FISHERY RESEARCH

LAKE PEND OREILLE RESEARCH, 2012
LAKE PEND OREILLE FISHERY RECOVERY PROJECT

ANNUAL PROGRESS REPORT
January 1, 2012—December 31, 2012

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IDFG Report Number 15-04
February 2015

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Bonneville Power Administration
Division of Fish and Wildlife
P.O. Box 3621
Portland, OR 97283-3621

Project Number 1994-047-00
Contract Numbers 52380, 57288

IDFG Report Number 15-04
February 2015

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INTRODUCTION

Lake Pend Oreille once provided the largest Kokanee *Oncorhynchus nerka* fishery in the state of Idaho. Between 1952 and 1966, 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 contributed to the initial Kokanee decline (Maiolie and Elam 1993). Additionally, the introduction of mysid shrimp *Mysis diluviana* likely reduced Kokanee production (Nesler and Bergersen 1991). 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). Low Kokanee abundance is a management concern because they provide a valuable sport fishery and serve as the primary prey source for Rainbow Trout *O. mykiss* and ESA-listed Bull Trout *Salvelinus confluentus*.

Two primary strategies have been implemented to recover the Kokanee population. The first strategy has assumed Kokanee spawning habitat to be a limiting factor. 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. The second strategy has been directed at reducing predation on Kokanee. In 2000, IDFG removed all bag limits on Lake Trout, followed by the removal of Rainbow Trout 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 Research, LLC (Bailey's Harbor, Wisconsin) since 2006 to remove Lake Trout with gill and trap nets.

During 2012, 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 final year of a two-year Rainbow Trout population assessment and a Bull Trout abundance estimate to assess the population response to recovery efforts.

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**,** Westslope Cutthroat Trout *O. clarkii lewisi*, Mountain Whitefish *Prosopium williamsoni*, and Pygmy Whitefish *P. coulterii.* Native nongame fishes include Slimy Sculpin *Cottus cognatus*, five cyprinid species, and two catostomid species. The most abundant nonnative sport fishes 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 pelagic predatory species are Lake Trout, Rainbow Trout, and Bull Trout.

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.

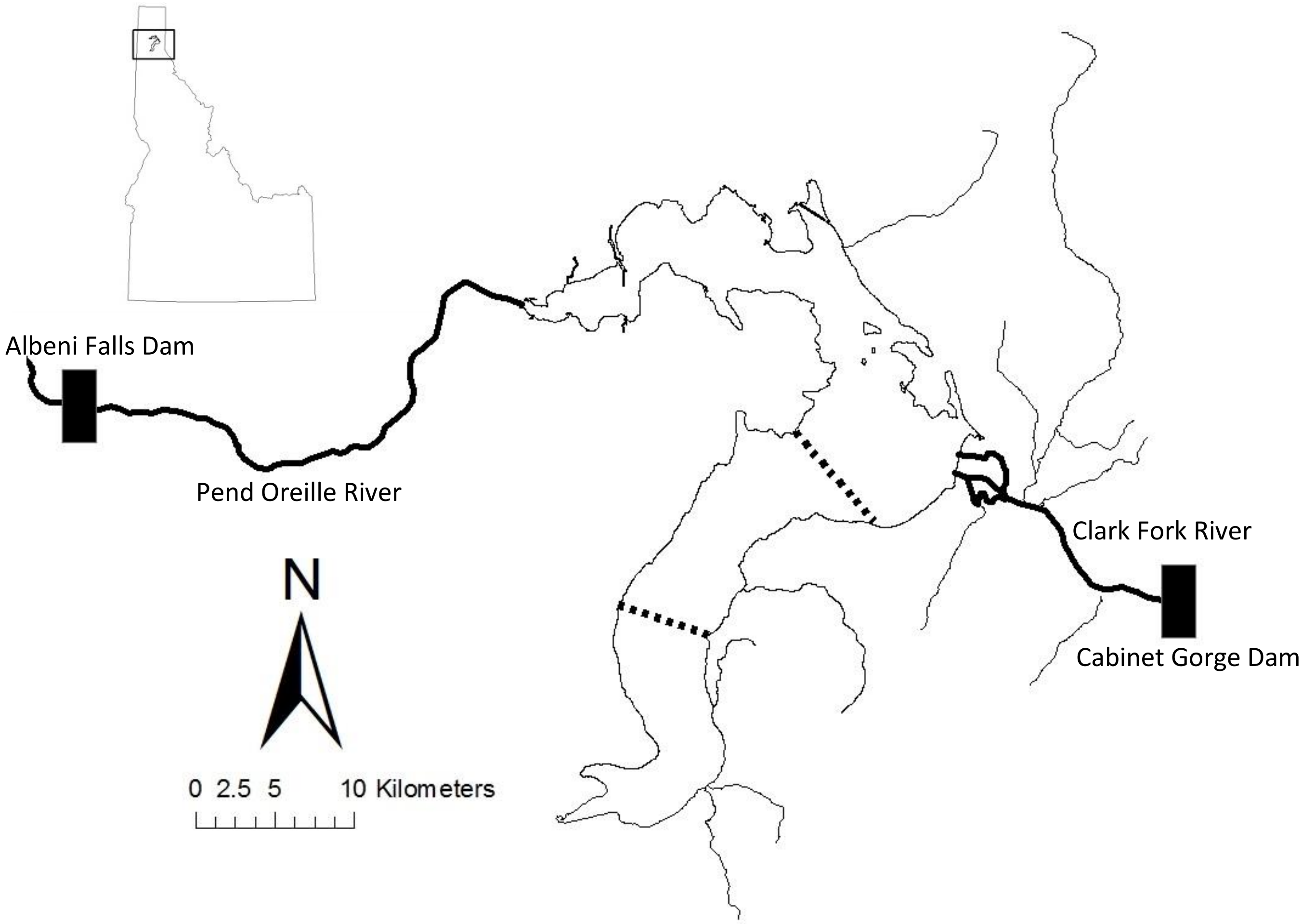

Figure 1. Map of Lake Pend Oreille, Idaho showing the three lake sections (separated by dashed lines) and primary Kokanee spawning tributaries. The main inflow and outflow rivers (Clark Fork River and Pend Oreille River) and dams (Cabinet Gorge Dam and Albeni Falls Dam) are shown.

CHAPTER 1: KOKANEE RESEARCH

ABSTRACT

During 2012, we examined the response of Kokanee *Oncorhynchus nerka* to a winter water level manipulation 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 2012 to assess the Kokanee population and determine the impacts of these recovery actions. Total Kokanee abundance was 15.4 million (680 Kokanee/ha), including 8.7 million fry (5.8 million wild and 4.7 million hatchery) and 6.7 million Kokanee ages 1-4. Kokanee biomass was 285 metric tonnes (t), with annual Kokanee production at 304 t, resulting in a production to biomass ratio of 1.1:1. Survival from age-1 to age-2 was 70%. Substrate assessment indicated no change in gravel composition for wild shoreline-spawning Kokanee following the low pool during winter 2011-12. Peak visual index counts of wild shoreline-spawning Kokanee and early and late tributary spawners were all above the third quartile of counts since 1972. Kokanee abundance increased, especially at age-1 and age-2, and biomass reached its highest point since 1996. While Kokanee abundance increased, the population is still below recovery levels. We documented a near collapse of the mysid population, and while we are unsure what caused the decline, we expect Kokanee to benefit from fewer mysids.

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

Benefits from lake level manipulations have been documented, including habitat improvement (substrate redistribution) following winters at 625.1 MSL (Maiolie et al. 2004) and higher Kokanee egg-to-fry survival following winters at 626.4 MSL (Maiolie et al. 2006b). Modeling work conducted in 2009 further corroborated the increased egg-to-fry survival at 626.4 MSL (Wahl et al. 2011b). However, conditions have not yet allowed the expected full benefits of lake level manipulations to be tested. Since starting experimental manipulations, mature Kokanee density has been low. Initially, Kokanee suffered high mortality from a record flood in 1997 (Maiolie et al. 2006b). This was followed by the predation issue in the early 2000s. In addition to unfavorable conditions for evaluating the lake level strategy, we have questioned the reliability of the estimator (egg-to-fry survival) being used. For these reasons, better evaluation of the lake level manipulation strategy is necessary to determine if it should continue to be implemented.

Since reaching record lows in 2007, Kokanee abundance and biomass have increased in response to predator reduction (Wahl et al. 2013). Continued success of predator reduction efforts will allow for increased Kokanee abundance and an improved ability to fully test the lake level manipulation strategy. Further, a more robust Kokanee population will provide opportunity for better understanding mysid and Kokanee competitive interactions and evaluating hatchery stocking practices.

During 2012, we evaluated the response of the Kokanee population to both lake level manipulations and predator reduction. Also, we evaluated Kokanee stocking timing. Additionally, we examined the quality and distribution of Kokanee spawning habitat with respect to the winter lake level. Mysid shrimp trend monitoring was conducted to evaluate food web dynamics and limnological changes in Lake Pend Oreille.

METHODS

Kokanee Population Dynamics

Abundance and Survival

We conducted a lakewide hydroacoustic survey on Lake Pend Oreille to estimate the abundance and survival rate of Kokanee. Surveys were performed at night between August 20 and 25, 2012 following the same protocol described in detail by Wahl et al. (2011a). Prior to the surveys, we calibrated the echo sounder for signal attenuation to the sides of the acoustic axis using Simrad's EK60 software. Analysis of hydroacoustic data to derive Kokanee density estimates and associated confidence intervals followed the protocol described in Wahl et al. (2010), except our estimates were based on arithmetic means with geometric confidence intervals around the means.

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 August 13 to 18, 2012. 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. 2011a). 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 this fry net began in 1999 and detailed methods have been previously described (Wahl et al. 2011a).

We collected Kokanee from each trawl transect, placed them on ice, and later placed them in a freezer for storage. To process Kokanee, we thawed out bags corresponding to each transect, counted the fish, recorded total length (mm) and weight (g), and checked for sexual maturity. We removed scales and otoliths from 10-15 fish in each 10 mm size interval, and otoliths from all fry. The scales were aged by two independent readers, and otoliths were used to determine hatchery or wild origin (see below). 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.

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 had 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 thermal marking success. To determine hatchery and wild Kokanee abundance, we sent otoliths to the Washington Department of Fish and Wildlife (WDFW) Otolith Laboratory where personnel checked them for 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.

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. (2011a) provide additional details on methods for estimating production and mortality by weight.

Standardized Spawner Counts

We counted spawning Kokanee in standard tributaries and shoreline areas where spawning was documented historically (Jeppson 1960) to continue time-series data dating back to 1972. Up to ten tributary streams have been counted with seven being surveyed annually by walking upstream from their mouth to the highest point utilized by Kokanee. In 2012, surveys for early-run Kokanee occurred in three streams on September 14 and 17, and surveys for late-run Kokanee occurred in three streams during the week of November 11. Shoreline counts for late-run Kokanee occurred at nine standardized sites during the weeks of November 18 and November 25. For all counts, we counted all Kokanee, either alive or dead.

We removed otoliths from 59 late-run Kokanee carcasses in Sullivan Springs Creek 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.

Fry Release Study

Kokanee fry released in 2012 received one of three different thermal marks to identify specific release groups. The first batch of fry was released in Sullivan Springs Creek, which is the standard stocking location. The additional two groups of fry were released on the west shore of Lake Pend Oreille at Talache Landing. The release date differed for these groups (June 11, July 10) to assess whether Kokanee experience differential survival based on release timing.

Calculations to estimate fry abundance within each of the two release groups was conducted by first estimating the number of hatchery fry in each lake section (see above). Next we used the proportion of each release group in both trawl surveys to estimate the proportion of each release group. For survival calculations, we generated a simple proportion of the number released that was still in the lake during fall surveys.

Lake Level Management Evaluation

Standardized Shoreline Substrate Sampling

We have sampled six standardized sites annually since 2004 to assess changes in shoreline substrate composition and assess the effectiveness of the winter-pool manipulation strategy. In August, 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 ANOVA.

Limnological Research

Mysid Trend Monitoring

We sampled mysids on June 18 to 20, 2012 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. (2011a).

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 2012, we estimated 15.4 million Kokanee (14.2-16.8 million, 90% CI) or 680 fish/ha in Lake Pend Oreille, based on our standardized hydroacoustic survey. This included 8.7 million Kokanee fry (8.1-9.4 million, 90% CI; Table 1, Figure 3), 4.4 million age-1, 1.8 million age-2, 450,000 age-3 Kokanee, and 30,000 age-4 Kokanee (Table 2, Figure 3). During the midwater trawl survey, we sampled 516 Kokanee, and these fish varied in length from 33-294 mm (Figure 4) and weight from 0.2-230 g. We estimated Kokanee survival at 40% from fry to age-1, 68% from age-1 to age-2, 98% from age-2 to age-3, and 9% from age-3 to age-4 (Table 3).

Hatchery and Wild Abundance

During spring 2012, Cabinet Gorge Fish Hatchery released 8.7 million thermally marked Kokanee fry into Lake Pend Oreille. Out of this total, 6.8 million late-run fry were stocked into Sullivan Springs Creek. Additionally, 1.9 million late-run Kokanee fry were stocked at Talache Landing along the west shore. Of these fish, 0.9 million were released on June 11-12, and the remaining 1.0 million were released on July 9-10.

We sent 110 otoliths from fry captured in the fry trawl to the WDFW Otolith Laboratory for thermal mark evaluation. Additionally, otoliths from 328 Kokanee fry and 188 Kokanee between ages 1-4 captured in the midwater trawl were sent to the WDFW Otolith Laboratory.

Wild Kokanee fry made up 65%, 74%, and 29% of the fry net catch in the southern, middle, and northern sections, respectively (Table 1). Based on these proportions, we estimated the wild fry population at 4.3 million (Table 1). Further, we estimated that wild Kokanee comprised 55%, 56%, 59%, and 100% of age-1, age-2, age-3, and age-4 abundance estimates, respectively (Table 2).

Biomass, Production, and Mortality by Weight

Based on the hydroacoustic estimates of Kokanee abundance, Kokanee biomass was 285 metric tonnes (t) and production was 304 t (Figure 5) for a production to biomass ratio of 1.1:1. Total mortality by weight was 197 t, which was 107 t lower than production (Figure 5).

Standardized Spawner Counts

In 2012, we observed a peak of 4,552 Kokanee spawning at the nine shoreline index sites. The majority of these fish (90%; 4,117) were on the shoreline around Bayview in Scenic Bay (Table 4). We observed a peak of 8,707 late-run Kokanee spawning in tributaries of Lake Pend Oreille, with 5,900 in South Gold Creek and 2,672 in North Gold Creek (Table 5). Hatchery fish comprised 95% of late-run Kokanee in Sullivan Springs Creek with an age structure of 39% age-2, 54% age-3, and 7% age-4. Additionally, peak abundance of early-run Kokanee was 4,359 with 2,470 in South Gold Creek and 553 in North Gold Creek (Table 6).

Fry Release Study

During the fall, we estimated 0.62 million Kokanee fry remained from the early release at Talache Landing and 0.73 million Kokanee fry remained from the late release. Based on the number released, survival to the fall trawling event was estimated to be 70% and 71% for the early and late releases, respectively.

Lake Level Management Evaluation

Standardized Shoreline Substrate Sampling

Following the low winter lake level during winter 2011-12, the mean percent gravel (67% ±19, 90% CI) was significantly higher than the mean percent cobble (29% ±19%, 90% CI; ANOVA; $F_{1,11}=5.69$, $p=0.038$) and mean percent fines (4% ±3%, 90% CI; ANOVA; $F_{1,11}=30.38$, $p<0.001$; Figure 6). There was no difference in substrate composition between 2010 and 2011 (Figure 6).

Limnological Research

Mysid Trend Monitoring

We estimated a total mean density of 45 mysids/m^2 during June 2012 (Table 7; Figure 7). This included 27 immature and adult mysids/m^2 (90% CI of ± 49%; Table 7; Figure 8) and 17 YOY mysids/m^2 (90% CI of ± 24%; Table 7; Figure 8).

DISCUSSION

Kokanee Population Dynamics

In the past year, Kokanee responded favorably to recovery actions. The abundance of Kokanee ages 1-4 increased by 90%. Age-1 abundance was the highest since hydroacoustic surveys began in 1995 and age-2 abundance reached its highest level since 2003. Additionally, despite the age-3 and age-4 cohorts being produced during years of record-low spawner returns, their combined abundance in 2012 was only 23% below the previous 15-year average. These recent abundance trends, along with survival rates for all age classes (except spawning losses from age-3 to age-4) that were among the highest since 1996, suggest that Kokanee are responding positively to recovery efforts. During 2011, we were encouraged by the increase in age-1 Kokanee, yet concerned that comparably strong age-1 cohorts did not survive to age-2 as recently as 2005-07. However, in 2012, both the age-1 and age-2 year classes were strong. Continued successive years of strong cohorts are needed for the Kokanee population to reach recovery. We are optimistic that reduced predation pressure on Kokanee, especially by Lake Trout, will lead to continued increases in survival and more Kokanee reaching maturity.

From 1996 to 2011, 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 the period of high mortality by weight was vital to slowing the decline of the Kokanee population (Wahl et al. 2010). From 2008 to 2012, Kokanee production ($\bar{x}$ = 209 t) was higher than mortality by weight ($\bar{x}$ = 175 t), and biomass in 2012 reached a level not attained since 1996. Kokanee production has increased 75% since 2010, although with a concurrent increase in biomass the production to biomass ratio has declined to about 1:1. Continued implementation of the Lake Trout reduction program should maintain Kokanee production levels above mortality by weight and lead to further increases in Kokanee biomass.

Spawner counts do not provide estimates of spawner abundance, but do provide a useful way to coarsely assess trends in spawning escapement and distribution. Late-run Kokanee counts increased following a near record-low in 2007 and have consistently been at a much higher level since 2010. Spawner count data suggest that spawner escapement during 2009-12 was consistently higher than one Kokanee generation (five years) earlier. Higher spawning escapement during the past three years has been correlated with higher spawner counts at index sites outside of Scenic Bay, which has been the primary spawning area used by Kokanee in recent years. Additionally, we documented spawning at other non-index sites in the lake that have not been occupied in recent years. As Kokanee density continues to increase, we anticipate the spatial extent of spawning will further expand.

Early-run Kokanee returned to Granite, Cedar, and North and South Gold creeks for the fifth straight year. 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 exception was South Gold Creek, where otolith analyses have shown that the majority of spawners in this creek have been of wild origin (Wahl et al. 2013). Previously we stated that early-run Kokanee were unlikely to substantially contribute towards recovery goals (Wahl et al. 2011a). 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, the 2012 returns should be the last early-run Kokanee spawners with contributions from hatchery origin fish. Beginning in 2013, early-run Kokanee should diminish because natural reproduction appears to be largely limited to South Gold Creek.

The survival of the two hatchery Kokanee release groups in 2012 was nearly identical, but the early release group actually had higher survival based on a greater number of days at-large. This survival pattern differed from previous research that found Kokanee fry stocked later had higher survival due to higher zooplankton abundance, especially *Daphnia* (Paragamian and Bowles 1995). However, with the collapse of mysids in 2012, zooplankton dynamics may have changed and provided more forage for Kokanee fry released in June than has typically been available. Replicating this evaluation over multiple years will be necessary before drawing conclusions about stocking strategies.

Lake Level Management Evaluation

The full drawdown to 625.1 MSL during winter 20011-12 did not alter the shoreline substrate composition, which was not unexpected as there had only been one year of elevated winter water levels since the last full drawdown. Substantial changes documented at individual sites (e.g., 54% gravel in 2011 to 31% gravel in 2012 at Ellisport Bay) suggested that some substrate movement occurred along the lakeshore. While the mean quantity of shoreline gravel remained unchanged, site-specific differences could still be meaningful if they occurred at highly used spawning areas. However, current substrate sampling methods do not accurately depict substrate distribution on a lakewide scale, and we recommend discontinuing annual sampling using this method

Limnological Research

Mysids in Lake Pend Oreille went through a cycle of expansion, decline, and stability since introduction. 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 remained relatively stable during 1997-2011. A similar pattern of population fluctuation occurred in other western lakes after mysid introductions (Beattie and Clancey 1991; Richards et al. 1991). However, mysid abundance collapsed in 2012 to roughly 2% of their 2011 abundance. We are unsure what mechanism caused this collapse, but believe it may be linked to regional climatic patterns as declines were also documented in Osoyoos, Okanagan, Arrow, and Kootenay lakes in British Columbia (T. White, P. Askey, E. Schindler B.C. Ministry of FLNRO, personal communication). Given the implications this collapse could have on the Lake Pend Oreille food web, especially the Kokanee and Lake Trout populations, mysid monitoring in coming years will be essential. Additionally, research to better understand food web interactions in Lake Pend Oreille may be possible if mysids remain at low abundance.

RECOMMENDATIONS

1. Continue to remove Lake Trout using targeted netting and incentivized angler harvest.

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

3. Continue research to evaluate effectiveness of the lake level management strategy, including completing the ongoing Kokanee spawning ecology study in collaboration with the University of Idaho.

4. Replicate the June and July Kokanee fry release strategies at Talache Landing to better understand how release timing affects survival.

5. Monitor the mysid population to determine if the population collapse that was documented persists.

6. Continue to collaborate on the mysid and zooplankton dynamics graduate project with the University of Idaho.

Table 1. Abundance estimates for Kokanee fry (millions) based on hydroacoustic surveys of Lake Pend Oreille, Idaho in 2012. 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	1.9	2.4	4.4	8.7	8.1-9.4
Percent wild fry in fry trawl	65	74	29	—	
Percent KL-H in fry trawl	35	26	71	—	
Wild fry abundance estimate	1.2	1.8	1.3	4.3	

Table 2. Age-specific abundance estimates for Kokanee in Lake Pend Oreille, Idaho, 2012. 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
Northern section					
Percent of age class by trawling	63.1	28.3	7.7	0.9	
Population estimate (millions)	2.14	0.96	0.26	0.03	3.39
Middle section					
Percent of age class by trawling	74.0	18.9	7.1	0	
Population estimate (millions)	1.28	0.33	0.12	0	1.73
Southern section					
Percent of age class by trawling	64.3	31.8	3.9	0	
Population estimate (millions)	1.02	0.51	0.06	0	1.59
Total population estimate for lake (millions)	4.44	1.79	0.45	0.03	6.71
90% confidence interval (millions)					5.91-7.60
Percent wild	55	56	59	100	
Percent KE-H	0	4	5	0	
Percent KL-H	45	40	36	0	

Table 3. Survival rates (%) between Kokanee year classes estimated by hydroacoustics, 1996-2012. Year refers to the year the older age class in the survival estimate was sampled.

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

Table 4. Counts of Kokanee spawning along the shorelines of Lake Pend Oreille, Idaho. The numbers shown indicate the highest weekly count and should be interpreted as a coarse-scale 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
2012	4,117	0	15	300	0	0	0	120	0	—	4,552
2011	4,214	35	124	1,500	0	0	0	20	0	—	5,893
2010	4,865	0	0	3,500	0	0	0	113	0	—	8,478
2009	2,635	36	1	0	0	6	0	9	0	—	2,687
2008	663	6	0	0	0	0	0	0	0	—	669
2007	325	0	0	0	0	0	0	0	0	—	325
2006	1,752	0	0	0	17	0	0	12	0	—	1,781
2005	1,565	0	5	1	0	1	0	66	0	—	1,638
2004	2,342	0	100	1	0	0	0	34	0	—	2,477
2003	940	0	0	0	0	20	0	0	0	—	960
2002	968	0	0	0	0	0	0	0	0	—	968
2001	22	0	0	0	0	0	0	0	1	—	23
2000	382	0	0	2	0	0	0	0	0	—	384
1999	2,736	4	7	24	285	209	0	275	0	—	3,540
1998	5,040	2	0	0	22	6	0	34	0	—	5,104
1997	2,509	0	0	0	0	7	2	0	0	—	2,518
1996	42	0	0	4	0	0	0	3	0	—	49
1995	51	0	0	0	0	10	0	13	0	—	74
1994	911	2	0	1	0	114	0	0	0	—	1,028
1993	—	—	—	—	—	—	—	—	—	—	—
1992	1,825	0	0	0	0	0	0	34	0	—	1,859
1991	1,530	0	—	0	100	90	0	12	0	—	1,732
1990	2,036	0	—	75	0	80	0	0	0	—	2,191
1989	875	0	—	0	0	0	0	0	0	—	875
1988	2,100	4	—	0	0	2	0	35	0	—	2,141
1987	1,377	0	—	59	0	2	0	0	0	—	1,438
1986	1,720	10	—	127	0	350	0	6	0	—	2,213
1985	2,915	0	—	4	0	2	0	0	0	—	2,921
1978	798	0	0	0	0	138	0	0	0	0	936
1977	3,390	0	0	25	0	75	0	0	0	0	3,490
1976	1,525	0	0	0	0	115	0	0	0	0	1,640
1975	9,231	0	0	0	0	0	0	0	0	0	9,231
1974	3,588	0	25	18	975	2,250	0	20	0	50	6,926
1973	17,156	0	0	200	436	1,000	25	400	617	0	19,834
1972	2,626	25	13	4	1	0	0	0	0	0	2,669

Table 5. Counts of late-run Kokanee spawning in tributaries of Lake Pend Oreille, Idaho. The numbers shown indicate the highest weekly count and should be interpreted as a coarse-scale index rather than a total estimate of spawner abundance.

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

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

Table 6. 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 a coarse-scale index rather than a total estimate of spawner abundance. Early-run Kokanee counts in east shore tributaries began in 2008; prior to this, only Trestle Creek was counted.

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

Table 7. Densities of mysids (per m^2), by life stage (young of year [YOY], and immature and adult), in Lake Pend Oreille, Idaho June 18-20, 2012.

Section	YOY/m^2	Immature & Adults/m^2	Total mysids/m^2
Northern	8	35	43
Middle	21	19	40
Southern	24	18	52
Whole lake mean	17	27	45

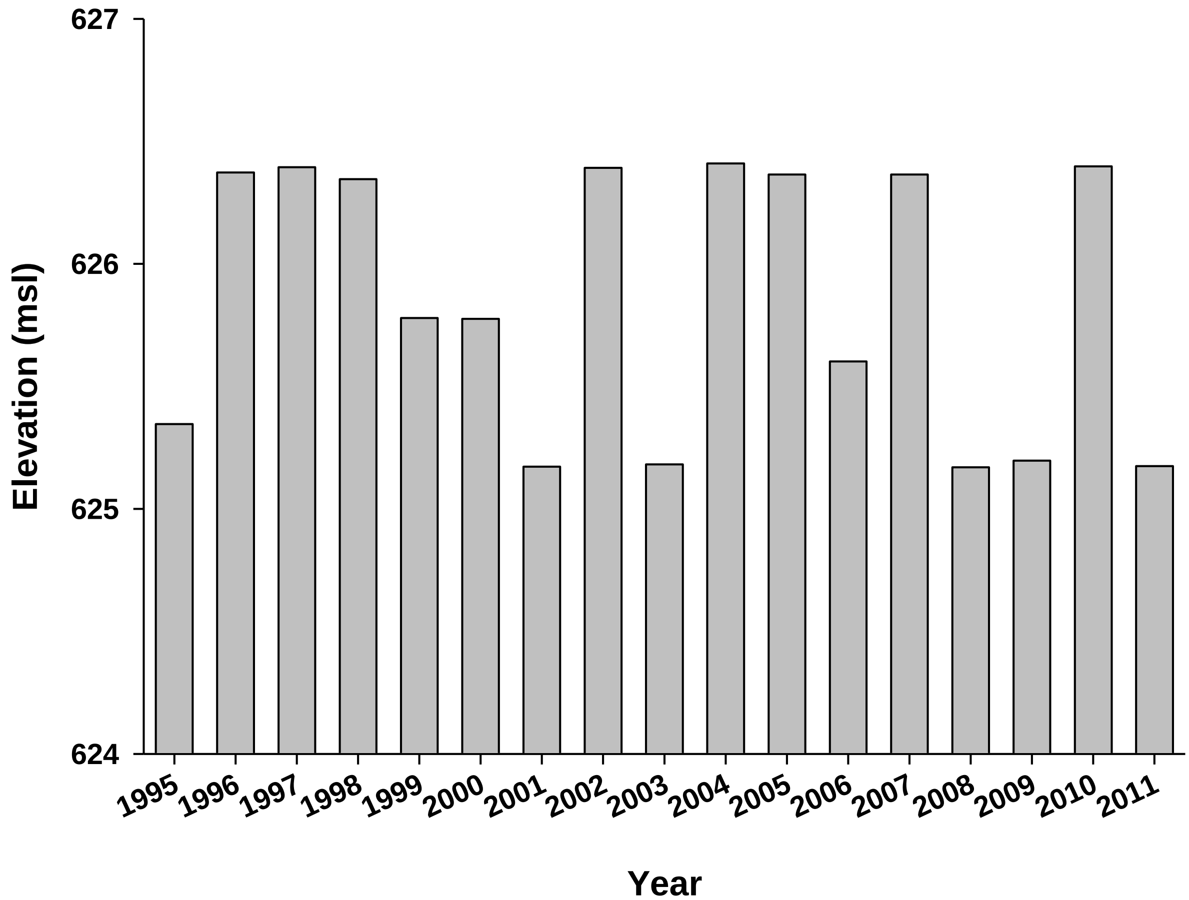

Figure 2. Minimum winter pool surface elevation in meters above mean sea level (MSL) during years of lake level experiment in Lake Pend Oreille, Idaho. Year shown represents the year the lake was drawn down (i.e., 1995 for winter 1995-1996).

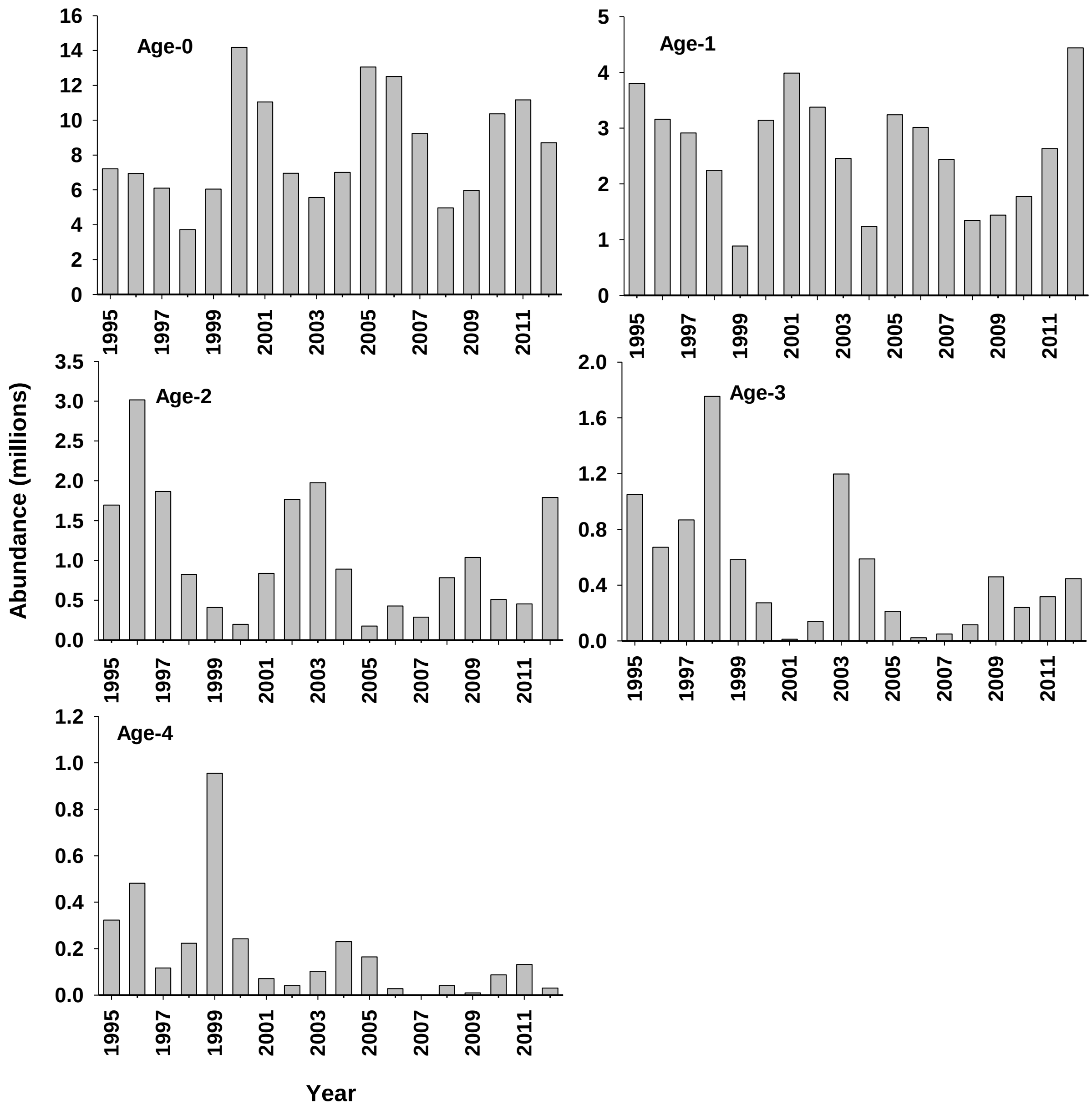

Figure 3. Kokanee age-specific abundance estimates based on hydroacoustics between 1996 and 2012.

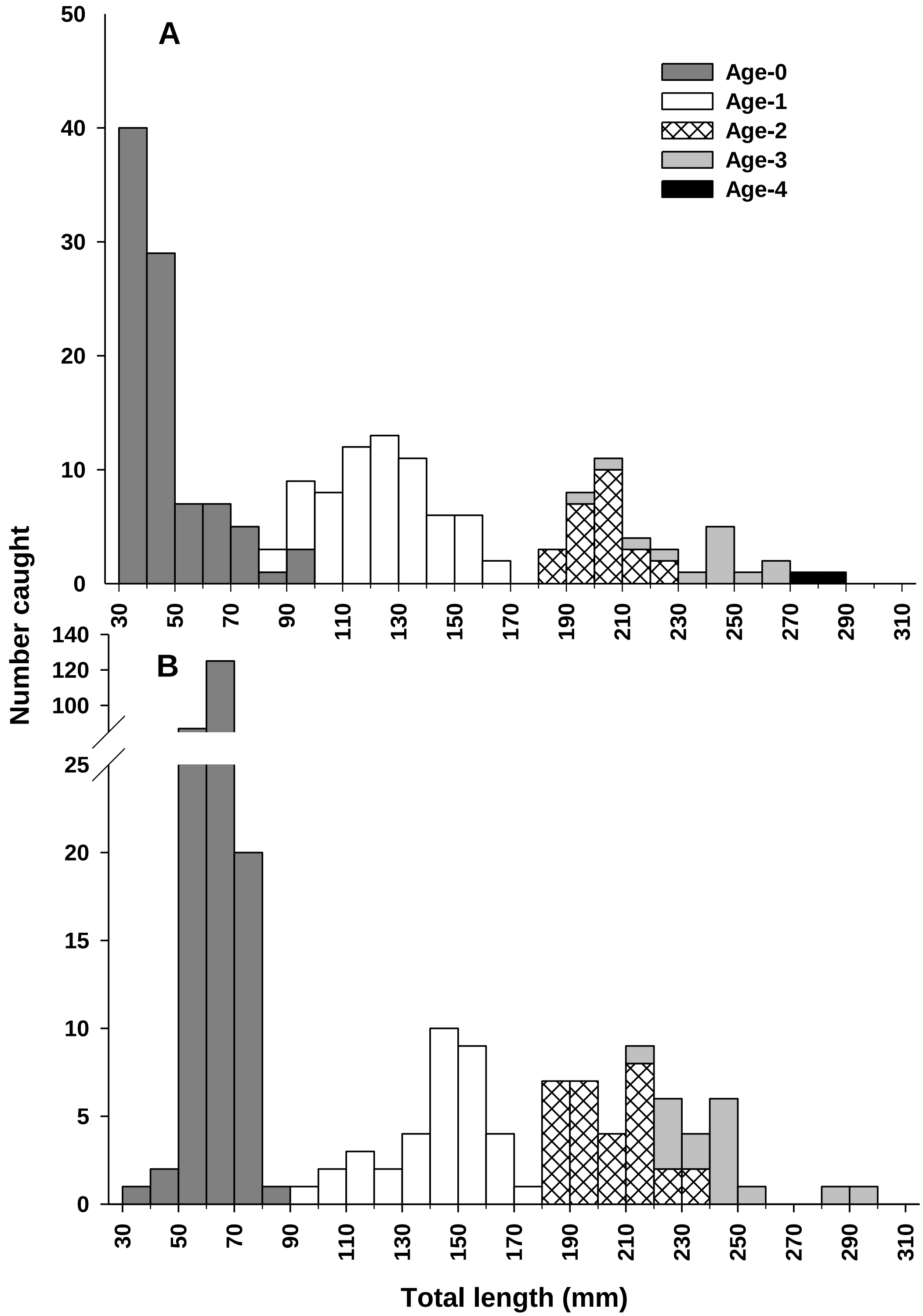

Figure 4. Length-frequency distribution of individual age classes of wild (A) and hatchery (B) Kokanee caught by midwater trawling in Lake Pend Oreille, Idaho during August 2012.

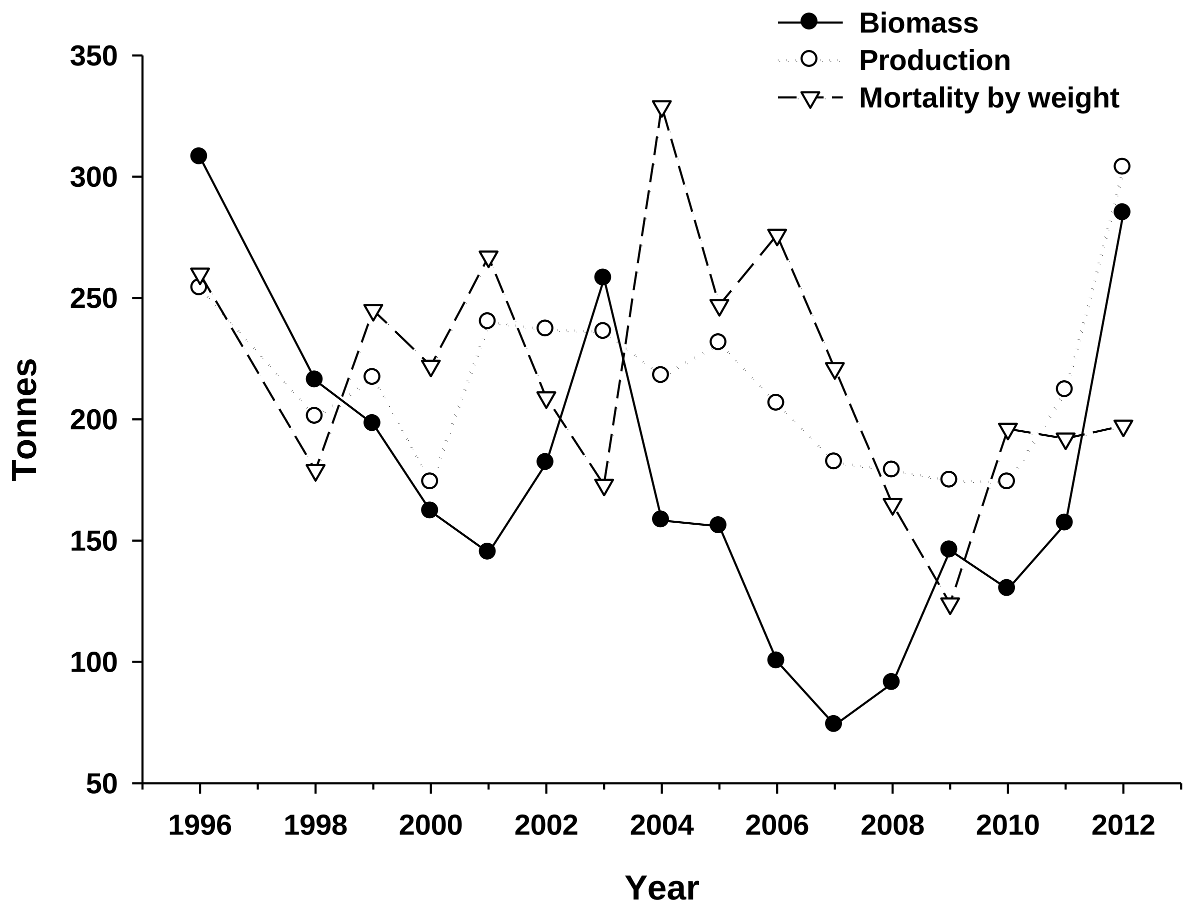

Figure 5. Kokanee biomass, production, and mortality by weight (metric tonnes) in Lake Pend Oreille, Idaho from 1996-2011, excluding 1997 due to a 100-year flood.

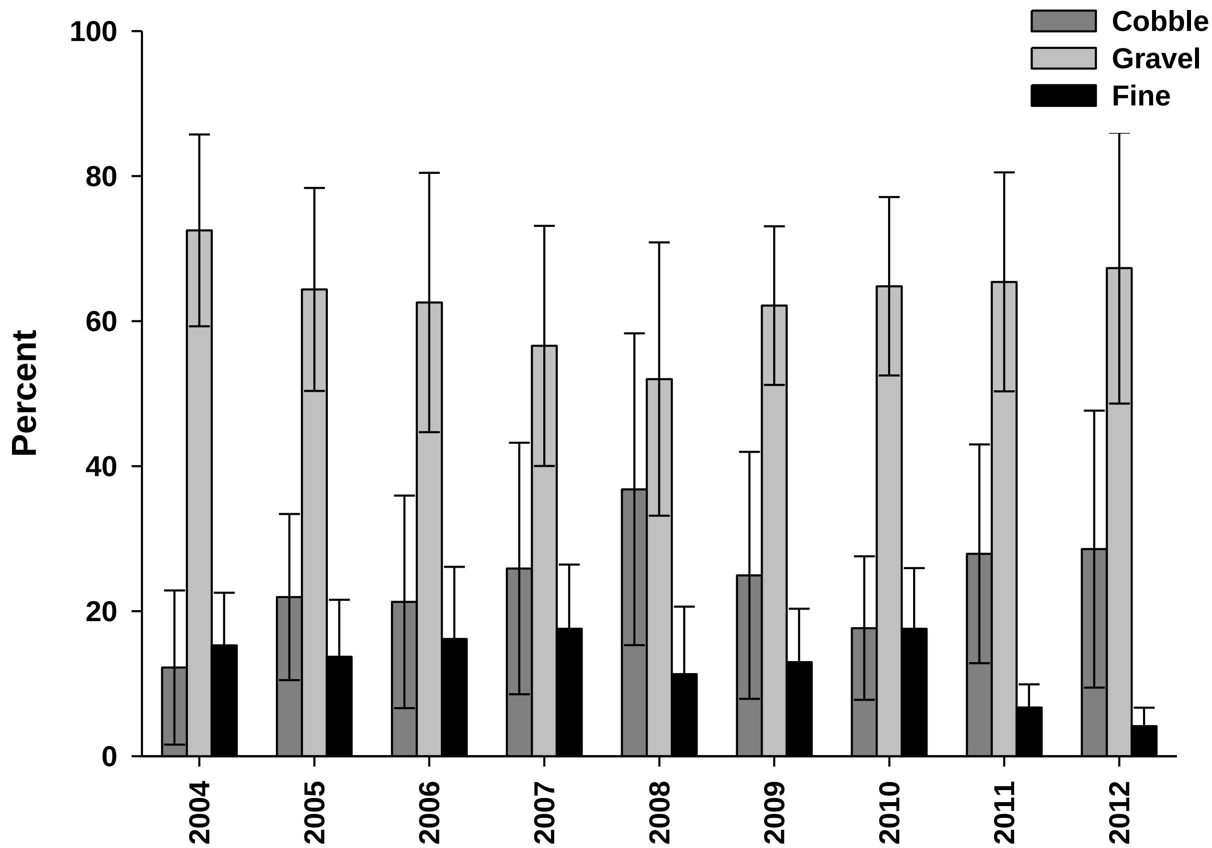

Figure 6. Mean shoreline substrate composition (± 90% CI) in Lake Pend Oreille, Idaho during summer 2004-2012. Full winter drawdowns to 625.1 MSL took place during the winters of 2003-04, 2008-09, 2009-10, and 2011-12. Winter pool remained above 626.6 MSL during all other winters.

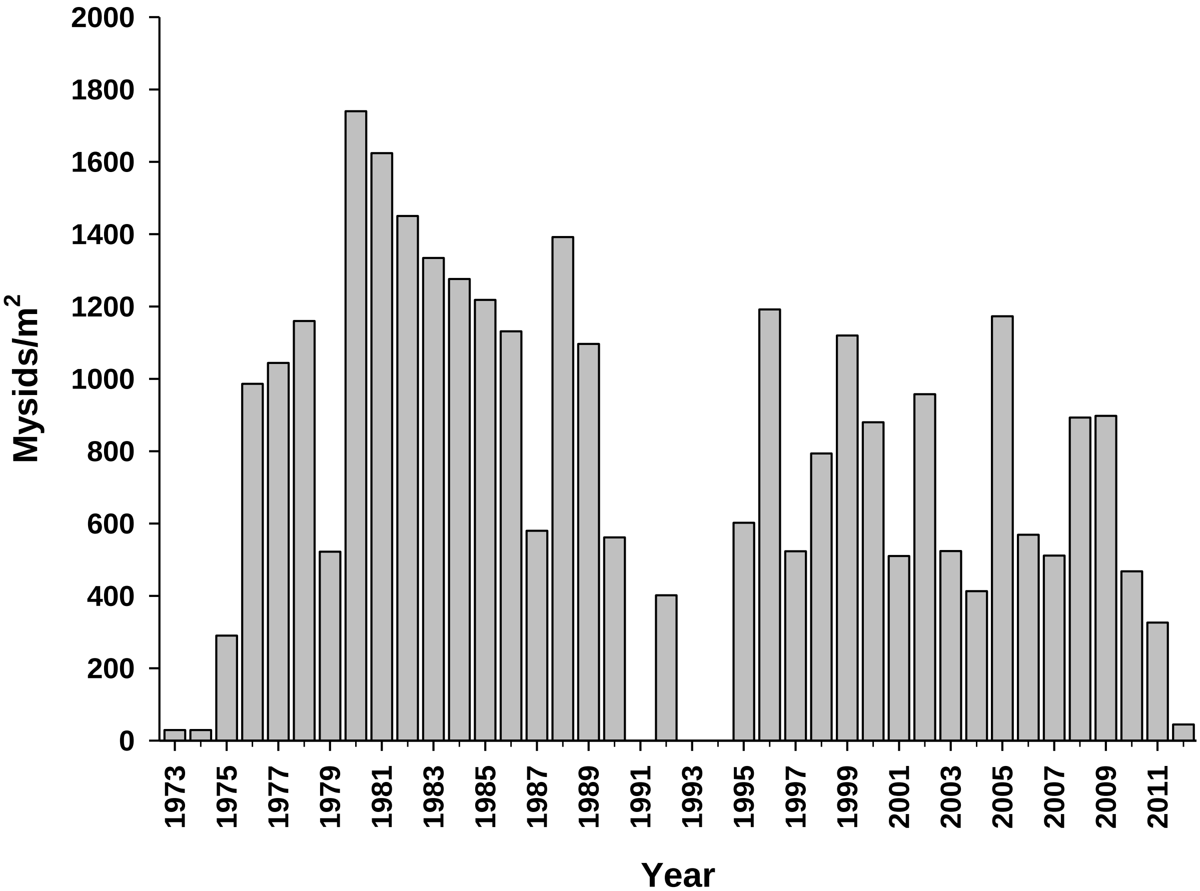

Figure 7. Annual mean density of mysids in Lake Pend Oreille, Idaho from 1973-2012. Data collected before 1989 were obtained from Bowles et al. (1991), and data from 1995 and 1996 were from Chipps (1997). Mysid densities from 1992 and earlier were converted from Miller sampler estimates to vertical tow estimates by using the equation y = 0.5814x (Maiolie et al. 2002). Mysids were first introduced in 1966.

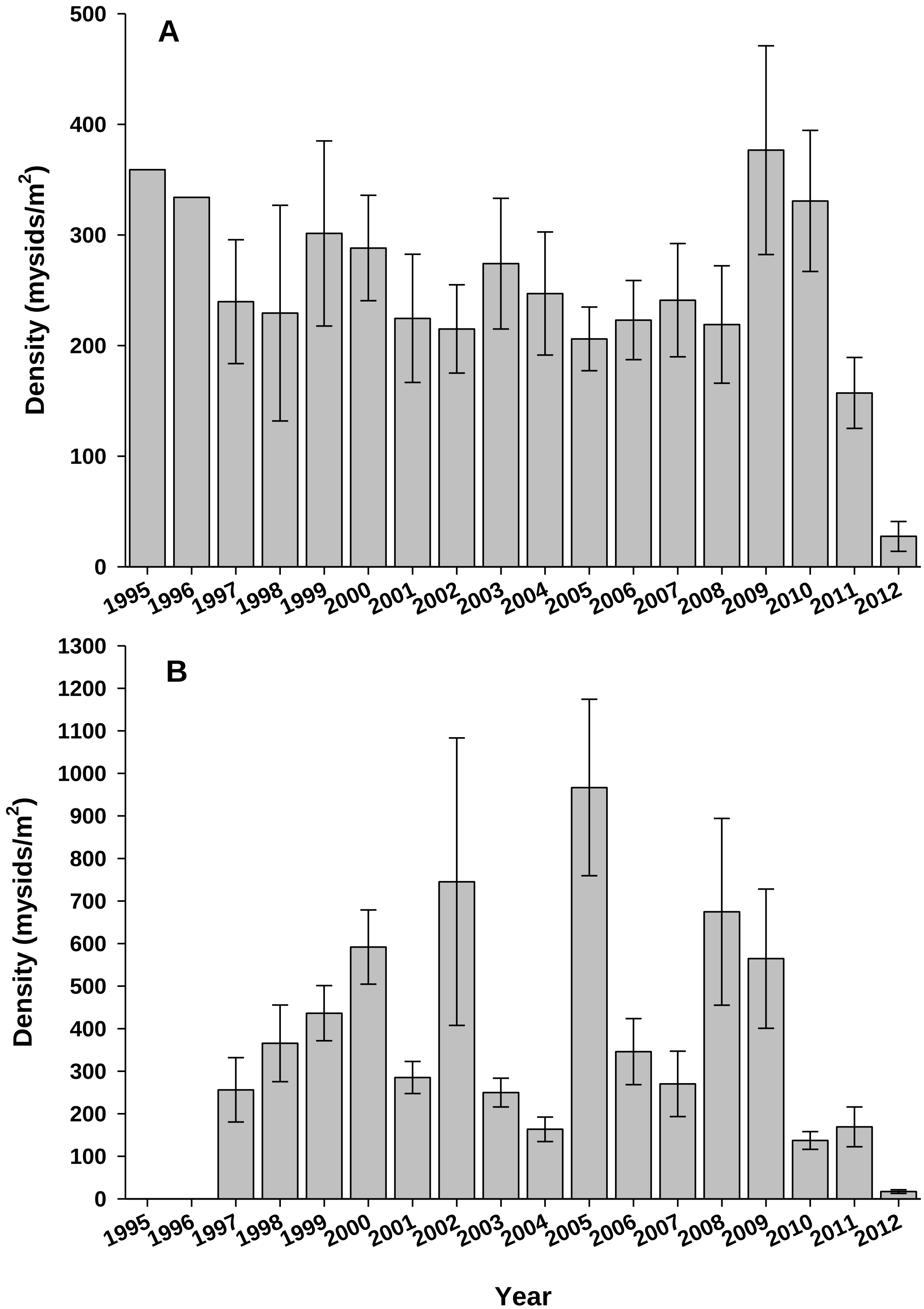

Figure 8. Density estimates of immature and adult (A) and young-of-the-year (B) mysids in Lake Pend Oreille, Idaho 1995-2012. Error bounds identify 90% confidence intervals around the estimate. Immature and adult densities from 1995 and 1996 were obtained from Chipps (1997).

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 an angler incentive program. To maximize Lake Trout removal efficiency, we have used acoustic transmitters to follow mature Lake Trout to spawning sites. Unfortunately, tags that were deployed for 2012 tracking were not functional because of an error by the manufacturer. During October 2012, we tagged 30 adult Lake Trout ranging from 591 to 960 mm total length ($\bar{x}$ = 794 mm) for 2013 telemetry research. A total of 1,565 Lake Trout was caught and removed from spawning sites in 2012 including 543 mature females and 815 mature males. A mark-recapture population estimate conducted in fall 2011 resulted in 3,456 (1,637-6,476 95% CI) Lake Trout, a 40% reduction since 2007. Additionally, we documented a decreased growth rate, decreased size structure, and increased age at 50% maturity.

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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 generally 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 collapsed 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 and valued sport 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. 2008). 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).

During 2007 and 2008, telemetry research identified two Lake Trout spawning sites in Lake Pend Oreille (Schoby et al. 2009; Wahl and Dux 2010). Intensive gill netting at these sites since 2008 yielded high numbers of mature Lake Trout and substantially increased the annual mortality rate on the reproductive segment of the population. In 2010, a third Lake Trout spawning site was identified (Wahl et al. 2011b). We continued telemetry research in 2012 to further evaluate whether Lake Trout spawning distribution changed in response to netting. Telemetry research also provided real-time data to guide netting during the spawning period. Additionally, we conducted a mark-recapture population estimate and examined Lake Trout growth, size structure, and maturity to evaluate the response to suppression.

METHODS

Lake Trout Telemetry

To evaluate Lake Trout spawning distribution, we have tracked mature Lake Trout using acoustic telemetry since 2006. Unfortunately, the acoustic tags that were implanted into Lake Trout during 2011 for tracking in 2012 (see Wahl et al. 2013) did not meet the manufacturer-specified battery life and therefore were not functioning during the fall spawning and tracking period. However, we captured and tagged Lake Trout during fall 2012 with a similar acoustic transmitter that had a longer battery life (MM-M16-33 TP, Lotek Wireless, Inc., Newmarket, Ontario) for 2013 telemetry research. Lake Trout were captured using either gill nets set at spawning sites or trap nets in the northern portion of the lake operated by Hickey Brothers Research, LLC. To ensure sexual maturity, we only tagged Lake Trout that were ripe or still contained eggs. Details on the surgical procedures can be found in Wahl and Dux (2010).

Lake Trout Spawning Site Assessment

To assess changes in Lake Trout spawning characteristics (i.e., size and relative abundance of fish), gill nets set by Hickey Brothers Research, 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, 2.0-4.0 m tall, and contained a single stretch mesh of 10.2, 11.4, or 12.7 cm. Several nets were tied together to form a gang that was set in a serpentine pattern that paralleled shore. Gill nets were set around dawn and 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 gauge the changes in Lake Trout abundance and the overall effectiveness of the predator removal efforts, a Lake Trout population estimate was initiated during fall 2011. Lake Trout captured in trap nets were marked with an individually-numbered spaghetti tag behind the dorsal fin. Population estimates were generated from trap net catch and a Schnabel (1938) multiple mark-recapture model described by the formula:

$$N = \frac{\sum_{t=1}^{n} C_t\, M_t}{\sum_{t=1}^{n} R_t}$$

where M is the number of marked fish, C is the number of fish sampled, and R is the number of fish recaptured after sample period t with n number of total sample periods. Confidence intervals were generated using a Poisson distribution around R (Ricker 1975). Estimates were generated for different size classes similar to previous research.

To capture Lake Trout for age structure and maturity analysis, we set gill nets at 100 randomly selected points around the lake during February and March 2012. Gill nets were comprised of four 91 m panels of randomly assigned stretch meshes from 5.1 to 14.0 cm in 1.3 cm increments. Two nets were haphazardly chosen for each site and set similar to described above. We recorded total length, sex, and maturity of all Lake Trout caught, and removed otoliths from 10 fish in each 50 mm length class. 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. We compared growth rates in 2012 to growth rates in 2004 using analysis of residual sum of squares (ARSS; Chen et al. 1992). Finally, we calculated age and size at maturity and mortality rates for the Lake Trout population.

RESULTS

Lake Trout Telemetry

As mentioned above, we were unable to collect any telemetry data during 2012. During fall 2012 (October 10-19), we captured and tagged 30 Lake Trout from gill nets set at the three spawning sites, with six from Bernard Beach, ten from Evans Landing, and 14 from Windy Point. Additionally, three Lake Trout were tagged out of trap nets, with two from Sheepherder Point and one from Mamaloose Island. These tagged Lake Trout averaged 794 mm total length (SE = 19; range = 591-960; Figure 9).

Lake Trout Spawning Site Assessment

During 33 days of the Lake Trout spawning period, a total of 173,919 m of gill net (634 individual nets) was set at the three spawning sites. We captured 1,565 Lake Trout (2.2 Lake Trout per 274 m net; 1.9-2.7 = 95% CI) and examined 1,540 fish for sexual maturity. Of those fish, 543 were mature females (mean TL = 748 mm; SE = 4.2; range = 499-995) and 815 were mature males (mean TL = 683 mm; SE = 3.5; range = 456-1100). This resulted in a sex ratio of 1.5 mature males per mature female. Length-frequency distributions of fish caught at the spawning sites are presented in Figure 10.

Lake Trout Population Characteristics

During fall 2011 we caught a total of 367 Lake Trout in trap nets, marked 211 with spaghetti tags, and recaptured five. This resulted in a population estimate of 3,456 (1,637-6,476 = 95% CI) including 2,961 (1,402-5,549 = 95% CI) ≥500 mm and 680 (207-1,094 = 95% CI) ≥650 mm (Table 8). At the end of 2011, 199 marked Lake Trout were at large, and 102 were recaptured during 2012 (49 via angling, 52 via netting, and 1 via electrofishing in the Clark Fork River) for an annual exploitation rate of 51%.

We aged 121 Lake Trout (257-840 mm) that ranged in age from 5 to 21 years. Lake Trout grew from a starting age of t_0 = 2.64 years toward their asymptotic length of L_∞ = 991 mm at an instantaneous rate of K = 0.148/year (Figure 11). The ARSS results showed a difference between the 2004 and 2012 growth curves ($F_{3,25}$ = 3.09, p = 0.045). Based on Lake Trout caught in the random gill nets, the Lake Trout size structure was skewed towards small individuals with RSD-Q = 44, RSD-P = 12, RSD-M = 3, and RSD-T <1. Lake Trout reached 50% maturity at 662 mm and 10.8 years for males and 650 mm and 9.8 years for females (Figure 12). From an age-length key developed from fish caught in the random gill nets, Lake Trout ages 6-14 in Lake Pend Oreille experience an instantaneous mortality rate of Z=0.47 for a total annual mortality of 48%.

DISCUSSION

Lake Trout Spawning Assessment

Although we did not have telemetry data to guide the gill netting efforts in 2012, total catch and catch rate remained at expected levels for a declining population based on data from past years. The length-frequency distributions during 2008-12 indicate that all size classes of mature Lake Trout have been vulnerable to removal efforts. Further, the size structure of Lake Trout caught at spawning sites continues to suggest fewer large Lake Trout are present in the population. Most importantly, the length-frequency distributions did not show any large year-classes recruiting to maturity. This suggests that a large proportion of fish in these cohorts have been removed prior to reaching maturity.

Lake Trout Population Characteristics

Lake Trout population estimates showed an increasing population trend from 1999 to 2006, followed by a declining trend since the removal programs began in 2006. Although the estimates do not represent the absolute abundance of Lake Trout in Lake Pend Oreille, the trend suggests that removal efforts have been effective. Various methods have been used to conduct Lake Trout population estimates over the years, and the two spring Chapman estimates in 2006 and 2007 may be higher than the others due in part to differing methodology. However, even if the population did not reach a peak of the magnitude suggested, the trend from 2005 to 2011 suggests a 68% reduction in Lake Trout abundance and a 40% reduction since 2007. Additionally, the estimates of Lake Trout ≥500 mm (size at which Lake Trout recruit to trap nets, Hansen et al. 2008) have decreased at a similar rate. We expect that the rate of decline in Lake Trout abundance should gradually increase as more year classes have been subjected to high exploitation during their entire lifetime.

Though we documented a difference in Lake Trout growth rates between 2004 and 2012, most of this difference is driven by the younger (<9 years) age classes and is likely a result of extensive exploitation on juveniles since 2008 rather than an actual change in growth rates. The fastest growing individuals recruit to the gear sooner and are removed leaving a higher proportion of slower growing fish. However, since 2006, there has been a shift in the size structure of Lake Trout away from fish greater than preferred length (650 mm) and towards fish less than quality length (300 mm). Decreasing size structures have been documented in other over-exploited, long-lived fish populations (Haedrich and Barnes 1997).

Since 2004, Lake Trout age at 50% maturity increased 4.3 and 2.5 years for males and females, respectively. The cause of this increase may be similar to the change in growth rates where the fastest growing, earliest maturing fish in the population were removed first. However, most studies have found the opposite pattern where exploitation leads to a reduced age at 50% maturity for Lake Trout populations (Healey 1978; Syslo et al. 2011). The Lake Trout population in Lake Pend Oreille was still expanding exponentially and had not yet reached density-dependence when the removal program began, so the compensatory mechanisms to reduce age at maturity may not have come into play.

The total mortality estimate generated from the catch curve (48%) was near the 50% mortality threshold beyond which Lake Trout populations typically cannot be sustained (Healey 1978). The exploitation rate (51%) was slightly higher than total annual mortality estimated from the catch curve, which indicates natural mortality of Lake Trout in Lake Pend Oreille is currently minimal. However, both catch curve and exploitation estimates provide evidence that total mortality for Lake Trout is near the morality threshold identified by Healey (1978). Lake Trout in Lake Pend Oreille are declining, which lends further support to the idea that the population is being harvested at an unsustainable level.

RECOMMENDATIONS

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

2. Track Lake Trout during spawning using mobile telemetry to verify traditional spawning sites are being used and that new sites are not colonized. Use patterns identified in spawning distribution to guide net placement during 2013.

3. Implant acoustic tags into adult Lake Trout captured at spawning sites during fall 2013 to guide netting efforts in 2014.

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

5. Experiment with reduced netting frequency at spawning sites. Evaluate catch rates and examine distribution from telemetry surveys to assess effectiveness.

6. Continue to periodically evaluate Lake Trout population dynamics, especially growth, fecundity, and age structure, to determine the response to removal efforts.

Table 8. Lake Trout population estimates (and 95% confidence intervals) during 1999-2011 in Lake Pend Oreille, Idaho. All estimates were conducted in the fall unless otherwise noted.

Year	Total Estimate	≥500 mm	Source
1999[1]	1,792 (1,054-5,982)		Vidergar 2000
2003[2]		6,376 (5,247-8,124)	Peterson and Maiolie 2005
2005[2]	10,741 (9,008-12,798)		Hansen et al. 2008
2006 (spring)[3]	35,801 (25,270-52,634)	18,607 (13,158-27,412)	Hansen et al. 2008
2007 (spring)[3]	21,824 (18,484-25,981)		IDFG unpublished
2007[2]	5,787 (5,756-7,400)	5,721 (5,074-6,557)	IDFG unpublished
2011[2]	3,456 (1,637-6,476)	2,961 (1,402-5,549)	

[1] Gill net and angling Chapman estimate of fish ≥406 mm.
[2] Trap net Schnabel estimate.
[3] Gill net and trap net Chapman estimate.

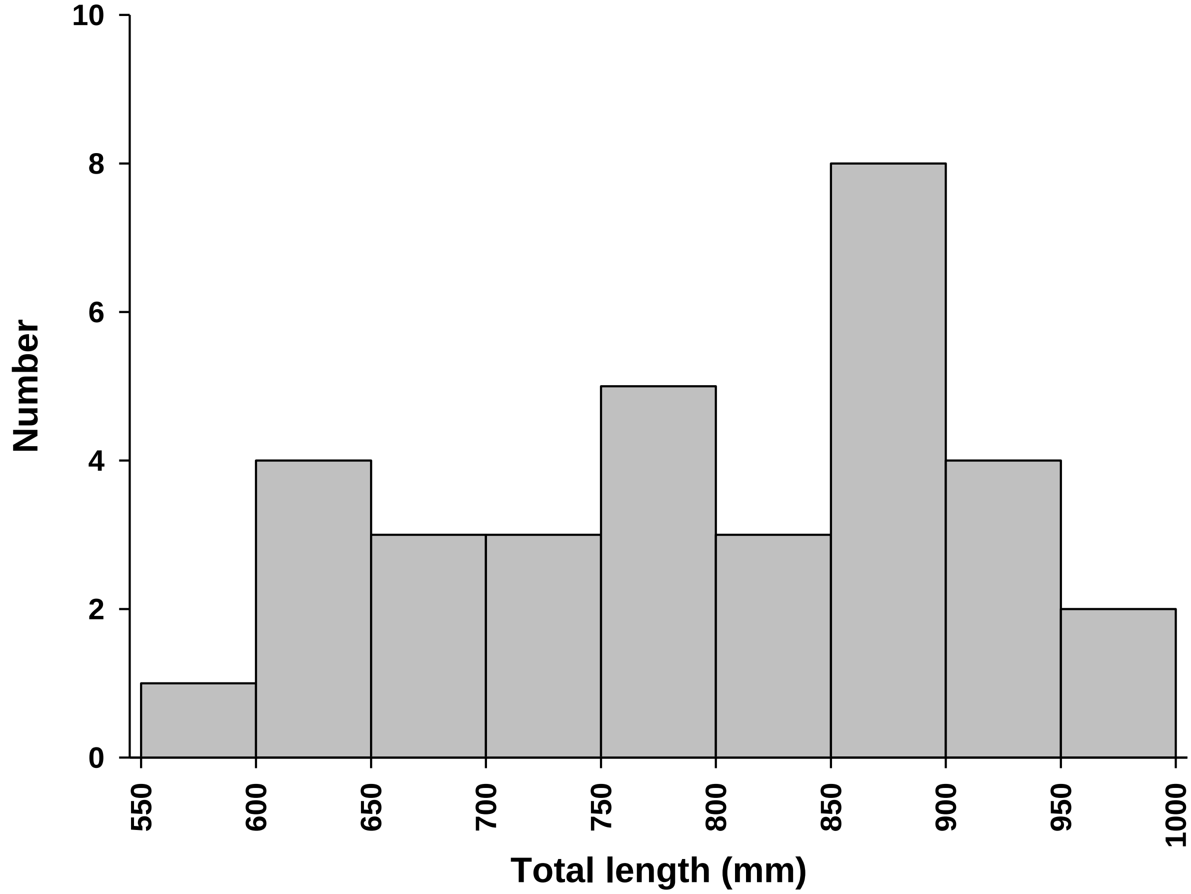

Figure 9. Length-frequency of Lake Trout (n = 30) captured and implanted with acoustic transmitters in Lake Pend Oreille during 2012.

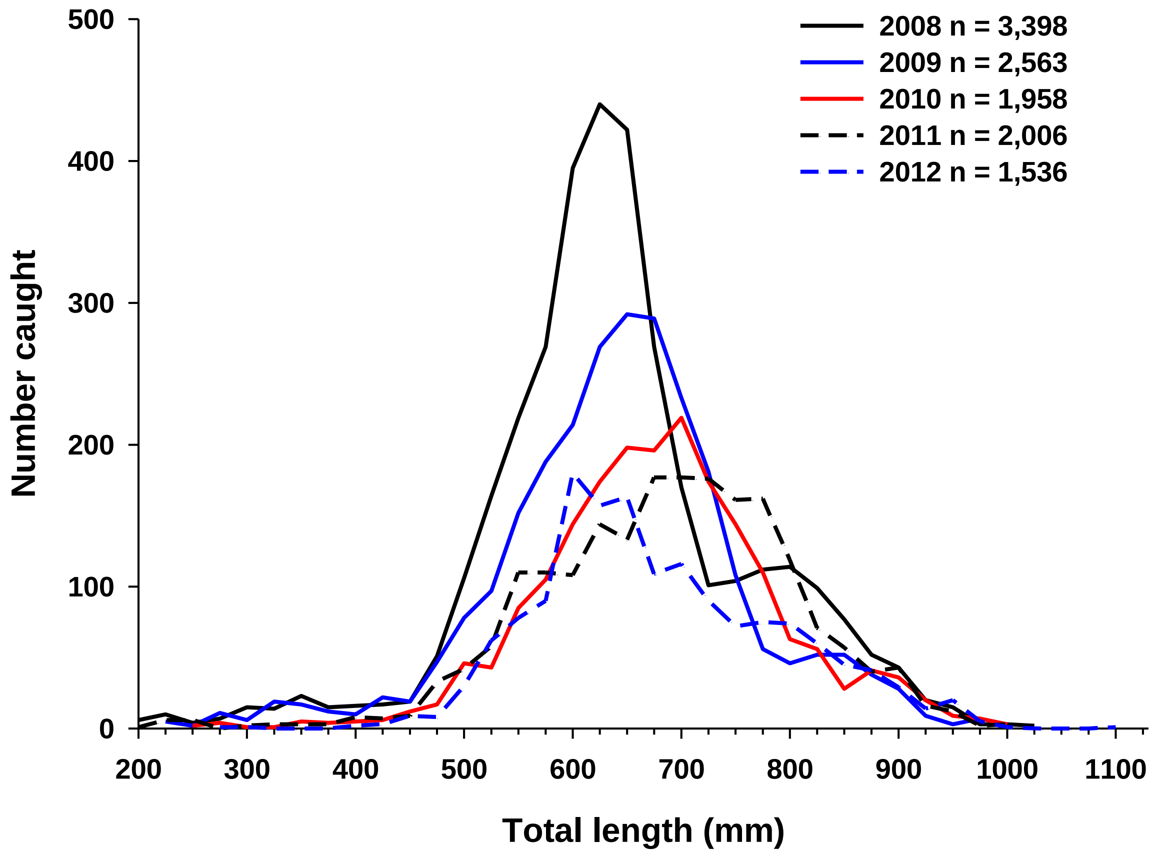

Figure 10. Length-frequency histogram of Lake Trout captured in gillnets at Windy Point, Bernard Beach, and Evans Landing during September and October, 2008-2012 in Lake Pend Oreille.

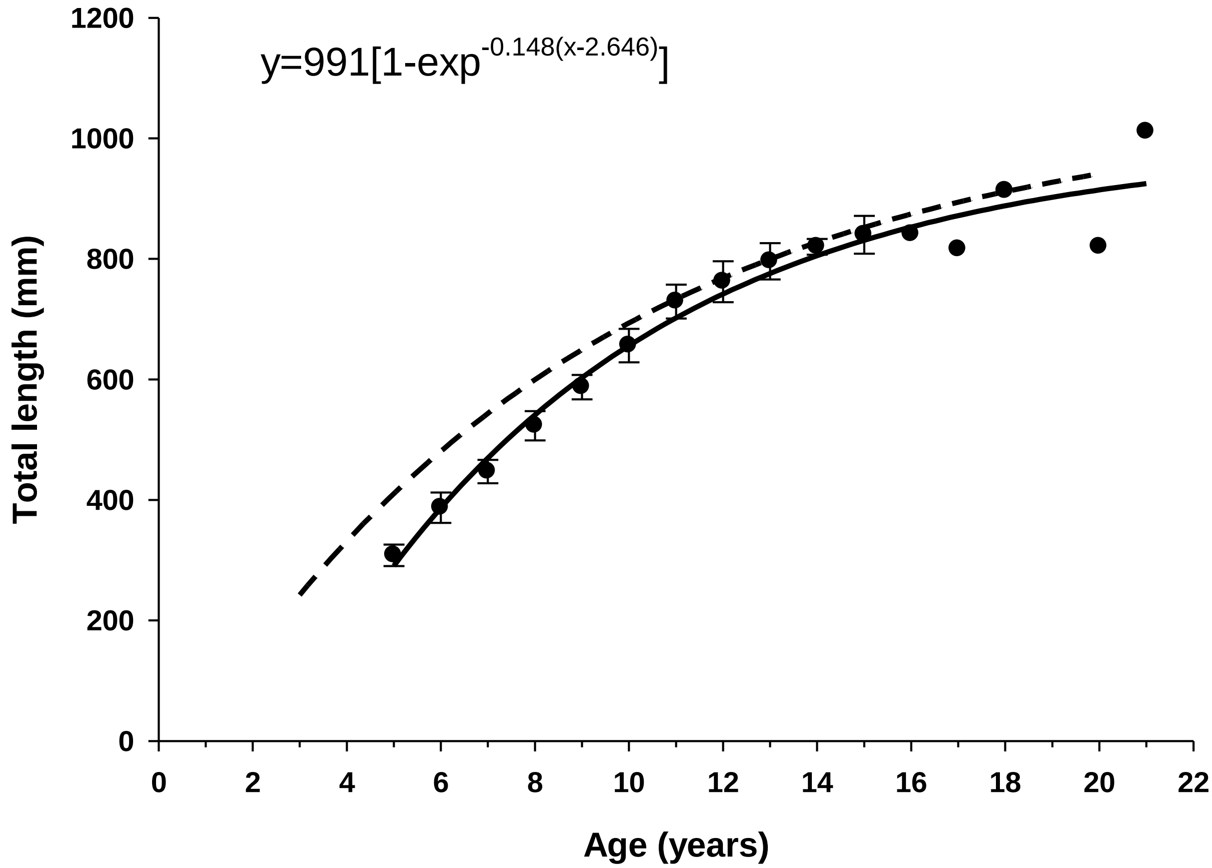

Figure 11. Mean total length-at-age with 95% confidence intervals for Lake Trout captured during spring 2012 in Lake Pend Oreille. Confidence intervals were not calculated for fish over age-15 because of low sample size. Growth is described by the fitted von Bertalanffy growth model (solid line). The dashed line represents the Lake Trout growth curve developed for Lake Pend Oreille in 2004.

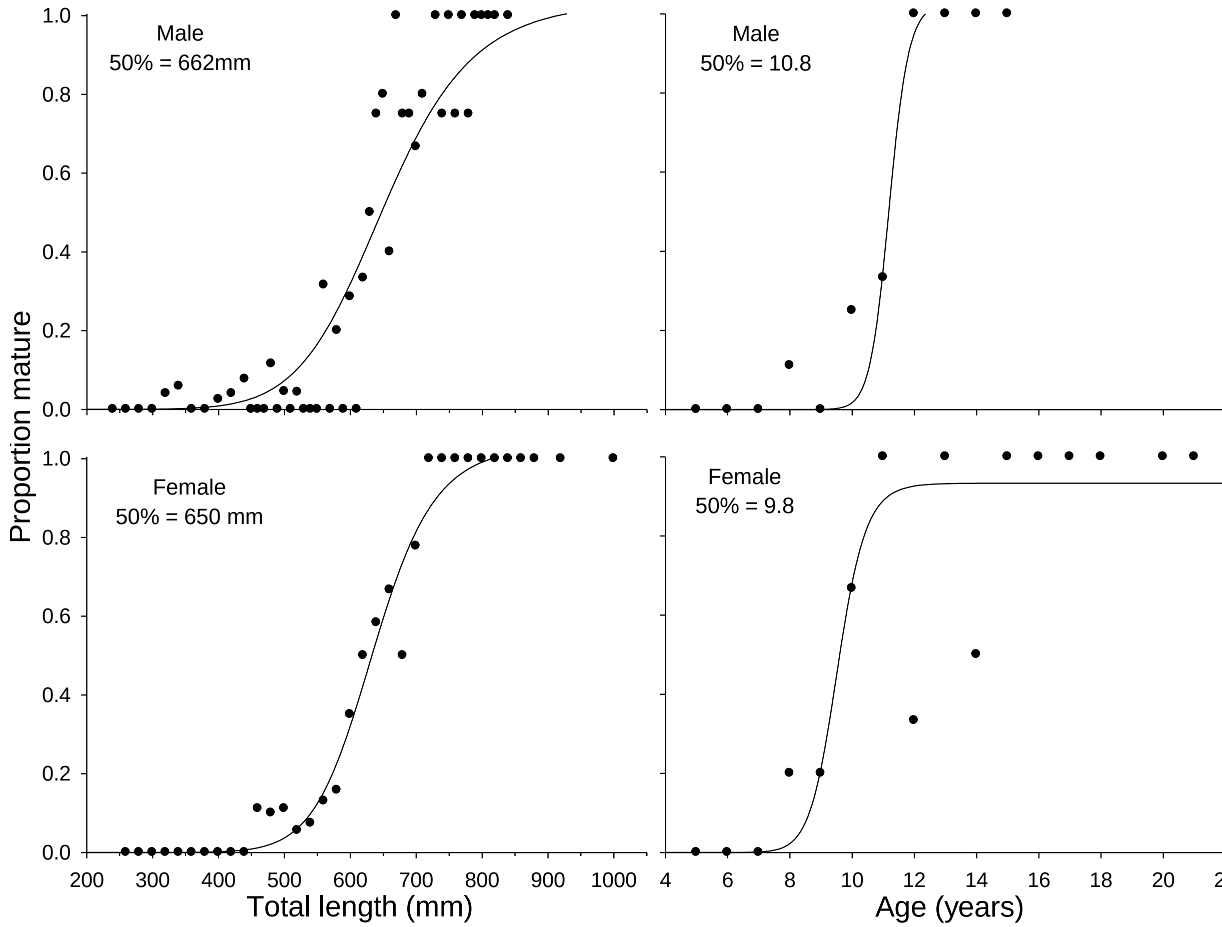

Figure 12. Proportion of mature male and female Lake Trout in 20 mm length classes and age classes collected during random gill netting in Lake Pend Oreille Idaho, 2012. Curves depict logistic models of proportion mature against length and age.

CHAPTER 3: RAINBOW TROUT RESEARCH

ABSTRACT

For over a decade, Kokanee *Oncorhynchus nerka* recovery in Lake Pend Oreille has been limited by excessive 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. Abundance estimates in 2009 and 2010 suggested the number of Rainbow Trout ≥406 mm had not been reduced by the incentivized harvest. In 2012, we conducted another population estimate for Rainbow Trout ≥406 mm and ≥300 mm. We estimated 50,758 (38,502-68,518 = 95% CI) Rainbow Trout ≥300 mm in Lake Pend Oreille with 24,472 (15,621-40,413 = 95% CI) ≥406 mm. Angling exploitation rate through December was 14% for Rainbow Trout ≥300 mm and 13% for those ≥406 mm. Genetics analyses revealed that although the Rainbow Trout in Lake Pend Oreille have some introgression with coastal hatchery strains of Rainbow Trout, these fish are still more closely related to the Gerrard strain that is native to Kootenay Lake.

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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, while 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. 2008), predation from the Rainbow Trout population (estimated at 19,157 fish ≥406 mm; Maiolie et al. 2008) still presented a threat to the Kokanee population in 2006. Population modeling suggested exploitation rates at that time were not sufficient to reduce Rainbow Trout abundance (Hansen et al. 2010). 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.

Rainbow Trout abundance estimates conducted since 2006 to evaluate responses to the AIP have been highly variable and had not suggested any consistent abundance trend (Wahl et al. 2011b, Wahl et al. 2013). Therefore, we conducted a final abundance estimate to better understand whether or not the AIP was effectively reducing the abundance of Rainbow Trout ≥300 mm and ≥406 mm. Additionally, we have documented decreasing size structure in the Rainbow Trout population, which likely has been driven by angler harvest. However, questions were raised by anglers about the influence of population genetics on Rainbow Trout growth potential. We conducted a genetic evaluation to better address these questions.

METHODS

Rainbow Trout Population and Exploitation

To estimate Rainbow Trout abundance and angling exploitation in Lake Pend Oreille, a mark-recapture study was initiated during spring 2012. We implanted coded wire tags (CWT) into the snout of all Rainbow Trout caught. We collected and tagged Rainbow Trout from Lake Pend Oreille using angling during spring 2012. Heads of Rainbow Trout caught by anglers and turned in to the AIP (see Predator Removal chapter below) 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. Because the AIP ended at the end of 2012, the estimate was only run with fish recaptured through December. This timing also matched previous estimates. To estimate abundance of Rainbow Trout ≥300 mm and ≥406 mm, we derived total length from a head length to total length regression developed for Rainbow Trout in Lake Pend Oreille (Wahl et al. 2011b). 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).

Rainbow Trout Genetic Evaluation

To assess the genetic composition of Lake Pend Oreille Rainbow Trout relative to their parent stock from Kootenay Lake, Canada, we collected a tissue sample from fish caught by anglers during October-December 2011. The genetic evaluation was performed to assess the extent that hybridization with other hatchery strains of Rainbow Trout has influenced the population and if any associated changes in growth potential should now be expected. Because the genetic samples had not been analyzed at the end of the 2011 contract, the results of the study are presented here.

A total of 354 Rainbow Trout samples were genotyped as part of this study. This included samples from Lake Pend Oreille (OmyPEND11C; N = 161), Kootenay Lake (OmyKOOL11C; N = 45), and the Kootenay Hatchery (OmyKOOT06C; N = 49). Samples from the Kootenay Hatchery are Gerrard strain Redband Trout. Gerrard Redband Trout (also referred to as Kamloops; hereafter Gerrard Rainbow Trout) are considered a unique strain that spawns in a limited 300 m stretch of the upper Lardeau River, which is a tributary of the Duncan River and flows into the north end of Kootenay Lake (Irvine 1978). Gerrard Rainbow Trout was one of the original strains stocked into Lake Pend Oreille in the early 1940s. However, Idaho Department of Fish and Game (IDFG) stocking records show that a variety of other Rainbow Trout strains have been stocked in numerous locations in the Lake Pend Oreille drainage over the years.

The 354 samples were screened with 187 single nucleotide polymorphic markers (SNPs) designed for genetic studies of *O. mykiss* throughout the Snake River basin (Ackerman et al. 2011). Genotyping was performed using Fluidigm 96.96 Dynamic Array IFCs "chips" following protocols described by Ackerman et al. (2011). Chips were imaged on a Fluidigm EP1 system and analyzed and scored using the Fluidigm SNP Genotyping Analysis Software version 3.1.1. Resulting genotypes were stored on a Progeny database server housed at IDFG's genetics lab.

Following SNP genotyping, sample collections were tested for deviations from Hardy–Weinberg equilibrium (HWE) using GENEPOP on the Web (Raymond and Rousset 1995). Genetic diversity was measured by the number of alleles per locus (N_A), observed heterozygosity (H_O), and expected heterozygosity (H_E) using the Microsatellite Toolkit for Microsoft Excel™ (Park 2001). GENEPOP on the Web was used to perform exact tests to assess the significance of allelic differentiation between pairs of populations and to estimate pairwise population differentiation (F_{ST}; Weir and Cockerham 1984). The following guidelines have been suggested for the interpretation of F_{ST}:

F_{ST} = 0 - 0.05, little genetic differentiation
F_{ST} = 0.05 - 0.15, moderate genetic differentiation
F_{ST} = 0.15 -0.25, great genetic differentiation
F_{ST} = > 0.25, very great genetic differentiation

To visualize genetic relationships among Lake Pend Oreille, Kootenay Lake, and Kootenay hatchery sample collections and compare them to previously genotyped reference Redband Trout and reference hatchery Rainbow Trout populations, a principal coordinate analysis (PCoA) of genotypes was performed based on pairwise F_{ST}; between sample collections using GenAlEx version 6.1 (Peakall and Smouse 2006).

A number of the SNP loci within the 187 SNP markers used in this study are diagnostic between hatchery Rainbow Trout strains (coastal origin) and Redband Trout native to the Columbia River basin (Ackerman et al. 2012). These are imperfect diagnostic markers in that only one of the alleles exhibit fixed or nearly fixed differences between the two forms, but are still useful in assessing intraspecific introgression. We compared allele frequencies at five of these diagnostic loci between study populations and reference Redband Trout from Southern Idaho and reference coastal Rainbow Trout populations described below.

Reference populations used for comparison purposes are as follows: Rainbow Trout collected from tributaries to Lake Pend Oreille (Caribou Creek, E.F. Lightning Creek, Grouse Creek, and N.F. Grouse Creek). Redband Trout (Upper Snake River)-Rice Creek, Hat Creek, Big Jacks Creek, Shack Creek, and Dry Creek; hatchery Rainbow Trout (coastal origin)-Harrison, Arlee, McConaughy and Harrison/Desmet (all from the Ennis Fish Hatchery, Montana). All reference populations/samples had been previously screened with the same set of 187 SNP markers used in this study (Ackerman et al. 2012; Campbell et al. 2013).

RESULTS

Rainbow Trout Population and Exploitation

A total of 353 Rainbow Trout was tagged between April 28 and May 27, 2012. Average size of tagged Rainbow Trout was 401 mm total length (SE = 4.7; range = 300-815). From June through December, anglers turned 7,075 Rainbow Trout heads ≥300 mm in to the AIP, including 3,262 ≥406 mm. From this, we estimated 50,758 (38,502-68,518 = 95% CI) Rainbow Trout ≥300 mm in Lake Pend Oreille with 24,472 (15,621-40,413 = 95% CI) ≥406 mm (Figure 13). Angling exploitation rate through December was 14% for Rainbow Trout ≥300 mm and 13% for those ≥406 mm. A summary of the number of heads in the AIP, recaptures, and abundance estimates by month is presented in Tables 9 and 10.

Rainbow Trout Genetic Evaluation

Tests for HWE indicated that samples collected from Lake Pend Oreille exhibited significant heterozygote deficiencies ($P<0.00001$), an observation consistent with having sampled more than one population (Wahlund effect). The remaining sample collections exhibited no significant deviations from HWE expectations. In an attempt to decompose the apparent admixture observed within the Lake Pend Oreille collection, samples were assigned back to a baseline consisting of all reference populations with the software program ONCOR (Kalinowski et al. 2008). Of the 161 samples within the Lake Pend Oreille collection, 35 (21.7%) assigned with highest probability to Caribou Creek, 95 (59.0%) assigned with highest probability to E.F. Lightning Creek, and 31 (19.3%) assigned with highest probability to Grouse Creek. Samples were then grouped according to their assignment population and re-analyzed for HWE. None of these sample groups deviated from HWE expectations following corrections for multiple tests.

Genetic diversity as measured by heterozygosity and alleles per locus was lowest in samples from Kootenay Lake and from the Kootenay Fish Hatchery (Table 11; HE = 0.17 – 0.18; NA = 1.74 – 1.78). Samples collected from Lake Pend Oreille as part of this study, as well as reference samples from tributaries to Lake Pend Oreille, exhibited higher diversity levels and these levels were uniform across the sample collections (Table 11; HE = 0.27 – 0.30; NA = 1.93 – 1.95). Tests for genetic differentiation showed low differences between sample collections from Lake Pend Oreille and reference collections from tributaries to Lake Pend Oreille (FST = 0.01-0.02; Table 12). Moderate genetic differentiation was observed between sample collections from Lake Pend Oreille and reference collections from tributaries to Lake Pend Oreille and reference "coastal" hatchery Rainbow Trout collections and reference Southern Idaho Redband Trout populations (FST = 0.09-0.18; Table 12). Significant but small differences were observed between Lake Pend Oreille collections and sample collections from Kootenay Lake and the Kootenay Fish Hatchery (FST = 0.03-0.06; Table 12).

Principal Coordinate Analysis (PCoA) distinguished three major clusters of sample collections along discriminate axes 1 and 2, which accounted for 42.7% and 22.6% of the genetic variation, respectively (Figure 14). Along the first axis, study and reference populations from Lake Pend Oreille and Kootenay Lake/Hatchery were resolved from reference coastal Rainbow Trout and Southern Idaho Redband Trout collections, while the second axis resolved Southern Idaho Redband Trout collections from the remaining collections.

Comparisons of allele frequencies at loci diagnostic between hatchery coastal origin Rainbow Trout and Redband Trout identified diagnostic coastal Rainbow Trout alleles in samples collected from Lake Pend Oreille and in reference samples from Lake Pend Oreille tributaries (3.4% - 24.2%), indicating that these populations are likely introgressed with coastal Rainbow Trout. No diagnostic coastal Rainbow Trout alleles were observed in samples from Kootenay Lake or the Kootenai Fish Hatchery (Table 13).

DISCUSSION

The abundance of Rainbow Trout ≥406 mm in Lake Pend Oreille was reduced by 46% during the first four years of the AIP (Wahl et al. 2011b). Since that time, the number of Rainbow Trout ≥406 mm has more than doubled. Similarly, the number of all harvestable-sized Rainbow Trout (≥300 mm) increased 46% since 2010 and was the highest estimate dating back to 2006. Overall, these data suggest that not only has the AIP failed to reduce the abundance of Rainbow Trout, but the population has actually grown since the program's inception.

Annual angling exploitation rates calculated in 2006-07 (19%), 2009-10 (29%), and 2010-11 (23%) were not high enough to reduce Rainbow Trout abundance as intended (Wahl et al. 2013), and the exploitation rate during 2012 was even lower. Similarly, incentivized Rainbow Trout harvest in the South Fork Snake River resulted in low exploitation rates and no change in relative population abundance (Schoby et al. 2013), and total annual mortality rates of around 60% did not reduce Rainbow Trout population abundance in many rivers throughout Idaho (D. Schill IDFG, personal communication). Andrusak and Thorley (2012) suggested an exploitation rate of 27% in Kootenay Lake, BC would maximize the total number of Rainbow Trout harvest, while exploitation rates of 13% maximized trophy Rainbow Trout harvest in Kootenay Lake, BC (Andrusak and Thorley 2012). Only during one year did the exploitation rate in Lake Pend Oreille exceed 27%, so the AIP likely only altered the size structure of the Rainbow Trout population without decreasing abundance. Other factors, such as dynamic flow conditions in Rainbow Trout spawning and rearing tributaries or Kokanee abundance may have been the driving forces behind the changes in Rainbow Trout abundance that we documented.

The primary goal of the genetics evaluation was to assess the ancestry of the current Rainbow Trout population within Lake Pend Oreille. It is thought that Rainbow/Redband Trout are not native to the Lake Pend Oreille drainage (Behnke 2002). Barrier falls on the Pend Oreille River, downstream of Lake Pend Oreille (Albeni and Metaline falls), prevented the upstream migration and colonization of *O. mykiss* following glaciation roughly 10,000 to 30,000 years ago (Behnke 2002). The present day population of Rainbow Trout in Lake Pend Oreille is believed to have come primarily from the stocking of Gerrard Rainbow Trout beginning in the early 1940s. However, significant numbers of other Rainbow Trout strains have also been stocked within the Lake Pend Oreille drainage. Results from this study support the idea that the current population of Rainbow Trout in Lake Pend Oreille has an ancestry primarily from the Gerrard strain. Genetic differentiation between collections from Lake Pend Oreille versus collections from Kootenay Lake and the Kootenay Fish Hatchery were significant but low, and these collections clustered together in the Principal Coordinate Analysis. Higher differentiation was observed between collections from Lake Pend Oreille and reference "coastal" hatchery Rainbow Trout and reference Southern Idaho Redband Trout.

Although samples from Lake Pend Oreille appear to have a predominantly Gerrard strain ancestry, they are still genetically differentiated from collections from Kootenay Lake and the Kootenay Fish Hatchery. Our results indicate that this differentiation is likely from the stocking and subsequent introgression of "coastal" hatchery Rainbow Trout. Samples from Kootenay Lake and the Kootenay Fish Hatchery do not exhibit any coastal Rainbow Trout alleles and display some of the lowest levels of diversity we have observed among the *O. mykiss* populations that we have screened. The reduced genetic diversity may be expected given that genetic variation is presumed to be lower at the periphery of a species' range due to isolation and smaller population sizes (Lesica and Allendorf 1995). Rainbow Trout in the Kootenay Lake drainage exist at the far end of the species' range in the Columbia River basin.

There have been recent concerns among anglers that Rainbow Trout within Lake Pend Oreille do not reach the trophy size of past catches because the original Gerrard strain has been replaced by other hatchery Rainbow Trout strains. Although our results do not support the idea that the Gerrard strain has been replaced by coastal hatchery strains, it is difficult to speculate what the effect coastal Rainbow Trout introgression would have on specific life history traits. It should be noted that Rainbow Trout as a species is capable of producing a wide variety of growth rates across varying environmental conditions (Juncos et al. 2011). An empirical comparison of growth rate between introgressed versus non-introgressed fish may be possible given the fact that the lake was recently stocked with juveniles produced from Gerrard strain broodstock captured from the Lardeau River.

RECOMMENDATIONS

1. Discontinue the AIP for Rainbow Trout beginning in 2013.

2. Institute restrictive harvest regulations for Rainbow Trout that are designed to improve population size structure and rebuild the trophy fishery.

3. Examine Rainbow Trout age structure and growth rates every 2-4 years to assess the population response to differing regulation strategies and changes in Kokanee abundance.

4. Stock pure-strain Gerrard Rainbow Trout from Kootenay Lake, B.C. in 2013 and compare the growth of these fish to other Rainbow Trout in Lake Pend Oreille.

Table 9. Monthly summary of Rainbow Trout heads ≥49 mm collected from Lake Pend Oreille, Idaho through the AIP, the number of recaptures, and cumulative population estimates of Rainbow Trout ≥300 mm with 95% confidence intervals.

				95% Confidence Interval	
	Number of heads in AIP	**Number of Recaptures**	**Cumulative estimate of Rainbow Trout ≥300 mm**	**Lower Limit**	**Upper Limit**
June	1075	8	42,322	22,673	86,569
July	535	5	40,734	24,476	72,189
August	351	1	46,302	28,349	79,833
September	728	4	50,118	32,390	81,390
October	1443	15	43,031	30,932	61,733
November	2002	12	47,212	35,487	64,254
December	891	3	50,758	38,502	68,518

Table 10. 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.

				95% Confidence Interval	
	Number of heads in AIP	**Number of Recaptures**	**Cumulative estimate of Rainbow Trout ≥406 mm**	**Lower Limit**	**Upper Limit**
June	405	2	18,269	6,684	45,675
July	267	3	15,142	7,154	34,944
August	218	0	20,047	9,471	46,263
September	365	1	24,222	12,026	52,988
October	685	7	18,716	11,246	33,169
November	968	4	21,817	13,926	36,029
December	354	0	24,472	15,621	40,413

Table 11. Sample location, sample size (N) of *O. mykiss* genotyped, expected (HE) and observed (HO) heterozygosity, and average number of alleles per locus (NA).

Sample Location	**N**	**H_E**	**H_O**	**N_A**
Caribou Creek	56	0.30	0.30	1.95
E. F. Lightning Creek	59	0.27	0.27	1.95
Grouse Creek	64	0.29	0.29	1.95
N. F. Grouse Creek	61	0.28	0.28	1.94
LPO1	35	0.31	0.29	1.94
LPO2	95	0.27	0.27	1.96
LPO3	31	0.29	0.28	1.93
Arlee	47	0.28	0.28	1.84
McConaughy	25	0.28	0.27	1.83
Harrison Lake/Desmet	26	0.33	0.32	1.92
Harrison Lake	28	0.33	0.33	1.91
Kootenay Lake	45	0.18	0.18	1.62
Kootenay F.H.	49	0.17	0.17	1.60
Big Jacks Creek	25	0.29	0.28	1.88
Hat Creek	24	0.25	0.24	1.78
Rice Creek	26	0.19	0.19	1.74
Shack Creek	24	0.27	0.28	1.78

Table 12. Pairwise estimates of genetic differentiation (FST) between study populations and reference Redband Trout and reference coastal Rainbow Trout. Values in italics refer to comparisons that yielded non-significant exact tests of allelic differentiation.

	Caribou Creek	**E.F. Lightning Cr.**	**Grouse Cr.**	**N.F. Grouse Cr.**	**LPO[1]**	**LPO[2]**	**LPO[3]**
E. F. Lightning Creek	0.02						
Grouse Creek	*0.01*	0.02					
N. F. Grouse Creek	*0.01*	0.02	*0.01*				
LPO[1]	*0.01*	0.02	*0.01*	*0.01*			
LPO[2]	0.02	*0.01*	0.02	0.02	0.02		
LPO[3]	*0.01*	0.02	*0.01*	*0.01*	*0.01*	0.02	
Arlee[RH]	0.15	0.18	0.15	0.16	0.15	0.18	0.16
McConaughy[RH]	0.15	0.17	0.15	0.16	0.15	0.17	0.15
Harrison Lake/Desmet[RH]	0.09	0.12	0.10	0.11	0.10	0.12	0.10
Harrison Lake[RH]	0.10	0.12	0.10	0.11	0.10	0.12	0.10
Kootenay Lake	0.05	0.03	0.05	0.05	0.05	0.03	0.05
Kootenay F.H.	0.06	0.04	0.05	0.05	0.06	0.03	0.06
Big Jacks Creek[RR]	0.09	0.11	0.09	0.09	0.09	0.11	0.09
Hat Creek[RR]	0.09	0.10	0.09	0.10	0.09	0.10	0.10
Rice Creek[RR]	0.14	0.15	0.15	0.16	0.15	0.15	0.15
Shack Creek[RR]	0.10	0.11	0.10	0.10	0.10	0.12	0.10

1 = Samples from LPO that assigned to Caribou Creek.
2 = Samples from LPO that assigned to EF Lightning Creek.
3 = Samples from LPO that assigned to Grouse Creek.
RH = Reference coastal hatchery rainbow trout.
RR = Reference redband trout from the Snake River basin (southern Idaho).

Table 13. Allele frequencies at five diagnostic loci within study populations and reference Redband Trout and reference coastal Rainbow Trout.

Locus	**Caribou Cr.**	**EF Lightning Cr.**	**Grouse Cr.**	**NF Grouse Cr.**	**Lake Pend Oreille[1]**	**Lake Pend Oreille[2]**	**Lake Pend Oreille[3]**	**[A]Coastal Rainbow Reference**	**Redband Reference Kootenay Lk.**	**Redband Reference Kootenay H.**	**[B]Redband Reference Up. Snake R.**
Omy_nach200											
1	13.4	5.9	19.5	15.6	**20.0**	**5.8**	**4.8**	56.0			0.9
2	86.6	94.1	80.5	84.4	80.0	94.2	95.2	44.0	100.0	100.0	99.1
Omy_LDHB2_i6											
1	17.0	3.4	12.5	20.5	**12.9**	**5.8**	**24.2**	33.3			1.3
2	83.0	96.6	87.5	79.5	87.1	94.2	75.8	66.7	100.0	100.0	98.7
OMS00014											
1	11.6	10.2	9.4	11.5	**10.0**	**20.5**	**9.7**	64.7			2.2
2	88.4	89.8	90.6	88.5	90.0	79.5	90.3	35.3	100.0	100.0	97.8
OMS00149											
1	4.5	6.8	7.1	4.1	**5.7**	**9.5**	**8.1**	33.3			0.9
2	95.5	93.2	92.9	95.9	94.3	90.5	91.9	66.7	100.0	100.0	99.1
Omy_sSOD1											
1	17.0	6.8	7.0	12.3	**10.0**	**5.8**	**11.3**	17.9			0.2
2	83.0	93.2	93.0	87.7	90.0	94.2	88.7	82.1	100.0	100.0	99.8

[A] = Allele frequencies at all four coastal hatchery rainbow trout populations were averaged for reporting purposes.
[B] = Allele frequencies at all six redband trout populations were also averaged for reporting purposes.
[1] = Samples from LPO that assigned to Caribou Creek.
[2] = Samples from LPO that assigned to EF Lightning Creek.
[3] = Samples from LPO that assigned to Grouse Creek.

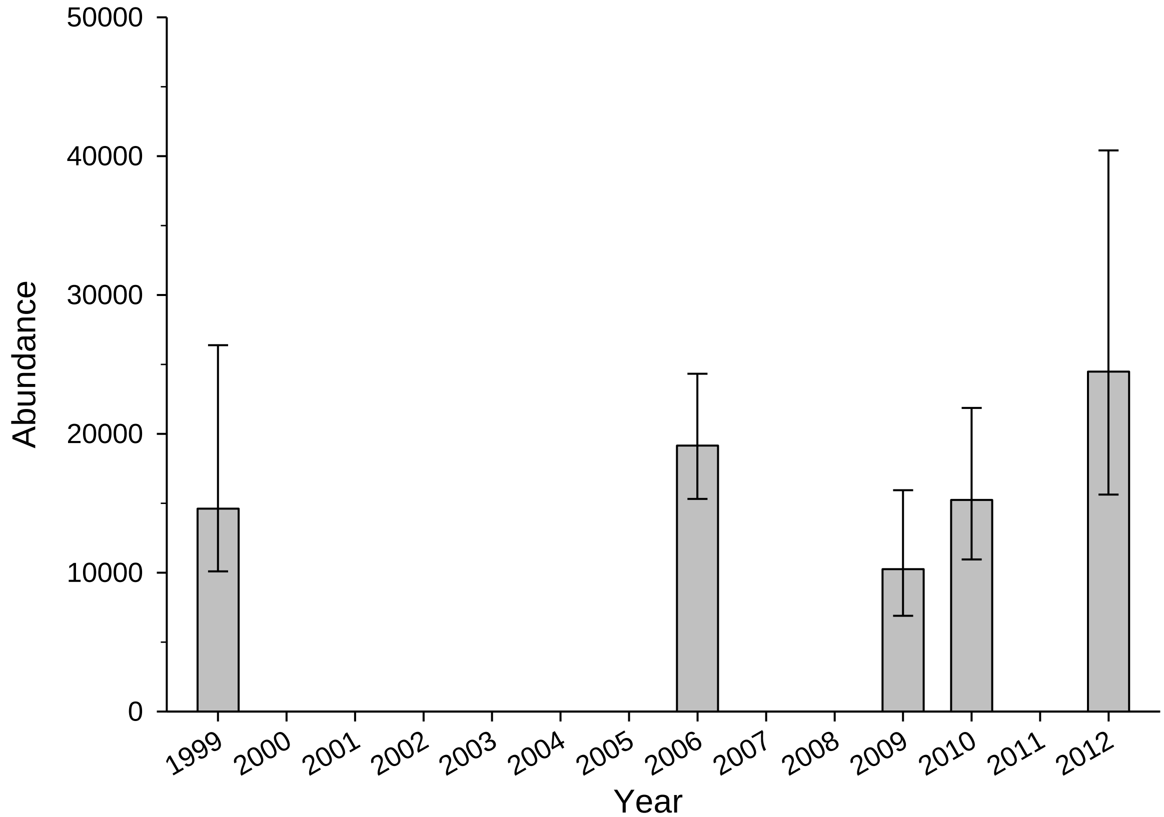

Figure 13. Estimate and 95% confidence intervals of the abundance of Rainbow Trout ≥406 mm in Lake Pend Oreille.

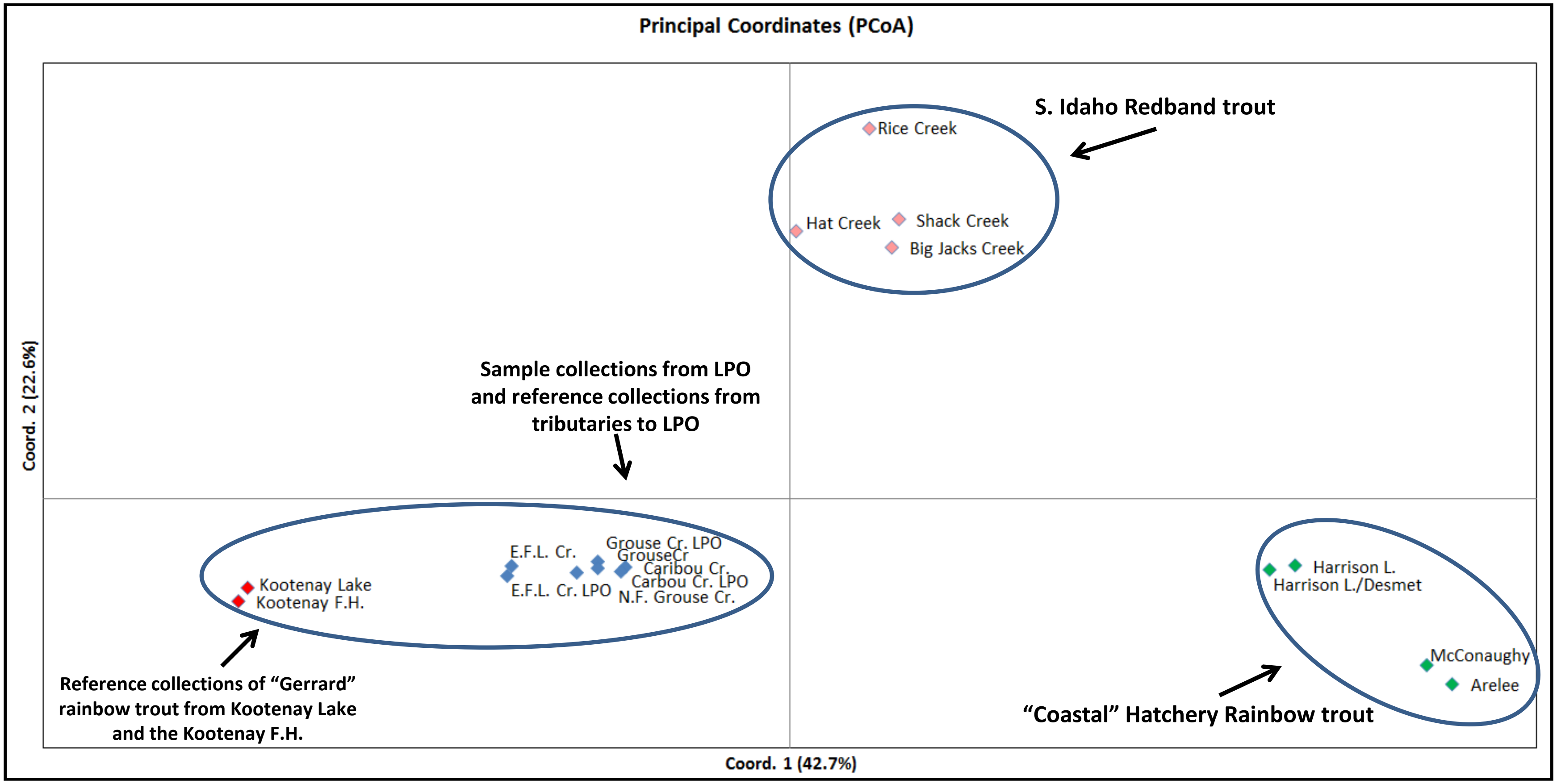

Figure 14. Principal Coordinate Analysis showing three major clusters of sample collections along discriminate axes 1 and 2: Southern Idaho Redband Trout (upper right quadrant); Coastal Hatchery Rainbow Trout (lower right quadrant); collections of Rainbow/Redband Trout from the Lake Pend Oreille (LPO) and Kootenay Lake drainages (lower left quadrant).

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*. To address this issue, 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 Research, LLC to remove Lake Trout from Lake Pend Oreille using gill nets and deepwater trap nets. During 2012, the contract netters removed 9,530 Lake Trout in gill nets and an additional 322 Lake Trout in trap nets. Anglers turned in 7,813 Lake Trout heads and 9,810 Rainbow Trout heads. Total biomass removed in 2012 was 20,016 kg for Lake Trout (0.61 kg/ha) and 9,121 kg for Rainbow Trout (0.28 kg/ha). Since the predator removal began in 2006, 151,194 Lake Trout and 50,998 Rainbow Trout have been removed from Lake Pend Oreille. An abundance estimate for Bull Trout suggested incidental netting bycatch has not negatively influenced the population.

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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 the risk (Hansen et al. 2010). 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. 2008). 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 initiated an Angler Incentive Program (AIP) which offered $15 rewards per Lake Trout or Rainbow Trout harvested. The rod limits have since been removed altogether. Additionally, IDFG contracted a commercial fishing operation with prior Lake Trout netting experience in the Great Lakes (Hickey Brothers Research, LLC) to remove Lake Trout with gill nets and deepwater trap nets in Lake Pend Oreille. A combination of gill nets, trap nets, and angling was necessary to maximize the likelihood of exerting high enough annual mortality to sufficiently reduce the Lake Trout population and prevent Kokanee extirpation (Hansen et al. 2010).

METHODS

Predator Removal

Hickey Brothers Research, LLC was contracted to remove Lake Trout from Lake Pend Oreille using gill nets and deepwater trap nets during 30 weeks (15 weeks in the spring and 15 weeks in the fall) in 2012. Gill nets contained stretch mesh of 4.4-12.7 cm. The contract netters set primarily 4.4-7.0 cm mesh in the spring (January-April) 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 adult Lake Trout at spawning sites. Additionally, during February and March mixed-mesh gill nets were set at random locations to sample Lake Trout and evaluate the population age structure (see Lake Trout Research chapter for more details). Methods for setting gill nets are described in Chapter 2. Gill nets were typically set around dawn and pulled several hours later. Four trap nets (described in detail by Peterson and Maiolie 2005) were set during the fall at locations standardized in previous years. Hickey Brothers Research, LLC set the trap nets during the first week of fall netting and lifted the nets 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.

For the AIP, anglers who 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. Previously developed head-length to total-length relationships for Rainbow Trout and Lake Trout in Lake Pend Oreille (Wahl et al. 2011b, Wahl et al. 2013) were used to extrapolate total length.

As a metric to evaluate the response of Lake Trout to removals, we used the combined catch rate of trap nets set at standardized locations during fall to index trends in mature Lake Trout abundance. We also used catch rates of Lake Trout caught in small mesh (4.4-7.0 cm) gill nets set in the north end of the lake as a trend for juvenile Lake Trout abundance.

Bull Trout Population Assessment

To gauge the Bull Trout population response to changes in Lake Trout and Kokanee abundances and the effects of netting bycatch, a Bull Trout population estimate was initiated during fall 2011. Bull Trout captured in gill and trap nets set by Hickey Brothers Research, LLC received a passive integrated transponder (PIT) tag in the dorsal sinus. The recapture netting occurred in the random gill net sets during spring 2012 which are described in Chapter 2. 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). Estimates were generated for different size classes similar to previous research (McCubbins 2013).

RESULTS

Predator Removal

During spring 2012, (from January 16 to April 26), Hickey Brothers Research, LLC set a total of 377,100 m of gill net (1,375 individual 274 m nets) and captured 4,683 Lake Trout (2.0 Lake Trout per net; 1.7-2.3 = 95% CI) and 576 Bull Trout (0.4 Bull Trout per net; 0.4-0.5 = 95% CI) with 135 direct mortalities (23%). All but one of the Lake Trout caught were removed. Weekly catch rates ranged from 0.4 Lake Trout per net (0.2-0.7 = 95% CI) during March 4-10 to 6.9 Lake Trout per net (5.0-9.4 = 95% CI) during January 15-21. Captured Lake Trout ranged in size from 177-1017 mm, but because primarily small mesh nets were set to target small Lake Trout, 87% of fish caught were <450 mm (Figure 15). Based on the length-weight relationship developed for Lake Trout in Lake Pend Oreille (Wahl et al. 2011b), the Lake Trout biomass removed during spring gill netting was 2,642 kg.

During fall 2012, (from September 3 to December 14), Hickey Brothers Research, LLC set a total of 351,861 m of gill net (1,283 individual 274 m nets) and captured 4,848 Lake Trout (2.9 Lake Trout per net; 2.5-3.3 = 95% CI) and 1,072 Bull Trout (0.8 Bull Trout per net; 0.7-0.9 = 95% CI) with 286 direct mortalities (27%). Of the Lake Trout caught, 4,818 were removed. From September 3 to October 19, when only spawning sites were targeted, mean catch rate was 2.2 Lake Trout per net (1.9-2.7 = 95% CI). Afterwards, netting targeted small Lake Trout, and mean catch rate was 4.3 Lake Trout per net (3.5-5.2 = 95% CI). Captured Lake Trout ranged in size from 198-1100 mm (Figure 15). Based on the length-weight relationship (Wahl et al. 2011b), the Lake Trout biomass removed during fall gill netting was 6,486 kg. Also during the fall (from September 4 to November 13), four trap nets captured 325 Lake Trout and 55 Bull Trout with 19 direct mortalities (35%). Of the Lake Trout captured, 322 were removed. Trap net-caught Lake Trout ranged in size from 380-926 mm. Based on the length-weight relationship (Wahl et al. 2011b), the trap nets removed 732 kg of Lake Trout biomass during the fall.

The catch rate of the standardized trap nets during the fall was 1.0 Lake Trout per net-night (0.7-1.5 = 95% CI; Figure 16). The catch rate of the small mesh gill nets used to target juvenile Lake Trout was 3.4 Lake Trout per net (3.0-3.8 = 95% CI; Figure 17).

During 2012, anglers turned in 7,813 Lake Trout heads to the AIP program with 78% of these fish turned in during May-September (Table 14). Based on head length to total length (Wahl et al. 2013) and length-weight (Wahl et al. 2011b) relationships developed for Lake Trout in Lake Pend Oreille, anglers removed 10,156 kg of Lake Trout biomass. Additionally, during 2012, anglers turned in 9,810 Rainbow Trout heads with 66% turned in during April-June and October-November (Table 15). Based on head length to total length (Wahl et al. 2011b) and length-weight (Wahl et al. 2013) relationships developed for Rainbow Trout in Lake Pend Oreille, anglers removed 9,121 kg of Rainbow Trout biomass. Anglers also mistakenly turned in 24 Bull Trout heads to the AIP program.

Bull Trout Population Assessment

During fall 2011, we marked and released 428 Bull Trout with PIT tags. During the recapture gill netting in spring 2012, 360 Bull Trout were captured with 5 recaptures. This produced a total population estimate of 25,812 (12,194-59,565 = 95% CI) Bull Trout that were vulnerable to gill nets and 11,744 (5,243-29,359 = 95% CI) Bull Trout ≥400 mm (Table 16).

DISCUSSION

Predator Removal

Since the predator removal program began in 2006, 151,194 Lake Trout have been removed from Lake Pend Oreille (Table 17) for a total of 146 metric tonnes of biomass or 4.43 kg/ha. Total angler catch and trap net catch rate have declined as larger Lake Trout have been removed from the population. In 2006, 72% of the Lake Trout were removed by angling (Table 17), which is selective for Lake Trout primarily age-5 to age-9 (Hansen et al. 2010). By 2009, only 30% of Lake Trout were removed by angling. The proportion has since increased slightly to 39% of Lake Trout removed by anglers, which is primarily due to reduced gill net catch rate for juvenile Lake Trout. Similarly, trap nets, which effectively target Lake Trout ≥age-8, have showed an 80% decrease in catch rate since 2006. Gill net total catch and catch rates have also declined, despite increases in gill net effort, shifting netting to target highest catch areas, and using mesh sizes that select for even smaller fish. The shift in contribution of each capture method over time demonstrates the importance of using multiple capture methods in a suppression program to exploit all sizes of Lake Trout (Hansen et al. 2010).

The catch rate of the standardized trap nets decreased 82% from 2006 to 2009, but has remained consistent since then. However, the consistent catch rates since 2009 may be misleading. Lake Trout telemetry data show high use of habitats on the north end of Lake Pend Oreille where trap nets are located. Trap net catch rates may be biased high if this portion of the lake is a preferred habitat for Lake Trout. Regardless, the Lake Trout catch rates in standardized trap nets suggest the population has been dramatically reduced since 2006 and, at a minimum, is being held at a low level.

Standardized trap net catch rates have value for trend monitoring, despite the potential bias from their locations overlapping high-use Lake Trout habitat. Trap net trend data have been similar to the trend from mark-recapture abundance estimates (Figure 16), indicating that catch rates provide a reasonable index to abundance. Conducting future abundance estimates is unlikely because it is difficult to get robust estimates at lower Lake Trout densities and the incidental Bull Trout mortality is higher during random netting events. Standardized trap net catch rates can be monitored annually with fewer resources, thus providing a more effective metric for assessing changes in relative abundance of adult Lake Trout in the future. Periodic random gill netting may be necessary to collect a representative sample for evaluating changes in population demographics.

High densities of juvenile Lake Trout (≤450 mm) were discovered in the relatively shallow (45-90 m) northern basin of the lake during 2008. This area is now the focal point of juvenile netting efforts in the lake. Since 2008, the mean annual catch rate of juvenile Lake Trout in the northern basin has declined 80% from a high of 16.9 Lake Trout per net (13.9-20.5 = 95% CI). With an exponentially growing population through 2006, and not exploiting Lake Trout at spawning sites until 2008, strong year classes likely were being produced until fairly recently. Based on the decreasing catch rate, recruitment overfishing appears to be occurring. With progressively fewer spawning adults since 2008, juvenile Lake Trout production is likely to decline. Additionally, targeted netting for these juvenile fish should reduce recruitment to maturity and further reduce spawning potential. In the coming years, we expect combined netting of adults and juveniles to result in fewer fish reaching maturity (~650 mm) and fewer juvenile fish recruiting to the gear (~250 mm).

The number of Rainbow Trout turned in to the AIP was the highest in the seven years of this program. 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, along with a stable to increasing trend in the Rainbow Trout abundance estimates, suggests that the AIP did not effectively reduce the population.

Bull Trout Population Assessment

Incidental bycatch of Bull Trout has been a concern since Lake Trout removal using commercial gill nets began. The Bull Trout abundance estimate we conducted was poor due to the low number of Bull Trout handled, especially recaptures. However, the lower bound of the estimate in 2012 was very similar to the abundance estimates in 1998 (Vidergar 2000) and 2008 (McCubbins 2013). This provides some support that Bull Trout are at least as abundant as in previous years and suggests that incidental Bull Trout mortality is not causing abundance to decline. This is also corroborated by stable Bull Trout redd count trends during the years of predator removal (Maiolie et al. 2013). By continuing to tag all Bull Trout caught in the nets and recording all recaptures, we will be able to develop a better estimate of population abundance and post-release survival in the future using a multiple mark-recapture model. Additionally, though not quantified, Bull Trout bycatch threats are likely outweighed by the benefit they receive from reduced interactions with Lake Trout and higher Kokanee abundance that have resulted from netting efforts.

RECOMMENDATIONS

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

2. Continue use of the AIP to reduce Lake Trout abundance in Lake Pend Oreille during 2013.

3. Discontinue the AIP for Rainbow Trout beginning in 2013.

4. Continue to PIT tag Bull Trout captured in gill and trap nets. Multiple years of tagging and recapture data will eventually allow population abundance and long-term survival estimates to be conducted.

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	2011	2012
January	--	415	58	144	330	146	140
February	--	789	241	156	351	78	103
March	--	895	363	179	380	105	96
April	--	1,261	544	263	343	256	233
May	1,317	2,445	771	1,033	873	347	928
June	2,136	3,107	2,117	1,321	1,558	2,049	1,552
July	1,033	2,809	2,612	1,178	1,354	1,115	1,534
August	2,200	1,949	1,878	1,051	988	718	977
September	1,755	1,864	2,178	969	1,261	940	1,119
October	1,561	1,046	862	409	766	930	419
November	661	831	940	483	330	348	388
December	250	254	298	180	206	292	324
TOTAL	**11,041**	**17,665**	**13,020**	**7,366**	**8,740**	**7,324**	**7,813**

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	2011	2012
January	--	124	216	27	42	162	306
February	--	78	33	45	68	53	182
March	--	154	96	79	176	182	249
April	--	1,050	357	241	616	922	918
May	1,211	1,376	548	948	1,254	930	1,010
June	510	1,212	711	602	953	1,161	1,080
July	206	396	337	392	461	636	548
August	375	526	244	369	387	276	357
September	544	654	391	447	828	561	777
October	1,561	1,114	644	967	1,696	1,560	1,463
November	1,412	1,288	1,073	1,452	1,216	1,684	2,013
December	129	171	203	224	217	570	907
TOTAL	**5,948**	**8,141**	**4,695**	**5,793**	**7,914**	**8,697**	**9,810**

Table 16. Total and size-specific Bull Trout population estimates (and 95% confidence intervals) during 1998 (Vidergar 2000), 2008 (McCubbins 2013), and 2012.

Year	1998	2008	2012
Total	12,134 (8,252-22,915)	12,513 (7,456-22,521)	25,812 (12,194-59,565)
≥400 mm	-	8,004 (4,580-15,135)	11,744 (5,243-29,359)
≥500 mm	-	3,893 (1,961-8,482)	6,094 (2,487-15,234)
≥600 mm	-	623 (262-1,537)	925 (338-2,313)

Table 17. Number of Lake Trout removed from Lake Pend Oreille, Idaho by different gear types each year.

Gear	2006	2007	2008	2009	2010	2011	2012	Total
Angling	11,041	17,665	13,020	7,366	8,740	7,324	7,813	**72,969**
Gill Nets	2,774	4,169	10,252	17,186	17,334	11,384	9,500	**72,599**
Trap Nets	1,500	1,335	1,509	410	400	150	322	**5,626**
TOTAL	**15,315**	**23,169**	**24,781**	**24,962**	**26,474**	**18,858**	**17,635**	**151,194**

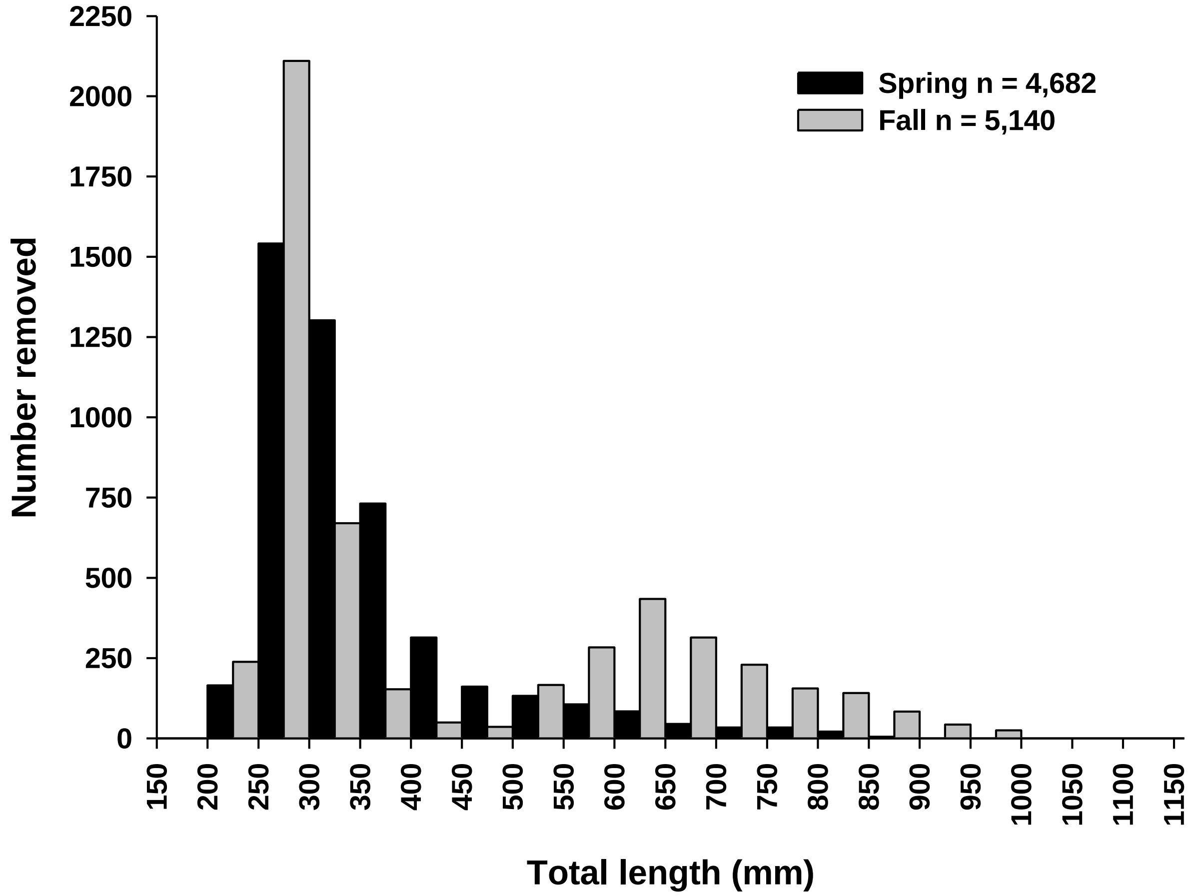

Figure 15. Length-frequency histogram for Lake Trout removed with gill and trap nets during the spring and fall of 2012 in Lake Pend Oreille.

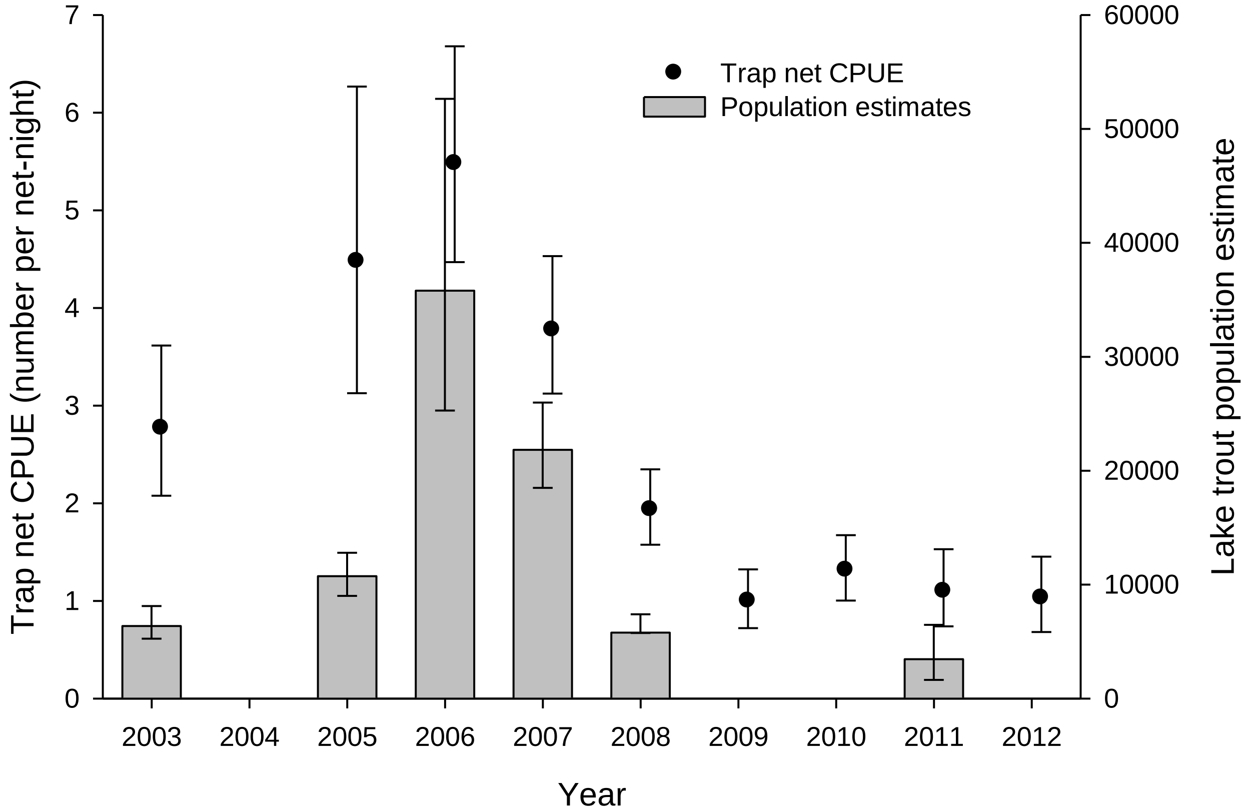

Figure 16. Mean Lake Trout catch rate with 95% confidence intervals for standardized trap nets set during fall and Lake Trout population estimates with 95% confidence intervals in Lake Pend Oreille, Idaho. See Table 8 for a description of the population estimates.

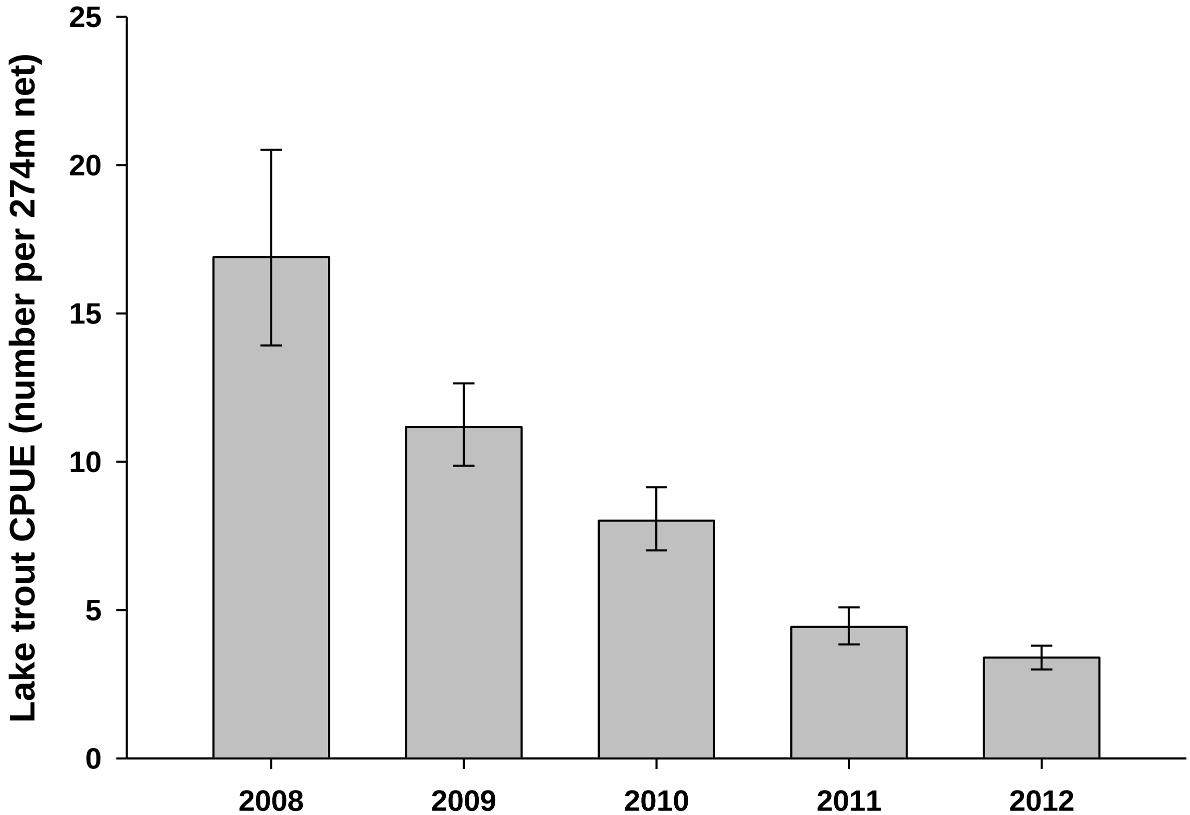

Figure 17. Mean Lake Trout catch rate and 95% confidence intervals for small-mesh gill nets set in the northern portion of Lake Pend Oreille during 2008-2012.

ACKNOWLEDGMENTS

Many people contributed to making this study possible. Fisheries technicians Mark Duclos, Brian Hammond, Chas Lawson, and Jordan Frye assisted with many of the field and laboratory activities and the maintenance of equipment. The U.S. Army Corps of Engineers made the necessary lake level changes, and the Bonneville Power Administration (BPA) provided funding for this study. We wish to thank Cecilia Brown for her help in administering our BPA contract. The help from these people and agencies was greatly appreciated.

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