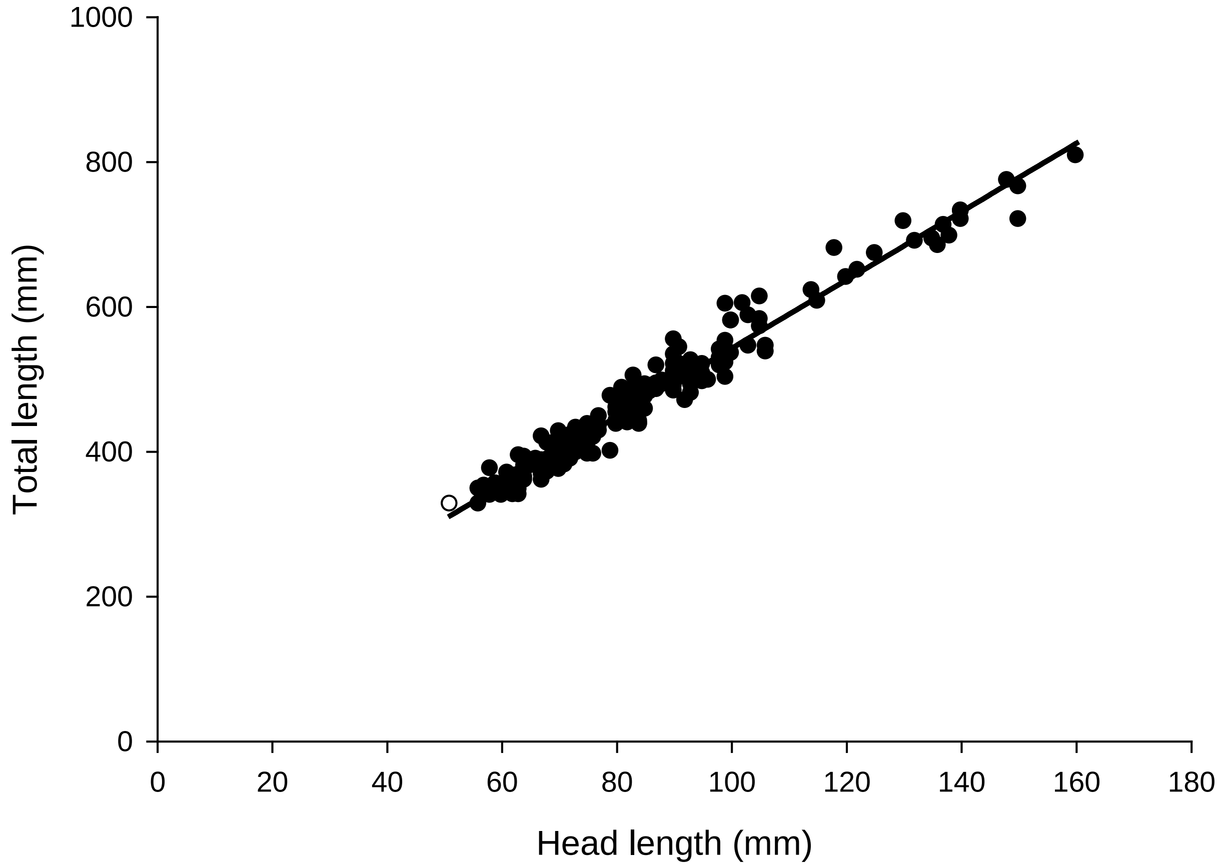

Figure 20. The relationship between head length and total length of rainbow trout from Lake Pend Oreille, Idaho during spring 2010. These data are described by the regression line and equation total length (mm) = 4.7167 head length (mm) + 71.332.

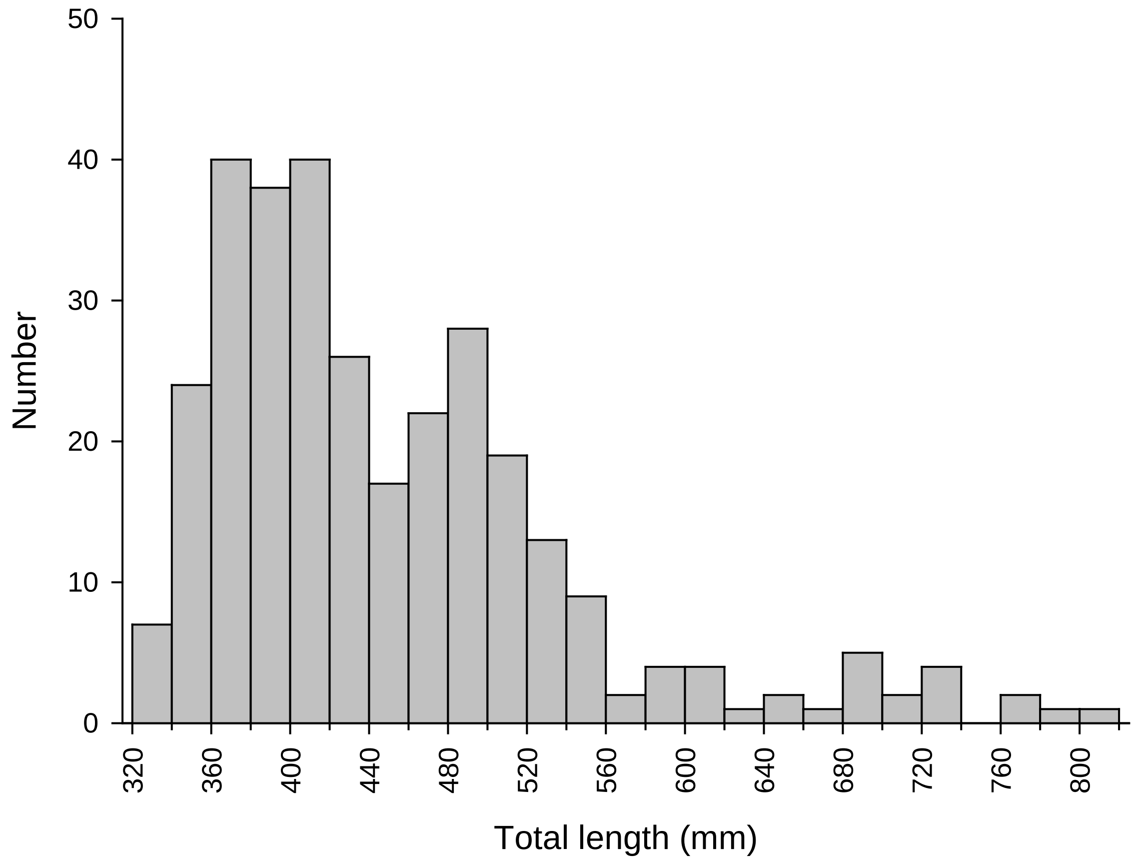

Figure 21. Length-frequency of rainbow trout tagged in Lake Pend Oreille, Idaho, during the spring of 2010 (n = 312).

CHAPTER 4: PREDATOR REMOVAL

ABSTRACT

For more than a decade, kokanee *Oncorhynchus nerka* recovery in Lake Pend Oreille has been limited by predation from lake trout *Salvelinus namaycush* and rainbow trout *O. mykiss*, so Idaho Department of Fish and Game (IDFG) implemented an aggressive predator removal strategy aimed at reducing lake trout and rainbow trout abundance. IDFG instituted unlimited harvest regulations and a $15 reward for each lake trout and rainbow trout harvested as part of the Angler Incentive Program. Additionally, IDFG contracted with Hickey Brothers, LLC to remove lake trout from Lake Pend Oreille using gill nets and deepwater trap nets. During 2010, the netters removed 12,319 and 5,014 lake trout in gill nets during the spring and fall, respectively. The netters removed an additional 400 lake trout in trap nets in the fall. Anglers turned in 8,740 lake trout heads and 7,914 rainbow trout heads. Total biomass removed in 2010 was 24,311 kg of lake trout (0.74 kg/ha) and 7,111 kg of rainbow trout (0.22 kg/ha). Since the predator removal began in 2006, 114,701 lake trout and 32,491 rainbow trout have been removed from Lake Pend Oreille.

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INTRODUCTION

Population modeling conducted in 2006 suggested the kokanee *Oncorhynchus nerka* population had a 65% chance of complete collapse due to predation, and exploitation rates of lake trout *Salvelinus namaycush* and rainbow trout *O. mykiss* at that time were not sufficient to reduce that risk (Hansen 2007). Additionally, the lake trout population was doubling every 1.6 years and was projected to reach 131,000 adults by 2010 without management intervention (Hansen et al. 2006). In an attempt to collapse the lake trout population and reduce rainbow trout predation until kokanee could recover, the Idaho Department of Fish and Game (IDFG) initiated a two-tiered predator removal program in 2006. First, IDFG liberalized the angling regulations for lake trout and rainbow trout on Lake Pend Oreille (removed creel limits and allowed anglers to fish with up to four rods) and offered $15 rewards per lake trout or rainbow trout harvested. Recently, the rod limits were removed altogether. Additionally, IDFG contracted with a commercial fishing operation that had prior lake trout netting experience in the Great Lakes (Hickey Brothers, LLC) to remove lake trout with gill nets and deepwater trap nets in Lake Pend Oreille. A combination of gill nets, trap nets, and angling was necessary to maximize the likelihood of exerting high enough annual mortality to sufficiently reduce the lake trout population and prevent kokanee extirpation (Hansen 2007).

METHODS

Hickey Brothers, LLC removed lake trout from Lake Pend Oreille using gill nets and deepwater trap nets during 30 weeks (16 weeks in the spring and 14 weeks in the fall) in 2010. Gill nets, described above, contained stretch mesh of 5.1-12.7 cm. The netters set primarily 5.1-7.0 cm mesh in the spring (February-May) and late fall (October-December) to target juvenile lake trout and 10.2-12.7 cm mesh in the early fall (September-October) to target large lake trout at spawning sites. Methodologies for setting gill nets are described in Chapter 2. Gill nets were typically set around dawn and pulled several hours later, although on occasion were set in the afternoon and pulled the following morning. Trap nets (described in detail by Peterson and Maiolie 2005) were set during the fall at locations standardized in previous years. Hickey Brothers, LLC set the trap nets during the first week of fall netting and lifted the nets at least weekly. Because rainbow trout primarily use pelagic habitats (Maiolie et al. 2006a), they are rarely caught in the commercial nets and cannot be effectively targeted.

Anglers that caught lake trout and rainbow trout from Lake Pend Oreille turned the heads in to freezers placed around the lake. Heads were collected from freezers weekly, thawed, identified, and measured from the tip of the snout to the posterior edge of the operculum.

We used recaptures of acoustic-tagged lake trout (see Chapter 2 for tagging details) 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 2011. As an additional metric to evaluate the response of lake trout to removals, we used the combined catch rate of trap nets set at four standardized locations during fall 2007-2010 (nets were set at only three of these locations in 2006) to index trends in mature lake trout abundance.

RESULTS

During spring 2010, (from February 1 to May 21), Hickey Brothers, LLC set a total of 333,116 m of gill net (1214 individual 274 m nets) and captured 12,338 lake trout (6.1 lake trout per net; 5.8-6.5 = 95% CI) and 627 bull trout (0.3 bull trout per net; 0.3-0.4 = 95% CI) with 149 direct mortalities (24%). Of the lake trout caught, 12,319 were removed. Weekly catch rates ranged from 0.2 lake trout per net (0.1-0.4 = 95% CI) during May 5-7 to 14.7 lake trout per net (11.9-18.1 = 95% CI) during February 2-5. Captured lake trout ranged in size from 181-950 mm, but because the netters set primarily small mesh nets to target small lake trout, 98% of fish caught were <450 mm (Figure 22). Based on the length-weight relationship developed for lake trout in Lake Pend Oreille (Chapter 2), the lake trout biomass removed during spring gill netting was 4,347 kg.

During fall 2010, (from September 7 to December 17), Hickey Brothers, LLC set a total of 206,837 m of gill net (754 individual 274 m nets) and captured 5,157 lake trout (3.7 lake trout per net; 3.4-4.1 = 95% CI) and 741 bull trout (0.7 bull trout per net; 0.6-0.7 = 95% CI) with 217 direct mortalities (29%). Of the lake trout caught, 5,014 were removed. From September 7 to October 21, when the netters were only fishing at spawning sites, mean catch rate was 2.8 lake trout per net (2.4-3.1 = 95% CI). After this point, netting targeted small lake trout, and mean catch rate was 5.1 lake trout per net (4.6-5.8 = 95% CI). Captured lake trout ranged in size from 199-1015 mm (Figure 22). Based on the length-weight relationship, the lake trout biomass removed during fall gill netting was 8,032 kg. Also during the fall (from September 2 to November 2), trap nets set by Hickey Brothers, LLC captured 400 lake trout, all of which were removed (1.3 lake trout per net-night; 1.0-1.7 = 95% CI; Figure 23), and 49 bull trout with 3 direct mortalities (6%). Peak weekly catch rate was 2.6 lake trout per net night (1.6-4.1 = 95% CI) during September 2-9, prior to the lake trout spawning period. Trap net-caught lake trout ranged in size from 414-925 mm. Based on the length-weight relationship, the trap nets removed 1,018 kg of lake trout biomass during the fall.

During 2010, anglers turned in 8,740 lake trout heads to the AIP program with 69% of these fish turned in during May-September (Table 14). Additionally, during 2010, anglers turned in 7,914 rainbow trout heads with 65% turned in during May-June and October-November (Table 15). However, anglers also mistakenly turned in 28 bull trout heads to the AIP program.

Of the 36 mature lake trout implanted with acoustic transmitters in the spring, 11 either died following surgery or went missing during the year. Eight of the remaining 25 were recaptured (six by the contract netters, two by anglers) for an exploitation rate of 32%. The catch rate of the standardized trap nets decreased 82% from 5.6 lake trout per net night (4.7-6.7 = 95% CI) in 2006 to 1.0 lake trout per net-night (0.7-1.3 = 95% CI) in 2009 (Figure 23). The catch rate increased slightly, although not significantly, in 2010 to 1.3 lake trout per net-night (1.0-1.7 = 95% CI; Figure 23).

DISCUSSION

Since the predator removal program began in 2006, 115,033 lake trout have been removed from Lake Pend Oreille (Table 16). However, there has been a dramatic shift in the contribution by capture method, partly because lake trout age- and size-structure has changed in response to removals. Total angler catch and trap net catch rate has declined as larger lake trout have been removed from the population. In 2006, 72% of the lake trout were removed by angling (Table 16), which is selective for lake trout primarily age-5 to age-9 (Hansen 2007). By

2009, only 30% of lake trout were removed by angling (Table 16). This pattern would have been even more pronounced in 2010, but some anglers caught large numbers of lake trout by targeting juveniles (rare previously). Similarly, trap nets, which effectively target lake trout ≥age-8, have showed a 77% decrease in catch rate since 2006. While angling and trap nets became less effective, gill nets made a bigger contribution. Gill nets increased in effectiveness once spawning sites were identified using telemetry and targeted starting in 2008. Further, gill nets have proven especially effective at capturing lake trout ≤400 mm, which were mostly unexploited until recently. Continued exploration of new netting sites allowed localized areas with high juvenile lake trout abundance to be identified and targeted starting in 2009. This increased catch substantially for lake trout that were previously unaffected and are not effectively targeted by other capture methods. The shift in contribution of each capture method over time demonstrates the importance of using multiple capture methods in a suppression program to exploit all sizes of lake trout (Hansen 2007).

Incidental bycatch of bull trout has been a concern since the lake trout removal using commercial gill nets began. A population estimate conducted in 2008 concluded that there were 8,004 (4,580-15,135 = 95% CI) bull trout in Lake Pend Oreille ≥400 mm (J. McCubbins, Avista Corp. personal communication). During 2010, 167 of the 369 mortalities were ≥400 mm, which equates to only about 2% of the estimated population size for fish in this size class. Based on these data, incidental bycatch of bull trout in the commercial netting gear has had minimal (if any) effects on this population. Further, we cannot quantify the benefit to the bull trout population from reduced predation and competition with lake trout and increased kokanee abundance from reduced lake trout predation. It is reasonable to assume that the benefit to bull trout has outweighed any negative influence from bycatch.

The number of rainbow trout turned in to the AIP was higher than the previous two years but was similar to 2007. We are unsure how angler effort, angler attitude, fishing conditions, and changes in rainbow trout abundance influence annual variation in AIP catch. However, the sustained angler catch for rainbow trout relative to reduced angler catch for lake trout suggests that reduction efforts may have had a lesser effect on rainbow trout than lake trout.

Based on the recapture rate of mature lake trout with acoustic tags, exploitation of the mature segment of the population was lower during 2010 than during the same time period in 2009 (37%; Wahl et al. 2011) and 2008 (60%; IDFG unpublished data). We suspect that decreased annual exploitation is related to behavioral response of lake trout to intensive gill netting at spawning sites. When spawning sites were first identified from telemetry in 2007, fish formed more distinct aggregations and appeared to spawn at the site nearest to where they were tagged in the lake (Schoby et al. 2009). Netting targeted spawning sites the following year and exploitation was high (60%). Since then, telemetry data has shown less distinct aggregations at spawning sites and movement of individuals among sites appeared to be more common (Chapter 2). Thus, it seems plausible that netting disrupts aggregated lake trout and leads to lower exploitation of fish at spawning sites. This needs to be further evaluated in coming years.

Despite the reduced annual exploitation, the recapture rate of lake trout tagged in previous years indicates high exploitation over a multiyear period. For instance, 60% of the mature lake trout have been removed since spring 2009 and 81% since spring 2008. Combined with a 65% reduction in standardized trap net catch rates since 2007, these data suggest that mature lake trout abundance has been dramatically reduced by predator reduction actions.

RECOMMENDATIONS

1. Continue the use of gill nets to remove mature lake trout from spawning sites in the fall and immature lake trout during other times of year. Target a level of fishing effort that results in lake trout total annual mortality ≥50%.

2. Continue the use of the AIP to reduce the numbers of lake trout and rainbow trout in Lake Pend Oreille during 2011.

3. Conduct a lake trout population and exploitation estimate during 2011-2012, and compare this to previous estimates to gauge changes in lake trout abundance and the overall effectiveness of the removal program.

4. Concurrent with the lake trout population estimate, conduct a bull trout population estimate to assess response to changes in kokanee and lake trout abundance and the influence of netting bycatch.

Table 14. Number of lake trout from Lake Pend Oreille, Idaho turned in to the AIP by month and year.

Month	2006	2007	2008	2009	2010
January	--	415	58	144	330
February	--	789	241	156	351
March	--	895	363	179	380
April	--	1,261	544	263	343
May	1,317	2,445	771	1,033	873
June	2,136	3,107	2,117	1,321	1,558
July	1,033	2,809	2,612	1,178	1,354
August	2,200	1,949	1,878	1,051	988
September	1,755	1,864	2,178	969	1,261
October	1,561	1,046	862	409	766
November	661	831	940	483	330
December	250	254	298	180	206
TOTAL	**11,041**	**17,665**	**13,020**	**7,366**	**8,740**

Table 15. Number of rainbow trout from Lake Pend Oreille, Idaho turned in to the AIP by month and year.

Month	2006	2007	2008	2009	2010
January	--	124	216	27	42
February	--	78	33	45	68
March	--	154	96	79	176
April	--	1,050	357	241	616
May	1,211	1,376	548	948	1,254
June	510	1,212	711	602	953
July	206	396	337	392	461
August	375	526	244	369	387
September	544	654	391	447	828
October	1,561	1,114	644	967	1,696
November	1,412	1,288	1,073	1,452	1,216
December	129	171	203	224	217
TOTAL	**5,948**	**8,141**	**4,695**	**5,793**	**7,914**

Table 16. Number of lake trout removed from Lake Pend Oreille, Idaho by different gear types each year.

Gear	2006	2007	2008	2009	2010	Total
Angling	11,041	17,665	13,020	7,366	8,740	57,832
Gill Nets	2,774	4,501	10,252	17,186	17,334	52,047
Trap Nets	1,500	1,335	1,509	410	400	5,154
TOTAL	**15,315**	**23,501**	**24,781**	**24,962**	**26,474**	**115,033**

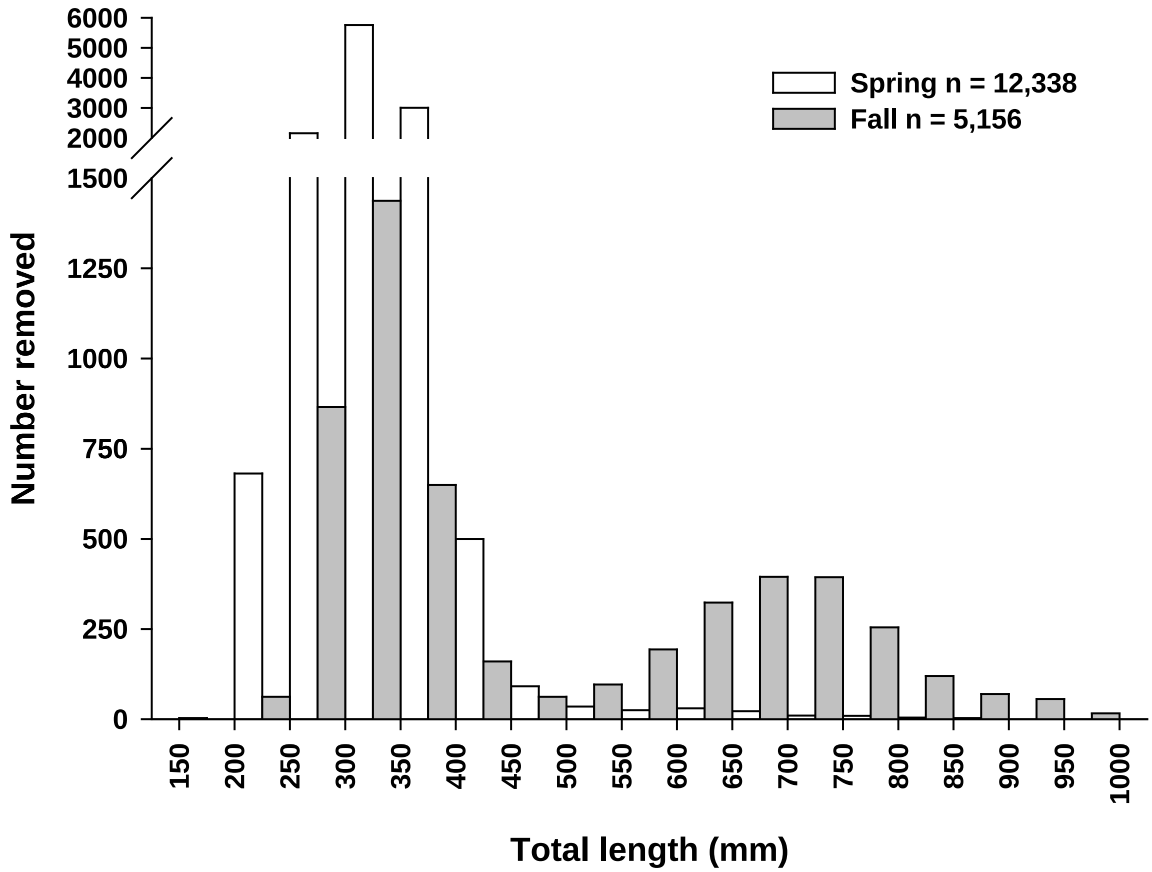

Figure 22. Length frequency histogram of lake trout removed during the spring and fall of 2010 in Lake Pend Oreille.

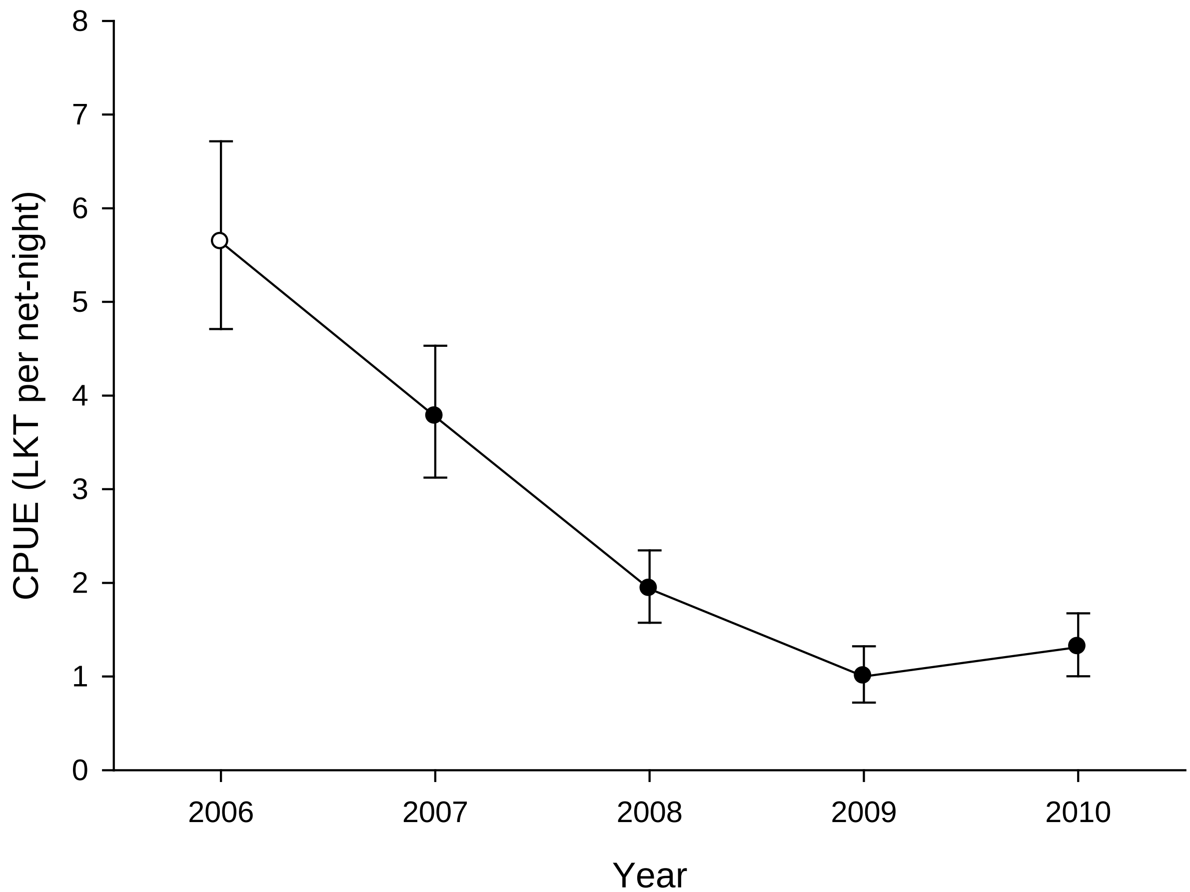

Figure 23. Mean catch rate and 95% confidence intervals of lake trout caught in trap nets set at four standardized locations during fall in Lake Pend Oreille, Idaho. The 2006 catch rate is based on three of the four standardized trap net locations.

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APPENDICES

Appendix A. 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.

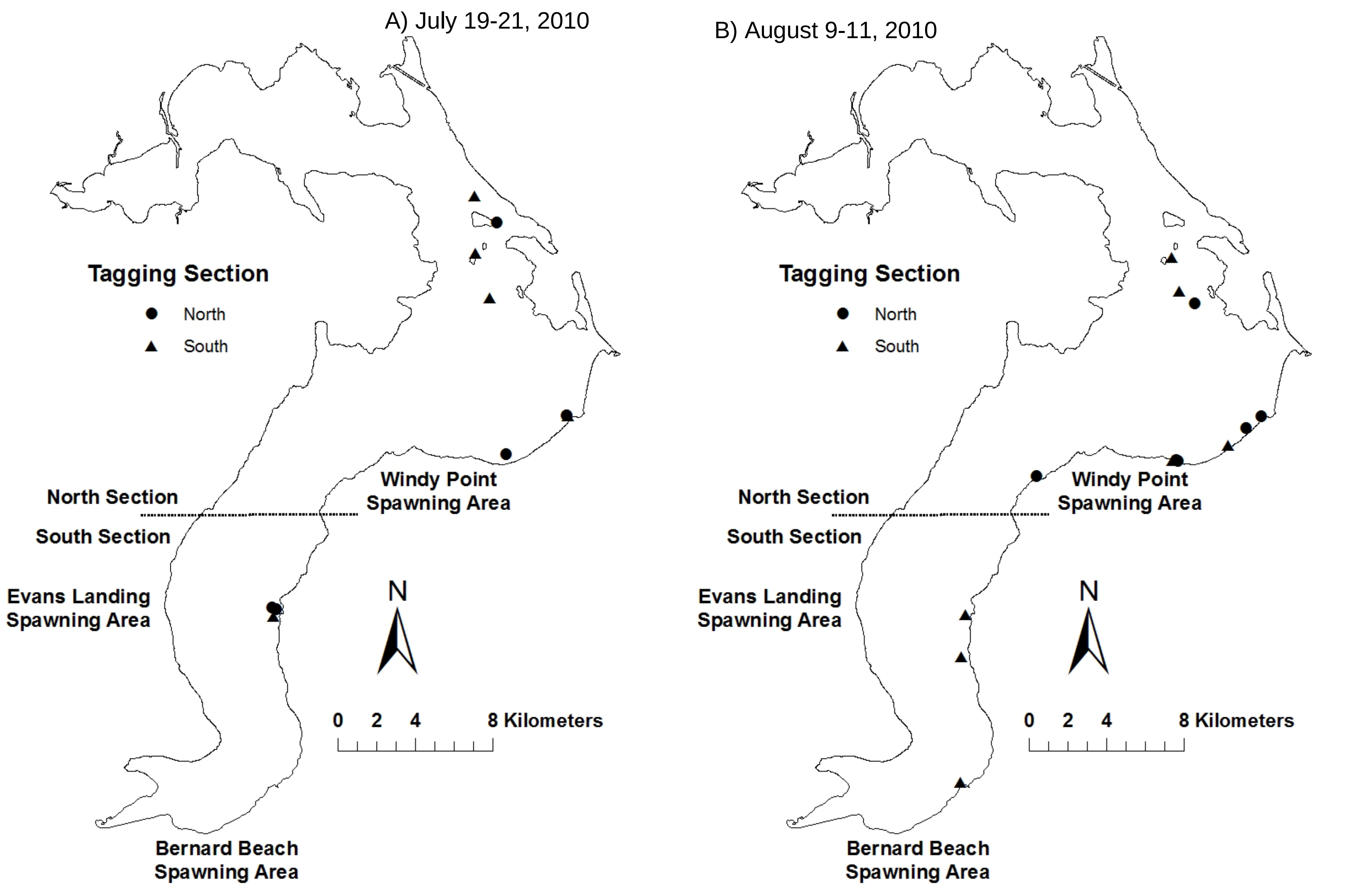
Appendix B. Tag number, tag date, capture location, size and sex of lake trout captured and tagged with acoustic transmitters in Lake Pend Oreille, Idaho in 2010. [A] This tag was used in a new fish after the original fish was harvested by an angler. Fate of fish was as of the end of February 2011; harvested fish were removed by either anglers (A) or the netters (N).

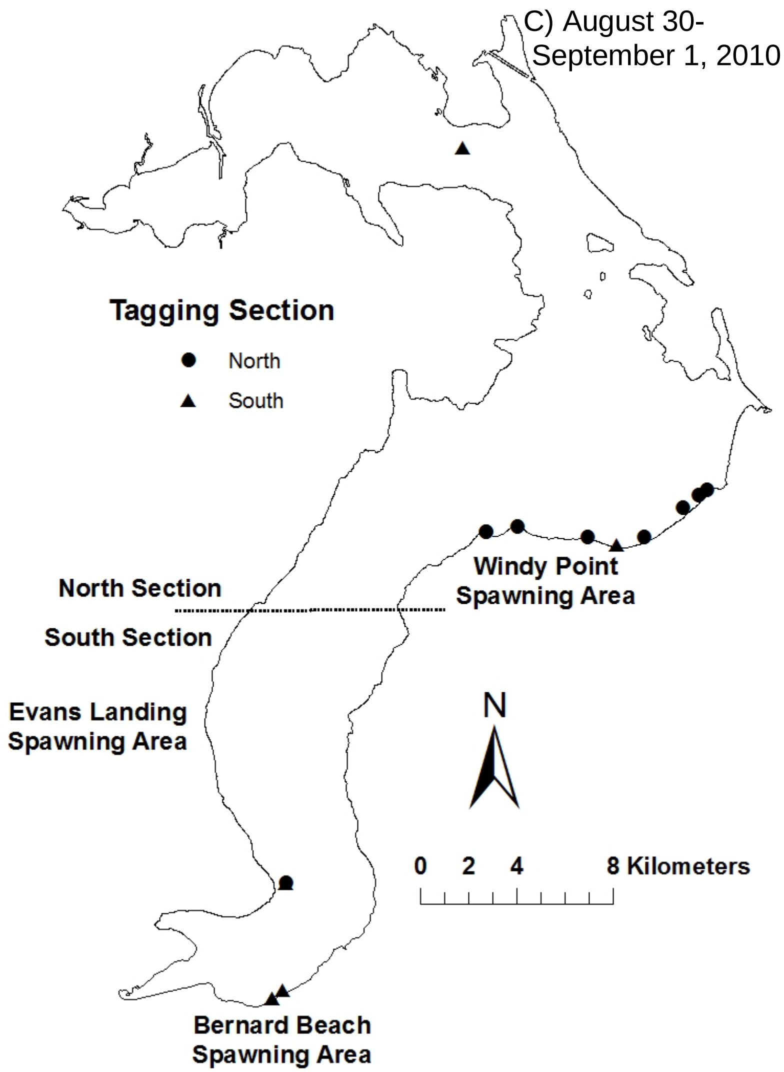
Tag ID	Date Tagged	Capture Method	Capture Location	Lake Section	Total Length (mm)	Weight (kg)	Sex	Number of Locations	Fate of Fish	Date of Last Record
5	4/30/2010	Angling	Mineral Point	North	655	2.85	U	1	Harvested (A)	8/2/2010
40800	5/18/2010	Angling	Granite Bay	North	772	5.14	U	8	At-Large	11/1/2010
40900	4/7/2010	Gill Net	Lee's Point	North	630	2.39	U	1	Dead	7/19/2010
41000	4/30/2010	Angling	Longbeach	North	802	4.98	U	6	At-Large	10/20/2010
41100	4/14/2010	Gill Net	Lee's Point	North	950	9.84	U	10	At-Large	12/7/2010
41200	4/7/2010	Gill Net	Lee's Point	North	641	2.60	U	9	Harvested (A)	2/11/2011
41300	4/7/2010	Gill Net	Lee's Point	North	677	3.10	U	9	At-Large	11/1/2010
41400	4/7/2010	Gill Net	Lee's Point	North	662	3.40	U	7	At-Large	12/8/2010
41500	4/7/2010	Gill Net	Lee's Point	North	630	2.43	U	5	At-Large	12/7/2010
41600	4/14/2010	Gill Net	Lee's Point	North	884	8.61	M	9	At-Large	12/7/2010
41700	4/7/2010	Gill Net	Lee's Point	North	695	3.40	U	1	Dead	9/29/2010
41800	4/7/2010	Gill Net	Lee's Point	North	604	2.66	U	1	Dead	8/9/2010
41900	4/7/2010	Gill Net	Lee's Point	North	695	3.78	F	6	At-Large	12/8/2010
42000	4/7/2010	Gill Net	Lee's Point	North	777	4.90	M	4	Dead	9/29/2010
42100	4/30/2010	Angling	Longbeach	North	605	2.11	U	1	Dead	8/9/2010
42200	4/30/2010	Angling	Off Clark Fork River	North	712	3.70	U	9	At-Large	11/1/2010
42300	5/1/2010	Angling	North of Whiskey Rock	South	625	2.35	U	9	At-Large	12/7/2010
42400	5/6/2010	Gill Net	Capehorn	South	843	7.05	U	7	At-Large	12/7/2010
42500	5/7/2010	Gill Net	Capehorn	South	627	2.37	U	1	Unknown	10/27/2010
42600	4/22/2010	Gill Net	Idlewilde Bay	South	648	2.20	U	1	Dead	8/31/2010
42700	4/22/2010	Gill Net	Idlewilde Bay	South	650	2.70	U	1	Dead	7/19/2010
42800	5/7/2010	Gill Net	Capehorn	South	613	1.94	U	0	Unknown	N/A
42900	4/22/2010	Gill Net	Scenic Bay	South	699	3.96	U	0	Unknown	N/A
43000	4/30/2010	Angling	Maiden Rock	South	733	4.35	F	1	Dead	7/19/2010
43100	4/27/2010	Angling	Whiskey Rock	South	636	3.08	U	2	Unknown	10/20/2010
43200	5/13/2010	Angling	South of Whiskey Rock	South	595	2.19	U	6	At-Large	11/1/2010
43300	5/14/2010	Angling	South of Cement Plant	South	650	2.46	F	4	At-Large	10/20/2010
43400	5/12/2010	Angling	North of Capehorn	South	641	1.80	U	4	At-Large	10/5/2010
43500	5/17/2010	Angling	Maiden Rock	South	764	4.64	F	0	Unknown	N/A
43600	5/19/2010	Angling	Maiden Rock	South	604	2.18	U	5	Harvested (N)	9/29/2010
43700	5/24/2010	Angling	North of Cedar Creek	South	705	3.17	U	10	At-Large	12/7/2010
43800	5/26/2010	Angling	North of Capehorn	South	786	5.33	U	6	At-Large	12/8/2010
43900	5/18/2010	Angling	Lakeview	South	851	6.27	U	9	At-Large	12/7/2010
45700	4/25/2010	Angling	Off Clark Fork River	North	638	2.71	U	2	Unknown	9/29/2010
45800	5/5/2010	Gill Net	Idlewilde Bay	South	618	2.37	U	1	Dead	8/10/2010
45900	4/30/2010	Angling	Off Clark Fork River	North	757	5.00	U	2	At-Large	11/1/2010
43600[A]	10/8/2010	Gill Net	Bernard Beach	--	892	--	F	1	At-Large	12/8/2010
44000	10/7/2010	Gill Net	Evans Landing	--	724	--	F	0	Unknown	N/A
44100	10/7/2010	Gill Net	Evans Landing	--	917	--	F	1	At-Large	12/7/2010
44200	10/7/2010	Gill Net	Evans Landing	--	810	--	M	0	Unknown	N/A
44300	10/7/2010	Gill Net	Evans Landing	--	858	--	M	1	At-Large	12/7/2010
44400	10/7/2010	Gill Net	Evans Landing	--	777	--	F	1	Unknown	N/A

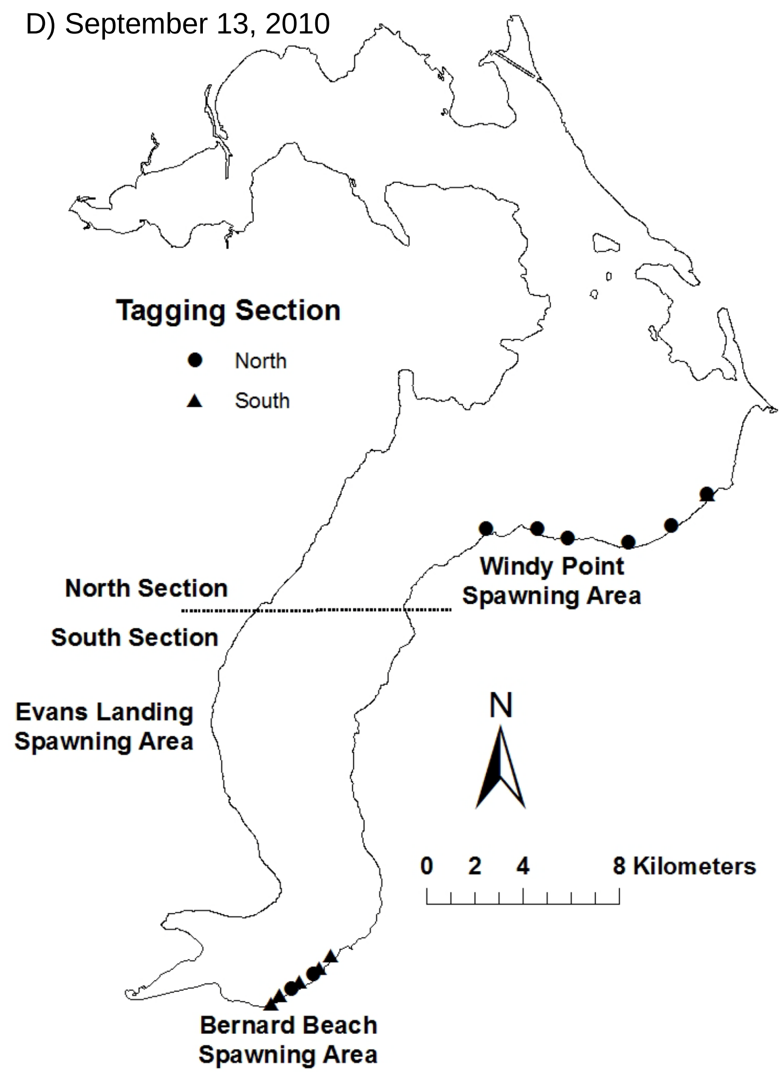
Appendix B. Continued.

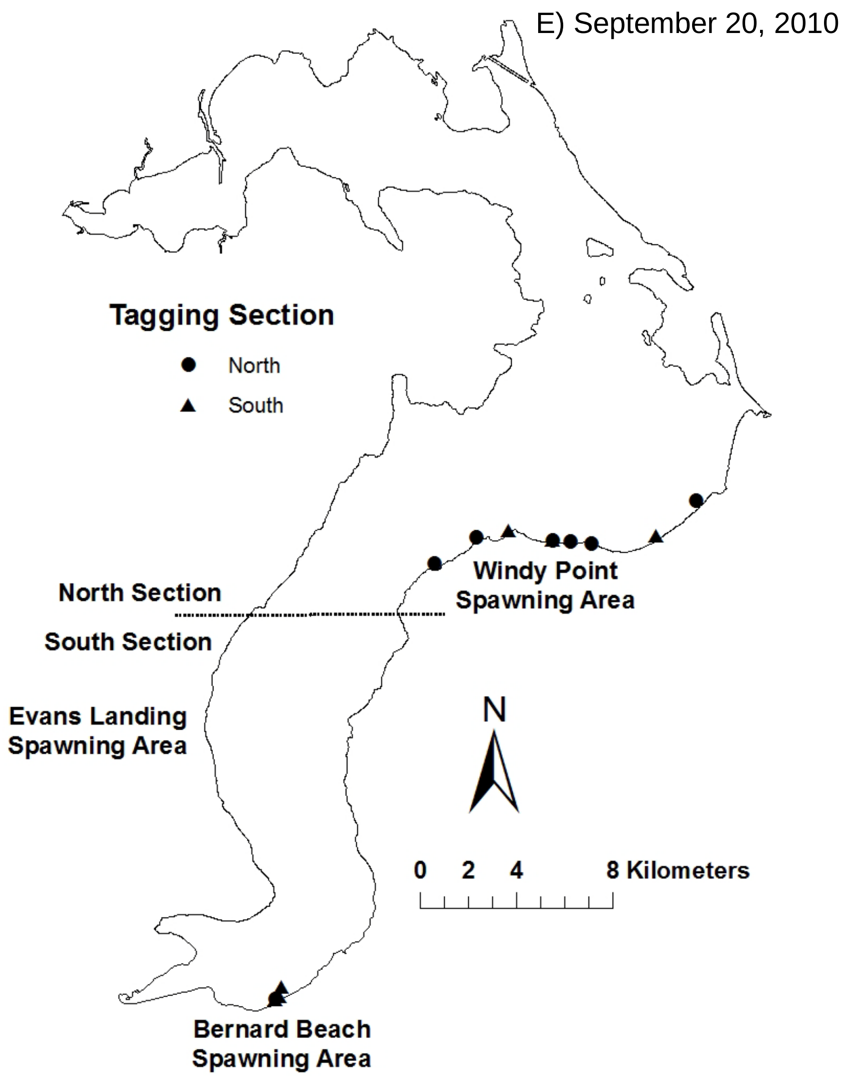
Tag ID	Date Tagged	Capture Method	Capture Location	Lake Section	Total Length (mm)	Weight (kg)	Sex	Number of Locations	Fate of Fish	Date of Last Record
44500	10/7/2010	Gill Net	Evans Landing	--	882	--	F	0	Unknown	N/A
44600	10/8/2010	Gill Net	Bernard Beach	--	690	--	F	1	At-Large	12/8/2010
44700	10/8/2010	Gill Net	Bernard Beach	--	816	--	M	2	At-Large	12/7/2010
44800	10/8/2010	Gill Net	Bernard Beach	--	791	--	F	1	At-Large	12/8/2020
44900	10/8/2010	Gill Net	Bernard Beach	--	817	--	M	1	At-Large	12/7/2010
45000	10/8/2010	Gill Net	Bernard Beach	--	627	--	M	2	Harvested (A)	12/23/2010
45100	10/14/2010	Gill Net	Windy Point	--	870	--	F	0	Unknown	N/A
45200	10/14/2010	Gill Net	Windy Point	--	872	--	F	1	At-Large	12/9/2010
45300	10/14/2010	Gill Net	Windy Point	--	912	--	M	1	At-Large	12/8/2010
45400	10/14/2010	Gill Net	Windy Point	--	775	--	F	1	At-Large	12/8/2010
45500	10/14/2010	Gill Net	Windy Point	--	872	--	F	0	Unknown	N/A
45600	10/14/2010	Gill Net	Windy Point	--	671	--	F	2	At-Large	12/8/2010

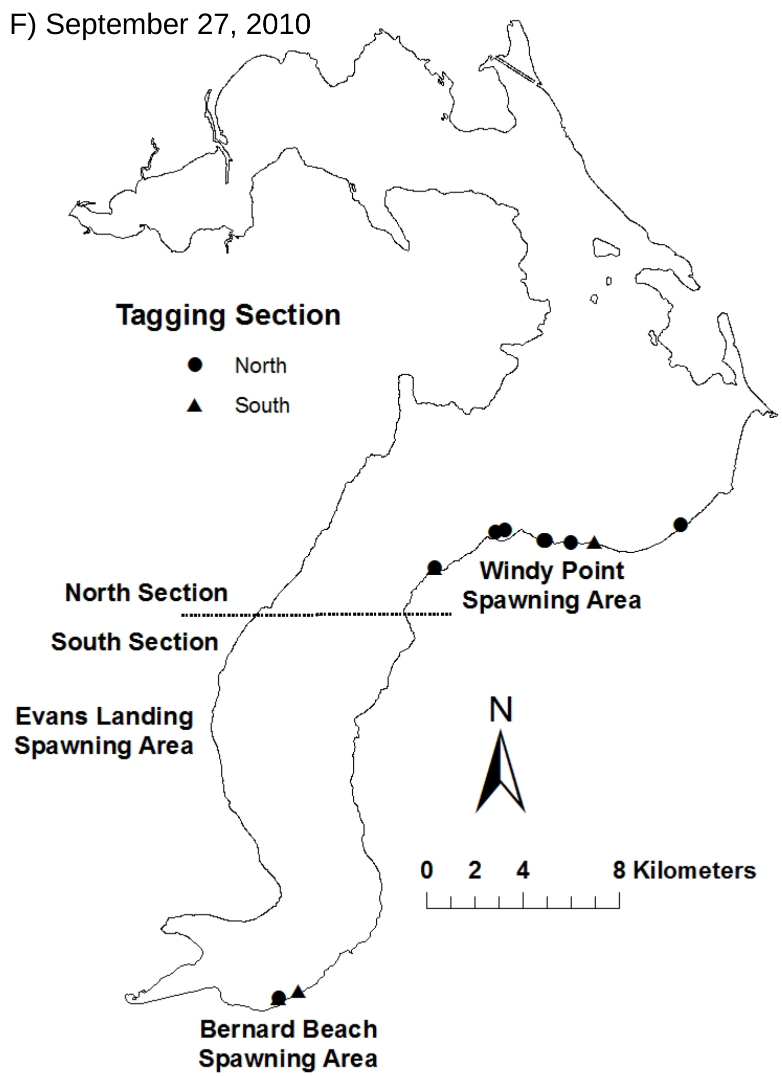
Appendix C. Telemetry locations of mature lake trout from July 19 to December 9, 2010 in Lake Pend Oreille. Only one location is shown for each fish during a tracking event.




C) August 30-
September 1, 2010
Tagging Section
North
South
North Section
South Section
Windy Point
Spawning Area
Evans Landing
Spawning Area
N
0 2 4 8 Kilometers
Bernard Beach
Spawning Area

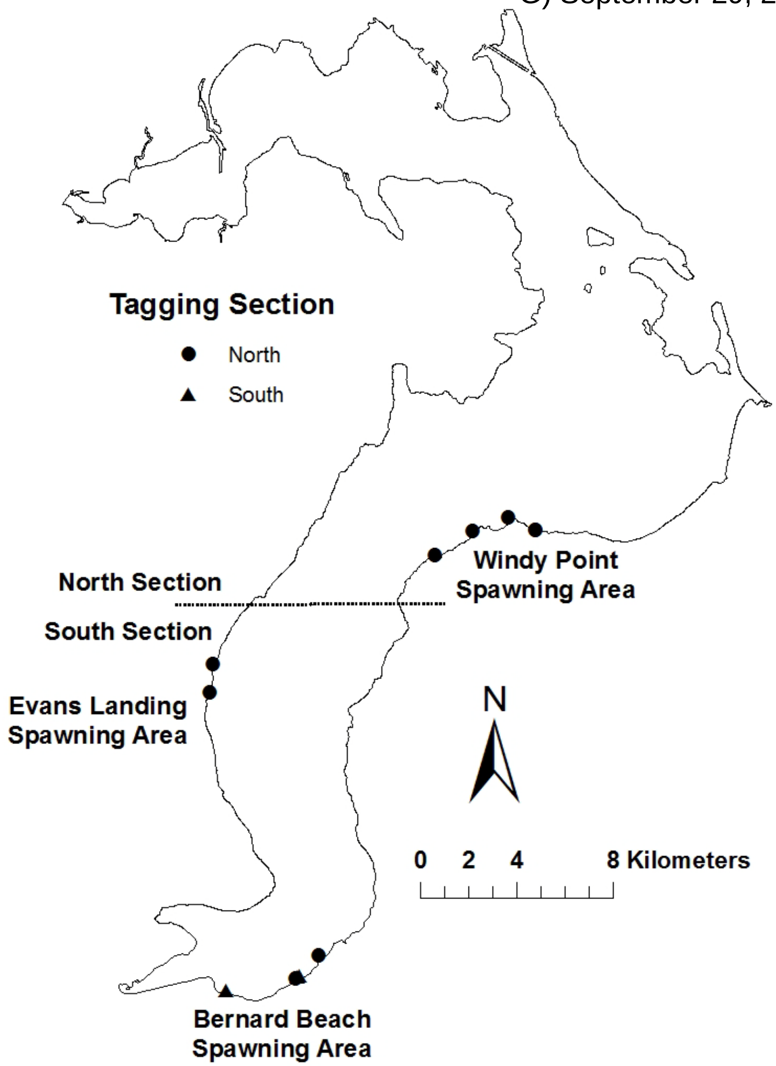

D) September 13, 2010
Tagging Section
North
South
North Section
South Section
Windy Point
Spawning Area
Evans Landing
Spawning Area
N
0 2 4 8 Kilometers
Bernard Beach
Spawning Area


E) September 20, 2010
Tagging Section
North
South
North Section
South Section
Windy Point
Spawning Area
Evans Landing
Spawning Area
Bernard Beach
Spawning Area
N
0 2 4 8 Kilometers

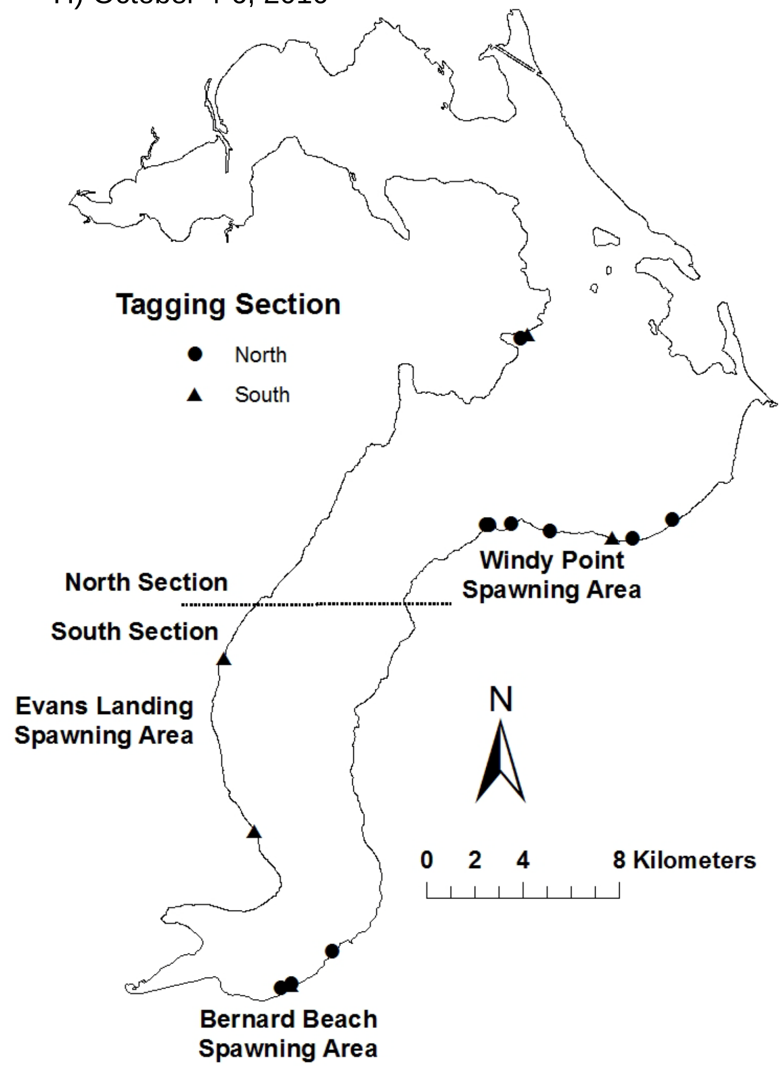

F) September 27, 2010
Tagging Section
North
South
North Section
South Section
Windy Point
Spawning Area
Evans Landing
Spawning Area
Bernard Beach
Spawning Area
N
0 2 4 8 Kilometers

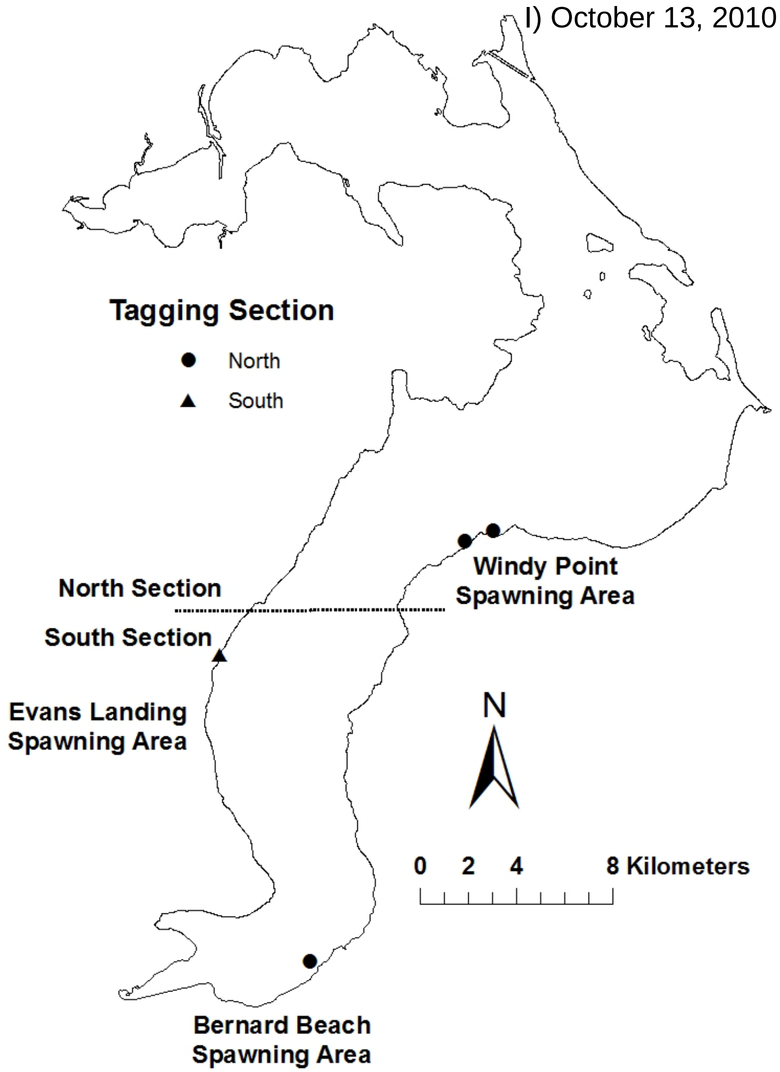
Appendix C. Continued.

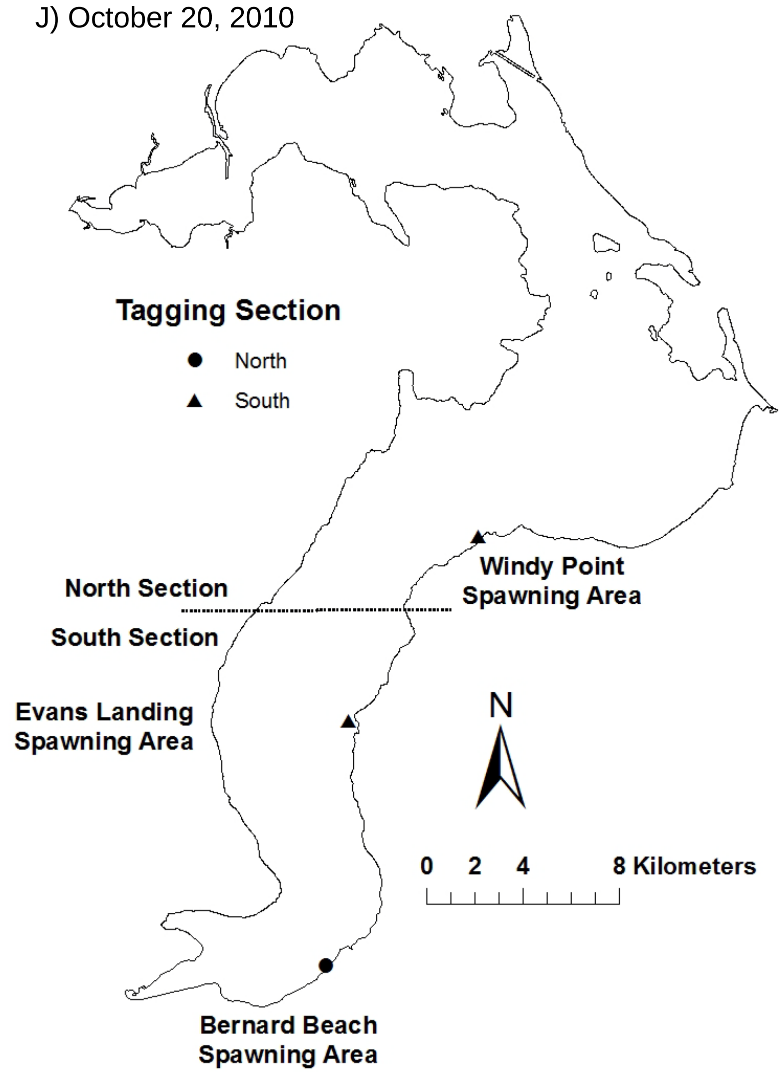
G) September 29, 2010



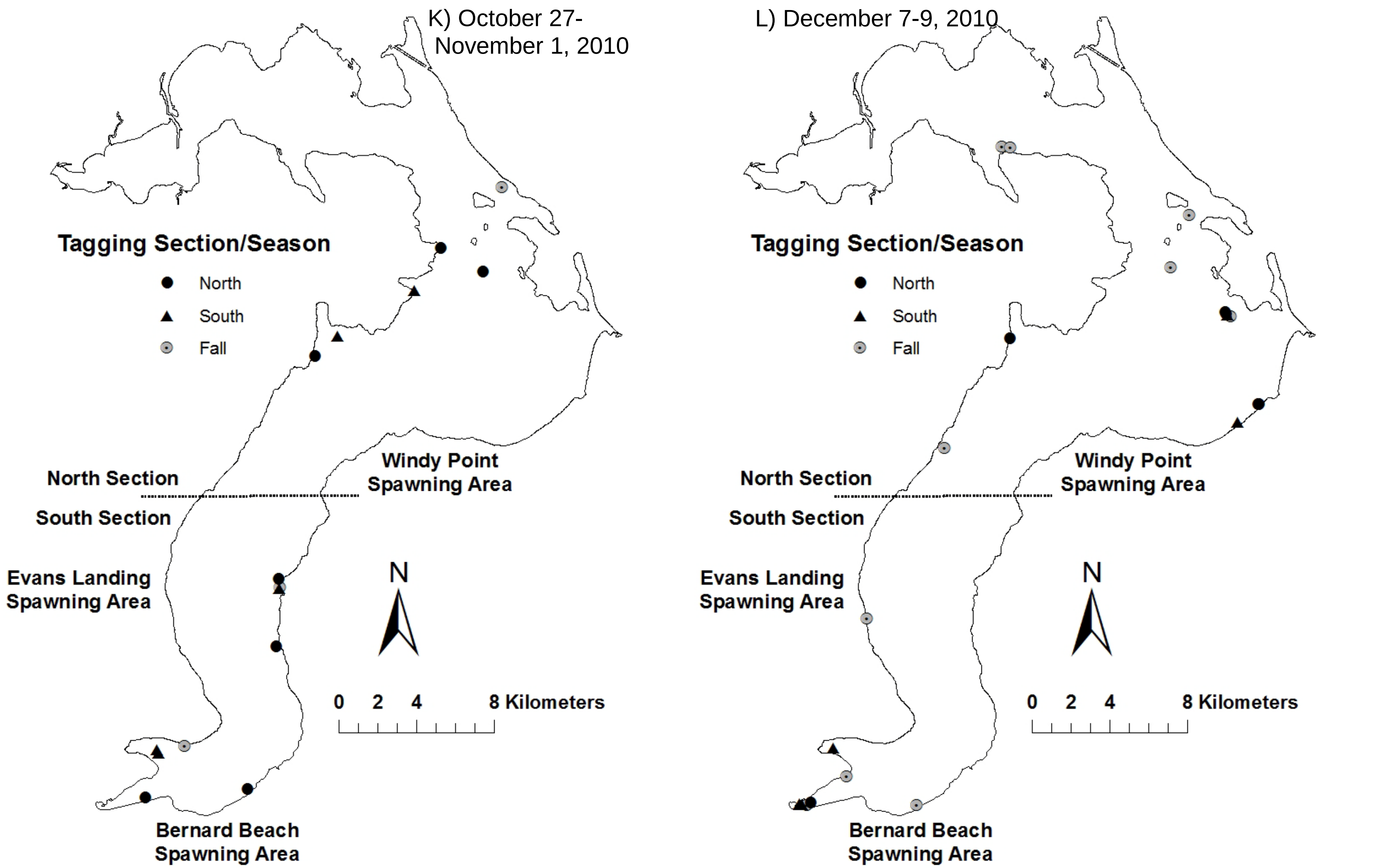
H) October 4-6, 2010




I) October 13, 2010
Tagging Section
North
South
North Section
South Section
Windy Point
Spawning Area
Evans Landing
Spawning Area
N
0 2 4 8 Kilometers
Bernard Beach
Spawning Area


J) October 20, 2010
Tagging Section
North
South
North Section
South Section
Windy Point
Spawning Area
Evans Landing
Spawning Area
N
0 2 4 8 Kilometers
Bernard Beach
Spawning Area

Appendix C. Continued.



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