FISHERY RESEARCH

LAKE PEND OREILLE RESEARCH, 2017 AND 2018
LAKE PEND OREILLE FISHERY RECOVERY PROJECT

ANNUAL PROGRESS REPORT
January 1, 2017—December 31, 2018

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TABLE OF CONTENTS

Page

INTRODUCTION

Lake Pend Oreille once provided the largest kokanee (landlocked form of the Sockeye Salmon *Oncorhynchus nerka*) fishery in the state of Idaho. Between 1952 and 1966, kokanee harvest averaged 1 million per year with up to 523,000 angler-hours (Jeppson 1953; Maiolie and Elam 1993). Beyond providing a popular sport fishery, kokanee serve as the primary forage for predatory salmonids including ESA-listed Bull Trout *Salvelinus confluentus* and Gerrard-strain Rainbow Trout *O. mykiss*. On a kokanee-based diet, Bull Trout (14.5 kg) and Rainbow Trout (16.8 kg) have reached world record sizes in Lake Pend Oreille, and angling for these trophy-sized predators contributed a major portion of the annual effort (46% in 1980, Ellis and Bowler 1981; 39% in 2014, Bouwens and Jakubowski 2016). These two predatory trout species are reliant upon a kokanee prey base in Lake Pend Oreille.

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

The primary strategy to restore the kokanee population has been directed at reducing predation by Lake Trout. Beginning in 2000, IDFG removed all harvest limits on Lake Trout and implemented an Angler Incentive Program (AIP), which paid anglers to harvest Lake Trout. To further reduce Lake Trout abundance, in 2006, IDFG contracted Hickey Brothers Research, LLC (Bailey's Harbor, Wisconsin) to fish commercial gill and trap nets in Lake Pend Oreille. A secondary restoration strategy focused on winter lake surface elevation management to enhance wild egg incubation success, although this strategy has not been shown to benefit kokanee recruitment (Whitlock 2013; Wahl et al. 2015b). However, this research did identify areas to add gravel to enhance kokanee spawning habitat at depths greater than those affected by lake surface elevation management (Rust et al. 2019). Since reaching record lows in 2007, overall kokanee abundance has increased, but biomass has declined after the peak in 2013 (Rust et al. 2019). For the first time in 14 years, a limited-harvest (six-fish limit) fishery was reopened in 2013, and the harvest limit was increased to 15 kokanee per day in 2014. Evaluating kokanee population responses to the restoration strategies continues to be a project priority.

Due to their relatively high cost per yield, use of trap nets was discontinued in 2018. Instead, gillnetting effort will increase to fill the trap net void, and we will incorporate a randomized assessment netting strategy in 2018 which will serve as a tool for population monitoring and evaluating Lake Trout removal efforts. Lake Trout spawning research with active telemetry will continue to be used to help guide removals efforts during the Lake Trout spawning season.

Management for a trophy Rainbow Trout fishery continues to be high priority in Lake Pend Oreille. We will initiate a detailed evaluation of angler catch rate and Rainbow Trout growth rate responses to the increases in kokanee biomass.

Walleye were illegally introduced into Noxon Reservoir in the early 1990s and through downstream dispersal have become established in Lake Pend Oreille. Walleye are opportunistic piscivores and their establishment is considered to be a direct threat to higher priority prey and predator species. Beginning in 2017, we initiated a focused Walleye research project to help us establish baseline information on their current status and life history characteristics in Lake Pend Oreille and the adjoining rivers. This baseline research will guide future management actions (suppression) and help to estimate the likely scope of their influence on the current fish community in Lake Pend Oreille. We will implement a test fishery approach that increases the scope and resolution of current management tools. We will implement an acoustic telemetry program that will allow us evaluate their residencies, habitat preferences, and spawning site selection and timing to help guide suppression efforts and answer key research questions regarding their long-term threat to the system.

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 portion of the lake, is the largest tributary. Outflow from the lake near Sandpoint forms the Pend Oreille River. Lake Pend Oreille is a temperate, oligotrophic lake in which thermal stratification typically occurs from late June to September (Maiolie et al. 2002) with epilimnetic temperatures averaging about 9°C (Rieman 1977). Operation of Albeni Falls Dam on the Pend Oreille River keeps the surface elevation high and stable at 628.7 m above mean sea level (MSL) during summer (June-September), followed by surface elevations of 626.4 m to 625.1 m during fall and winter. Littoral areas are limited and most shorelines are steeply sloped. Detailed maps of tributaries, landmarks, and shoreline areas referenced in this report can be found in Appendix A.

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

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

PROJECT OBJECTIVES

1. Restore kokanee abundance to a population level that can support catch rates of 1.5 fish per hour by 2019 and ages 1-3 kokanee abundances at or above five million fish to support growth of adfluvial Bull Trout and Rainbow Trout.

2. Suppress Lake Trout populations and maintain them at or below pre-1999 levels.

3. Gain an understanding of growth, survival, movements, and diet of walleye to evaluate the potential effects of walleye predation on kokanee abundance and various means to control the walleye population, including sport angling and suppression netting. Maintain Walleye population at or below current levels of abundance.

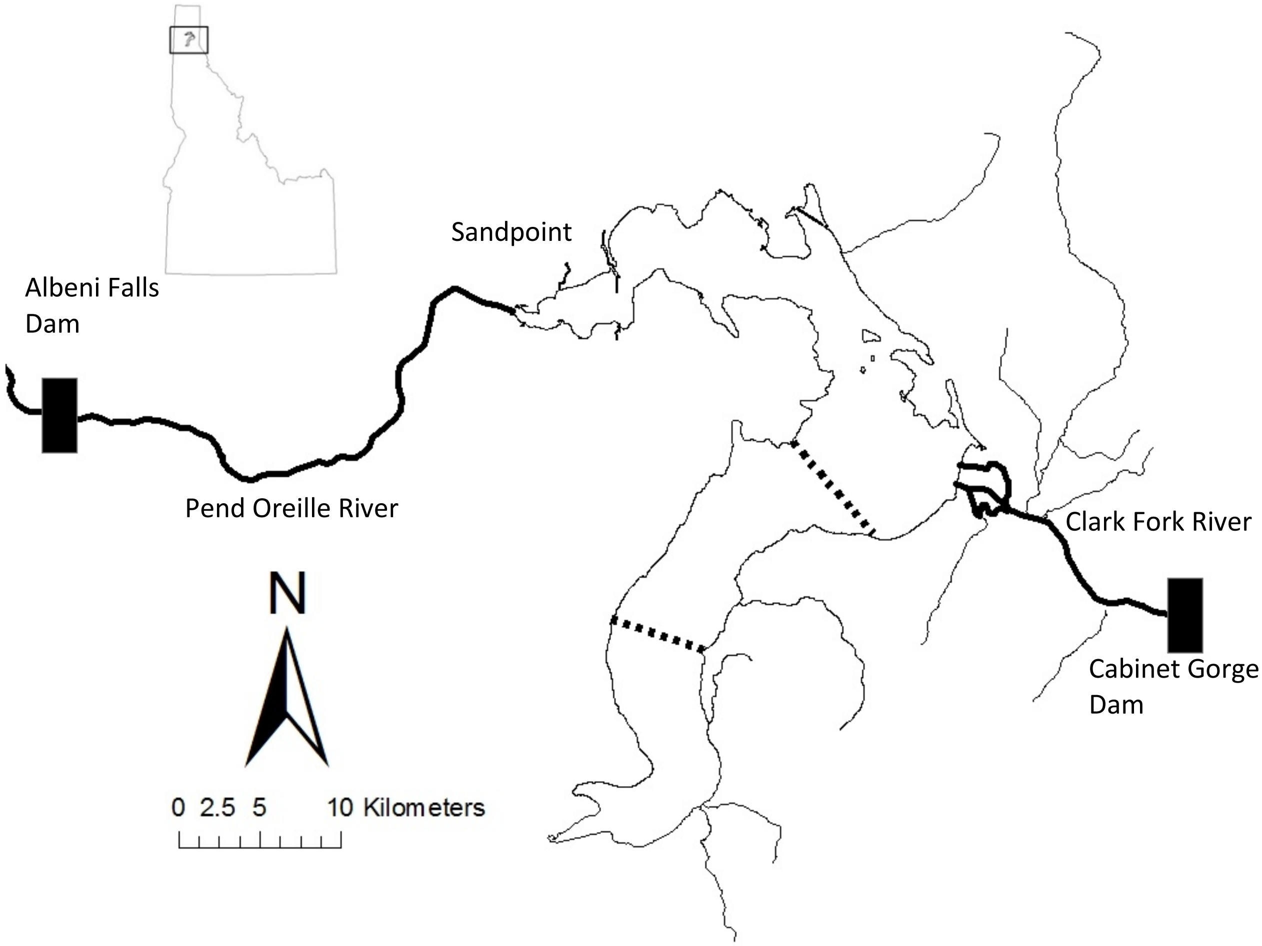

Figure 1. Map of Lake Pend Oreille, Idaho showing the three lake sections (separated by dashed lines) and primary kokanee spawning tributaries. The main inflow and outflow rivers (Clark Fork River and Pend Oreille River) and dams (Cabinet Gorge Dam and Albeni Falls Dam) are shown.

CHAPTER 1: KOKANEE RESEARCH

ABSTRACT

During 2017 and 2018, we examined the response of kokanee (the landlocked form of Sockeye Salmon *Oncorhynchus nerka*) to restoration efforts. We conducted hydroacoustic surveys and midwater trawling during August and September to assess the kokanee population status. During 2017, total kokanee abundance was 24.5 million (1,084 kokanee/ha), which was comprised of 15.6 million fry (10.4 million wild and 5.2 million hatchery) and 8.8 million kokanee ages 1-3. During 2018, total kokanee abundance was 13.8 million (610 kokanee/ha), which was comprised of 6.4 million fry (1.8 million hatchery and 4.6 million wild) and 7.4 million kokanee ages 1-3. Kokanee fry abundance during 2017 was slightly lower than the record high 2016 levels, and the second highest since surveys began in 1996. Similarly, age-1 and age-2 abundance was also among the highest recorded. Fry abundance during 2018 was the lowest since 2010, and seventh lowest since 1995, whereas the abundance of age-1 and age-2 fish was higher than most years. Survival from age-1 to age-2 was 73% between 2016 and 2017, and 58% between 2017 and 2018. Kokanee biomass was 324 metric tonnes (t) in 2017 and 241 t in 2018. Annual kokanee production was 310 t from 2016 to 2017 and 402 t between 2017 and 2018. Scenic Bay near Bayview was sampled for indexing shoreline kokanee spawning. A total of 2,887 kokanee were counted during 2017, which is among the lowest since 2009. In 2017 and 2018, mysid density were lower than 2016 levels, which were the highest levels since 2009, and well below the historical range.

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INTRODUCTION

Numerous factors have contributed to the decline of kokanee (the landlocked form of Sockeye Salmon *Oncorhynchus nerka*) from their historical abundance. The winter drawdowns of Lake Pend Oreille (Figure 1, Appendix A) occurring after kokanee spawning, thereby leaving many shoreline redds above the waterline, was implicated as the most detrimental factor contributing to the decline (Maiolie and Elam 1993). Operational strategies began in the early 1990s to maintain a stable minimum lake level after mid-November. Additionally, an experimental approach was initiated in 1996 to evaluate if lake levels affected kokanee egg survival. The premise behind this approach was that survival would be greater when the lake was held at the higher elevation (626.4 m above MSL), and periodically holding the lake at the lower elevation (625.1 MSL) would allow wave action to redistribute gravel spawning substrate (Maiolie et al. 2004; Maiolie et al. 2006b). Recent research has concluded that this approach did not directly create the desired outcome (Wahl et al. 2015b; Whitlock 2013). However, operation of Albeni Falls Dam has altered the hydrology of Lake Pend Oreille and changed the shallow water habitat used by kokanee for spawning (Maiolie and Elam 1993).

Along with winter lake drawdowns, other factors have also negatively impacted the kokanee population. The introduction of mysid shrimp *Mysis diluviana* in the 1960s likely contributed to the kokanee decline (Martinez and Bergersen 1991; Nesler and Bergersen 1991), and *Mysis* likely determine the productive capacity of Lake Pend Oreille for Kokanee (Corsi et al. 2019). A newer threat to kokanee restoration emerged in the early 2000s. At that time, predation by an increasing Lake Trout *Salvelinus namaycush* population became the primary limiting factor for kokanee restoration (Maiolie et al. 2006b). An aggressive predator removal program was initiated in 2006 to address this issue (Hansen et al. 2008).

Since reaching record lows in 2007, kokanee abundance and biomass have increased annually in response to predator reduction, and an unexplained mysid shrimp collapse in 2012 may have accelerated observed kokanee increases (Corsi et al. 2019). With kokanee biomass at its highest since the mid-1990s, a limited harvest fishery (six fish daily limit) was reopened in 2013, and in 2014 the daily limit was increased to 15 (the standard for other regional lakes). The more robust kokanee population will provide opportunities for investigating mysid shrimp and kokanee competition and evaluation of hatchery stocking practices.

We continued to evaluate the response of the kokanee population to restoration efforts using hydroacoustic surveys and trawling. In 2016 and 2017, also we conducted a creel survey focused on evaluating kokanee catch rates in response to Lake Trout suppression and other recovery efforts.

METHODS

Kokanee Population Dynamics

Abundance and Survival

We conducted a hydroacoustic survey on Lake Pend Oreille to estimate the abundance and survival rate of kokanee. Hydroacoustic surveys were performed at night within seven days of the trawl survey, with four survey transects in each lake section (see Figure 1). Further protocol details have been described by Wahl et al. (2011a). Prior to the surveys, we calibrated the echo sounder for signal attenuation to the sides of the acoustic axis using Simrad's EK60 software

(Simrad Fisheries, Lynnwood, WA). We estimated kokanee abundance with echo integration techniques using Echoview software version 6.1.60.27483 (Echoview Software Pty Ltd, Hobart, Tasmania). This technique calculated densities along each transect using the following equation (see Parker-Stetter et al. 2009):

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

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

Once density estimates for kokanee were determined, we calculated 90% confidence intervals (CI) for using standard formulas for stratified sampling designs (Scheaffer et al. 1979):

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

where $\bar{x}$ is the estimated mean density of kokanee in the lake (fish/ha), *t* is the Student's t value, N_i is the number of possible samples in section *i*, n_i is the number of samples collected in section *i*, and s_i is the standard deviation of the samples in section *i*. Confidence intervals were then converted to total abundance based on the total area of the three lake sections.

We were able to separate kokanee fry (<100 mm) from the older age-classes using the Echoview software. A target-strength frequency histogram was established, and the low point was used as the break between fry and larger kokanee. To separate hydroacoustic estimates of larger kokanee into age-classes (age-1 through age-4), we used the results of midwater trawling. Trawling occurred during August 16–21, 2017 and August 12-14, 2018. These dates were during the dark phase of the moon, which optimized the capture efficiency of the trawl (Bowler et al. 1979). The trawl net had graduated mesh increments ranging from 13 to 32 mm stretch, and sampling procedures for midwater trawling have been described by Rieman (1992) and Wahl et al. (2011a). To sample kokanee fry for assessing origin (hatchery or wild), we also conducted a midwater trawl survey during the 2017 time window using a smaller mesh trawl net (0.8 x 1.6 mm bar) previously described (Wahl et al. 2011a). The fry trawl was discontinued in 2018.

We collected kokanee from each trawl transect, placed them on ice, then placed them in a freezer for storage. To process kokanee, we thawed out sample bags corresponding to each transect, counted the fish, recorded total length (mm) and weight (g), and checked for sexual maturity. We removed scales and otoliths from 10-15 fish in each 10 mm size interval, and otoliths from all fry. The scales were aged by two independent readers, and otoliths were used to determine hatchery or wild origin (see below). From these data, we created an age/origin-length key to assign an age and origin to every fish captured. Next we estimated the mean density of each kokanee age-class within a lake section using the assigned ages and origins of fish. We then used these proportions of each age-class of kokanee in a lake section to separate the age-

1 through age-4 hydroacoustics data in that section. After repeating this process for each section, we totaled the values to generate lakewide age-specific abundance estimates. From these age-specific abundance estimates, we calculated annual survival for each age-class (i.e., from one age class to the next) by comparing to the previous year's estimates.

Hatchery and Wild Abundance

All kokanee produced at the Cabinet Gorge Fish Hatchery since 1997 have been marked using thermal mass-marking techniques (or cold branding) described by Volk et al. (1990). Therefore, all hatchery-origin kokanee otoliths had distinct thermal marks that were used to identify brood year, stock (early vs. late), and origin (hatchery vs. wild). Fish with an identifiable thermal mark were designated as either early run hatchery (KE-H) or late-run hatchery (KL-H). Fish without a thermal mark were designated as wild. Hatchery personnel initiated thermal treatments five to ten days after fry entered their respective raceways and sacrificed ten fry from each raceway to verify thermal marking success. Methodologies for evaluating thermal marks are described in Wahl et al. (2010).

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

Biomass and Production

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

Production was the growth in weight of the kokanee population regardless of whether the fish was alive or dead at the end of the year (Ricker 1975). To determine production of a kokanee age-class between years, we first calculated the increase in mean weight of a cohort since the previous year and averaged the abundance estimates for that cohort between the two years. Next we multiplied the increase in mean weight by the average cohort abundance. This process was repeated for all cohorts, and we summed the results for all of the age-classes to determine population-wide production (i.e., within the entire lake). Production P for year t is estimated using the formula

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

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

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

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

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

Spawning Kokanee Index Counts

We counted spawning kokanee at standardized tributary and shoreline index transects where spawning was documented historically (Jeppson 1960). Surveys at index transects built upon annual trend data dating back to 1972. Surveys for late-run kokanee occurred along the shoreline at several locations in Scenic Bay.

Kokanee Creel Survey

In 2016 and 2017 we conducted a creel survey focused on evaluating kokanee catch rates trends. The goal of this creel survey was to evaluate angler catch statistics under higher kokanee abundances and also to evaluate the relative contribution of wild versus hatchery, and early versus late-run kokanee stocks. The creel survey focused on kokanee catch rates and did not include total effort, total catch, and total harvest. The survey occurred during the primary 2016 and 2017 kokanee fishing season (May-October). Our objectives for this survey include:

- Estimate the mean catch rate of kokanee throughout the season.
- Estimate the size structure of harvested kokanee during each month.
- Estimate the age-structure of harvested kokanee during each month.
- Estimate each stock's (KE-H, KL-H, wild) contribution to the fishery.

We were primarily interested in anglers targeting kokanee, and the creel occurred at access points most-commonly used by kokanee anglers. Three access points were identified: Idlewilde Bay, Garfield Bay, and Trestle Creek/Boat Basin. Creel times were divided into two 4-hour blocks, 0800-1200 and 1200-1600, which encompassed the period when most kokanee anglers were returning to the ramps. All estimates were stratified by month and weekdays and weekends/holidays were estimated separately. Starting times and locations were randomly selected. Four weekdays and four weekends/holidays were selected for each month.

Limnological Research

Mysid Shrimp Trend Monitoring

We sampled mysid shrimp during June 22-25, 2017 and June 11-12, 2018 to estimate their density within Lake Pend Oreille. All sampling occurred at night during the dark phase of the moon, when mysid shrimp are found at shallower depths (Boscarino 2009). We collected mysids at eight sites per lake section (24 sites total) using a 1 m hoop net. Further details on methods can be found in Wahl et al. (2011a).

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

RESULTS

Kokanee Population Dynamics

Abundance and Survival

In 2017, we estimated a total of 24.5 million kokanee (19.9–29.2 million, 90% CI) or 1,084 fish/ha in Lake Pend Oreille, based on our hydroacoustic survey. This included 15.6 million kokanee fry (12.8–18.3 million, 90% CI; Table 1, Figure 2), 4.1 million age-1, 4.1 million age-2, 0.55 million age-3, and 234,000 age-4 kokanee (Table 1, Figure 2). During the midwater trawl survey, we sampled 1,692 kokanee that varied in total length from 27 to 284 mm (Figure 3) and in weight from 0.20 to 142 g. We estimated kokanee survival at 24% from fry to age-1, 73% from age-1 to age-2, 27% from age-2 to age-3, and 23% for age-3 to age-4 (Table 2).

In 2018, we estimated a total of 13.8 million kokanee (11.5–16.1 million, 90% CI) or 610 fish/ha in Lake Pend Oreille, based on our hydroacoustic survey. This included 6.4 million kokanee fry (5.6–7.2 million, 90% CI; Table 3, Figure 2), 4.8 million age-1, 2.3 million age-2, 299,000 age-3, and 11,000 age-4 kokanee (Table 3, Figure 2). During the midwater trawl survey, we sampled 1,725 kokanee that varied in total length from 25 to 258 mm (Figure 4) and in weight from 0.08 to 151 g. We estimated kokanee survival at 33% from fry to age-1, 58% from age-1 to age-2, 8% from age-2 to age-3, and 2% for age-3 to age-4 (Table 2).

Hatchery and Wild Abundance

During spring 2017, the Cabinet Gorge Fish Hatchery released 9.9 million kokanee fry, 5.4 million at Sullivan Springs, 2.4 million at Garfield Bay, and 2.1 million at Ellisport Bay. During the spring of 2018, 5.9 million fry were released, all at Sullivan Springs. All fry released during both years were late-run fry and were thermally marked.

During 2017, wild kokanee fry made up 91%, 70%, and 42% of the fry net catch in the southern, middle, and northern sections, respectively (Table 4). Based on these proportions, we estimated the wild fry population at 10.4 million (Table 4). Wild kokanee comprised 82%, 79%, 73%, and 72% of age-1, age-2, age-3, and age-4 abundance estimates based on the fixed frame trawl in 2017 (Table 1). In 2018, wild kokanee comprised 29%, 78%, 93%, 87%, and 100% of the age-0, age-1, age-2, age-3, and age-4 abundance estimates based on the fixed frame trawl (Table 3).

Biomass, Production, and Mortality by Weight

Based on the hydroacoustic estimates of kokanee abundance, kokanee biomass during 2017 was 324 metric tonnes (t) and production (from 2016 to 2017) was 310 t (Figure 5). Total mortality by weight was 347 t, which was 36 t more than production. During 2018, biomass was 241 metric tonnes (t) and production (from 2017 to 2018) was 402 t. Total mortality by weight was 458 t, which was 56 t more than production.

Spawning Kokanee Index Counts

In 2017, we observed 2,887 late-run kokanee spawning on the shoreline near the town of Bayview in Scenic Bay (Figure 6). Additionally, we observed 2,178 early-run kokanee spawning in South Gold, North Gold, and Trestle Creeks (Figure 6).

In 2018, we observed 5,291 late-run kokanee spawning on the shoreline near the town of Bayview in Scenic Bay (Figure 6). Additionally, we observed 382 early-run kokanee spawning in South Gold, North Gold, and Trestle Creeks (Figure 6).

Kokanee Creel

One of the objectives of this creel survey was to evaluate relative contributions of early returning hatchery kokanee (KE-H) and late-run hatchery kokanee (KL-H). Very few KE-H kokanee were collected either year in the creel. Subsequently, catch estimates and stock contributions were combined for KE-H kokanee and KL-H kokanee when making comparisons between wild versus hatchery kokanee.

A total of 116 anglers were interviewed in 2016 and 130 were interviewed in 2017. In 2016, angling effort was relatively even in May, July, and September. In 2017, angling effort was highest in August and September.

Kokanee catch rates were higher every month during the creel period in 2016 than in 2017 (Figure 7). The highest catch rates in 2016 were in June and the lowest were in October. Catch rates in 2016 were relatively even throughout the sampling period, and ranged from 1.6 to 2.3 kokanee per angler hour (Figure 7). Catch rates in 2017 were generally lower and much more variable ranging from 0.3 to 1.8 kokanee per hour. The highest catch rates were in July and October in 2017 (Figure 7).

Mean length of kokanee captured in 2016 increased consistently during the May to October creel period (Figure 8). Mean lengths were consistently higher each month for the wild kokanee compared to the hatchery kokanee in 2016 (Figure 8). In 2017, mean lengths varied monthly within and between the two stocks (Figure 9). The largest hatchery kokanee collected were in May in 2017. Mean lengths of the wild kokanee collected varied little throughout the six-month sampling period (Figure 9). Mean length of the wild and hatchery kokanee was similar in August and September during both years (Figure 9).

The highest kokanee catch was in September in 2016. The bulk of the catch every month in 2016 was from age-3 kokanee (Figure 10). Although age-4 kokanee were not a significant part of the catch in 2016, the highest catch came in September (Figure 10). In 2017, age-3 and age-4 kokanee were well represented in the catch in the summer months (Figure 11). Age-3 hatchery kokanee had the highest representation in the 2016 creel and age-4 hatchery kokanee had the highest representation in the 2017 creel (Figure 12).

Limnological Research

Mysid Shrimp Trend Monitoring

We estimated a mean density of 243 mysid shrimp/m^2 during June 2017 (Table 7; Figure 13). This included 105 immature and adult mysids/m^2 (90% CI of $\pm$ 29.9%; Table 7; Figure 13) and 138 YOY mysids/m^2 (90% CI of $\pm$ 25.6%; Table 7; Figure 13).

We estimated a mean density of 273 mysid shrimp/m^2 during June 2018 (Table 7; Figure 13). This included 66 immature and adult mysids/m^2 (90% CI of ± 29.6%; Table 7; Figure 13) and 207 YOY mysids/m^2 (90% CI of ± 44.7%; Table 7; Figure 13).

DISCUSSION

Kokanee Population Dynamics

Kokanee continue to respond favorably to management actions. Age-0 kokanee abundance remained high through 2017, with the second highest abundance (highest in 2016) since hydroacoustic surveys began in 1995. While age-0 abundance dropped in 2017, good survival from this cohort could still result in a strong age-1 component in 2019. Strong cohorts continue to be the norm with five consecutive years with over two million age-1 kokanee and four consecutive years of over one million age-2 kokanee. Although overall kokanee abundance is high, age-3 abundance has declined from the high levels of 2013 and 2014 (over 1.5 million each year), and size has declined as well. Recent abundance trends, combined with survival rates commonly exceeding 60% for age-1 through age-3 for the past four years, suggest that kokanee have responded positively to restoration efforts. During 2011 and 2012, we documented an increasing trend in age-1 kokanee abundance, but were concerned that the comparably strong age-1 cohorts did not survive well to older ages in recent years. Both of these cohorts resulted in over 1.5 million kokanee at age-3 in 2013 and 2014. High age-0 recruitment and high age-1 survival since 2014 has allowed the kokanee population to build to current high abundance. We expect that ongoing Lake Trout suppression will lead to continued high survival and higher abundances of mature kokanee, although the low survival from age-2 to age-3 and the reduced length at age in 2017 are concerning for the kokanee fishery moving forward.

From 1996 to 2011, kokanee production was relatively constant, ranging from 174 t to 254 t. However, during 2004-2007, kokanee mortality by weight was on average 59 t higher than production, leading to decreases in kokanee biomass. Pronounced increases in the production to biomass ratio during this period were vital to slowing the decline of the kokanee population (Wahl et al. 2010). From 2008 to 2013, kokanee production was on average 80 t higher than mortality by weight, and biomass in 2013 reached the highest level on record. Biomass declined by over a third in 2014 but was still the second highest on record. This decline was related to a mortality by weight estimate that was twice as high as any other estimate recorded. We are unsure as to what led to the increased mortality by weight as a whole, but roughly one third can be attributed to losses that occurred when most age-3 kokanee spawned during 2013. In the past, kokanee maturing at age-3 was rare. However, the size at age of adult fish increased concurrently with the decline in *Mysis* abundance, likely due to decreased competition for resources (Klein 2019). This increase in growth may have led to an earlier onset in sexual maturation (Grover 2005). Overall, continuation of the Lake Trout reduction program should help kokanee production remain at the same level or higher than mortality by weight and lead to further increases in kokanee biomass. We will also continue to monitor and manage other predators in Lake Pend Oreille, including Walleye and Rainbow Trout, to ensure total predation doesn't exceed production.

In 2017 and 2018, late-run shoreline spawning kokanee counts were made only at the Scenic Bay area near Bayview (Wahl et al. 2015a). Although spawner counts have varied considerably over the period and may not be a reliable index for future abundances, counts in 2017 were only 14% of the 2016 value and the lowest since 2009 from the Scenic Bay site. While this seems alarming, standard hydroacoustic and trawl surveys provide a more reliable measurement of trends in the kokanee population. In 2018, counts in Scenic Bay nearly doubled, yet the estimate of mature fish from the acoustic and trawl surveys were similar. These counts may be a better indicator of spawning distribution than spawner abundance, particularly when performed on a limited spatial scale.

Historically, most of the early-run kokanee returning to tributaries were individuals that strayed from Sullivan Springs Creek where they were stocked as fry in prior years. The exception was South Gold Creek, where otoliths determined that the majority of early spawning kokanee in this tributary were of wild origin (Wahl et al. 2011b; Wahl et al. 2013). Stocking early-run fry was discontinued in 2010, so spawning kokanee in 2013 and 2014 were comprised of only wild-origin fish. Previously we stated that early-run kokanee were unlikely to substantially contribute towards restoration goals (Wahl et al. 2011a). However, now that the kokanee population is not at risk of collapse, early-run kokanee supplementation was resumed in 2013 to potentially supplement the kokanee fishery. Unlike late-run kokanee, we have not collected mature early-run kokanee in our standard trawling surveys, so tributary spawner counts are the only viable way to evaluate their distribution and relative abundance. Tributary counts in 2017 were made at Trestle Creek and North and South Gold creeks. Early-run kokanee densities in 2017 were down dramatically compared to the same sites in 2015, and although densities are quite variable over time, it appears as though early run kokanee in Lake Pend Oreille are trending downward over time. To better understand the distribution of kokanee spawning, the lakewide spawning survey conducted in 2013 (Wahl et al. 2015b) should be periodically repeated.

Limnological Research

Mysid shrimp abundance in Lake Pend Oreille cycled through growth, decline, and stability since their introduction in 1966. A similar pattern of population fluctuation occurred in other western lakes after mysid introductions (Beattie and Clancey 1991; Richards et al. 1991). Mysid shrimp abundance in Lake Pend Oreille remained relatively stable during 1997-2011. However, the mysid shrimp population in Lake Pend Oreille collapsed in 2012. From 2013 through 2017, the abundance of both the YOY and the immature and adult portions of the population have increased, but the overall density was less than 30% of the long-term average prior to the collapse. In 2017, the abundance of immature and adult mysids increased slightly from 2016, but the YOY portion of the population decreased substantially from 2016. Densities in 2018 were similar to 2017. We are unsure what mechanism caused the collapse and whether mysid shrimp will return to their historical densities, but it appears as though mysid shrimp will remain at a relatively low abundance at least through 2018. An in depth understanding of the spatiotemporal distribution of Mysids, zooplankton, and kokanee would further our understanding of how these interact and allow us to better evaluate management options should Mysid abundance increase in the future.

Kokanee Creel

The return to creel of early-run kokanee was low each year with only four collected in 2016 and three collected in 2017. Those few that were collected earlier in the summer were much larger than their late-run counterparts. This addition of only a few larger early retuning kokanee to the mean length calculations may explain why hatchery fish lengths were highest during May in 2016. Wild kokanee recruitment has improved consistently with the predator removal and subsequently higher kokanee spawner densities. Wild kokanee have dominated the abundance estimates generated from hydroacoustic data that were separated into age-classes based on midwater trawling (Table 2 this chapter, Rust et al. 2019). However, the creel survey results suggest that hatchery kokanee show up in the creel disproportionately to their abundance.

Age-3 kokanee dominated the catch in 2016, whereas age-4 were more numerous in 2017, even though abundance of age-3 kokanee was estimated to be nearly double that of age-4. However, age-3 kokanee were much larger in 2016, with lengths ranging from 220 to over 270 mm TL. Conversely, most age-3 kokanee were less than 220 mm TL in 2017, while age-4 fish were of a similar size in both years, but more abundant in 2017. This shift in age composition in the creel was likely due to the increase in abundance of age-4 fish along with the decreased size of age-3 fish (Rieman and Maiolie 1995). At their current sizes, age-2 kokanee in Lake Pend Oreille are not fully recruited to angling gear and their catch statistics are of little value for catch comparisons. Comparing age specific relative creel returns (percentage by age and stock, Figure 12) to age-specific abundance estimates (Table 2, Rust et al. 2019) suggests some useful trend similarities. Age-3 abundance in 2016 was relatively high (0.97 million, Rust et al. 2019), and with stocks combined, the 2016 creel was dominated by age-3 kokanee. In 2017, age-3 abundance decreased to 0.55 million, and the relative proportion of age-3 kokanee in the creel decreased accordingly in 2017. With increasing densities, age-3 kokanee are now a significant part of the spawning stock, which complicates stock contribution comparisons beyond age-3. Kokanee specific creel surveys may provide a general and acceptable picture of the relative stock contribution of age-3 and age-4 wild and hatchery kokanee in the Lake Pend Oreille fishery.

RECOMMENDATIONS

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

2. Continue to assess the effects of predator removal on kokanee survival, abundance, and growth

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

4. Begin a more in-depth study into the spatiotemporal distribution of zooplankton, mysid shrimp, and kokanee in Lake Pend Oreille.

Table 1. Age-specific abundance estimates for kokanee in Lake Pend Oreille, Idaho, 2017. Estimates were generated from hydroacoustic data that were separated into age-classes based on midwater trawling. Percentage of wild, late-run hatchery (KL-H), and early-run hatchery (KE-H) were based on the proportions of each caught in the trawl net.

Area	Age-0	Age-1	Age-2	Age-3	Age-4	Total
Northern Section						
Percent of age-class by trawling	62.8	26.1	16.6	2.2	1.0	
Population estimate (millions)	5.10	2.12	0.86	0.02	0.01	8.12
Middle Section						
Percent of age-class by trawling	61.1	14.3	21.9	1.8	0.9	
Population estimate (millions)	6.25	1.47	2.24	0.18	0.09	10.23
Southern Section						
Percent of age-class by trawling	68.5	8.0	15.9	5.5	2.1	
Population estimate (millions)	4.24	0.50	0.98	0.34	0.13	6.19
Total population estimate (millions)	15.59	4.08	4.08	0.55	0.23	24.54
90% confidence interval (millions)	12.8–18.3					19.92–29.15
Percent wild	56	82	79	73	72	
Percent KL-H	44	15	21	26	28	
Percent KE-H	0	2	0	2	0	

Table 2. Survival rates (%) among kokanee year classes estimated by hydroacoustics, 1996-2017. 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
2018	33	58	8	2
2017	24	73	27	23
2016	36	49	65	39
2015	35	42	43	4
2014	30	65	36	0
2013	23	99	85	15
2012	40	68	98	9
2011	25	26	62	55
2010	30	35	23	19
2009	29	77	59	8
2008	15	32	40	83
2007	19	10	11	0
2006	23	13	12	13
2005	46	14	24	25
2004	22	36	30	19
2003	35	58	68	73
2002	31	44	17	36
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 3. Age-specific abundance estimates for kokanee in Lake Pend Oreille, Idaho, 2018. Estimates were generated from hydroacoustic data that were separated into age-classes based on midwater trawling. Percentage of wild, late-run hatchery (KL-H), and early-run hatchery (KE-H) were based on the proportions of each caught in the trawl net.

Area	Age-0	Age-1	Age-2	Age-3	Age-4	Total
Northern Section						
Percent of age-class by trawling	21.0	68.9	9.4	0.6	0.1	
Population estimate (millions)	0.99	3.26	0.44	0.03	0.0	4.42
Middle Section						
Percent of age-class by trawling	59.1	22.0	17.2	1.6	0.1	
Population estimate (millions)	3.34	1.24	0.97	0.09	0.0	5.65
Southern Section						
Percent of age-class by trawling	60.0	7.9	26.8	5.3	0.1	
Population estimate (millions)	2.07	0.27	0.92	0.18	0.0	3.44
Total population estimate (millions)	6.40	4.77	2.34	0.30	0.01	13.82
90% confidence interval (millions)						11.53-16.10
Percent wild	29	78	93	87	100	
Percent KL-H	70	16	2	13	0	
Percent KE-H	1	7	5	0	0	

Table 4. Abundance estimates and 90% confidence intervals (CI) for kokanee fry (millions) based on hydroacoustic surveys in Lake Pend Oreille, Idaho in 2017. Percentage of wild, late-run hatchery (KL-H), and early-run hatchery (KE-H) fry was based on the proportions of fry caught using a fry net.

	Southern Section	Middle Section	Northern Section	Lakewide Total	90% CI
Total	4.2	6.3	5.1	15.6	12.8–18.3
Percent wild fry in fry trawl	91	70	42	—	
Percent KL-H in fry trawl	100	100	100	—	
Percent KE-H in fry trawl	0	0	0	—	
Wild fry abundance estimate	3.8	4.4	2.1	10.4	

Table 5. Densities of mysid shrimp (per m^2), by life stage (young of year [YOY], and immature/adult), in Lake Pend Oreille, Idaho June 22-25, 2017 and June 11-12, 2018.

Lake Section	YOY/m^2	Immature/adult/m^2	Total mysid shrimp/m^2
2017			
Northern	49	51	101
Middle	184	104	289
Southern	195	177	372
Lakewide average	138	105	243
2018			
Northern	464	120	584
Middle	151	66	217
Southern	60	25	86
Lakewide average	207	66	273

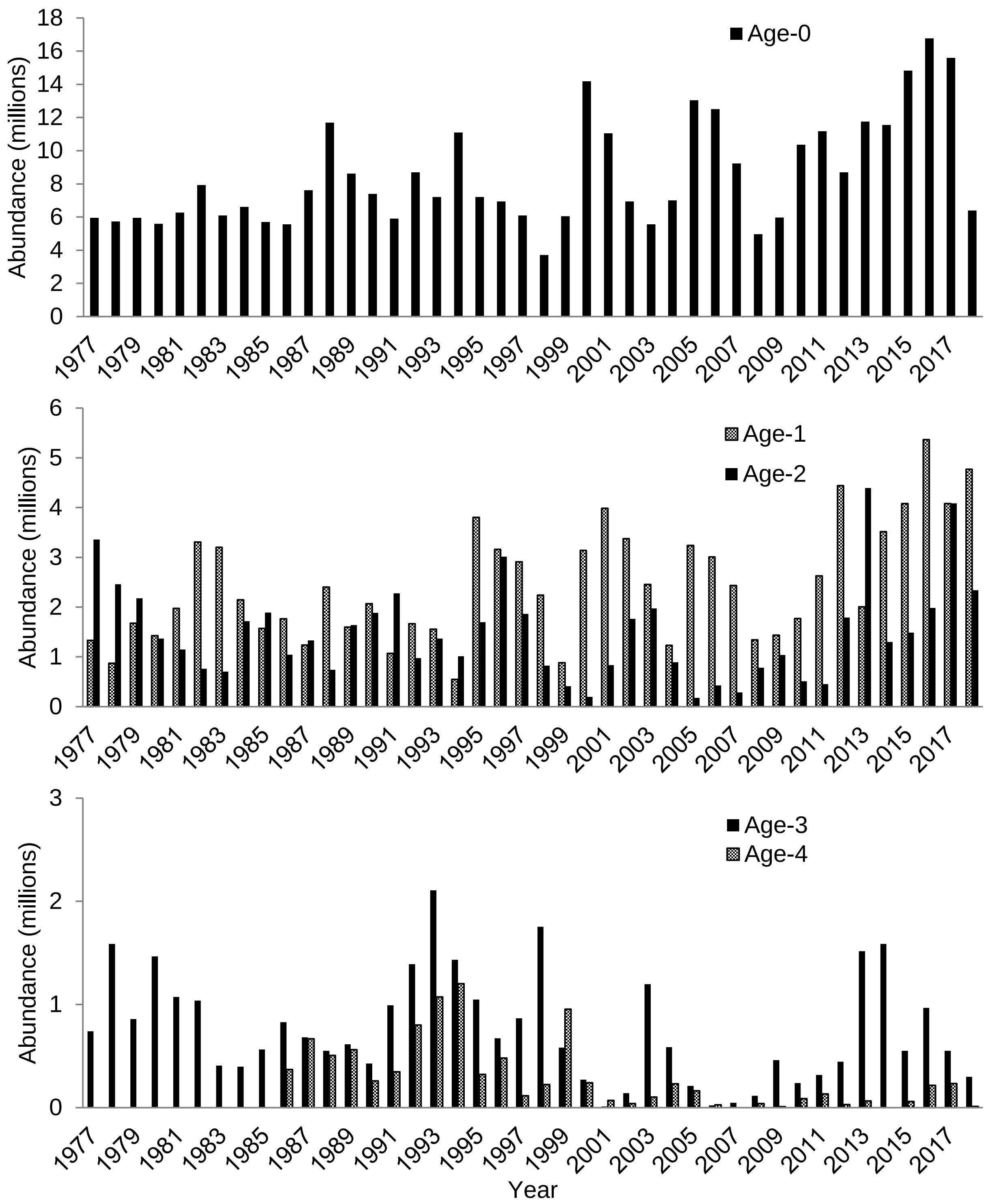

Figure 2. Kokanee age-specific abundance estimates based on hydroacoustic surveys. Estimates prior to 1995 were converted from trawl abundance estimates (Wahl et al. 2016). Age-3 and age-4 kokanee were not separated before 1986.

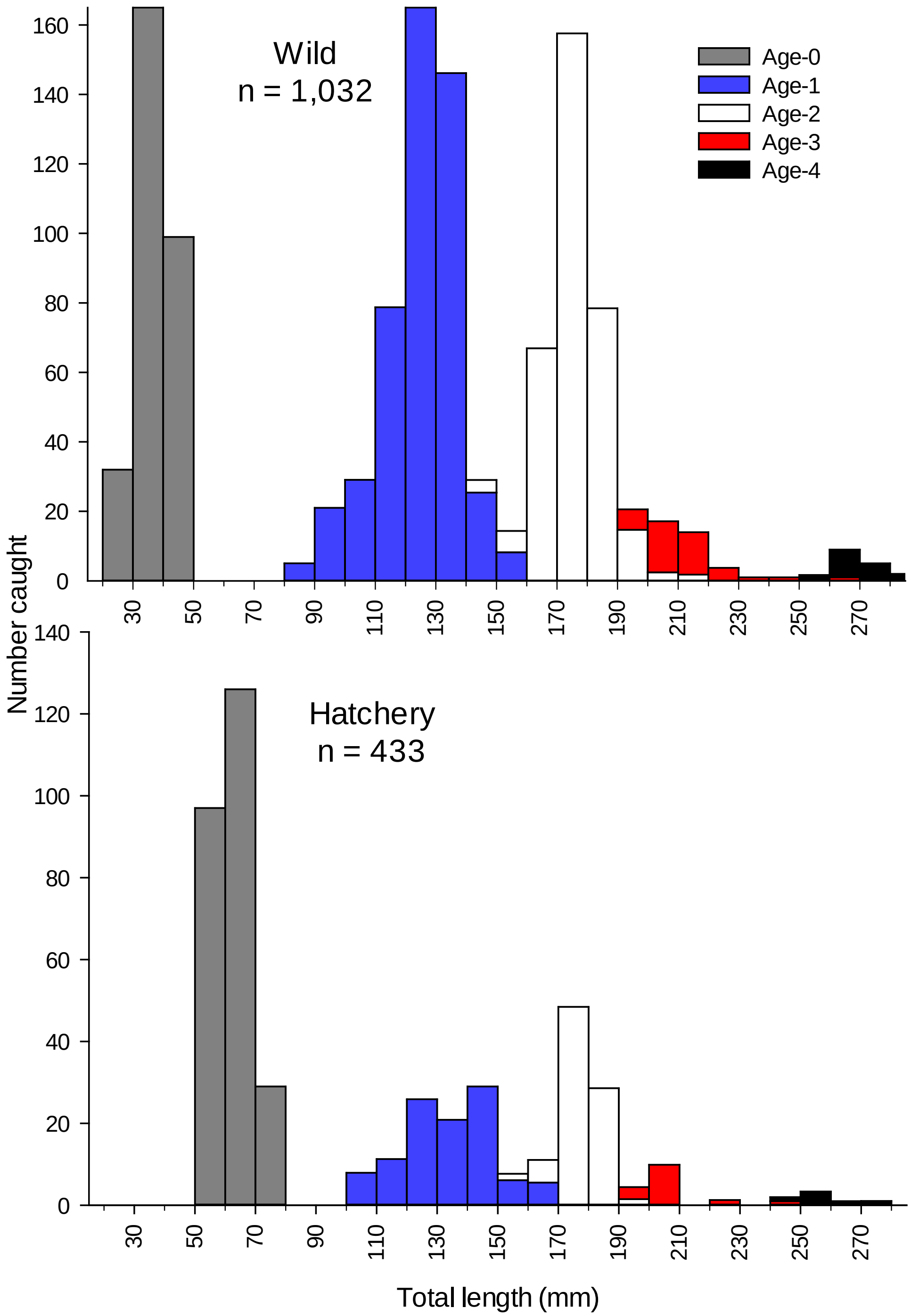

Figure 3. Length-frequency distribution of individual age-classes of wild and hatchery kokanee caught by midwater trawling in Lake Pend Oreille, Idaho during August 2017. Origin or age could not be determined from all sampled kokanee.

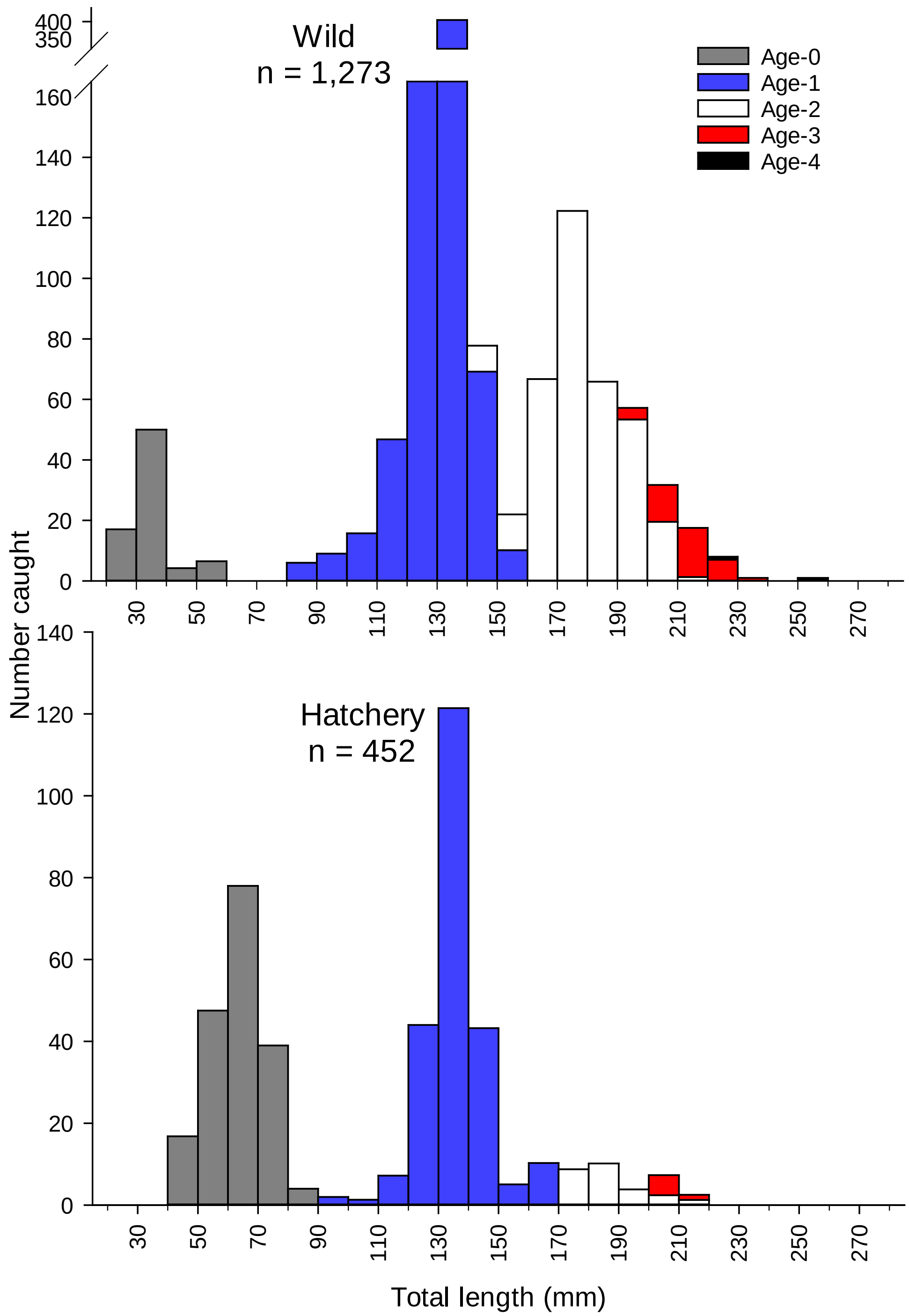

Figure 4. Length-frequency distribution of individual age-classes of wild and hatchery kokanee caught by midwater trawling in Lake Pend Oreille, Idaho during August 2018. Origin or age could not be determined from all sampled kokanee.

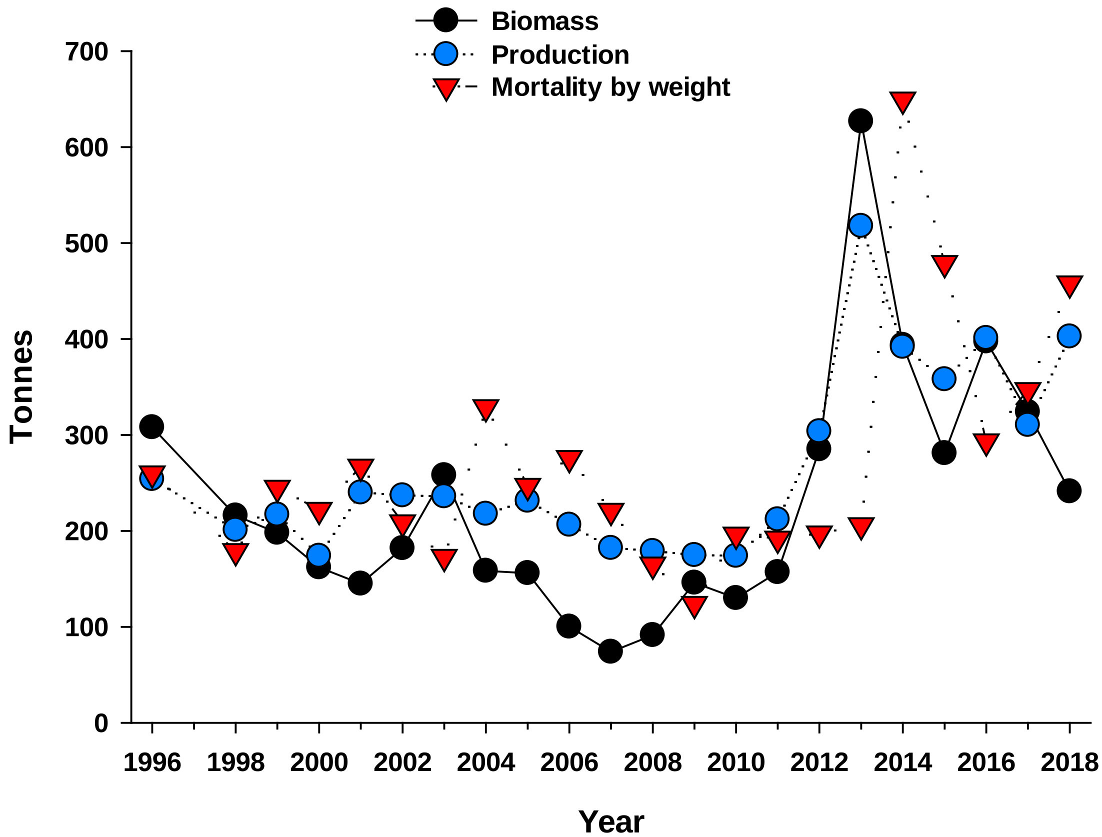

Figure 5. Kokanee biomass, production, and mortality by weight (metric tonnes) in Lake Pend Oreille, Idaho from 1996-2018, excluding 1997 due to a 100-year flood event.

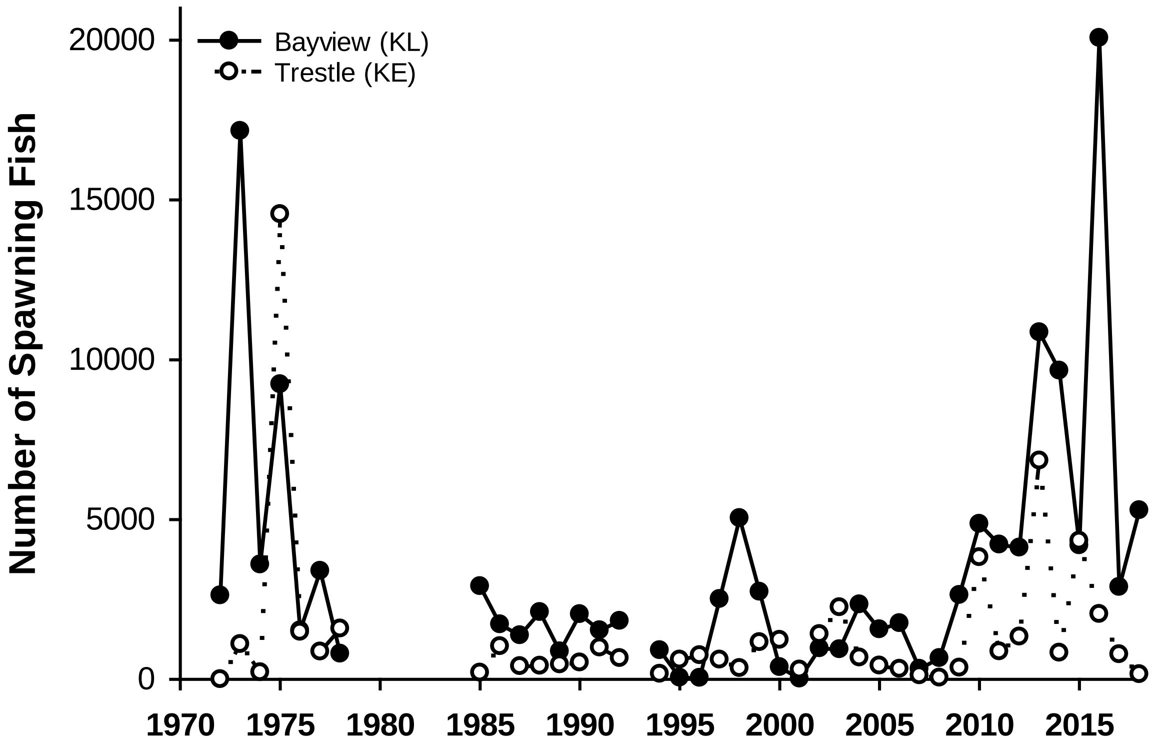

Figure 6. Numbers of early spawning kokanee (KE) counted in Trestle Creek and late-run kokanee (KL) counted along shorelines of Scenic Bay near Bayview, Idaho from 1972-2018. Counts were not available from 1979-1984 and in 1993.

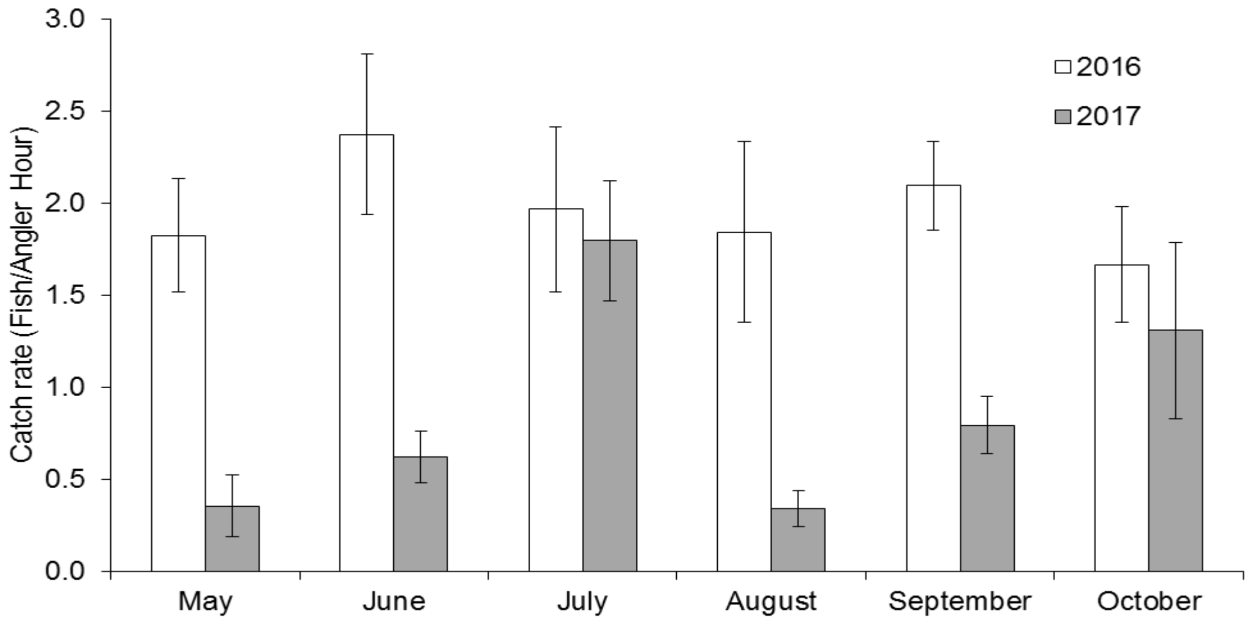

Figure 7. Mean monthly kokanee catch rate during 2016 and 2017 creel surveys, Lake Pend Oreille.

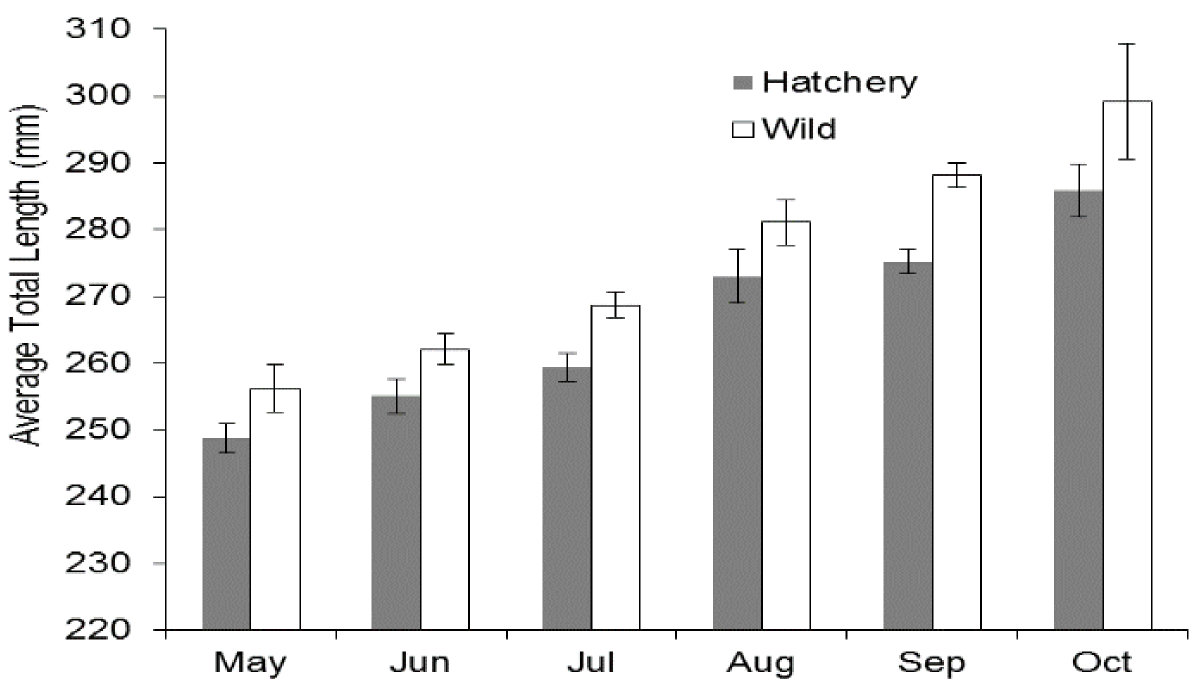

Figure 8. Mean total length of hatchery and wild kokanee catch by month from creel survey, Lake Pend Oreille, 2016.

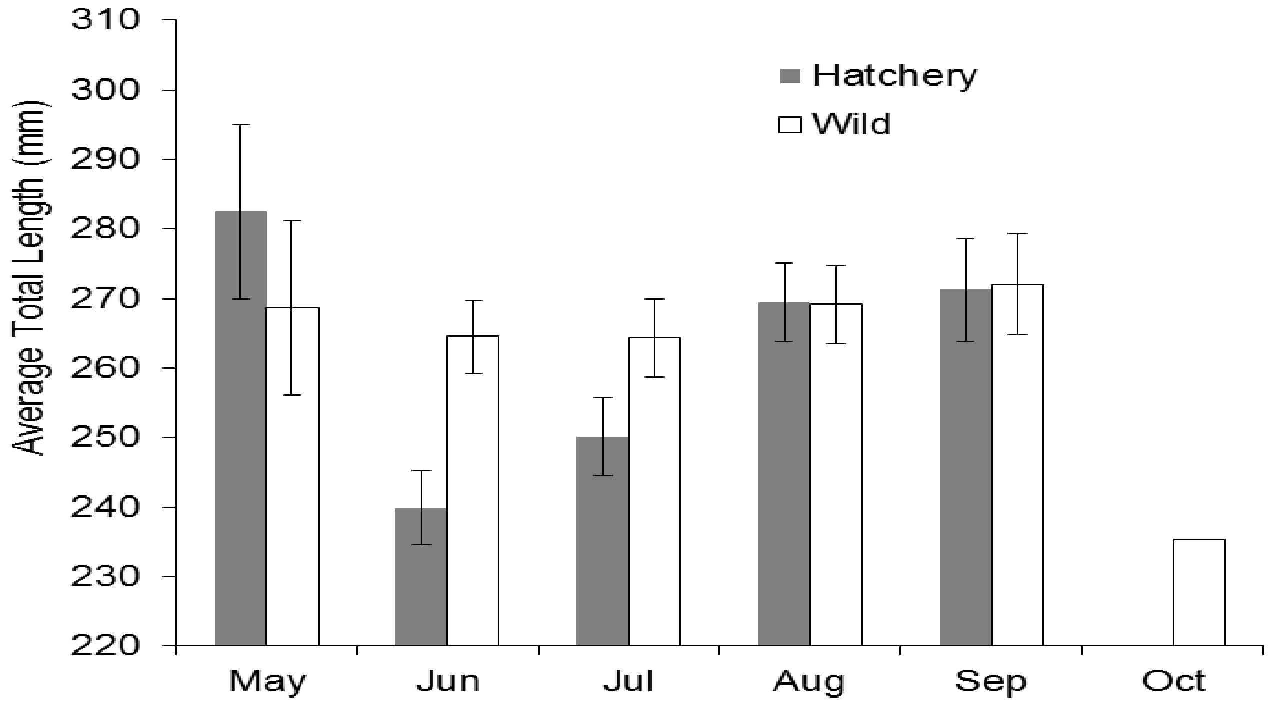

Figure 9. Mean total length of hatchery and wild kokanee catch by month from creel survey, Lake Pend Oreille, 2017.

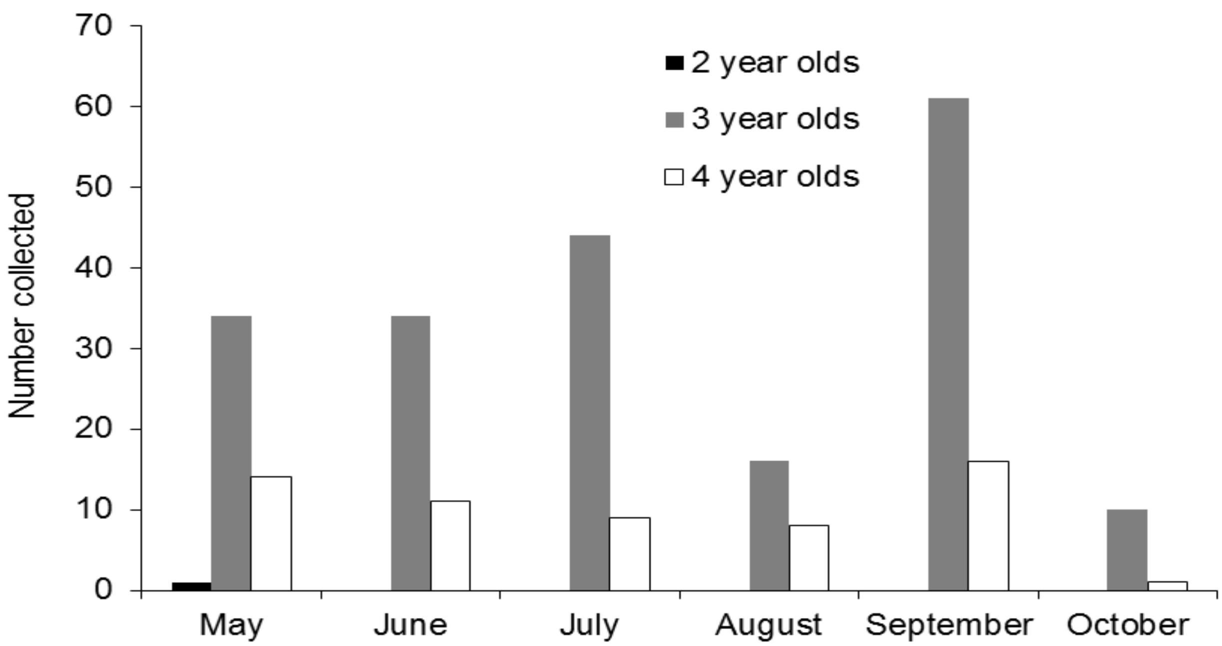

Figure 10. Kokanee catch by month and by age in 2016 creel survey, Lake Pend Oreille.

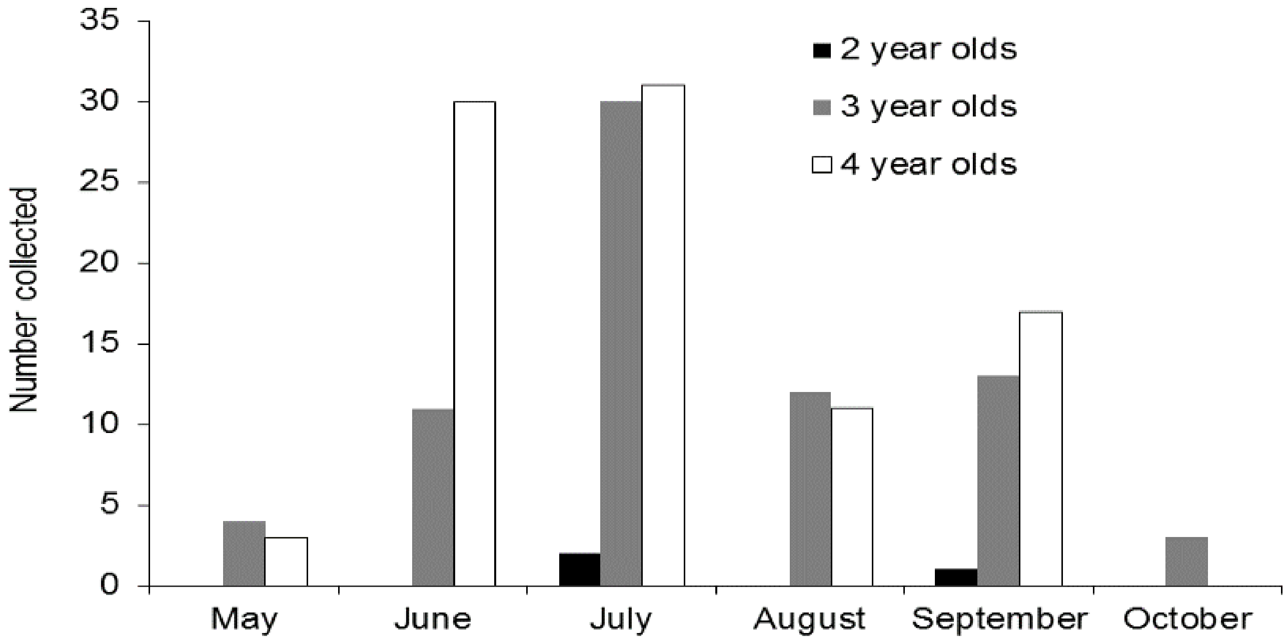

Figure 11. Kokanee catch by month and by age in 2017 creel survey, Lake Pend Oreille.

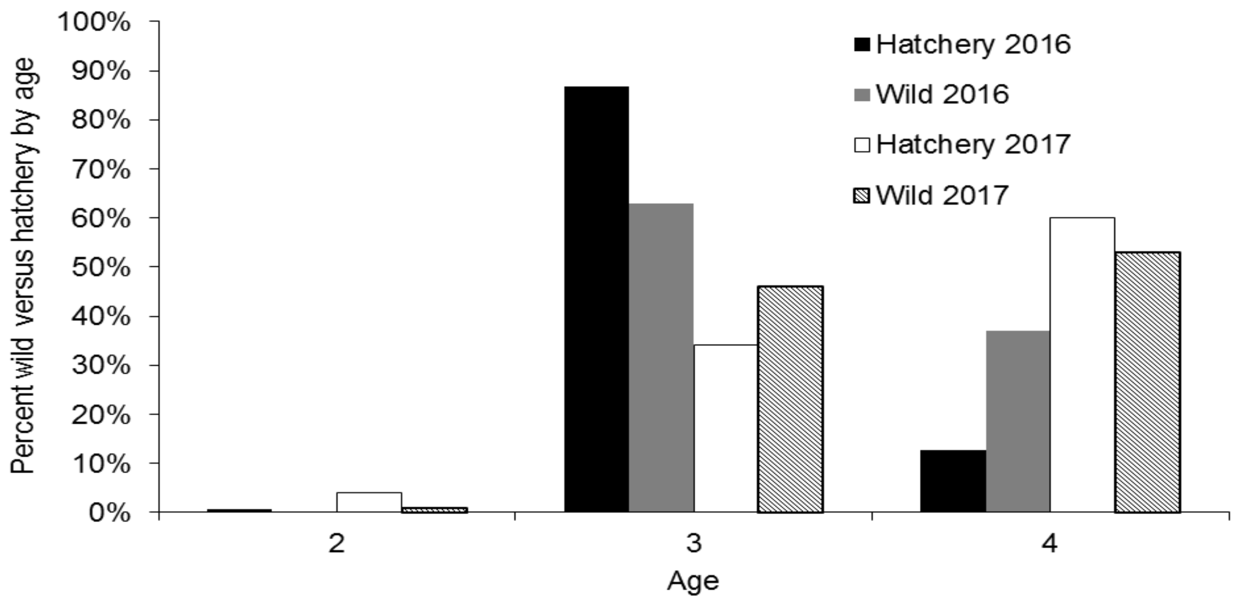

Figure 12. Age and stock contribution of kokanee captured during 2016 and 2017 creel surveys, Lake Pend Oreille.

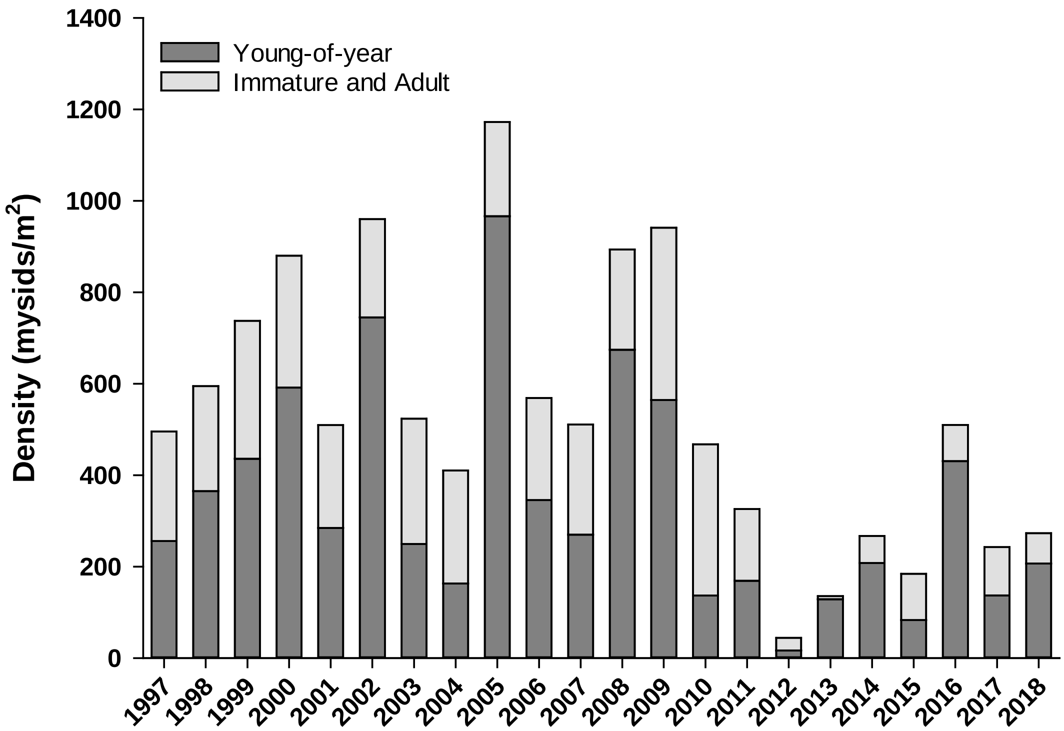

Figure 13. Density estimates of young-of-year and immature/adult mysids in Lake Pend Oreille, Idaho 1997-2018.

CHAPTER 2: PREDATOR REMOVAL PROGRAM EVALUATION

ABSTRACT

For more than a decade, kokanee *Oncorhynchus nerka* recovery in Lake Pend Oreille has been limited by predation, primarily from Lake Trout *Salvelinus namaycush*. To address this issue, Idaho Department of Fish and Game (IDFG) implemented an aggressive predator removal strategy aimed at reducing Lake Trout. IDFG instituted unlimited harvest regulations and a $15 reward for each Lake Trout harvested as part of the angler incentive program (AIP). Additionally, IDFG contracted with Hickey Brothers Research, LLC to remove Lake Trout from Lake Pend Oreille using gill nets and deepwater trap nets. Due to their relatively high cost per yield, use of trap nets was discontinued in 2018. Instead, three weeks of gillnetting effort was dedicated to assessment sets at stratified random locations throughout the lake. This randomized assessment netting will be repeated on an annual basis and will serve as a tool for population monitoring and evaluating Lake Trout removal efforts. During 2017, a total of 10,747 Lake Trout were removed from Lake Pend Oreille during predator suppression efforts. The majority of Lake Trout removed in 2017 were captured during contracted gill netting efforts (65%). In 2018, a total of 10,463 Lake Trout were removed during suppression efforts. Of these fish, 7,845 (75%) were removed during targeted gill netting operations. The percent of Bull Trout catch that resulted in direct mortalities during contracted netting operations was lower in 2018 than in 2017 (23% vs. 31%, respectively). Catch rates during assessment netting averaged 3.14 (±0.36) Lake Trout per 274.3 m net and catch ranged in size from 180 mm to 1010 mm. Since the predator removal began in 2006, 220,444 Lake Trout have been removed from Lake Pend Oreille. Total Lake Trout catch over the three-week assessment netting period in 2018 was more than double that of the total catch from ten weeks of trap netting in 2017. This may indicate that Lake Trout removal and population monitoring via randomized assessment gill netting is an effective and cost efficient alternative to trap nets.

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INTRODUCTION

Population modeling conducted in 2006 indicated the kokanee *Oncorhynchus nerka* population in Lake Pend Oreille (Figure 1, Appendix A) 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). With those conditions, Lake Trout posed a threat to federally-threatened Bull Trout *S. confluentus* through predation and competition (Fredenberg 2002; Martinez et al. 2009; Guy et al. 2011). To protect Bull Trout and restore kokanee, the Idaho Department of Fish & Game (IDFG) started a two-part predator removal program in 2006 aimed at collapsing the Lake Trout population and reducing Rainbow Trout predation. First, IDFG liberalized angling regulations on Lake Trout and Rainbow Trout and initiated an angler incentive program (AIP) on Lake Pend Oreille which offered $15 rewards for any Lake Trout and Rainbow Trout harvested. Because the program did not decrease Rainbow Trout abundance, the AIP for Rainbow Trout was discontinued after 2012, and harvest regulations were reestablished to rebuild the trophy fishery (Wahl et al. 2015a). Secondly, IDFG contacted Hickey Brothers Research, LLC who had previous experience netting Lake Trout on the Great Lakes to remove Lake Trout from Lake Pend Oreille using gill nets and deep water trap nets. A combination of gill nets, trap nets, and angler harvest was necessary to impose high enough annual mortality to sufficiently reduce the Lake Trout population and prevent kokanee extirpation (Hansen et al. 2010).

Following the implementation of the predator removal program, the population of Lake Trout in Lake Pend Oreille declined nearly 60% from 2006 to 2016 (Dux et al. 2019). In response to this successful reduction in population size, Hansen et al. (2019) conducted a simulation exercise to determine optimal suppression techniques for further population reduction and indefinite maintenance of abundance below a target level (i.e. 10% of the peak abundance in 2006). They found that allocating more effort towards large-mesh gillnets would reduce the amount of time before a target abundance was reached. The simulation model indicated that the most-effective mesh size combination for reducing both adult and juvenile Lake Trout was comprised of 5.1, 6.4, 12.7, and 14.0 cm mesh. In addition, model predictions showed that if total gillnetting effort was sustained at the 2014 level, it would take between seven and thirteen years of utilizing an optimal mesh size combination to reach the target suppression abundance. However, if effort is reduced to 60% of the 2014 level, it will take twice the amount of time to reach the target abundance. Furthermore, model predictions showed 14 weeks of trap-netting effort could be replaced by one week of gillnetting effort for the same yield.

These findings led to the discontinuation of trap netting following the 2017 season and the implementation of a three-week randomized assessment gillnetting protocol in 2018 (hereafter referred to as assessment netting). This assessment netting protocol will serve as a new monitoring tool for evaluating the status of the Lake Trout population and the success of the predator removal program. As an additional response to these findings, gillnetting effort was increased in 2018 and relied on the four most-effective mesh sizes for targeting adult and juvenile Lake Trout as determined from the simulation model.

METHODS

In 2017, Hickey Brothers Research, LLC was contracted to remove Lake Trout from Lake Pend Oreille using gill nets and deepwater trap nets for 14 weeks during the winter/spring netting season (January 9-April 14) and 10 weeks during the fall netting season (September 11-November 17). Gill nets contained stretch mesh of 3.8–12.7 cm. The contract netters set primarily 3.8–7.6 cm mesh in the winter/spring (January-April) and late fall (October-December) to target juvenile Lake Trout (hereafter referred to as nursery netting) and 11.4–12.7 cm mesh in the early fall (September-October) to target adult Lake Trout at spawning sites (hereafter referred to as spawner netting). Several nets were tied together to form a gang that was set in a serpentine pattern that paralleled shore. Gill nets were set around dawn and retrieved in the late morning (typically 4-6 hour sets). We enumerated and measured total length of all Lake Trout captured in gill nets. Sex and sexual maturity were determined for most of the Lake Trout captured throughout the spawning period. In addition, four trap nets (described in detail by Petersen and Maiolie 2005) were set during the fall at standardized locations. Hickey Brothers Research, LLC set the trap nets during the first week of fall netting and lifted the nets weekly through early November. On each lift, fish were removed from the trap nets, identified to species, enumerated, and measured for total length.

In 2018, Hickey Brothers Research, LLC was contracted to remove Lake Trout from Lake Pend Oreille using gill nets for 14 weeks during the winter/spring netting season (January 8 – April 13) and 13 weeks during the fall netting season (September 10 – November 16, November 26 – December 14) in 2018. Gill nets contained stretch mesh of 3.8–14.0 cm. The contract netters set 5.1 and 6.4 cm mesh in the winter/spring (January - April) and late fall (October - November) to target juvenile Lake Trout (i.e. nursery netting) and 12.7 and 14.0 cm mesh in the early fall (September - October) to target adult Lake Trout at spawning sites (i.e. spawner netting). During assessment netting (November 26 - December 14), gill nets were set along the shoreline in water depths ranging from 18 m to 76 m in randomly selected locations stratified to include approximately 40% of sites from the relatively shallow “north end” and 60% of sites from the remainder of the lake. These gill nets were constructed of 91.4 m panels of translucent stretch mesh ranging from 3.8 cm to 14.0 cm. Each panel contained a single size (cm) mesh (i.e. 3.8, 4.4, 5.1, 6.4, 7.6, 8.9, 10.2, 11.4, 12.7, 14.0) and panels were strung together to create 274.3 m “boxes.” Boxes were randomly strung together to create a ten box “gang,” and a single gang was set at each randomly selected site. Each gang contained equal effort (274.3 m) of the aforementioned mesh sizes. Lake Whitefish *Coregonus clupeaformis* were enumerated and measured from a stratified random subset of gangs during assessment netting in order to assess current population characteristics. Trap nets were not utilized in 2018.

Lake Trout, Bull Trout, Walleye *Sander vitreus*, Northern Pike *Esox lucius*, kokanee, Smallmouth Bass *Micropterus dolomieu*, Largemouth Bass *M. salmoides*, Yellow Perch *Perca flavescens*, Black Crappie *Pomoxis nigromaculatus*, Rainbow Trout, Brown Trout *Salmo trutta*, Westslope Cutthroat Trout *O. clarkii lewisi* were enumerated and measured for total length upon encounter. Biological samples were opportunistically obtained from a subset of species of interest for use in age and growth analyses. Lake Trout, Walleye, and Northern Pike captured during gill and trap netting efforts were subsequently removed and donated to local food banks, with the exception of Lake Trout or Walleye that were implanted with telemetry tracking devices and released alive (see chapters 3 and 5).

Trap net catch rates were calculated as the number of fish captured in a trap net divided by the number of nights that net was set (per net-night). Gill net catch rates were calculated as the number of Lake Trout captured per 274 m net. No time component was included in gill net catch rates because Lake Trout catch has typically not increased with the duration of net sets (IDFG, unpublished data). Total effort (m) for each mesh size utilized in 2017 and 2018 was compared to the optimal allocation of effort by mesh size required to achieve target abundance levels in minimal time (see Hansen et al. 2019).

For the AIP in 2017 and 2018, anglers that caught Lake Trout from Lake Pend Oreille turned the heads in to freezers that IDFG had placed around the lake. Heads were collected from freezers weekly, identified to species, and measured from the tip of the snout to the posterior edge of the operculum. Previously developed head-length to total-length relationships for Lake Trout in Lake Pend Oreille (Wahl et al. 2013) were used to estimate total length.

RESULTS

In 2017, Hickey Brothers Research, LLC captured a total of 7,216 Lake Trout and 1,418 Bull Trout (Table 6). Of the total Bull Trout captured during netting operations in 2017, 446 were direct mortalities (31%). Gill net effort totaled 585,905 m (71% of 2014 effort) and contributed 97% of the Lake Trout catch during contracted netting operations. In 2017 during the Lake Trout spawning period, a total of 573 individual 274.3 m gill nets (157,174 m of net) were set at the spawning sites. We captured 1,678 Lake Trout (2.7 Lake Trout per net; 2.0-3.7 = 95% CI) and examined 1,523 fish for sex and maturity (Figure 14). Of those fish, 558 were mature females with a mean total length (TL) of 696 mm (SE = 5.0; range = 448-1042) and 640 were mature males with a mean TL of 694 mm (SE = 3.8; range = 410-1042). The remaining 325 Lake Trout were immature. This resulted in a sex ratio of 1.14 mature males per mature female. Standardized trap net effort totaled 254 net-nights and catch rates averaged 1.0 Lake Trout per net-night (0.7–1.4, 95% CI; Figure 15) and 0.56 Bull Trout per net-night (0.4–0.8, 95% CI; Figure 16). A total of 248 Lake Trout and 92 Bull Trout were captured in trap nets in 2017. Of the Bull Trout captured, 18 were direct mortalities (20%). Lake Trout captured in trap nets ranged from 305 to 995 mm, with 36% of catch greater than 650 mm.

In 2018, Hickey Brothers Research, LLC captured a total of 7,857 Lake Trout and 1,462 Bull Trout (Table 6). Of the total Bull Trout captured during netting operations in 2018, 339 were direct mortalities (23%). Gill net effort totaled 766,724 m (92% of 2014 effort). During the Lake Trout spawning period, a total of 697 individual 274.3 m gill nets (191,110 m of net) was set at the spawning sites. We captured 1,723 Lake Trout (2.3 Lake Trout per net; ±0.21 SE) and examined 1,711 fish for sex and maturity (Figure 14). Of those fish, 693 were mature females with a mean total length (TL) of 778 mm (SE = 3.8; range = 415-1010) and 708 were mature males with a mean TL of 702 mm (SE = 3.7; range = 490-1080). The remaining 322 Lake Trout were immature. This resulted in a sex ratio of 1.02 mature males per mature female. During assessment netting, Hickey Brothers Research, LLC set 200 gill nets and captured 628 Lake Trout and 241 Bull Trout. Of the Bull Trout captured, 55 were direct mortalities (23%). Assessment netting catch rates varied by mesh size (Table 7) and averaged 3.14 (±0.36 SE) Lake Trout per net. Lake Trout captured during assessment netting ranged in size from 180 to 1010 mm, with 4% of catch greater than 650 mm.

During 2017 and 2018, gill net catch rates of Lake Trout and Bull Trout varied by mesh size. In 2018, less effort was allocated towards 3.8, 4.4, 7.6, and 11.4 cm mesh and more effort was allocated towards 5.1, 6.4, 12.7, and 14.0 cm mesh than in 2017 (Table 8). In both years, the amount of effort allotted to 14.0 cm mesh was less than the Hansen et al. (2019) estimated optimal amount (Figure 17). Anglers participating in the AIP captured and removed 3,531 Lake Trout from Lake Pend Oreille in 2017, and 2,618 in 2018. Calculated total length for Lake Trout caught in the AIP ranged from 248 to 1161 mm. The size distribution of Lake Trout captured during removal efforts varied by gear type (Figure 18). During suppression efforts, a total of 10,747 Lake Trout were removed in 2017 and 10,463 were removed in 2018. To date, 220,444 Lake Trout have been removed from Lake Pend Oreille during targeted Lake Trout suppression efforts (Table 6).

DISCUSSION

The predator removal program continues to effectively remove Lake Trout from Lake Pend Oreille in an effort to reach and maintain a target abundance of 10% of the peak abundance in 2006. Since the predator removal program began in 2006, over 55% of the Lake Trout removed have been captured via gill net, 41% via angling, and 3 % via trap nets. Initially, a larger proportion of catch was attributed to angling and trap nets (72% and 10%, respectively, in 2006). However, proportional catch using these methods has declined over time (33% and 2%, respectively, in 2017). While trap nets initially had a substantial influence on fishing mortality, they have been a minor source of mortality relative to gill netting and angling over the course of the removal program (Dux et al. 2019) and were discontinued following the fall of 2017. Despite the change over time in proportional catch by gear type, the use of multiple techniques in combination over the course of the suppression program has resulted in greater fishing mortality than would have been feasible while using only a single suppression technique (Dux et al. 2019) and it still remains important to use multiple methods in order to exploit all sizes of Lake Trout in the system (Hansen et al. 2010). Angling has shown to have a higher relative selectivity for age-6 and age-7 Lake Trout than the four main mesh sizes utilized in 2018 (i.e. 5.1, 6.4, 12.7 and 14.0 cm; Hansen et al. 2019) and remains an effective method of population suppression when used in concert with netting.

Randomized assessment netting was implemented in 2018 in place of standardized trap nets and showed to be an effective suppression strategy. Total Lake Trout catch over the three week assessment netting period in 2018 was more than double that of the total catch from ten weeks of trap netting in 2017. In addition to being an effective suppression strategy, randomized assessment netting enables the opportunistic collection of trend data from non-target species caught as bycatch during netting operations. For instance, yearly catch per unit effort and size data collected from a subset of Lake Whitefish bycatch may provide better insight into the status of this population in Lake Pend Oreille. Furthermore, capture and removal of Lake Trout during assessment netting provides the opportunity to collect a random sample of biostructures from Lake Trout that will aid in future population assessments. Otoliths collected from Lake Trout that were captured during assessment netting in 2018 will be examined to determine age and length at capture information. This information will be utilized in a von Bertalanffy growth model to assess somatic growth and a cohort analysis to obtain age specific lake-wide abundance estimates (see Dux et al. 2019 for methods and current results). Additional annual information on somatic growth and age specific abundances will supplement the evaluation of the predator removal program and benefit our ability to adapt management strategies in response to population demographics.

The increase in total gillnetting effort and allocation of effort towards 5.1, 6.4, 12.7, and 14.0 cm mesh in 2018 aims to promptly achieve suppression of the population to the target abundance level. The addition of 14.0 cm mesh appears to be an effective suppression strategy. Annual catch rates and percent mature catch (≥650 mm, Wahl et al. 2015a) were greater in the 14.0 cm mesh than in the 12.7 cm mesh. This empirical data supports the model prediction that 14.0 cm mesh is the most effective mesh size for Lake Trout suppression in Lake Pend Oreille (Hansen et al. 2019). In addition, catch rates in the large mesh gill nets during assessment netting demonstrate that it may be effective to utilize 12.7 and 14.0 cm mesh outside the spawning period. While effort allotted to large mesh gill nets was increased in 2018, the total effort of 14.0 cm mesh utilized was less than the estimated optimal amount. An additional allocation of effort to 14.0 cm mesh may further benefit suppression efforts.

Total catch of Lake Trout at spawning sites increased slightly between 2016 and 2018. However, catch rates have decreased steadily since 2014, with 2018 having the lowest catch rates in 10 years of targeted netting at the spawning sites (Figure 14). Despite the variation in catch over the past few years, the change in length-frequency distribution from 2008 to 2018 indicates that size-classes of mature Lake Trout have been vulnerable to removal efforts. Most importantly, the major reduction of Lake Trout less than 700 mm in the length-frequency distributions compared to those earlier in the program suggest a lack of year-classes recruiting to gill nets set at spawning sites. A large proportion of fish in these cohorts was removed prior to reaching maturity, either through juvenile netting or angler harvest.

Over the past several years, we have effectively used data from gillnetting at Lake Trout spawning sites to assess the spawning segment of the population. Length-frequency distributions since 2013 suggested that the level of effort expended has been sufficient to achieve desired effects at all of the spawning sites. This is particularly important given that the Evans Landing spawning site has not been targeted for as many years as the other two sites, and we documented fish along more of the Evans Landing shoreline in 2013. The peak of the length-frequency distribution shifted towards smaller Lake Trout during 2012-13, and this could be related to year classes recruiting to maturity. Over the past five years, we have effectively removed Lake Trout as juveniles, and the shift in size structure of spawning Lake Trout back towards larger individuals should continue. Therefore, we do not expect to see any more large cohorts reaching maturity.

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

Total and proportional Bull Trout mortality was lower in 2018 than in 2017 despite the increase in gillnetting effort and discontinuation of trap netting. In addition, proportional Bull Trout mortality during randomized assessment netting in 2018 was equal to the total annual proportional Bull Trout mortality from 2018. Therefore, proportional mortality did not increase with the inclusion of additional mesh sizes during assessment netting.

RECOMMENDATIONS

1. Continue the use of gill nets to remove mature Lake Trout from spawning sites in the fall.

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

3. Continue the use of randomized assessment netting in place of trap nets as a tool to monitor the Lake Trout population and assess removal efforts.

4. When feasible, increase the amount of effort allocated to 14.0 cm mesh gill nets.

Table 6. Number of Lake Trout removed during predator suppression efforts from Lake Pend Oreille, Idaho by different gear types from 2006 - 2018.

Year	Angling	Gill nets	Trap nets	Total
2006	11,041	2,774	1,500	15,315
2007	17,665	4,169	1,335	23,169
2008	13,020	10,252	1,509	24,781
2009	7,366	17,186	410	24,962
2010	8,740	17,334	400	26,474
2011	7,324	11,384	150	18,858
2012	7,813	9,500	322	17,635
2013	3,537	10,402	359	14,298
2014	2,511	8,873	259	11,643
2015	3,194	8,634	215	12,043
2016	2,871	6,761	424	10,056
2017	3,531	6,968	248	10,747
2018	2,618	7,845	0	10.463
TOTAL	91,231	122,082	7,131	220,444

Table 7. Mean (±SE) catch per unit effort (274.3 m net) by mesh size (cm) for Lake Trout, Bull Trout, and Lake Whitefish caught during assessment netting in 2018. Lake Whitefish catch is derived from the subsample of assessment netting sites where Lake Whitefish were enumerated.

Mesh Size (cm)	Lake Trout CPUE (±SE)	Bull Trout CPUE (±SE)	Bull Trout Mortality CPUE (±SE)	Lake Whitefish CPUE (±SE)
3.8	8.90 (±2.06)	0.20 (±0.09)	0	63.67 (±36.61)
4.4	6.67 (±1.49)	0.56 (±0.18)	0.06 (±0.06)	59.33 (±27.83)
5.1	7.20 (±1.45)	1.00 (±0.24)	0.40 (±0.15)	60.00 (±21.12)
6.4	2.10 (±0.43)	1.47 (±0.22)	0.42 (±0.12)	48.67 (±21.40)
7.6	1.75 (±0.40)	1.35 (±0.37)	0.40 (±0.18)	60.00 (±21.61)
8.9	1.78 (±0.52)	2.39 (±0.36)	0.67 (±0.21)	39.00 (±8.91)
10.2	1.10 (±0.25)	2.85 (±0.59)	0.40 (±0.13)	13.78 (±3.85)
11.4	1.20 (±0.35)	1.35 (±0.29)	0.30 (±0.15)	2.44 (±1.11)
12.7	0.72 (±0.24)	0.61 (±0.20)	0.11 (±0.08)	0.22 (±0.15)
14.0	1.05 (±0.27)	0.74 (±0.17)	0.11 (±0.07)	0.22 (±0.15)
Average	3.14 (±0.36)	1.21 (±0.11)	0.28 (±0.04)	33.76 (±13.54)

Table 8. Annual mean (±SE) catch per unit effort (274.3 m net) by mesh size (cm) for Lake Trout and Bull Trout caught in gill nets during Lake Trout suppression efforts in Lake Pend Oreille during 2017 and 2018.

Year	Mesh Size (cm)	Effort (m)	Lake Trout CPUE (±SE)	Bull Trout CPUE (±SE)	Bull Trout Mortality
2017	3.8	80,650	5.25 (±0.71)	0.13 (±0.03)	19 %
	4.4	47,457	4.19 (±0.57)	0.04 (±0.01)	29 %
	5.1	97,658	3.33 (±0.40)	0.36 (±0.06)	34 %
	6.4	108,356	2.67 (±0.32)	0.77(±0. 14)	35 %
	7.6	78,181	1.38 (±0.19)	0.80 (±0.12)	35 %
	8.9	0	NA	NA	NA
	10.2	0	NA	NA	NA
	11.4	102,870	3.28 (±0.30)	1.44 (±0.11)	32 %
	12.7	52,121	2.85 (±0.30)	0.54 (±0.08)	22%
	14.0	0	NA	NA	NA
2018	3.8	5,486	8.90 (±2.06)	0.20 (±0.09)	0%
	4.4	5,486	6.00 (±1.41)	0.50 (±0.17)	10%
	5.1	265,542	3.97 (±0.39)	0.41 (±0.06)	24%
	6.4	265,542	2.34 (±0.20)	0.60 (±0.07)	29%
	7.6	5,486	1.75 (±0.40)	1.35 (±0.37)	30%
	8.9	5,486	1.60 (±0.48)	2.15 (±0.36)	28%
	10.2	5,486	1.10 (±0.25)	2.85 (±0.59)	14%
	11.4	5,486	1.20 (±0.35)	1.35 (±0.29)	22%
	12.7	107,168	1.84 (±0.19)	0.77 (±0.08)	22%
	14.0	95,463	2.19 (±0.22)	0.74 (±0.08)	15%

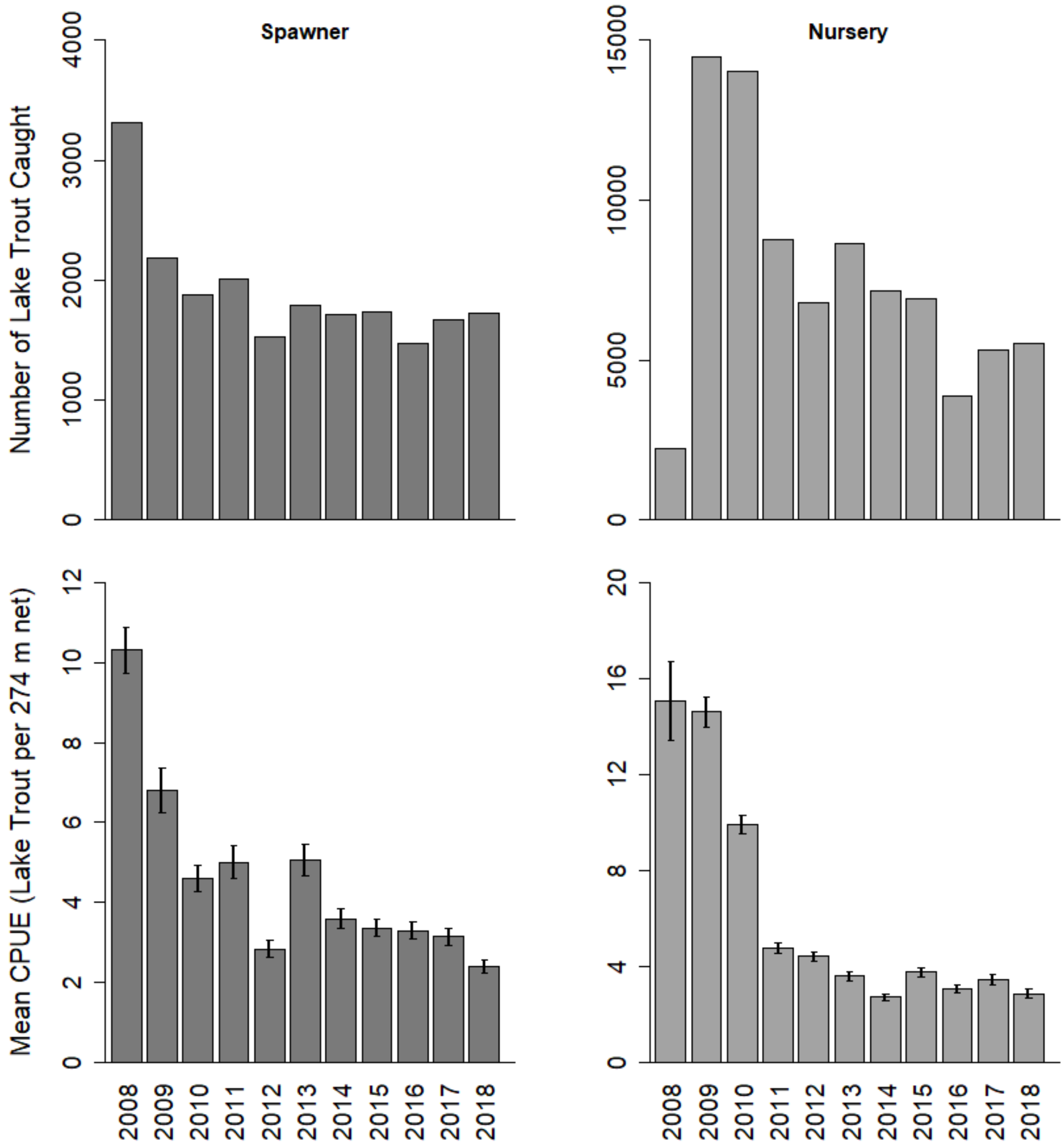

Figure 14. Yearly catch and mean (±SE) catch per unit effort of Lake Trout captured in gillnets during spawner and nursery netting efforts in Lake Pend Oreille, 2008-2018.

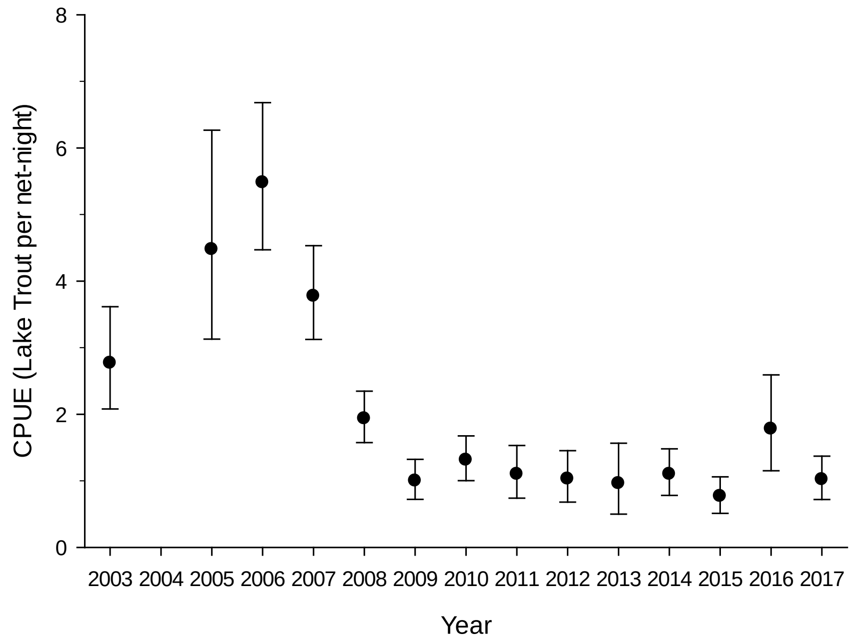

Figure 15. Mean Lake Trout catch rate (CPUE) with 95% confidence intervals for standardized trap nets set during fall in Lake Pend Oreille, Idaho. Trap nets were discontinued in 2018.

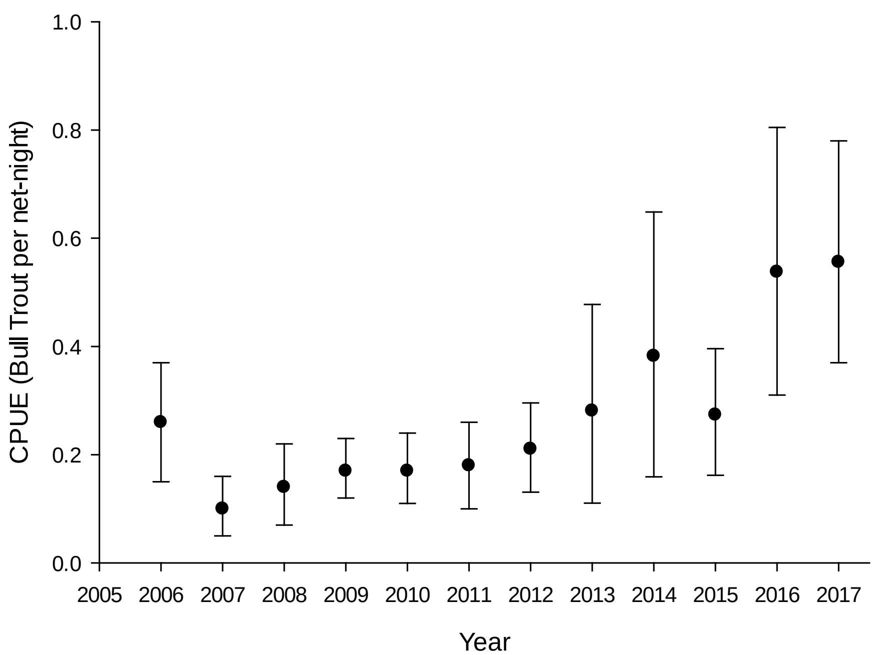

Figure 16. Mean Bull Trout catch rate (CPUE) with 95% confidence intervals for standardized trap nets set during fall in Lake Pend Oreille, Idaho. Trap nets were discontinued in 2018.

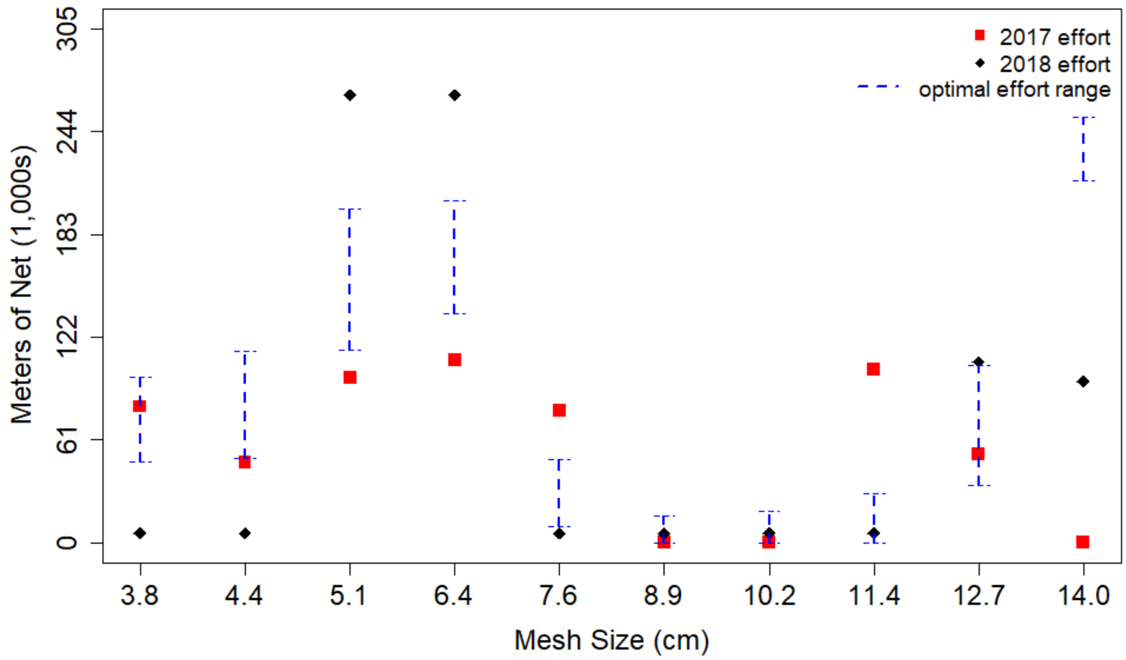

Figure 17. Allocation of gillnetting effort by mesh size in 2017 and 2018 during Lake Pend Oreille Lake Trout suppression netting. Dotted lines depict the estimated optimal allocation of effort by mesh size in order to achieve target abundance levels in minimal time (Hansen et al. 2019).

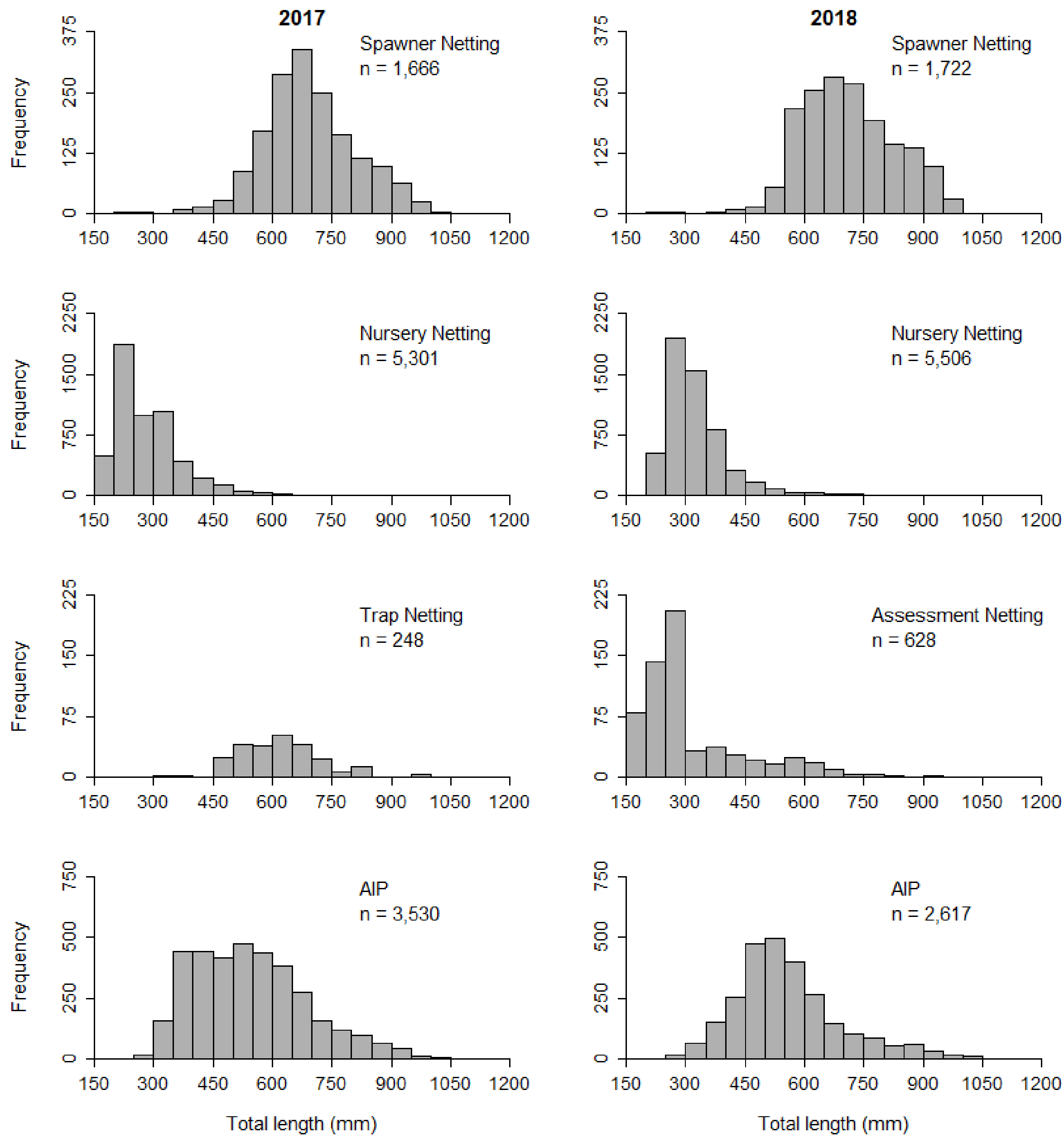

Figure 18. Gear-specific length-frequency histograms for Lake Trout removed during predator suppression efforts in 2017 and 2018 in Lake Pend Oreille.

CHAPTER 3: SPAWNING LAKE TROUT RESEARCH

ABSTRACT

The kokanee (landlocked form of Sockeye Salmon *Oncorhynchus nerka*) and Bull Trout *Salvelinus confluentus* populations in Lake Pend Oreille have been threatened by Lake Trout *S. namaycush* for more than a decade, and kokanee were on the verge of total collapse in 2007. To increase kokanee survival and protect Bull Trout, Lake Trout removal actions were implemented, including commercial netting and an angler incentive program. We used mobile telemetry receivers to follow acoustically-tagged mature Lake Trout to spawning sites where we could target spawning aggregations with gill nets and maximize removal efficiency. During September and October 2017 and 2018, we tracked Lake Trout with mobile telemetry once or twice per week to identify spawning aggregations in order to provide the commercial netters with precise locations of where to set nets. Tracking events occurred along the entire shoreline of the lake, and we used three stationary receivers (one at each known spawning site) to document movement among spawning sites. In 2017, 14 Lake Trout were located a total of 34 times using mobile telemetry and 12 were located on the stationary receivers, two of which were not located during mobile telemetry. By combining mobile and stationary telemetry, 88% visited at least one of the three spawning sites and 19% visited all three sites. A total of 1,523 Lake Trout were caught in gill nets and removed from spawning sites by the contract netters in 2017, including 558 mature females and 640 mature males. In October 2017, we tagged an additional 12 adult Lake Trout ranging in size from 570 to 966 mm total length for telemetry studies in 2018. In 2018, we located eleven of the 13 Lake Trout during telemetry efforts. Nine of the 11 were located during mobile telemetry and six of the 11 were recorded on the Bernard Beach and Evans Landing stationary receivers. Lake Trout used all three spawning sites in 2018. In October 2018, 12 mature Lake Trout ranging in size from 623 to 910 mm were implanted with Vemco V16-6X (4-year tag life) transmitters for future telemetry studies. A total of 1,723 Lake Trout were caught in gill nets and removed from spawning sites by the contract netters in 2018, including 693 mature females and 708 mature males.

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

During 2007 and 2008, telemetry research identified two Lake Trout spawning sites in Lake Pend Oreille (Schoby et al. 2009a; Wahl and Dux 2010). Intensive gill netting at these sites since 2008 has yielded high 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). Telemetry research has continued annually, but the tags deployed for 2012 research all had battery failures prior to data collection (Wahl et al. 2015a). We continued telemetry research in 2017 and 2018 to further evaluate whether Lake Trout spawning distribution changed in response to netting and used real-time data to guide netting during the spawning period.

METHODS

Lake Trout Telemetry

To evaluate Lake Trout spawning distribution, we have tracked mature Lake Trout using Lotek Wireless Inc. (Newmarket, Ontario) acoustic telemetry equipment from 2007 to 2018. We surgically implanted acoustic transmitters (MM-M16-33 TP) equipped with temperature and depth (effective to 100 m) sensors into the peritoneal cavity of mature Lake Trout. All Lake Trout were anesthetized with 30 mg/L of Aqui-S (AquaTactics Fish Health, Kirkland, WA). Transmitters were inserted through a 4.5 cm incision just off the centerline of the abdomen of the fish anterior to the pelvic fins and pushed back to sit on the pelvic girdle. Incisions were closed with non-absorbable sutures.

Lake Trout tracked during 2017 were captured for tag insertion during fall 2016 and Lake Trout tracked during 2018 were captured and tagged in fall 2017 (see Wahl et al. 2015b for details).

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

Additionally, we captured and tagged Lake Trout during fall 2018 for future telemetry research and incorporated Vemco telemetry equipment (Vemco Inc, Shad Bay, Nova Scotia). Lake Trout were tagged with Vemco acoustic transmitters (V16H-6X-69 khz,) and telemetry locations will be monitored by active tracking (Vemco VR-100) and with a passive array of acoustic telemetry receivers (Vemco VR2W). Fish were captured using gill and trap nets operated by Hickey Brothers, LLC. To ensure sexual maturity, we tagged only Lake Trout that were ripe or were greater than 600 mm (IDFG, unpublished data).

RESULTS

Lake Trout Telemetry 2017

Fourteen of the 24 Lake Trout tagged in 2015 were implanted with 2-year transmitters, which were active in 2017. In 2016, 14 Lake Trout were implanted with 2-year transmitters. A total of 28 Lake Trout were potentially available for telemetry movement evaluation in 2017, of which 16 were recorded during the 2017 Lake Trout spawning season and provided movement data. The other 12 Lake Trout (or the transmitters within them) were either captured and removed during the netting program, returned by anglers, had tags that never turned on, were in fish that died in water too deep for the tags to be heard, or were shed by fish that survived but could no longer be located. We actively tracked twice weekly during the spawning period in late September and early October. Additionally, three stationary receivers were positioned near the spawning sites from September to October 2017.

During the spawning period, a total of 16 Lake Trout were located. Fourteen of those 16 were located a total of 34 times using mobile telemetry. Four of the 16 were only found during mobile telemetry and were not found on the stationary receivers. Conversely, during their deployment, the stationary receivers recorded 46,435 detections from 12 Lake Trout. Two were located only on the stationary receivers and not during mobile telemetry. Lake Trout used all three spawning sites in 2017 (Figure 19) with most of the use in 2017 at the Bernard Beach spawning site. A large part of the movement detected occurred during the mobile tracking period (September 9 to October 10, 2017). From the combination of mobile telemetry and stationary receiver detections, we documented extensive Lake Trout movement during the spawning period and 14 (88%) were located at one of the three known spawning locations and three (19%) Lake Trout visited all three spawning sites. The remaining two (12%) Lake Trout were located near Picard Point and nowhere else.

Twelve mature Lake Trout were implanted with 2-year transmitters from October 10-13 in fall 2017 for 2018 telemetry studies. All were captured in gill nets (four each near Evans Landing, Bernard Beach, and Windy Point). Tagged Lake Trout averaged 842 mm total length (range = 726-980 mm). A complete list of tagged Lake Trout at-large during the 2017 tracking season is provided in Appendix B.

Lake Trout Telemetry 2018

Fourteen mature Lake Trout were implanted with 2-year transmitters in fall 2016 and 12 mature Lake Trout were implanted with 2-year transmitters in fall 2017. A total of 26 Lake Trout were potentially available for movement evaluation in 2018, of which 13 were recorded during the 2018 Lake Trout spawning season and provided movement data. The other 13 Lake Trout were either captured and removed during the netting program, returned by anglers, had tags that never turned on, were in fish that died in water too deep for the tags to be heard, or were shed by fish that survived but could no longer be located. We located nine Lake Trout a total of 23 times using mobile telemetry. Seven of these were only found during mobile telemetry and were not found on the stationary receivers, although the stationary receiver at Windy Point was lost and not recovered after deployment. During their deployment, the Bernard Beach and Evans Landing stationary receivers recorded 13,377 detections from six Lake Trout. Four were located only on the stationary receivers and not during mobile telemetry. Lake Trout used all three spawning sites in 2018 (Figure 19), although use in 2018 was based on mobile tracking because of the missing Windy Bay receiver. Using the two recovered stationary receivers, most of the use in 2018 was at the Evans Landing spawning site, whereas in 2017 most of the use was at the Bernard Beach site with the least amount of use at the Windy Bay site. Windy Bay, Evans Landing, and Bernard Beach continue to be the main Lake Trout spawning areas in Lake Pend Oreille. Similar to 2017, results from mobile telemetry in 2018 suggest that Lake Trout are continuing to use the Camp Bay and Picard Point area more frequently during the spawning period.

Twelve mature Lake Trout were implanted with Vemco V16-6X (4-year tag life) transmitters on October 10 and 11, 2018 for future telemetry studies. All were captured in gill nets (six near Bernard Beach and six near Camp Bay, see Appendix B for location data). Tagged Lake Trout averaged 813 mm total length (range = 623-910 mm). A complete list of tagged Lake Trout at-large during the 2017 and 2018 tracking season is provided in Appendix B.

DISCUSSION

During 2017 and 2018, Lake Trout in Lake Pend Oreille primarily used the same three spawning sites that were identified in the past (Wahl et al. 2011b; Wahl et al. 2013; Wahl et al. 2015b). Additionally, we did not document any changes in the spatial extent of spawning along these three spawning areas. However, Lake Trout distribution has changed within the stretches of spawning shoreline that have been identified and targeted with gill nets for several years. Contrary to 2016, in 2017 Lake Trout were located more frequently and for a longer duration at the Bernard Beach and Windy Point spawning sites, and less frequently during a shorter duration at the Evans Landing spawning site. Fish at the Evans Landing site were primarily in small aggregations in sections of shoreline rather than spread out across the entire spawning site as was the case in previous years (Wahl et al. 2013; Wahl et al. 2015a). Additionally, two Lake Trout were located near Camp Bay in 2017 and were never located at any of the three traditional sites. Results from 2018 showed similar high use and likely spawning of several individuals near both Picard Point and Camp Bay. This suggests some Lake Trout are spawning in new areas of the lake and additional passive telemetry receivers deployed at new sites in addition to continued active telemetry may help locate new spawning areas or additional areas where Lake Trout congregate to focus netting efforts.

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

Although spawning aggregations have become more dispersed and fish moved among sites more than in the early years of our telemetry research, the fish were still vulnerable to netting at these primary spawning sites. Even if Lake Trout were not at a single spawning site for the duration of the spawning period, they moved to other spawning sites where netting also occurred. There would be travel time through areas where netting did not take place, but if overall Lake Trout travel rate was higher at the sites than in the past, this might provide a netting advantage where Lake Trout were more likely to encounter a net. Additionally, we do not know whether gill net disturbances negatively influenced spawning success by fish that were not captured and removed, but the apparent influence of gillnetting on fish distribution highlights the importance of continued telemetry research. Determining where Lake Trout are most concentrated within each spawning site will be important for identifying the most effective location to set gill nets as fish shift their distribution during the spawning period. In the future, setting gill nets in more gangs comprised of fewer nets may prove to be more effective than a single long gang if spawning aggregations within each spawning site continue to shrink. Additionally, continued telemetry research is needed to assess whether disturbances from netting cause fish to seek new spawning sites, given this species' ability to colonize new areas (Gunn 1995).

Overall, the use of telemetry to guide gill net placement at Lake Trout spawning sites has been a useful tool over the past several years which has maximized the efficiency of removal efforts. Telemetry has proven to be a successful method for helping increase exploitation of spawning Lake Trout (Wahl et al. 2015a), and increase the effectiveness of the Lake Trout removal program as a whole. With Lake Trout maturing at age-10 and maximum ages in Lake Pend Oreille beyond age-20, it will likely take many more years to fully collapse the population. However, the spawning segment of the population has been drastically reduced since 2008, and netting juveniles has become more effective in the last several years. Although we continue to see signs of a reducing Lake Trout population at all life stages, we must continue removal efforts in a similar fashion to reach collapse, and using telemetry to guide gill net placement on spawning aggregations will be a key component.

RECOMMENDATIONS

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

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

3. Use stationary telemetry receivers to examine movement among the three spawning sites and add additional receivers throughout the lake to learn more about system-wide movements to continue to improve netting efficiencies.

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

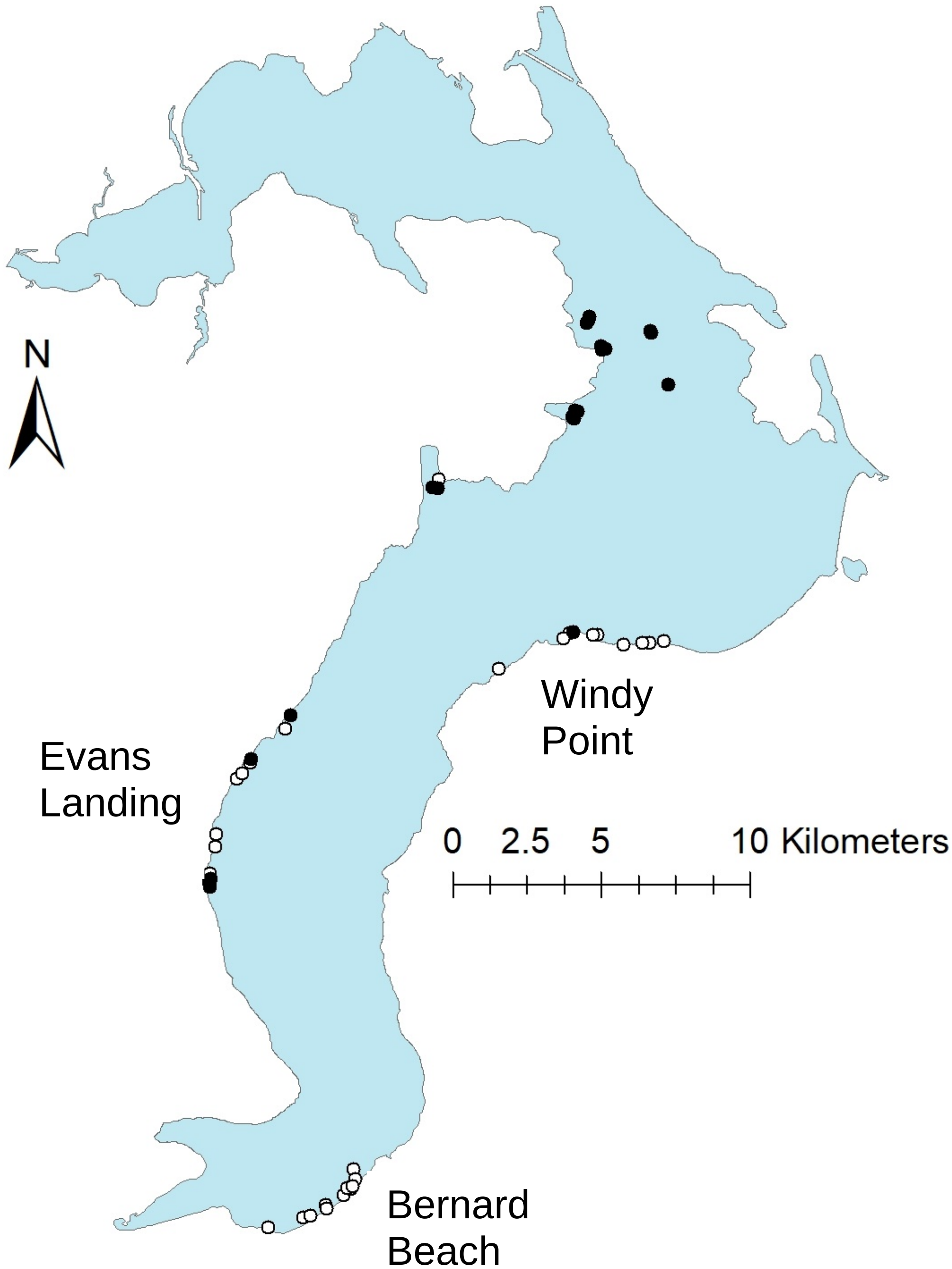

Figure 19. Locations of sonic tagged Lake Trout determined by active telemetry tracking during spawning period in 2017 and 2018, Lake Pend Oreille, Idaho. White circles are 2017 locations and dark circles are 2018 locations.

CHAPTER 4: RAINBOW TROUT RESEARCH

ABSTRACT

The historic abundance of kokanee *Oncorhynchus nerka* in Lake Pend Oreille provided the forage base necessary for Rainbow Trout *O. mykiss* to grow to world record sizes. However, predation on kokanee by an introduced population of Lake Trout *Salvelinus namaycush* poses a potential threat to Rainbow Trout abundance and growth. In recent years, kokanee abundance has increased following the implementation of a Lake Trout suppression program. The objectives of this research are to assess Lake Pend Oreille Rainbow Trout catch rates and somatic growth trends and evaluate the impact of kokanee abundance on annual incremental growth. Between 2011 and 2018, volunteer anglers have assisted in the collection of Rainbow Trout catch data and 480 pectoral fin rays that we aged and used to develop year-specific von Bertalanffy growth models. Back-calculated length at age was estimated from fin ray samples. Year-specific growth intercepts were isolated from a mixed effects model and used as a response variable in a simple linear regression with kokanee abundance as a predictor variable. Angler catch per unit effort and length frequency of catch was assessed on a yearly basis from 2016 through 2018. Annual catch rates ranged from 0.28 (±0.03) to 0.45 (±0.04) Rainbow Trout per hour and were greatest in 2016. The proportion of annual catch greater than 635 mm ranged from 17 to 24 percent and was greatest in 2018. Predicted mean length at age was significantly greater in 2018 than in 2011 and increased consistently from 2014 through 2018 for both age-five and age-six individuals. Kokanee abundance is a significant positive predictor of Rainbow Trout yearly incremental growth and explains 73 percent of the variation in this response variable. Rainbow Trout yearly incremental growth was predicted to increase by 9.04 mm (±1.96 mm) per million increase in kokanee abundance. These findings provide quantitative evidence to validate the biological hypothesis that Rainbow Trout somatic growth is linked to kokanee abundance. This suggests management actions that improve kokanee abundance may also improve the trophy Rainbow Trout fishery in Lake Pend Oreille.

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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 per year with up to 523,000 angler-hours of fishing pressure (Jeppson 1953; Maiolie and Elam 1993). In addition to historically providing a popular fishery, kokanee are the forage base that enable Gerrard-strain Rainbow Trout *O. mykiss* in Lake Pend Oreille to reach trophy sizes, including the former world record. However, kokanee abundance substantially declined from historic values, and in the early 2000s the population was at risk of complete collapse (Hansen et al. 2010). High predation rates, primarily created by a rapidly expanding Lake Trout *Salvelinus namaycush* population, were implicated as the primary factor limiting kokanee abundance. In 2006, Lake Trout suppression via commercial netting techniques and an Angler Incentive Program (AIP) was implemented. In order to aid in the recovery of kokanee, Rainbow Trout were added to the AIP program with a $15 bounty and unlimited harvest was allowed during 2006-2012. After kokanee started to rebound following Lake Trout suppression efforts, the management strategy for Rainbow Trout returned to the historical goal of providing a trophy fishery. However, aside from anecdotal evidence from anglers and very sporadic creel surveys, there is little data available to advise the management of this population. Standard fishery sampling techniques (i.e. netting, electrofishing, etc.) are not effective capture strategies for Rainbow Trout once they inhabit the pelagic waters of the lake. As a result, Idaho Department of Fish and Game has solicited the help of anglers to record catch and effort data in journals used as a standardized annual monitoring tool to assess the relative abundance and size structure of Rainbow Trout in Lake Pend Oreille. In addition to catch and effort data, anglers also provided pectoral fin rays from Rainbow Trout for use in annual growth analyses. Rust et al. (2018) determined that ages derived from pectoral fin rays sections (non-lethal) were comparable to otoliths for evaluating age and growth parameters. The objectives of this research are to assess Lake Pend Oreille Rainbow Trout catch rates and somatic growth trends and evaluate the impact of kokanee abundance on annual incremental growth.

METHODS

Rainbow Trout pectoral fin rays were collected by anglers during 2011 and 2014-2018. During these years, additional fin rays were opportunistically collected from incidental bycatch during Lake Trout suppression gillnetting efforts. Only samples collected from September through January were utilized in analyses. At capture, total length was recorded to the nearest ¼ inch (6 mm) and pectoral fin rays were non-lethally removed.

Rainbow Trout catch and effort data were recorded by volunteer anglers from 2016 through 2018. When feasible, anglers provided information on daily catch including total hours fished, number of Rainbow Trout caught, and total length and weight of each Rainbow Trout caught. These data were utilized in calculating catch per unit effort (CPUE) in terms of total angling hours and summarizing length frequency of angler catch. Rainbow Trout weight data were not analyzed because available data were limited.

Pectoral fin rays were mounted in epoxy following the method described by Koch and Quist (2007). Multiple cross-sections (0.9 mm thickness) were cut near the proximal end of each fin ray using a low-speed saw. Samples were examined and imaged under magnification and annuli were enumerated by multiple independent readers in order to determine age at capture. Differences in age determination were settled by collaborative re-examination. Age and length at capture were used to develop year-specific von Bertalanffy (1938) growth models. An additive error structure was used in the von Bertalanffy models because graphical examination of the model residuals did not indicate heteroscedasticity. Models were parameterized using the typical parameterization (Beverton and Holt 1957), except for in 2014 where the Francis parameterization (1988) was used due to model convergence failure under the typical parameterization. Following age determination, the distance from the nucleus to each annulus (in units of pixels) was quantified by a single experienced reader. Pixel measurements were converted to individual back-calculated length at age measurements following the Dahl-Lea method (Dahl 1907, Lea 1910).

Back-calculated lengths at age were used in a mixed-effects model with age as a fixed effect and year as a random effect, and year-specific growth intercepts were isolated from this model following the methods of Weisberg et al. (2010). The first two incremental growth measurements representing years while Rainbow Trout reside in lake tributaries were not included in this model. Year-specific growth intercepts were used as a response variable in a simple linear regression with age one through three kokanee abundance as a predictor variable. Age one through three kokanee abundance was specifically selected because individuals within this age range represent the size of kokanee found in the diet of Lake Pend Oreille Rainbow Trout (see Vidergar 2000). Age-specific kokanee abundance was estimated from annual trawl data (see chapter 1).

RESULTS

From 2016 to 2018, annual angler catch rates ranged from 0.28 (±0.03) to 0.45 (±0.04) and the proportion of catch greater than 635 mm has ranged from 17% to 24%. Catch rates were greatest in 2016 and have decreased consistently over the course of the study (Figure 20). However, the proportion of annual catch greater than 635 mm was greatest in 2018 and has increased consistently since 2016 (Figure 21).

From 2011 to 2018, pectoral fin rays were collected from 480 Rainbow Trout ranging in size from 213 mm to 940 mm. Age-at-capture was assigned to 65 individuals in 2018, ranging from age three to age nine. Due to truncated datasets, the asymptotic average length ($L\infty$) and growth rate coefficient (K) parameters from the von Bertalanffy growth models (Figure 22) were determined to not be informative and as such are not reported here. However, predicted mean length at age five and age six was significantly greater in 2018 at 621 mm (LCI: 589 mm, UCI: 655 mm) and 707 mm (LCI: 683 mm, UCI: 729 mm) than in 2011 at 469 mm (LCI: 454 mm, UCI: 487 mm) and 587 mm (LCI: 572 mm, UCI: 604 mm) for age five and age six individuals respectively (Figure 23). Kokanee abundance explains 73% of the variation in Rainbow Trout incremental growth ($p = 0.0017$), with an estimated 9.04 mm (±1.96) increase in incremental growth per one million increase in kokanee abundance (Figure 24).

DISCUSSION

While angler catch rates in 2018 were slightly lower than in previous years, the percent of annual angler catch greater than 635 mm (25 inches) has increased consistently since 2016. This may be indicative of an increase in trophy potential of catch, which is a management objective for Rainbow Trout in Lake Pend Oreille (Idaho Department of Fish and Game 2019). Moreover, predicted mean length for age five and age six individuals has seen a consistent increase over time, substantiating the likely rise in trophy potential for Rainbow Trout in this system. The magnitude of increase in length at age over the course of this study is of particular note, with age five fish in 2016 as large as age six fish were in 2014 (see figure 23).

While the aforementioned angler catch demographics and predicted mean length at age for this population are promising, these metrics are based on Rainbow Trout total length and do not take into account weight information. Fish weight can be an important metric in evaluating trophy potential and condition of fish within a population. In previous years, length-weight ratios have been used to assess the condition of Rainbow Trout in Lake Pend Oreille (Rust et al. 2018, Rust et al. 2019). However, limited sample sizes of weight data in recent years have prevented informative analyses of fish condition. Future analyses of length-weight relationships will provide a more robust indicator of Rainbow Trout trophy potential in Lake Pend Oreille.

Multiple factors such as age, individual specific characteristics (Gjerde 1986), and environmental conditions (Fry 1971, Brett 1979, Sadler and Lynam 1986) can influence yearly somatic growth in fishes. Assessing annual growth using a mixed effects model allows for the influence of these factors on growth to be isolated and evaluated (Weisberg et al. 2010). Therefore, yearly growth specifically attributable to environmental conditions can be assessed. Previous studies have demonstrated the utility in applying this approach to assess factors influencing Salmonid and Catostomid growth (Watkins et al. 2017). We applied this approach to assess the influence of kokanee abundance on annual Rainbow Trout growth and found kokanee abundance explains the majority of variation in this element of growth over the timeframe. This finding indicates that availability of this forage base is an important driver of the quality of the trophy Rainbow Trout fishery in Lake Pend Oreille.

The finding that kokanee abundance explains the majority of the variation in Rainbow Trout growth over the course of this study is not unexpected as kokanee are the main prey source for piscivorous predators in Lake Pend Oreille. Previous research in Kootenay Lake has also shown that kokanee abundance can be an important predictor of Gerrard Rainbow Trout growth (Andrusak and Andrusak 2015). The impact of kokanee abundance on Rainbow Trout growth demonstrated in this study suggests that management actions that promote abundant kokanee will also likely facilitate the goal of providing a trophy Rainbow Trout fishery in the lake. Additional years of incremental growth data will help validate the magnitude of the relationship between kokanee abundance and Rainbow Trout somatic growth.

RECOMMENDATIONS

1. Increase the sample size of Rainbow Trout weight data and assess condition in 2019.

2. Continue to back-calculate growth increments from Rainbow Trout samples collected in future years and validate the relationship between incremental growth and kokanee abundance.

3. Continue to utilize anglers to collect Rainbow Trout fin rays for annual age and growth analyses.

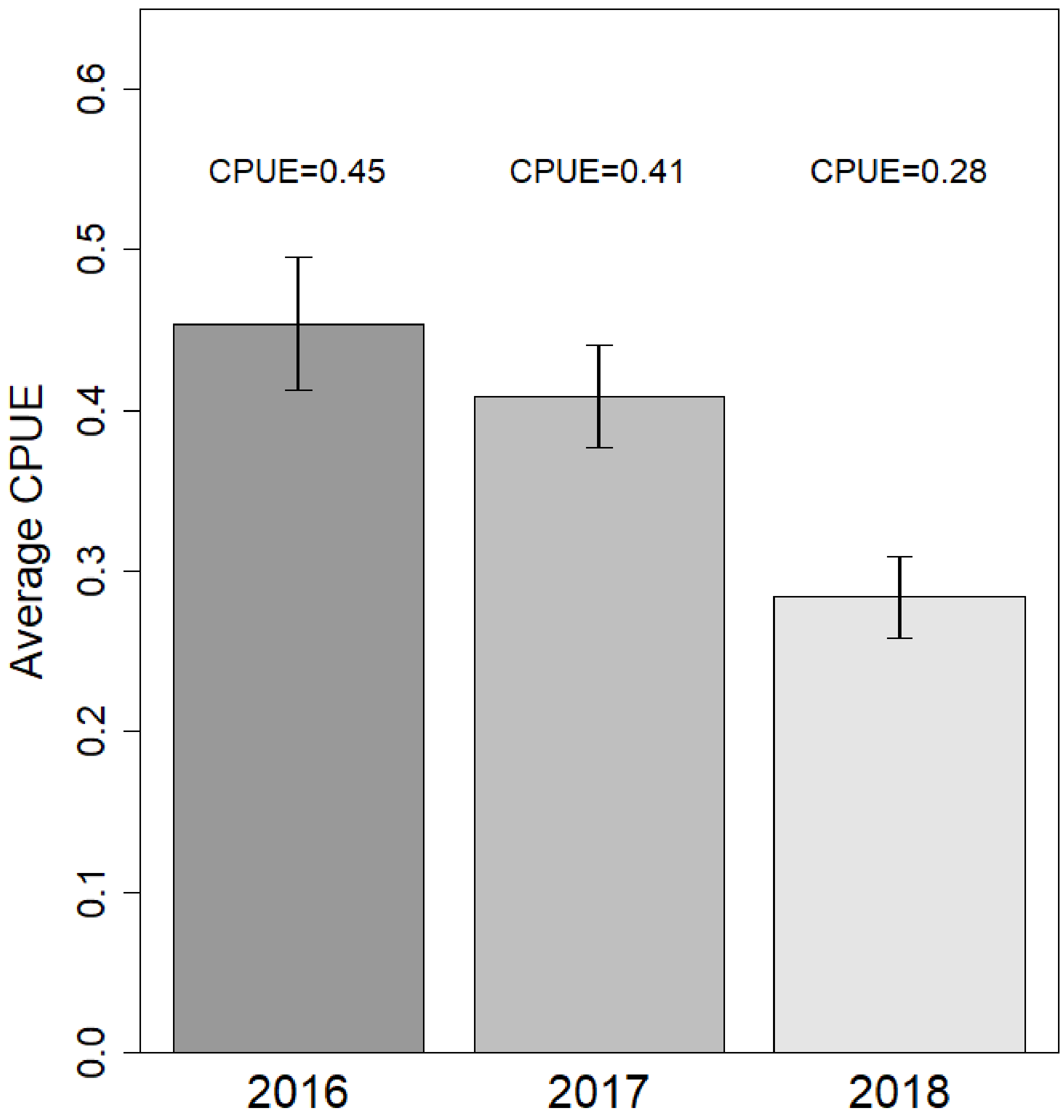

Figure 20. Mean angler catch per unit effort in terms of Rainbow Trout caught per angling hour from 2016 through 2018 in Lake Pend Oreille, Idaho. Error bars denote standard error.

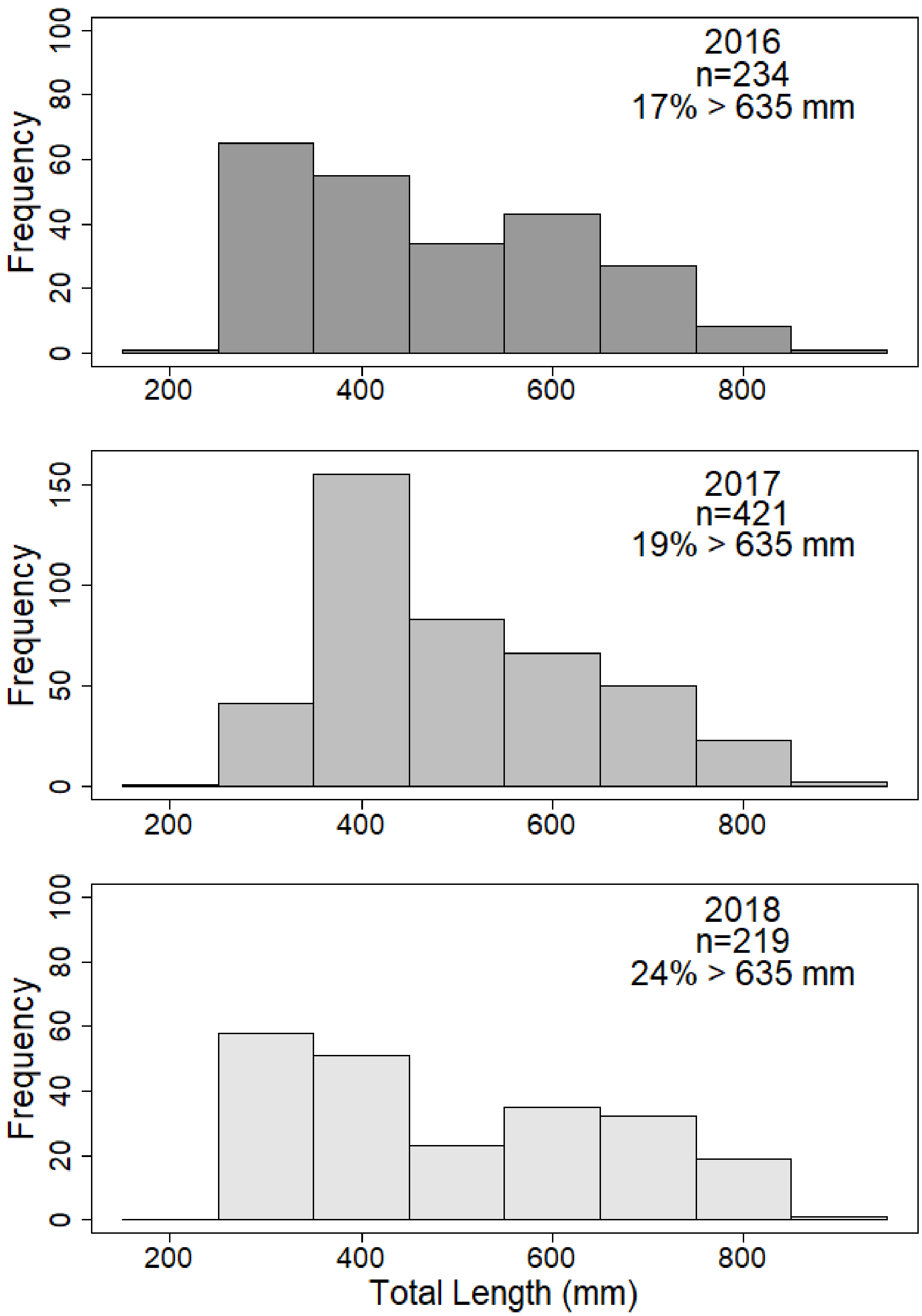

Figure 21. Year-specific length frequency distributions of Rainbow Trout caught via angling from 2016 through 2018 in Lake Pend Oreille, Idaho.

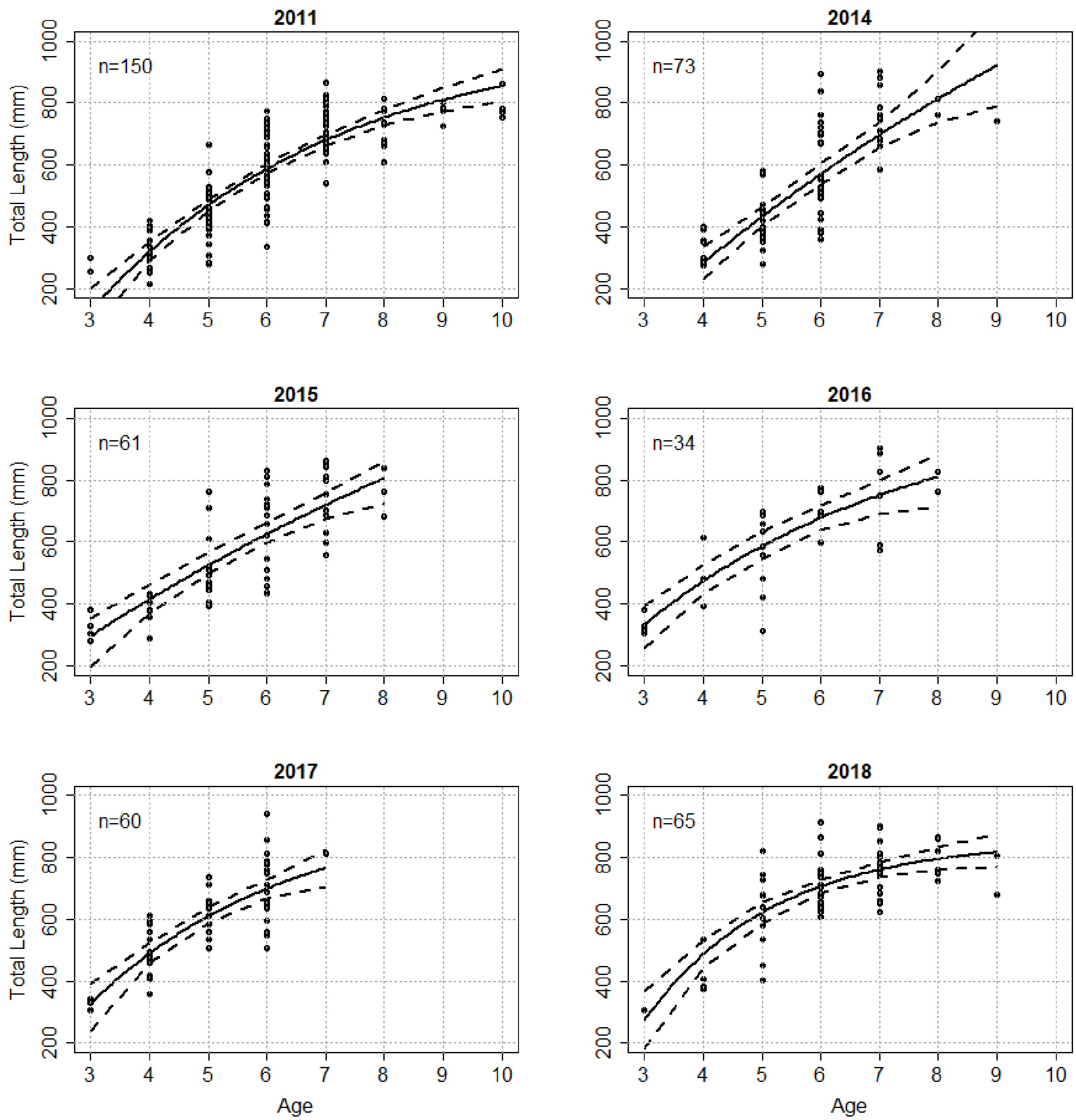

Figure 22. Year-specific von Bertalanffy growth models for Rainbow Trout from 2011 through 2018 in Lake Pend Oreille, Idaho. Dashed lines indicate 95% bootstrapped confidence intervals.

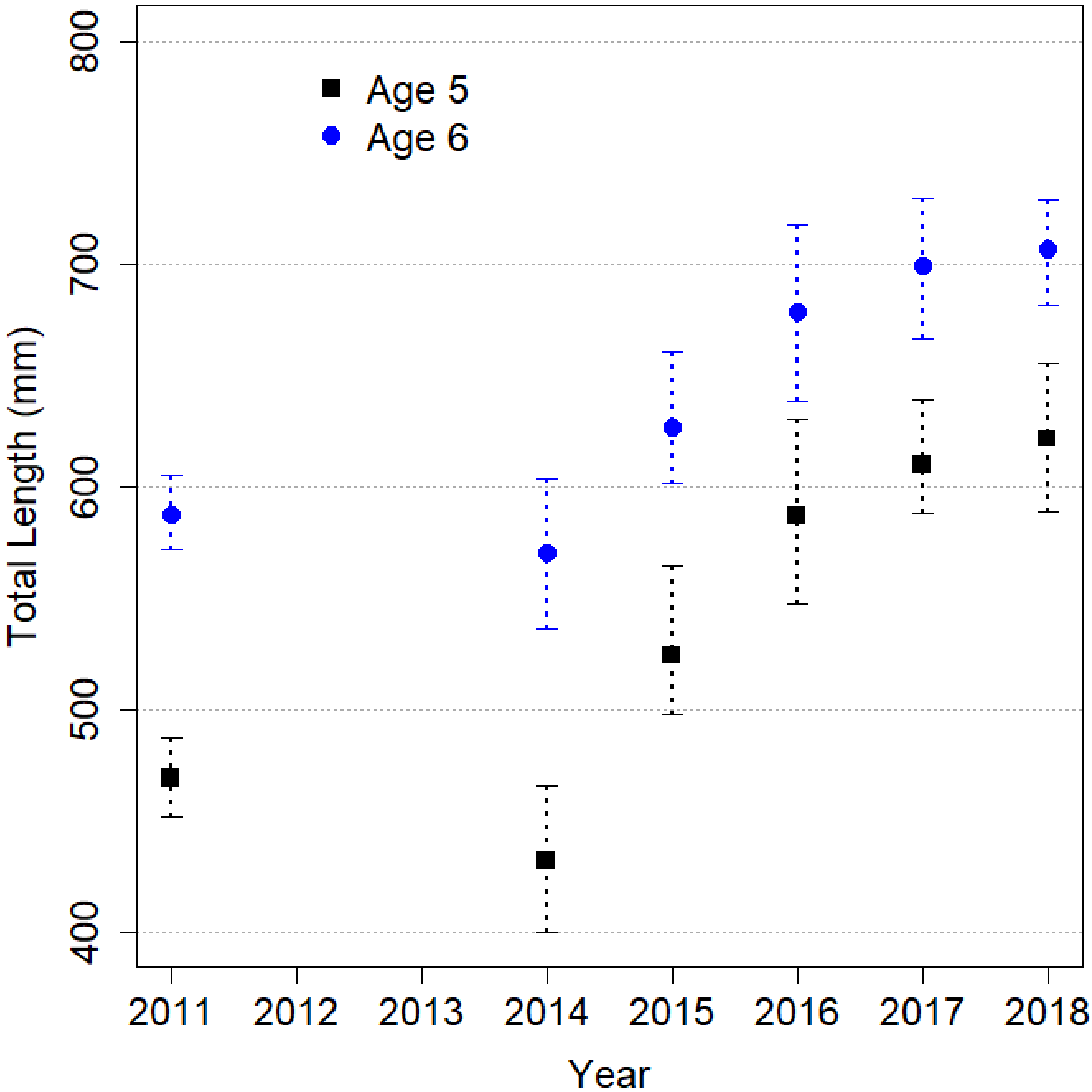

Figure 23. Predicted mean length at age five and six for Rainbow Trout from 2011 through 2018 in Lake Pend Oreille, Idaho. Dashed lines indicate 95% bootstrapped confidence intervals.

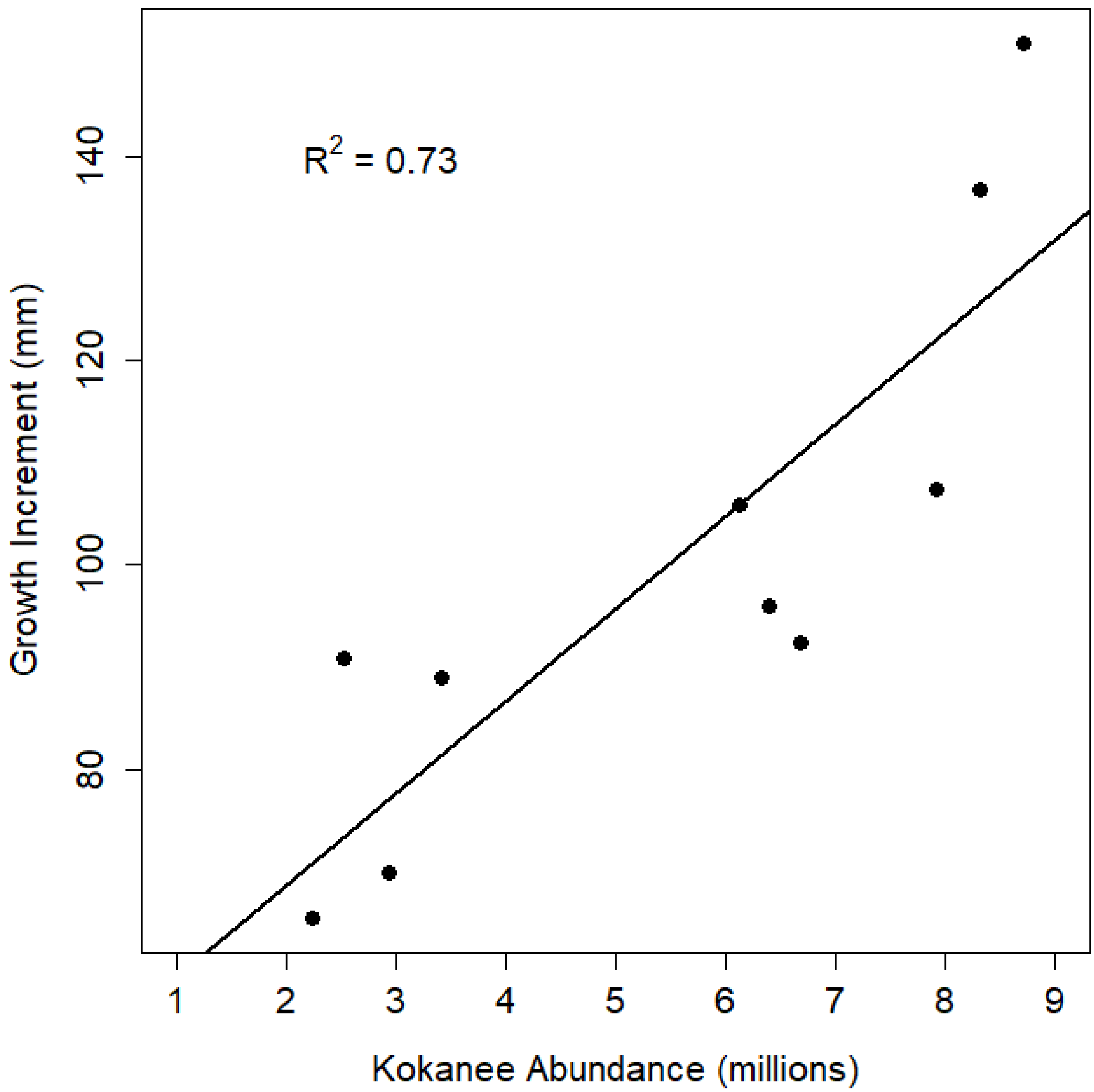

Figure 24. Relationship between kokanee abundance and somatic growth increments (mm) of Rainbow Trout in Lake Pend Oreille, Idaho.

CHAPTER 5: WALLEYE RESEARCH

ABSTRACT

Walleye were illegally introduced into Noxon reservoir, Montana, upriver of Lake Pend Oreille in the early 1990s. Walleye were established in Lake Pend Oreille at low densities by the mid-2000s and their densities have been steadily increasing. Idaho Department of Fish and Game is concerned about the potential for predation from Walleye to negatively impact the Lake Pend Oreille fish assemblage. As such, we have been investigating opportunities to manage the abundance of Walleye. A tagging study initiated in 2017 suggests that Walleye exploitation is currently around 16%, which is similar to other Walleye fisheries in Idaho, but too low to effectively limit Walleye population expansion without other exploitation alternatives. Walleye in Lake Pend Oreille are feeding primarily on kokanee in the deeper parts of the lake and yellow perch and assorted warmwater fish in the shallower areas. We initiated a three-week targeted Walleye suppression netting program in spring 2018 and removed 1,233 Walleyes. This effort will be repeated in 2019 and 2020, and resulting effects on population parameters will be evaluated in fall 2020 with a standardized Fall Walleye Index Netting program. Telemetry studies initiated in 2017 suggest Walleyes primarily use the northern section of the lake and the Clark Fork and Pend Oreille rivers. Walleyes concentrate seasonally near the Clark Fork and Pack river deltas and other shallow warm bays in the northern sections of the lake but widely redistribute throughout the lake during the summer months. Beginning in fall 2018, we began tagging Walleyes with acoustic transmitters and will begin implementing a passive telemetry receiver (in conjunction with Lake Trout research) array to further evaluate Walleye movements and seasonal movement timing throughout the lake-river system. These data will be used to direct anglers to areas where Walleye concentrate, and will help improve netting efficiency for future research studies and management actions.

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INTRODUCTION

Suppression of piscivorous fishes, including Lake Trout and Rainbow Trout, has been the focus of the Lake Pend Oreille fishery recovery since 2006. Previous suppression programs have included incentivized sport harvest of Rainbow Trout (ended in 2013) and Lake Trout (ongoing) as well as commercial scale trap net and gillnet operations targeting Lake Trout. Through previous research, we had established that reduced kokanee productivity, in concert with an over-abundance of upper trophic level predators had created a predator pit that would have likely led to a complete collapse of kokanee in the system (Hansen et al. 2010, Corsi et al. 2019). The predator suppression program has been a major success and the kokanee population has responded positively.

Walleye, which were illegally introduced into Noxon Reservoir approximately 30 years ago, have become well established throughout Noxon and Cabinet Gorge reservoirs. These reservoirs have provided suitable spawning and rearing habitat for Walleye and downstream drift has led to subsequent invasions into the Idaho portion of the Clark Fork River, Lake Pend Oreille, and downstream into the Pend Oreille River. These fish appeared to exist in Lake Pend Oreille and the adjoining rivers at low densities in localized habitats. Over the last three years, catch per unit effort of Walleye collected as by-catch from gillnetting efforts focused on Lake Trout suppression has nearly doubled, and densities are increasing throughout the northern and southern basins of the lake. Walleye catch rates during targeted Walleye monitoring efforts (fall Walleye index netting, FWIN) conducted by IDFG Fisheries Management staff in 2011, 2014, and 2017 suggest that densities are doubling about every three years.

An expanding Walleye population has the potential to put several fish populations in Lake Pend Oreille at risk through direct predation and competition. Walleye are obligate piscivores and their establishment in other western lentic systems has led to significant fishery management challenges, particularly where they overlap with salmonid fisheries (MFWP 2016). Lake Pend Oreille represents a critical stronghold for Bull Trout within their native range. Cutthroat Trout populations in Lake Pend Oreille are depressed relative to historic abundances, but they appear to be reasonably ubiquitous, thus providing some diversity to the sport fishery as well as life history diversity and conservation value. Rainbow Trout provide a popular world-class trophy fishery that largely depends on abundant kokanee for forage. Kokanee provide a popular yield fishery on the lake and represent a forage base for adfluvial Bull Trout.

Lake Trout suppression programs were instituted to reduce predation risk when rapid population increases were observed. Should Walleye abundances continue to increase and the scope of their niche expand to include ecologically significant predation on kokanee, Cutthroat Trout, and juvenile Bull Trout and Rainbow Trout, some of the conservation advancement made through previous suppression programs may be jeopardized. This project proposes to establish fundamental information to help us assess the status of the Walleye population, to evaluate the opportunities for management actions (suppression), and estimate the likely scope of their influence on the current fish community in the Pend Oreille system. We will accomplish this by implementing a test fishery approach that increases the scope and resolution of current management tools. We will implement a strategic acoustic telemetry program that will allow us to evaluate the number, location, and spatial extent of spawning aggregations, and we will then attempt to target one or several aggregations using commercial gill net gear to collect biological data and assess our fishing power. Finally, we will continue to evaluate Walleye diet and trophic status in order to determine the scope of their predator interactions. There will be synergy among these approaches that will improve their success. For example, identification of spawning aggregations will not only help clarify opportunities for suppression, but will facilitate our understanding of current distribution and life history of Walleye in Lake Pend Oreille.

Ultimately, this information will be used to establish tolerable management thresholds for Walleye densities and help identify a range of potential management options. Given burgeoning Walleye populations have a track record of negative fishery consequences in western waters, we will be focusing this project on the efficacy of suppression tools, including physical removal and use of emerging suppression technologies including Trojan Y-chromosome hatchery fish (e.g. Schill et al. 2016).

METHODS

Exploitation

Walleyes were collected on Lake Pend Oreille with gill nets by Hickey Brothers Research LLC from winter 2016 to spring 2017 and tagged with FD-94 T-bar anchor tag (76 mm; Floy Tag Inc., Seattle Washington, USA). We attempted to spread the tagging throughout the lake and rivers as much as possible and additional tagging events occurred in the Clark Fork River by both IDFG personnel and by AVISTA during unique annual trout monitoring events. Each fish was measured for total length (TL) and tagged near the posterior end of the dorsal fin prior to release. Minimum tagging size was 400 mm, based on angler interest. All tags also possessed the telephone number and web address for IDFG's "Tag! You're It!" reporting hotline. Approximately 10% of the fish were double tagged to estimate tag loss (Miranda et al. 2002) and tag loss (*Tag* l) was calculated from angler returns as the proportion of double tagged fish that lost or retained tags (Muoneke 1992). To estimate reporting rate, tags were either nonreward or $50 reward (Meyer and Schill 2014). Reporting rate (λ) was estimated as the ratio of nonreward tags returned relative to that of high-reward tags returned (Pollock et al. 2001). Angler exploitation was estimated using the nonreward tag reporting estimator described by Meyer et al. (2012), namely,

$$u' = \frac{\mathrm{u}}{\lambda(1 - Tag_l)(1 - Tag_m)}$$

where µ' is the adjusted angler exploitation rate, µ is the unadjusted exploitation rate (i.e., number of fish reported divided by the number of fish tagged). Annual angler exploitation rate was estimated from fish that were one year at-large between May 1, 2017 and May 1, 2018.

Stomach Content Analysis

To evaluate Walleye food habits, Walleye stomachs were collected during three distinct sampling events in 2016 and 2017. In fall 2016, Walleye stomachs were removed from individuals opportunistically caught during Lake Trout suppression spawner netting. In spring 2017, Walleye stomachs were removed from individuals opportunistically caught during Lake Trout nursery netting. In fall 2017, Walleye stomachs were removed from Walleyes targeted during Fall Walleye Index Netting (FWIN) performed by IDFG Fish Management staff. The three sampling events encompassed three sampling seasons and two distinct habitat types (Table 11). The fall 2017 and spring 2017 sampling occurred in the main basin of the lake, primarily along the shoreline in deep water >30 m from the mid-point in the lake directly south of the Sunnyside area extending along the deep shorelines around the Islands, south to Scenic bay (Appendix A1–A3). The samples collected during the fall 2017 FWIN were primarily in littoral habitats, with relatively shallow water <15 m, near more traditional Walleye habitats near the Clark Fork River delta, westward including the shallow northern bays and down into the Pend Oreille River (Table 11). Our main objective was to determine relative abundance of kokanee in the Walleye stomachs over three distinct spatial and temporal scales.

Stomachs were removed using a scalpel or scissors, and stored in denatured alcohol. Contents were enumerated and identified to the lowest possible taxonomic grouping.

Suppression Netting

To evaluate the feasibility of gill netting as a tool to control Walleye expansion, Hickey Brothers Research LLC was contracted to gill net for three weeks between April 16 and May 4, 2018. Netting effort was focused in areas where concentrations of Walleye were identified from previous telemetry research. Netters used short duration (4-5 hour) gill net sets to target and remove Walleye, while minimizing incidental mortality on other species. Methods are generally similar to those used in Lake Trout suppression netting efforts, which are discussed in detail in Chapter 2 of this report.

Telemetry Research

To begin understanding general Walleye movements and their basic biology in Lake Pend Oreille, we initiated a telemetry study in 2017. We surgically implanted Combined Acoustic and Radio Transmitters (CART, model MM-MC-11-28-TP, Radio Frequency 150.380, Lotek Wireless Inc., Newmarket, Ontario) equipped with temperature and depth (effective to 100 m) sensors into the abdomen. Walleye were anesthetized with 30 mg/L of Aqui-S (AquaTactics Fish Health, Kirkland, WA). Transmitters were inserted through a 4.5 cm incision just off the centerline of the ventral side of the abdomen anterior to the pelvic fins and pushed back to sit on the pelvic girdle. Incisions were closed with non-absorbable sutures. Walleyes were captured using electrofishing, angling, and as bycatch during Lake Trout suppression efforts by Hickey Brothers, LLC. To ensure sexual maturity, we tagged only Walleye that were greater than 400 mm.

RESULTS

Exploitation

We tagged a total of 466 Walleye with T-bar anchor tags during multiple tagging events in 2017 (Table 12). Walleye tagged during winter 2017 were primarily collected by Hickey Brothers Research LLC during Lake Trout netting efforts in the main basin of the lake (see Chapter 2). Walleye tagged in the Clark Fork River were collected during salmonid sampling by AVISTA personnel throughout the year and by IDFG management personnel during spring annual salmonid monitoring (Table 12). Walleye tagged during the targeted sampling effort by Hickey Brothers Research LLC were tagged primarily in the north basin of the lake in shallower areas presumed to be more traditional Walleye staging or spawning habitats (Table 11, Appendix A1–A3). Length of Walleye captured during the targeted netting by Hickey Brothers Research LLC (April 3–14) ranged from 201 to 771 mm and averaged 462.8 mm (Figure 20). Sex was not determined.

Walleyes were collected and tagged from all three sampling types. Anderson Point and Martin Bay had high catch during winter, the Clark Fork River had high catch rates throughout April, and during the targeted Walleye netting, the Pack River and Sunnyside areas provided many individuals for tagging in mid-April (Table 13).

Anglers reported catching 35 non-reward and five reward tagged Walleyes between May 1, 2017 and May 1, 2018 (Table 14). Angler reported catch locations generally corresponded to tagging locations, and fish were reportedly caught primarily in the Clark Fork River and in the northwest basin from the Pack River west to the Sandpoint long bridge area. We estimated adjusted annual exploitation at 16% (Table 14).

Stomach Content Analysis

Seventy of the 99 stomachs (71%) analyzed from the fall 2016 sampling contained at least some items (Table 11, Figure 21). Sixty-six (94%) of the stomachs with items contained fish, and of those fish that could be identified, 24 (36%) were kokanee (Figure 21). During the spring 2017 netting, 30 of the 106 stomachs (28%) contained food items (Table 11, Figure 22). Sixteen (53%) of the 30 stomachs contained fish, and 41% of the fish were identified as kokanee. Thirteen of the 30 (43%) stomachs analyzed contained mysids (Figure 22). During the fall 2017 FWIN sampling, 93 of the 135 (69%) stomachs contained food items (Table 11, Figure 23). Sixty-eight of the 93 (73%) stomachs contained at least some fish, of which 13% were identified as kokanee (Figure 23). Yellow perch and other warmwater fish were common in the stomachs during the FWIN sampling (Figure 23).

Suppression Netting

We sampled eight sites in 2018 and collected a total of 1,284 Walleye, 1,233 of which were removed (Table 15). Walleyes were distributed among most of the sampling sites, but the highest catch rates came from the Pack River delta, the area north of the Sandpoint railroad bridge, and the Clark Fork delta (Table 13). Incidental mortality on Bull Trout and other non-target species was low (Table 15). Length of female Walleyes sampled ranged from 435 mm to 775 mm and averaged 561 mm, while males ranged from 365 mm to 690 mm and averaged 467 mm (Figure 24). Over 1,050 Walleye, Lake Trout, and Northern Pike were brought to either the Bonner County Food Bank in Sandpoint or the ABC Food Bank (Athol Gleaners) in Athol for distribution to those in need.

Telemetry Research

Twenty-one Walleye between 435 and 740 mm were implanted with Lotek CART tags (Appendix C). Tagging occurred between October 8 and October 31, 2017 at four locations within the Clark Fork River, Lake Pend Oreille, and in the Pend Oreille River (Appendix C). Tags activated in March 2018 and we located Walleye a total of 188 times between April 9 and September 7, 2018. Using fixed wing aircraft, we flew 12 flights between April 20 and August 28 and located Walleyes 115 times, but were only able to determine specific codes from 13 Walleyes. We tracked by boat 33 days between April 9 and September 7, 2018. Walleyes were located 72 times and 18 of the 21 tagged Walleyes were located during boat tracking.

The depth sensor on each telemetry tag allowed us to determine how deep the fish were in the water column and lake depth at each location was also measured. Walleyes were shallowest during April and deepest during May and were located at or near the shallowest lake depths in April and the deepest in May (Table 16). Fish depth use and measured lake depth use at each location varied greatly among and within each month (Table 16).

Walleyes were located primarily in the northern section of the lake, and only a few individual fish were found south of Garfield Bay and only on a few occasions during 2018 (Figure

25). In general, Walleyes were concentrated near the Clark Fork River delta, the Pack River delta, and the Sandpoint Longbridge area, but many of these concentrations were seasonal (Figure 25). Monthly Walleye habitat use was variable and while Walleyes concentrated or staged in specific areas during April, May, and early June, their distribution was more scattered later in the summer (Figure 25).

DISCUSSION

Walleye exploitation rates averaged 16%, which is about average compared to other Walleye fisheries in Idaho (Meyer and Schill 2014). Although Walleye have only been in the system since about the mid-2000s, anglers are targeting them, and learning how to catch them. From the exploitation tags survey questionnaire, anglers reported catching Walleyes primarily from the Clark Fork River and the Highway 95 (Sandpoint long-bridge) areas. These areas have been popular with Walleye anglers since at least 2010.

Walleye stomach content analyses to date have provided a snapshot into Walleye food habits in Lake Pend Oreille. From the three datasets, the frequency of occurrence of food items appears dependent on food availability. From the fall 2016 and spring 2017 datasets where Walleyes were collected primarily in the main basin of the lake in deep water during Lake Trout netting, kokanee appeared to be the most important food item. This is not surprising since these areas are primarily kokanee habitat, and few other fish are available as a prey source. Data from the 2017 FWIN, which occurs in shallower, littoral habitats, suggested that yellow perch and other warmwater fish (Black crappie, Pumpkinseed sunfish, Peamouth, and Northern Pike Minnow) were the most frequent in stomach. Although warmwater fish were found most frequently in stomachs from these areas, kokanee were still an important component. Some of the FWIN nets were set near drop-offs, where the littoral zones quickly change to pelagic zones, areas where kokanee are more common. Walleye stomachs collected from these transition areas contained warmwater fish and kokanee.

The spring 2017 two-week Walleye netting effort was our first concerted effort to target and tag Walleyes. Results from that sampling effort along with results from 2018 telemetry studies provided a good foundation for where to target Walleyes during the spring 2018 three-week targeted suppression effort. At this point, we have identified three prespawn staging areas at the Clark Fork and Pack River deltas, above the Burlington Northern Railroad Bridge near Sandpoint. We plan to continue spring Walleye suppression netting for three weeks in 2019 and 2020, and population level effects on density and size structure will be evaluated in fall 2020 with a standardized Fall Walleye Index Netting (FWIN). This FWIN netting has been completed on a three-year rotation beginning in 2011 and is our main tool for tracking system-wide density changes in this Walleye population. Based on results of the previous FWIN surveys, the density has been steadily increasing and doubling about every three years since 2011. The basis for our concerns for this new Walleye population to expand and have negative effects on kokanee and potentially other focal species comes primarily from the FWIN density metrics. After the 2020 FWIN, we will reevaluate the effectiveness of relatively small-scale Walleye suppression netting and consider other management actions.

Telemetry studies initiated in 2017 suggest Walleyes primarily use the northern section of the lake and the Clark Fork and Pend Oreille rivers. Walleyes concentrate seasonally near the Clark Fork and Pack river deltas and other shallow warm bays in the northern sections of the lake but widely redistribute throughout the lake and rivers during the summer months, making it difficult to consistently locate Walleyes seasonally using active telemetry techniques. Generally, Walleyes were shallowest in the water column over the shallowest lake depths in April. Conversely, Walleyes were deepest in the water column over the deepest lake depths in May, but depth use varied considerably within and among months. Some Walleyes likely suspend in response to kokanee behavior (kokanee layer) after the thermocline forms in June. Evaluating such relationships would shed some light on potential pelagic feeding behavior of Walleyes in Lake Pend Oreille, but this detail was beyond the scope of this telemetry research. Beginning in fall 2018, we began tagging Walleyes with acoustic transmitters and will begin implementing a passive telemetry receiver array to further evaluate Walleye movements and seasonal movement timing throughout the lake-river system. These data will be used to direct anglers to areas where Walleye concentrate, and will help improve netting efficiency for future research studies or management actions.

Table 11. Walleye stomach content analysis from three distinct netting efforts in 2016 and 2017.

Sampling Period/Event	Site info	No. stomachs analyzed	No. Items	No. Fish	No. KOK	No. UNID	No. Mysids
Fall 2016	Deep, mostly >30 m, main basin	99	70	66	24	53	2
Spring 2017	Deep mostly >30 m, main basin	106	30	16	7	8	13
FWIN 2017*	Shallow, <15 m, littoral habitat	135	93	68	9	22	0

* FWIN refers to Fall Walleye Index Netting completed by Region 1 Fish Management in October 2017.

Table 12. Location and number of T-bar anchor tags deployed for Walleye in Lake Pend Oreille, 2016 and 2017.

Tagging location	Number of fish tagged	Sampling frequency	Tagging event type
Anderson Point	54	2	LKT suppression netting (Jan – Feb)
Bottle Bay	3	1	WAE targeted netting (April 3 – 14)
Cabinet Gorge dam tailwater	69	15	AVISTA or IDFG annual monitoring*
Garfield Bay	2	2	WAE targeted netting (April 3 – 14)
Idlewilde Bay	2	1	WAE targeted netting (April 3 – 14)
Long beach	1	1	WAE targeted netting (April 3 – 14)
Martin Bay	49	2	LKT suppression netting (Jan – Feb)
Memaloose Island	4	1	WAE targeted netting (April 3 – 14)
Owens Bay	8	1	WAE targeted netting (April 3 – 14)
Pack River	151	2	WAE targeted netting (April 3 – 14)
Sandpoint - above RR bridge	29	1	WAE targeted netting (April 3 – 14)
Sheepherder Point	20	2	WAE targeted netting (April 3 – 14)
Sourdough Point	3	1	WAE targeted netting (April 3 – 14)
Sunnyside	66	2	WAE targeted netting (April 3 – 14)
Trestle Creek	4	1	WAE targeted netting (April 3 – 14)
Warren Island	1	1	LKT suppression netting (Jan – Feb)
Total	466	36	

*Sampling occurred primarily in April, with additional fall sampling

Table 13. Walleye catch rates (Walleyes per 900 ft. of net) by location from spring 2017 and 2018 targeted Walleye netting.

Sampling Location	**2017**		**2018**	
	Number	**CPUE**	**Number**	**CPUE**
Bottle Bay	3	0.5	0	0.0
Clark Fork delta			80	6.7
Ellisport Bay	8	2.0	6	0.5
Garfield Bay	1	0.1		
Idlewilde Bay	1	0.1		
Kootenai Point			44	3.7
Lees Point	0	0.0		
Long Beach Southward	2	0.3		
Martin Bay			1	0.8
Memaloose Island	4	0.7		
Owens Bay	13	2.2		
Pack River delta	189	9.5	975	11.6
Sandpoint - north of RR bridge	61	5.1	147	16.3
Sheepherder Point	16	3.2		
Sheepherder to Denton	25	4.2		
Sourdough Point	3	0.5		
Sunnyside	93	7.8	31	2.6
Total	466		1284	

Table 14. Exploitation data for Walleye tagged (T-bar anchor tags) and returned by anglers for 2017.

Walleye Exploitation Data	
Number non-reward released	434
Number high reward released	32
Number non-reward reported	35
Number high reward reported	5
Number double tagged released	20
Number double tagged reported single tagged	1
Number of double tagged fish reported	3
Reporting rate	0.516
Tag loss	0.005
U (uncorrected) - Rr/Rt	0.078
U' (corrected)	0.157

Table 15. Species caught and numbers removed in gillnets during spring 2018 Walleye netting. Fifty-one Walleyes were released after being coded wire tagged for an angler incentive program. Asterisk indicated fish that were dead at the time of capture.

Species	Number Caught	Number Released	Number Removed
Black Crappie	10	10	0
Bull Trout	59	32	27
Brown Trout	31	19	12*
Cutthroat hybrid	2	2	0
Lake Trout	36	0	36
Largemouth Bass	1	1	0
Northern Pike	33	0	33
Rainbow Trout	15	13	2*
Smallmouth Bass	452	452	0
Walleye	1284	51	1233
Westslope Cutthroat Trout	38	32	6*
Yellow Perch	39	39	0

Table 16. Mean monthly fish depth, lake depth, and surface temperature of Walleyes located during active tracking in 2018, Lake Pend Oreille, Idaho.

Month	Average Fish depth (m)	Average Measure depth (m)	Average Surface Temperature ©
April	3.9 (Range 0 - 8.4)	9.8 (Range 3.0 - 18.6)	4.7 (Range 3.6 - 6.8)
May	6.4 (Range 0.7 - 21.1)	18.3 (Range 5.2 - 70.0)	8.3 (Range 3.6 - 12.4)
June	5.9 (Range 0.5 - 21.0)	11.2 (Range 1.5 - 35)	12.3 (Range 3.6 - 16.4)
July	5.1 (Range 0.5 - 21.0)	12.6 (Range 2.0 - 26.5)	15.6 (3.6 - 22.8)
August	4.3 (Range 0 - 21.1)	15.5 (Range 2.0 - 41.0)	16.0 (Range 3.6 - 22.0)

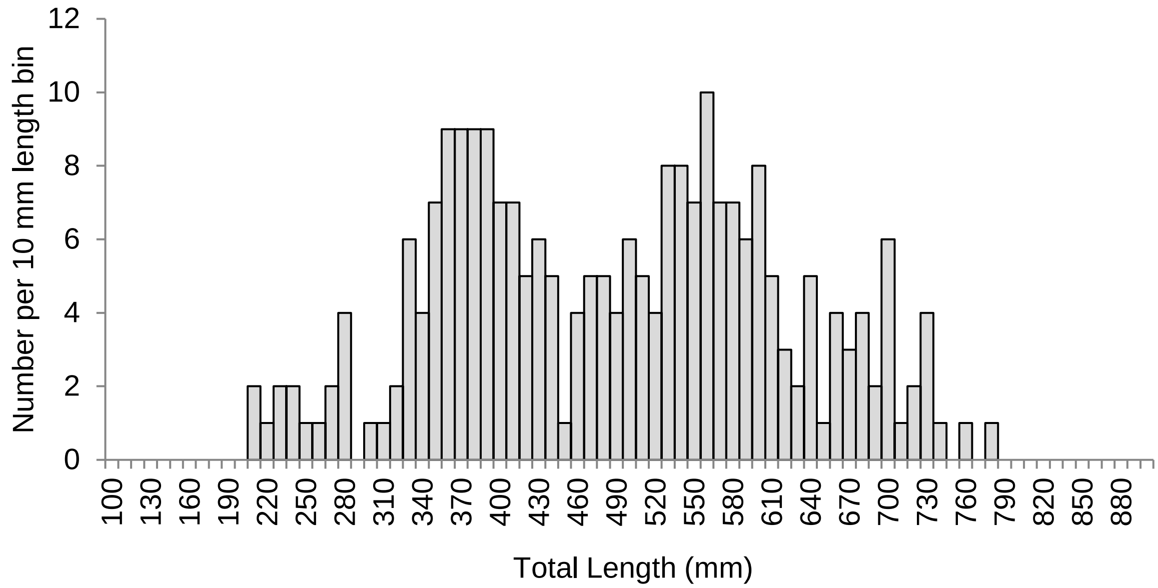

Figure 25. Length-frequency histogram for Walleye captured and T-bar anchor tagged during target Walleye netting by Hickey Brothers Research LLC with gill nets from April 3 – April 14, 2017, Lake Pend Oreille, Idaho.

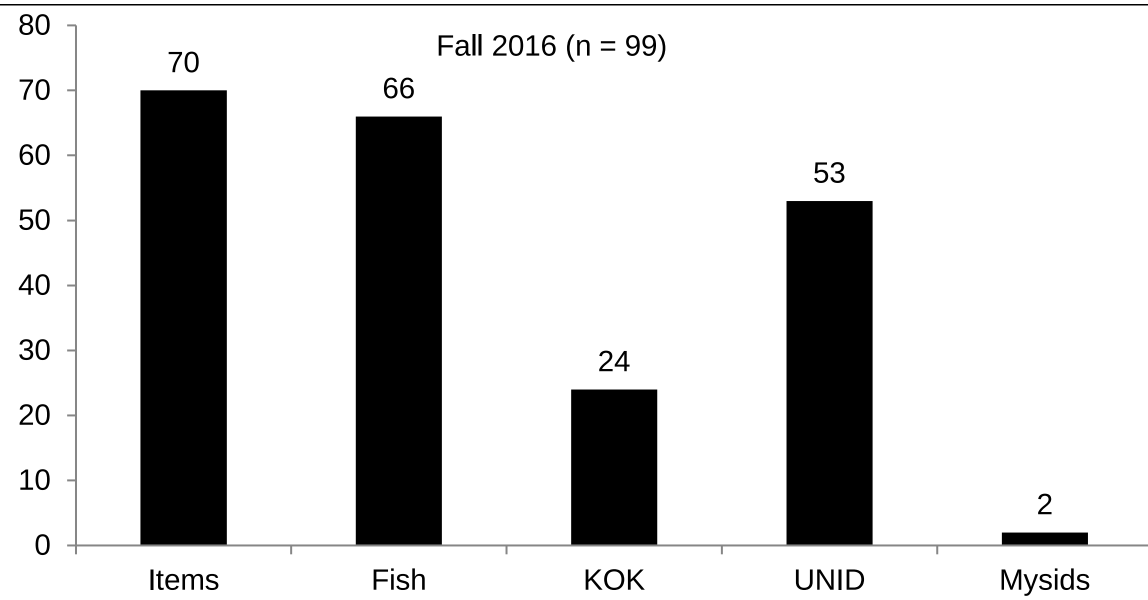

Figure 26. Stomach content analysis from Walleye collected as by-catch during fall 2016 Lake Trout suppression netting efforts.

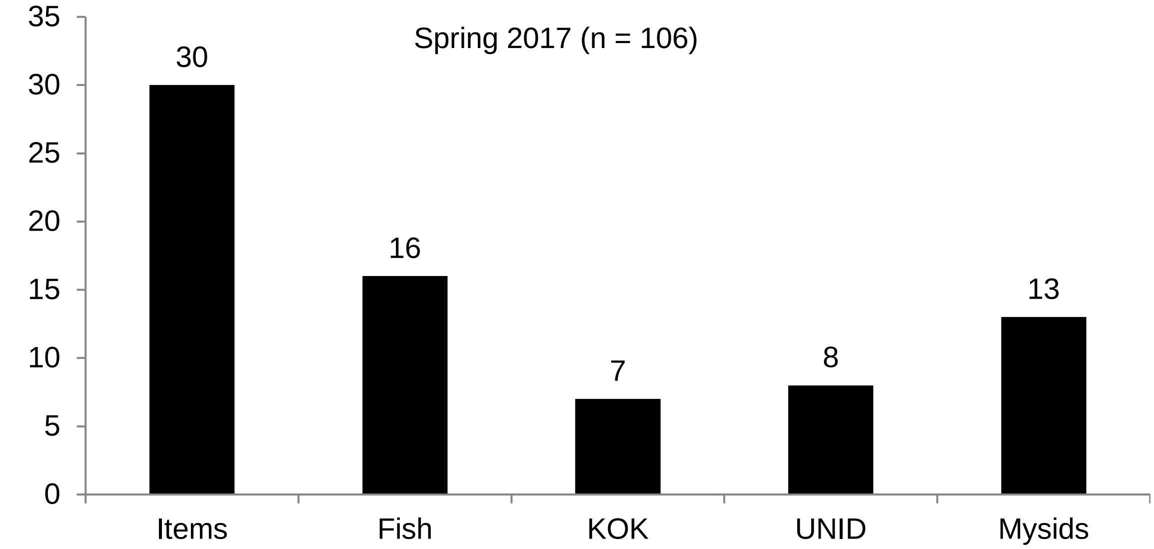

Figure 27. Stomach content analysis from Walleye collected as by-catch during spring 2017 Lake Trout suppression netting efforts.

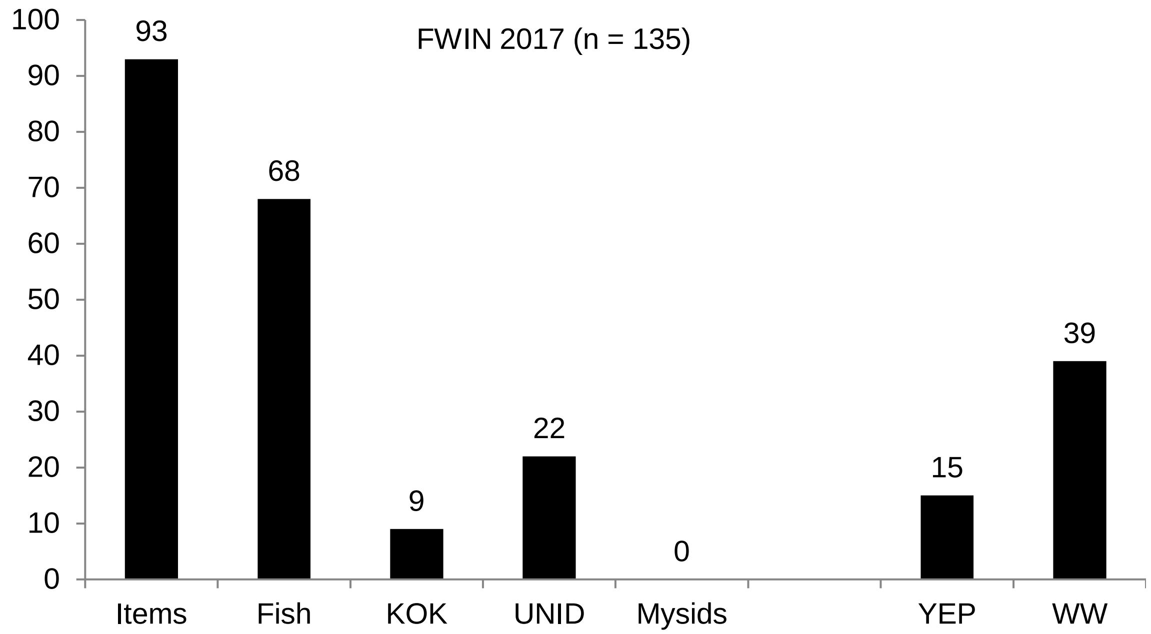

Figure 28. Stomach content analysis from Walleye targeted during 2017 Fall Walleye Index Netting conducted by Region 1 Fish management staff.

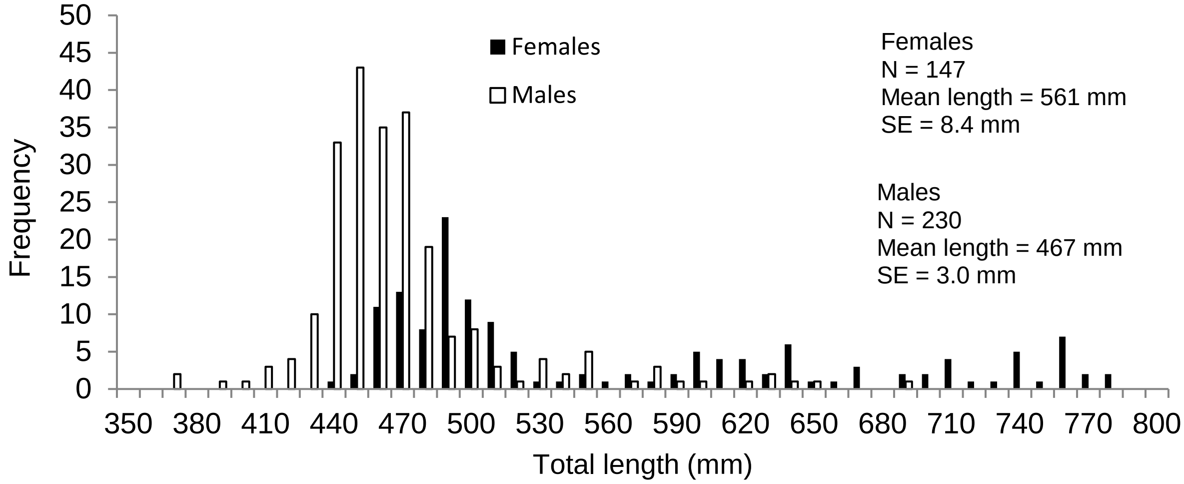

Figure 29. Length-frequency histogram of male and female Walleye captured and removed during targeted suppression netting by Hickey Brothers research LLC with gill nets from April 16 –May 5, 2018, Lake Pend Oreille, Idaho.

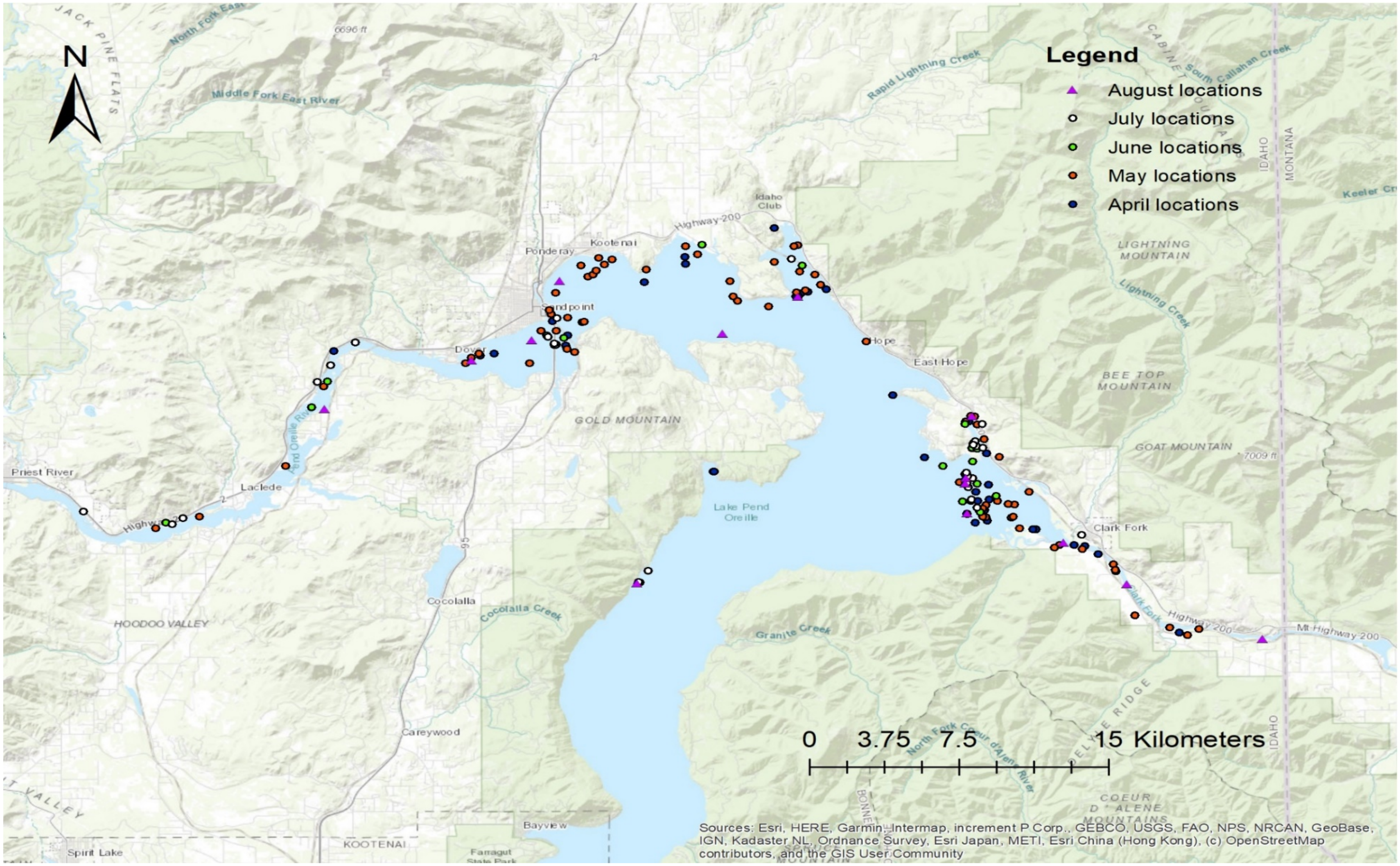

Figure 30. Monthly locations of Walleye tagged with combined radio/sonic (CART) tags in 2018.

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

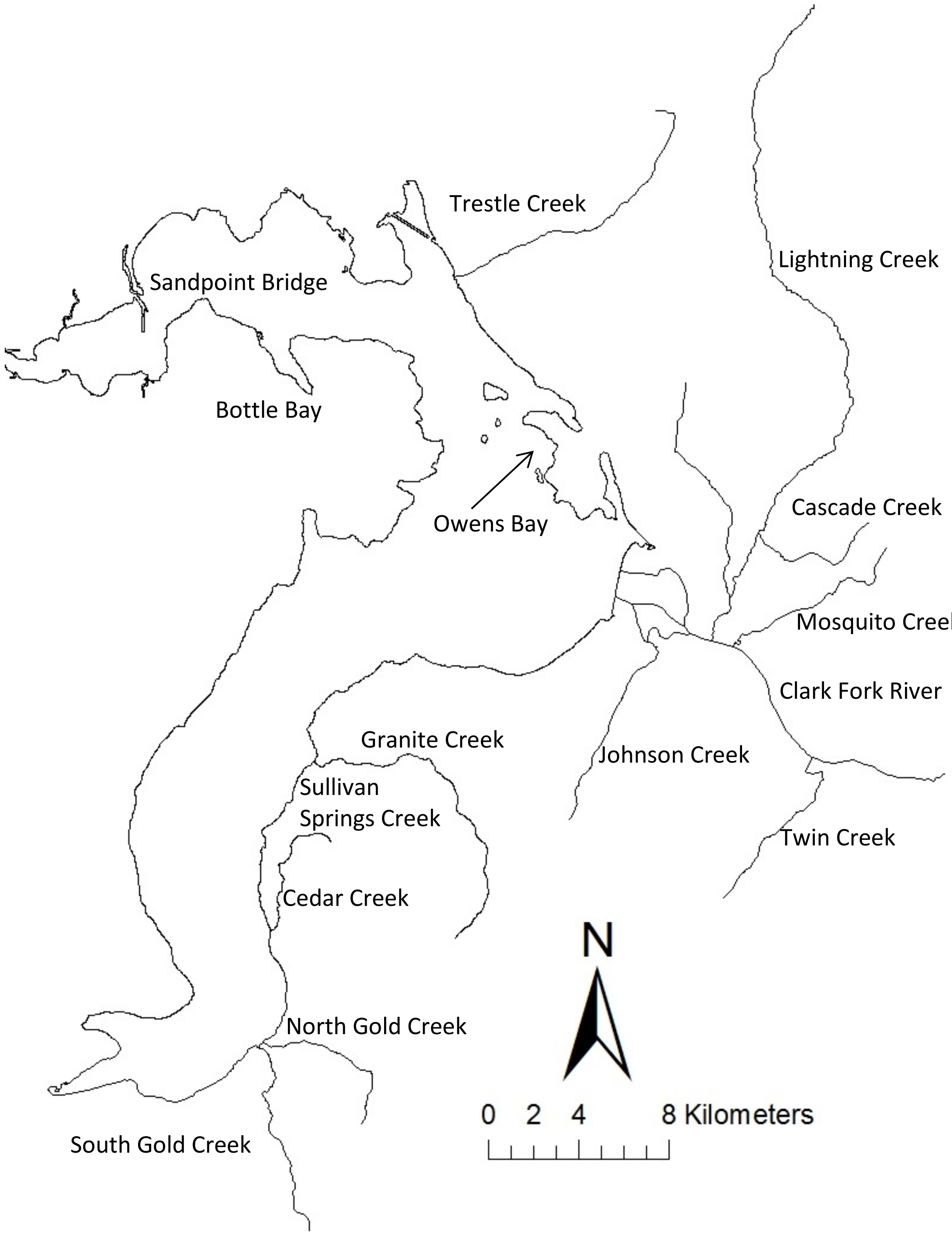

Figure A1. Map of Lake Pend Oreille showing tributaries.

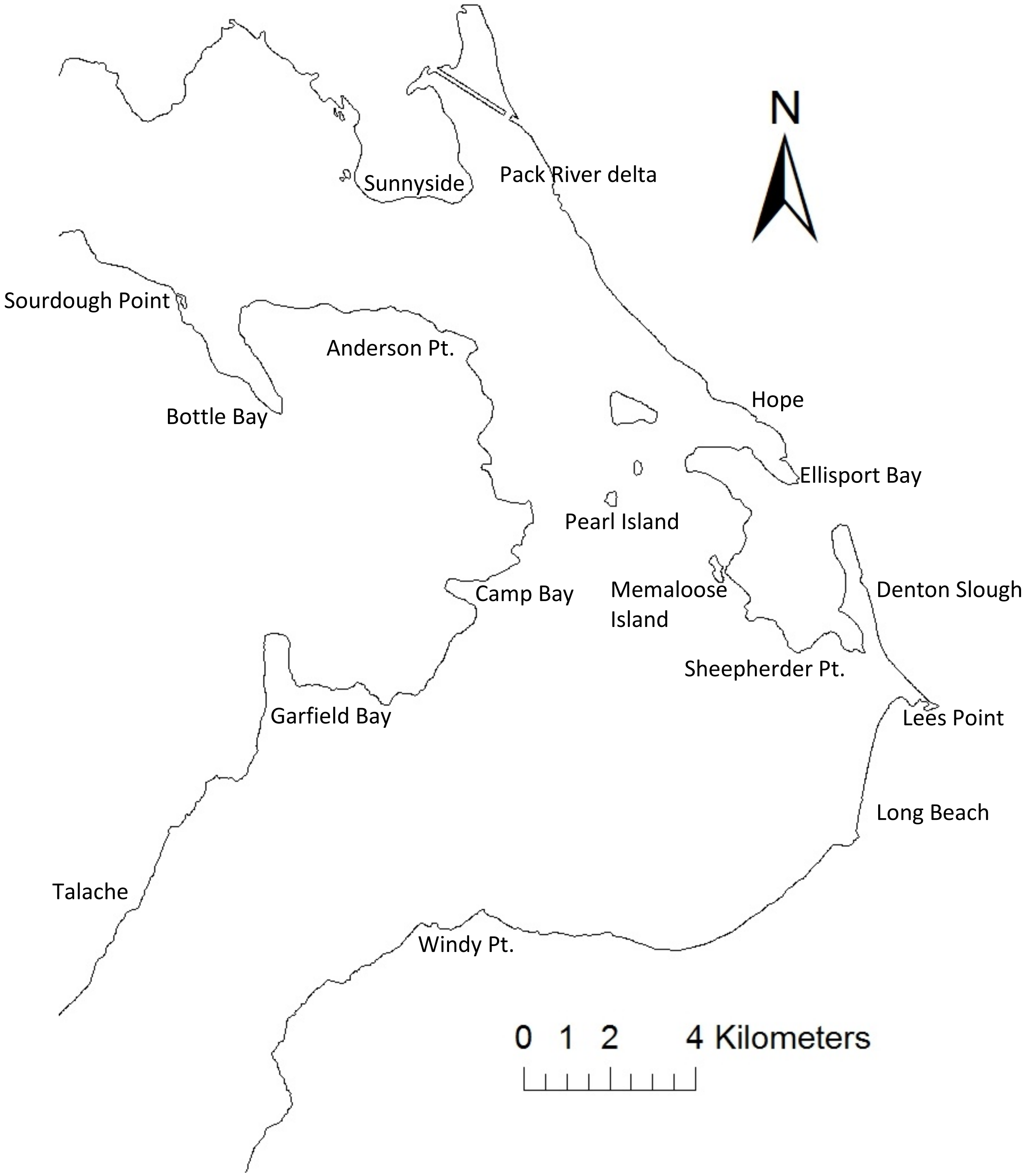

Figure A2. Map of the north half of Lake Pend Oreille showing major landmarks on the lake.

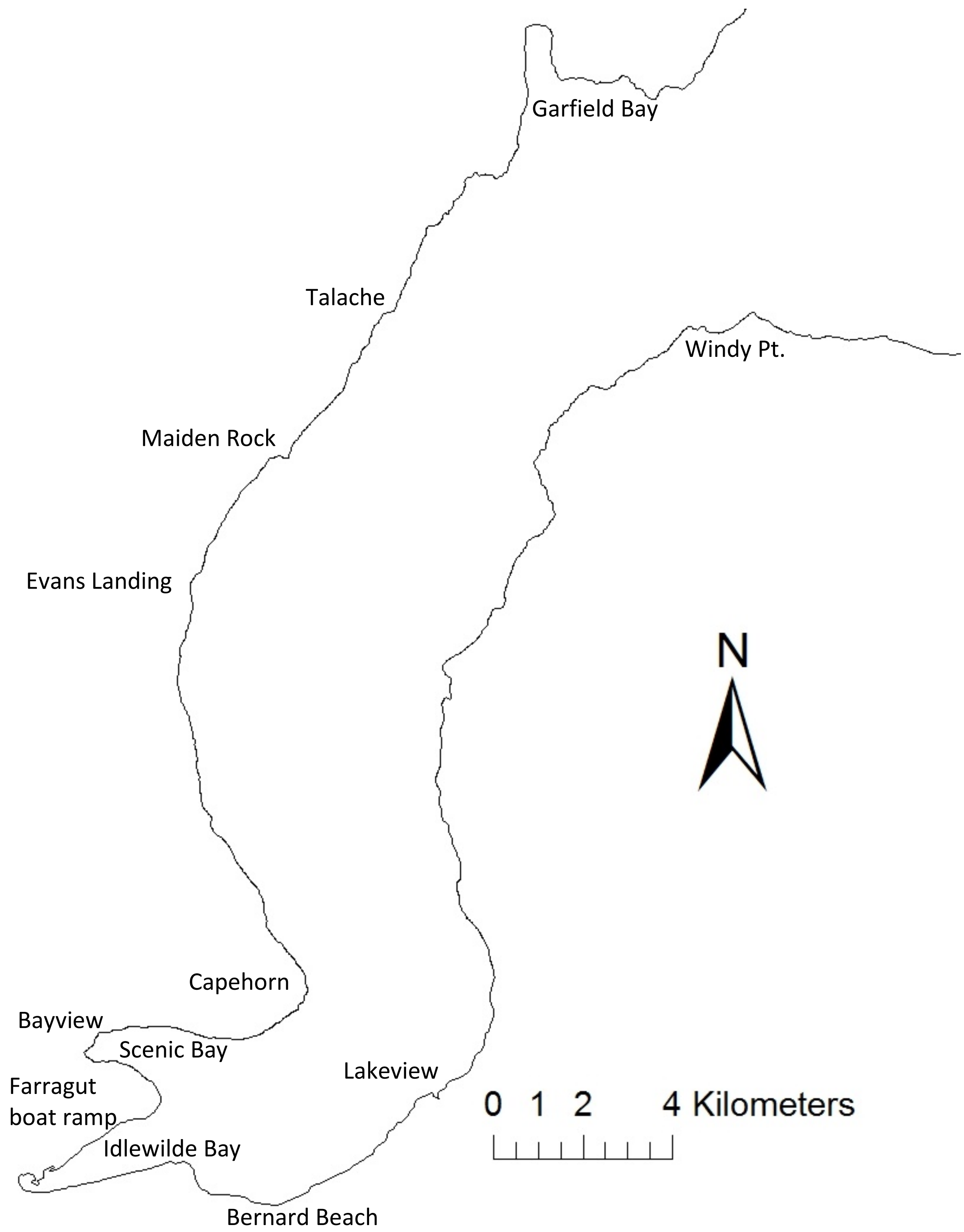

Figure A3. Map of the south half of Lake Pend Oreille showing major landmarks on the lake.

Appendix B. Acoustic telemetry tag specifications for Lake Trout that were active and available for tracking during 2017 and 2018, Lake Pend Oreille, Idaho.

Tag ID	Date Tagged	Transmitter Type	Tag Life (Years)	Capture Location	Total Length (mm)	Sex
63100	10/11/16	Lotek	2	Bernard Beach	656	M
63500	10/12/16	Lotek	2	Evans Landing	622	M
64500	10/11/16	Lotek	2	Bernard Beach	743	F
64600	10/11/16	Lotek	2	Bernard Beach	688	M
64700	10/11/16	Lotek	2	Bernard Beach	652	M
64800	10/12/16	Lotek	2	Evans Landing	966	M
64900	10/12/16	Lotek	2	Evans Landing	683	M
65000	10/11/16	Lotek	2	Bernard Beach	635	F
65100	10/12/16	Lotek	2	Evans Landing	618	M
65200	10/12/16	Lotek	2	Evans Landing	695	M
65300	10/13/16	Lotek	2	Indian to Deadman	855	F
65400	10/13/16	Lotek	2	Indian to Deadman	574	M
65500	10/13/16	Lotek	2	Indian to Deadman	570	U
65600	10/13/16	Lotek	2	Indian to Deadman	950	F
35000	10/10/17	Lotek	2	Indian to Deadman	685	F
34900	10/10/17	Lotek	2	Indian to Deadman	740	F
34600	10/10/17	Lotek	2	Indian to Deadman	960	F
34700	10/10/17	Lotek	2	Indian to Deadman	820	M
34800	10/11/17	Lotek	2	Plaque rock to Bernard	862	F
35100	10/11/17	Lotek	2	Plaque rock to Bernard	726	M
34400	10/11/17	Lotek	2	Plaque rock to Bernard	761	F
34300	10/11/17	Lotek	2	Plaque rock to Bernard	945	F
35300	10/13/17	Lotek	2	Evans Landing	908	F
34500	10/13/17	Lotek	2	Evans Landing	935	F
35200	10/13/17	Lotek	2	Evans Landing	980	M
35400	10/13/17	Lotek	2	Evans Landing	782	F
8499	10/10/18	Vemco	4	X-slide to plaque rock	795	M
8500	10/10/18	Vemco	4	X-slide to plaque rock	700	M
8501	10/10/18	Vemco	4	X-slide to plaque rock	905	F
8502	10/10/18	Vemco	4	X-slide to plaque rock	750	M
8503	10/10/18	Vemco	4	X-slide to plaque rock	835	F
8504	10/10/18	Vemco	4	X-slide to plaque rock	910	M
8505	10/11/18	Vemco	4	Camp Bay south	871	F
8506	10/11/18	Vemco	4	Camp Bay south	786	F
8507	10/11/18	Vemco	4	Camp Bay south	870	F
8508	10/11/18	Vemco	4	Camp Bay south	623	M
8509	10/11/18	Vemco	4	Camp Bay south	846	M
8510	10/11/18	Vemco	4	Camp Bay south	870	F

Appendix C. Tag ID, tag date, capture location, and size of Walleye with Lotek CART tags and Vemco acoustic tags in Lake Pend Oreille, 2017 and 2018.

Tag Date	Radio Freq.	Radio Code	Sonic code	Length (mm)	Tagging Location	Spaghetti Tag (orange)
10/8/2017	150.38	111	32700	520	LPO River - Dover RR bridge	17-15017
10/8/2017	150.38	108	32400	650	LPO River - Dover RR bridge	17-15036
10/8/2017	150.38	114	33000	450	LPO River - Dover RR bridge	17-15042
10/17/2017	150.38	103	31900	695	Garfield bay	17-15002
10/17/2017	150.38	105	32100	475	Garfield bay	17-15013
10/18/2017	150.38	113	32900	486	CF delta to Lees Point	17-15032
10/18/2017	150.38	102	31800	481	CF delta to Lees Point	17-15023
10/18/2017	150.38	101	31700	614	CF delta to Lees Point	17-15012
10/18/2017	150.38	112	32800	554	CF delta to Lees Point	17-15019
10/18/2017	150.38	110	32600	473	CF delta to Lees Point	17-15008
10/18/2017	150.38	104	32000	710	CF delta to Lees Point	17-15010
10/18/2017	150.38	106	32200	740	CF delta to Lees Point	17-15018
10/18/2017	150.38	109	32500	641	CF delta to Lees Point	17-15004
10/18/2017	150.38	115	33100	447	CF delta to Lees Point	17-15015
10/18/2017	150.38	107	32300	475	CF delta to Lees Point	17-15006
10/24/2017	150.38	118	33400	610	LPO River - Dover RR bridge	17-15037
10/24/2017	150.38	120	33600	470	LPO River - Dover RR bridge	17-15007
10/31/2017	150.38	116	33200	435	Cabinet gorge hatchery	17-15020
10/31/2017	150.38	121	33700	452	Cabinet gorge hatchery	17-15024
10/31/2017	150.38	119	33500	451	Cabinet gorge hatchery	17-15041
10/31/2017	150.38	123	33900	440	Cabinet gorge hatchery	17-15021
10/16/2018	Vemco	NA	23128	435	LPO River - Dover RR bridge	NA
10/17/2018	Vemco	NA	23125	546	LPO River - Dover RR bridge	NA
10/30/2018	Vemco	NA	23123	553	LPO River - Dover RR bridge	NA
10/30/2018	Vemco	NA	23126	584	LPO River - Dover RR bridge	NA
11/01/2018	Vemco	NA	23132	724	Cabinet gorge hatchery	NA
11/01/2018	Vemco	NA	23124	610	Cabinet gorge hatchery	NA
11/01/2018	Vemco	NA	23131	597	Cabinet gorge hatchery	NA
11/01/2018	Vemco	NA	23134	533	Cabinet gorge hatchery	NA

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