Minnesota Department of Natural Resources
Division of Fisheries and Wildlife

Completion Report

Large Lake Sampling Program Assessment Report
for
Leech Lake
2014

by

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Walker Area Fisheries Office

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Large Lake Program Assessment Report
Leech Lake
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INTRODUCTION

Statewide, Minnesota’s ten largest Walleye *Sander vitreus* lakes account for 18% of total angler pressure (Andrew Carlson, unpublished data) and 40% of the annual Walleye harvest (MNDNR 1997). Prior to 1983, fisheries assessments on these lakes were infrequent and highly variable in their methods. As a result, these surveys were unreliable for assessing fishery status as well as any fishery response to management actions. Recognizing the importance of these systems and the need for robust data to effectively identify and evaluate trends in fish stocks, the Minnesota Department of Natural Resources initiated the Large Lake Program (LLP) in 1983. Goals of the LLP include annual fishery surveys using standardized methods to facilitate comparisons among years and lakes, to detect management needs and evaluate management actions, and to enhance public outreach.

Sampling guidelines for the large lakes were outlined in the Large Lake Sampling Guide (Wingate and Schupp 1984). Since being published in 1984, large lake sampling methods have been adapted on a lake-specific basis to ensure information collected is valid for both research and management applications; ineffective sampling gears or those with poor reliability have been eliminated or de-emphasized. In some cases, additional targeted sampling has been added to augment methods delineated within the LLP. The primary focus of the LLP and its survey methods is to promote sound management of Walleye, Yellow Perch, and Northern Pike populations while garnering additional but less targeted information on other species.

Leech Lake is the third largest lake within state boundaries and is one of eleven lakes monitored by the LLP (MNDNR 1997). The lake is renowned among anglers as an exceptional multi-species fishery; however, most anglers target and harvest walleye. As a result of declines in Walleye numbers in the early to mid-2000s, a formal regulation review and public input process occurred in 2004. As a result of this process, management changes initiated in 2005 included conservative Walleye regulations, Walleye fry stocking, and double-crested cormorant management. In 2009-2010, the MN DNR convened a citizen input committee (Leech Lake Advisory Committee; LLAC) comprised of stakeholders representing local and statewide interests in Leech Lake management (LLAC 2010). These recommendations of this group were incorporated into DNR’s Leech Lake Management Plan, 2011-2015 (Schultz 2010a). These management goals, where appropriate, are referenced in this report. This report primarily addresses the 2014 Leech Lake fishery assessment.

Aquatic invasive species currently found in Leech Lake include rusty crayfish, heterosporosis, curly-leaf pondweed, Eurasian watermilfoil, and banded mystery snail. Invasive plant species are not widely distributed within Leech Lake, but Eurasian water milfoil is expanding and beds are establishing in new areas outside of harbors. Other aquatic invasive species are increasing in prevalence throughout Minnesota and pose a likely risk. Anglers and boaters alike are encouraged to properly dispose of bait in the trash, to drain all water from bait containers, livewells, and watercraft, and properly inspect and remove all vegetation from their watercraft, anchor, and trailer when leaving a lake.

STUDY AREA

Leech Lake has approximately 112,000 surface acres. In its original state the lake covered about 106,000 acres. In 1884, a dam was built on the Leech River, raising the water level about two feet and increasing the surface area to its present size (Wilcox 1979). The maximum depth of the lake is near 150 feet; however, nearly 80 percent of the lake is less than 35 feet deep. Leech Lake has approximately 57,994 littoral acres (≤15 feet).

Leech Lake is located in three glacial zones and has an irregular shape with many large and small bays. Leech Lake varies considerably from a morphological perspective. Some large bays, such as Steamboat and Boy, display highly eutrophic water characteristics whereas other large bays, such as Walker and Kabekona, have properties more congruent with oligotrophic lakes. The main portion of the lake, like most large Minnesota Walleye lakes, is mesotrophic. Previous estimates of total shoreline length have varied, but remote sensing technology, has estimated it to be 201 miles. Approximately 23% of the shoreline consists of a windswept gravel-rubble-boulder mixture, nearly all of which is suitable Walleye spawning habitat (Wilcox 1979), and numerous off-shore gravel-rock-boulder reefs are also available. The main lake portion of Leech Lake, which includes Portage, Sucker, Boy, Headquarters, and Traders bays, is 93,914 acres, while the western bays are 17,927 acres and consist of Walker, Kabekona, Agency, and Steamboat.

The diversity of the Leech Lake shoreline and substrate, as well as its extensive littoral zone, provides excellent spawning and nursery habitats for a number of species, including Percids and Esocids which dominate the fish community. Walleye, Northern Pike *Esox lucius* and Muskellunge *E. masquinongy* are the principal predators and are common throughout the lake. Although most fish species are found in every portion of the lake, the largest Walleye and Muskellunge abundances exist in the mesotrophic areas. Northern Pike are most prominent in vegetated eutrophic bays. Yellow Perch *Perca flavescens* are abundant throughout the lake and are the primary forage for most predators. Cisco *Coregonus artedi* and Lake Whitefish *C. clupeaformis* are an important forage base for larger predators (Engstrom-Heg et al. 1986) and are typically found in the mesotrophic and oligotrophic areas. Juvenile Cisco also comprise larger proportions of predator diets when large year classes are present. Other species present in the lake include: White Sucker *Catostomus commersoni*, Burbot *Lota lota*, Rock Bass *Ambloplites rupestris*, Bowfin *Amia calva*, Shorthead Redhorse *Moxostoma macrolepidotum*, Bullheads *Ameiurus spp.*, Pumpkinseed *Lepomis gibbosus*, Bluegill *L. macrochirus*, Largemouth Bass *Micropterus salmoides*, Smallmouth Bass *M. dolomieu*, and Black Crappie *Pomoxis nigromaculatus*.

YOUNG-OF-YEAR ASSESSMENT

Introduction

Recruitment variability, or the variability in the size or strength of a year class, is influenced by a host of factors. These include spawner abundance (Ricker 1975), spawning conditions (Hansen et al. 1998), juvenile density (Hansen et al 2012), length and intensity of growing season (Venturelli et al. 2010), predation (Hansen et al. 1998; Quist et al. 2003), and prey abundance (Chevalier 1973), among others.

In Minnesota's large lakes, strong year classes, as indexed by gillnet catch rates of age-1 through age-3 Walleye, are defined as cohorts having a relative abundance in the upper 75th percentile of long-term observed values. Strong year classes of Walleye have typically occurred every 3 to 5 years in the large lakes. Factors limiting the frequency of strong year classes include prey abundance (Forney 1974), temporary climate shifts (Schupp 2002), or high abundances of adults (Ricker 1975). Variability in angler catch and harvest rates have typically paralleled occurrence of strong or weak year classes as they reach the fishery at age-3.

The decline of the Leech Lake Walleye fishery during the early to mid-2000s was a product of several consecutive below-average year classes. Factors that likely contributed to declines in recruitment during this time include increases in Walleye predation by double-crested cormorants (Schultz et al. 2013), increases in angler pressure and harvest of Walleye in the late 1990s and early 2000s (Sledge 1999, Sledge 2000), and increased harvest of larger adults (Stevens and Ward 2015). Mixed ages of Walleye were infrequently stocked at low densities from 1922 through1987. Stocking was discontinued from 1988-2004, and the strongest year class observed to date occurred in 1988. Higher densities of Walleye fry were stocked as part of recent efforts to rebuild the Walleye population (Table 1).

From 1983 through 1992 seining was conducted at as many as 16 stations in attempts to refine station selection and from early July through early September in attempts to refine time period selection. These evaluations resulted in the establishment of five long-term stations and the selection of the four week time period in July. A minimum of 40 seine hauls have been conducted annually at the five stations throughout July from 1983 through 2010. Seining was not conducted in 2011 due to a state shutdown, and in 2012 stations were not sampled according to standardized protocols due to staffing shortages. In 2012, each of the five stations was seined on three occasions in mid-July solely to collect YOY Walleye for stocking evaluations. The four week time period in July was reduced to the middle two weeks in July (Julian Weeks 28-29) in 2013, and is now the standardized time period. Standardized Julian time periods established for all three assessment techniques were weeks when stations were most consistently sampled since 1983. Seine catch rates can be strongly influenced by several factors, including fish behavior and size. Furthermore, seining occurs relatively early in the life-history stages before numerous first-year mortality processes have fully acted on the cohort. For these reasons seining is reserved for collecting early information on YOY growth and is not used for estimating year class strength.

Three long-term trawling stations were established in 1987. Other stations had been attempted in the past but were discontinued due to the inability to be sampled effectively. The relationships between YOY Walleye and YOY Yellow Perch catch rates in various gears and recruitment to the adult population remain subject to the numerous mortality processes driving recruitment variability.

Fall electrofishing was added to the suite of YOY Walleye assessment tools in 2005 and standardized long-term stations were established in 2007 to improve on year class strength estimation. Electrofishing has shown to be a useful method for predicting Walleye year class strength on some of Minnesota's other large lakes and, in time, may have the potential to more precisely estimate year class strength on Leech Lake. Electrofishing catch rates are highly dependent on water temperature, water clarity, and weather. Consequently, not all stations may be sampled during years of frequent inclement weather.

The objectives of this assessment include: 1) estimate wild fry hatch rates and compare those to other Minnesota lakes; 2) estimate wild and total fry densities; 3) index the relative abundance of YOY Walleye and Yellow Perch; 3) characterize early growth rates for both species; 4) estimate Walleye year class strength (YCS); and 5) evaluate factors effecting recruitment.

Methods

Stocking

Newly hatched Walleye fry (<24 hours post hatch) were treated by immersion in OTC, an antibiotic that leaves an indelible mark on fish bones that allows biologists to identify them as stocked fish (Lucchesi 2002, Logsdon 2006). To reduce handling stress fry were treated directly in the transport containers. Each container was five gallons and contained approximately 50,000 fry, three gallons of OTC solution, and oxygen. Fry remained in the solution for a minimum of 6 hours to ensure mark retention. Efforts to minimize mortality during marking included applying crushed ice to the containers as needed to maintain temperature and moving the vehicle hourly to reduce settling of fry into corners of the jugs. After 6 hours, fry were transported in a boat to stocking locations around the lake. For a more detailed description of methods, see Logsdon (2006). From 2005 to present, stocking rates ranged from of 129-389 fry per littoral acre (Table 2).

Hatch rates and fry densities

By stocking a known number of fry, the total number of wild fry at the time of stocking was estimated using the Chapman modification of the Peterson single census method (Ricker 1975):

$$N = (M+1)\ (C+1)/(R+1)$$

where M is the number of marked Walleye fry stocked, C is the number of YOY Walleye from seine, trawl, and electrofishing catches that were inspected for the presence of an OTC mark, and R is the number of inspected Walleyes with a visible mark.

This provides the ratio of marked (stocked) to unmarked (wild) YOY Walleye collected overall during seining, trawling, and electrofishing. The hatch rate of wild fry can then be estimated as a percentage of estimated eggs carried the previous fall by mature females that hatched into fry the following spring (Logsdon 2006).

Seining

Two seine hauls were completed at each of the five stations (Figure 1; SE-1: Whipholt Beach, SE-2: Stony Point, SE-3: Traders Bay, SE-4: Ottertail Point, and SE-5: Five Mile Point) per week over a two week time period in mid-July (Julian Weeks 28-29). Two hauls per week were made at each station using a bag seine (100-ft. long, 5-ft. deep, 0.25-in. untreated mesh) for a total of 20 seine hauls. The area seined was determined by assuming the distance from shore covered by the seine was 90 feet, which compensated for the bow in the seine created by water resistance during pulling. This figure was then multiplied by the distance of the pull (150 feet) and resulted in an area of 13,500 ft^2 (0.310 acres) per seine haul. All gamefish were identified to species and measured (TL, mm). All non-gamefish were identified and counted. Gamefish were recorded as either young-of-year (YOY) or age-1 or older. When necessary, seine hauls were sub-sampled due to large numbers of fish captured. In these instances a representative portion of fish in a volumetric sub-sample were processed as stated above, and the total number obtained in the sub-sample was expanded to the total volume sampled. Age-0 Walleye and age 1+ sportfish were individually measured before sub-sampling occurred. Up to 20 YOY Walleye and Yellow Perch per station per date were retained for individual measurement (total length (TL), mm; weight (WT), g).

Trawling

Trawling was conducted at the three long-term stations (Figure 1) using a semi-balloon bottom trawl (25-ft. head rope, 0.25-in. mesh cod end liner) in mid-August (Julian Weeks 33-34). Eight hauls were conducted at Five Mile Point (TR-1), six at Goose Island (TR-2), and six at Whipholt Beach (TR-3), for a total of 20 hauls. Hauls at the three long-term stations consisted of five-minute tows at a fixed speed of 3.5 mph for a total effort of 100 minutes of trawl time. Depths trawled ranged from 6-12 feet depending on transect and location. Fish were identified, measured, and enumerated as per the methods described for shoreline seining. Up to 20 YOY Walleye and Yellow Perch per station per date were retained for individual measurement (TL, mm; W, g).

Fall Electrofishing

Electrofishing was conducted using a MLS-Infinity pulsed-DC electrofishing boat (twin spider array anode) in mid-September (Julian Weeks 37-38). Standardized stations consisted of four clusters of sites, each of which contain three transects (Figure 1). Three transects are located on the east side of the main basin near Bear Island and Brevik, the south side of the main basin near Roger’s Point, the west side of the main basin near Stony Point, and the southern portions of Walker Bay. The twelve transects were approximately 3-5 feet deep on sand/gravel/cobble shorelines. Transects consisted of 20 minutes of continuous on-time from the starting point. Up to 25 age-0 Walleye per transect were retained for individual measurement (TL, mm; W, g) and otolith removal. All age-1 Walleye captured were measured (TL, mm) and released.

YOY Growth Indices

Growth of YOY Walleye and Yellow Perch sampled from seining, trawling, and electrofishing was indexed by mean length sampled by week from July through September. Mean lengths were determined for Julian Weeks 28-29 for seining, 33-34 for trawling, and 37-38 for electrofishing.

Walleye Year Class Strength

Year class strength (YCS) is an index of the respective relative strength of Walleye year classes by age from age-0 through age-3. For example, to predict YCS of the 2014 cohort we used a model of YCS as a function of age 0 gillnet and trawl catch rates fit to 1987-2014 data; model predictions give the predicted mean YCS for this cohort based on 2014 trawling and age-0 gillnet CPUE. For all cohorts except 2014, we used the Maciena and Pereira (2007) catchability corrected model of cohort strength to calculate the YCS fit to 1983-2013 gillnet data. This is a two-way ANOVA of age-specific CPUE rates for ages 1 through 3 as a function of age and cohort (both categorical variables); the least-squares mean of the cohort effect for each year class is the YCS measure. For the 2013 and 2012 cohorts there are only observations at ages 1 and ages 1 & 2, respectively, thus for these cohorts, the YCS is a prediction based on limited observations; however, we note these predictions from limited data have been found to be useful predictors of a cohort's ultimate YCS. Predictive models will continue to be refined in response to additional data collection, such as electrofishing, or changing environmental conditions that could limit gear effectiveness. For example, colonization of zebra mussels at trawling sites could reduce the effectiveness of trawling for YOY Walleye (E. Jensen, MN DNR, personal communication), while factors that reduce water clarity could adversely affect electrofishing. Year class strength values between the 25th to 75th percentile ranges are classified as average. Values that exceed the 75th percentile are classified as strong, while values that fall below the 25th percentile are classified as poor. Year classes fully recruit to the fishery at age-3.

Factors Affecting Recruitment

The mean length of Walleye sampled electrofishing in mid-September (Julian weeks 37-38) were compared to initial fry density, the year class strength index, and the length/ intensity of the growing season (growing degree days; GDD_{50}=GDD ≥50°F). Annual GDD_{50} values were calculated using air temperature data from the Walker Ranger Station, which is coordinated by the National Climate Data Center (2014). The length and intensity of the growing season (GDD_{50}) was calculated by giving each day in which the mean air temperature was ≥50°F one degree day, and an additional degree day for every degree over 50°F; example 55°F = 5 degree days). A linear relationship between air and lake surface temperature during ice-free months on Leech Lake supports the use of this method as a robust surrogate for lake water temperature in the north-temperate zone (Stefan et al. 1998).

Results

Hatch rates and fry densities

From May 24 through 26, 2014, approximately 7,500,512 Boy River strain Walleye fry stocked throughout the lake (Table 1). A total of 1,038 YOY Walleye were sampled by seining (n = 782), trawling (n = 593), and electrofishing (n = 439). A subsample of 360 individuals equally distributed between gear types and among stations within gear types were examined for the presence of an OTC mark. Of the fish examined, 54% (n = 196) were identified as stocked fish (Table 2). Fish held in ponds to determine mark efficacy demonstrated 100% mark retention (n =

100). The 2014 wild fry hatch rate was estimated to be 0.10% (Table 2). These compare to the 2005-2013 ranges of 23-86% (mean: 47%) for percent marked and 0.12-0.89% (mean: 0.38%) for hatch rates. The estimated number of wild (6,244,083) and stocked (7,500,512) fry combined in 2014 was 13,744,595. These result in fry densities of 108 wild fry/littoral acre (LA) and 129 stocked fry/LA, totaling 237 total fry/LA (Table 2, Figure 2). These compare to 2005-2013 ranges of 61-779 (mean: 319) for wild fry/LA, 129-390 (mean: 257) for stocked fry/LA, and 237-908 (mean: 574) for overall fry/LA.

Seine Catch Rates

Twenty seine hauls (6.2 acres) were completed from July 14-28, 2014 at five standard stations, sampling 13 species (Table 3). A total of 782 YOY Walleye were sampled, while 149 were retained for OTC mark detection. Overall catch rates of YOY Walleye were 39/haul (Figure 3). This was the sixth highest catch rate since standardized sampling began in 1983, and was higher than the long-term mean of 16/haul. Overall catch rates of YOY Yellow Perch were 92/haul (Figure 4). This is lower than the long-term mean of 215/haul. Catch rates (number/haul) of YOY Walleye were the highest and Yellow Perch were the lowest since rehabilitation efforts began in 2005.

Trawl Catch Rates

Twenty trawls (100 minutes) were completed from August 11- 19, 2014 at the three index stations, sampling 19 species (Table 4). A total of 593 YOY Walleye were sampled, while 188 were retained for OTC mark detection. The overall catch rate of YOY Walleye was 356/hour (Figure 3). This was the third highest catch rate since standardized sampling began in 1987, and was higher than the long-term mean of 152/hour. The overall catch rate of YOY Yellow Perch was 2,777/hour (Figure 4), and was lower than the long-term mean of 9,060/hour and the lower quartile. Catch rates of YOY Walleye were the second highest and YOY Yellow Perch were the second lowest since rehabilitation efforts began in 2005.

Electrofishing Catch Rates

Twelve transects (240 minutes) were electrofished from September 11-17 2014. A total of 439 YOY Walleye were sampled, while 186 were retained for OTC mark detection. The overall catch rate of YOY Walleye was 98 fish/hour (Figure 3), which is higher than the long-term mean of 88/hour.

YOY Growth

The mean length of YOY Walleye was below the long-term average during all three evaluation periods in 2014 (Figure 5). Respectively, Walleye mean length was 3.4, 5.0, and 5.8 inches while seining, trawling, and electrofishing in 2014, and was below the long-term averages of 3.4, 5.3, and 5.9 inches. The mean length of YOY Yellow Perch was slightly below the upper quartile range in mid-July and exceeded the upper quartile range in mid-August (Figure 6). The mean YOY Yellow Perch length was 1.6 and 2.0 inches while seining and trawling in 2014, and was above the long-term averages of 1.5 and 1.8 inches, respectively.

Walleye Year Class Strength

Based on trawl and gill net catch rates of YOY Walleye, a YCS index value of 1.51 is predicted for the 2014 year class (Table 5). This value exceeds the management plan objective range of 1.35. All three of the incomplete Walleye year classes (2012-2014) are predicted to exceed the management plan objective, while five of the seven year classes that have completely recruited to the fishery since 2005 (2005-2011) also exceed the objective (Figure 7). No year classes were below the lower quartile range and considered poor.

Factors Affecting Recruitment

Based on these data, Walleye fry densities ranging from 300-600 fry/LA have resulted in the greatest number of individuals recruiting to the fishery since 2005 (Figure 8). A higher stocking rate (20-22.5 million vs. 7.5) has not resulted in greater recruitment (Figure 9). First-year growth was negatively related to total fry density, as indicated during the mid-September electrofishing assessment (Figure 10). The average length of fish in mid-September was positively associated with eventual recruitment of year classes at age-3 (Figure 11). Other than initial fry density, another factor influencing first-year growth has been the length and intensity of the growing season (Figure 12, GDD_{50}). A longer and warmer growing season has resulted in more individuals recruiting to the fishery at age-3 (Figure 13). The 2008 and 2009 year classes, which were below the lower quartile range for year class strength, had the two shortest growing seasons (Figure 13) and had the two highest densities for complete year classes (Figure 9). There was no strong relationship between total fry density and GDD_{50}, suggesting each factor tested acted independently on YOY Walleye growth and survival.

Discussion

Walleye recruitment in natural lakes is highly variable across years and is influenced by a number of physical and biological factors. High abundances of adult Walleye can suppress ensuing year classes via predation (Chevalier 1973) and competition (Madenjian et al. 1996; Beard et al. 2003). Similarly, high adult abundances of other species, such as Yellow Perch, can exert enough predation on a Walleye year class to significantly influence its outcome (Hansen et al. 1998). Spring warming rates have a strong influence on incubation times, egg survival and hatch rates, and food availability for newly-hatched fry (Madenjian et al. 1996; Hansen et al. 1998). Furthermore, first-winter survival of YOY Walleye is size-specific and therefore strongly influenced by growth rate during the first year (Forney 1976, Madenjian et al. 1996, Kampa and Hatzenbeler 2009). The larger an individual becomes during its first growing season, the higher the likelihood it survives its first winter and eventually recruits to the fishery (Madenjian et al. 1996; Hansen et al. 2012).

Walleye hatch rates in Red Lake were estimated from 1999-2003 and serve as a benchmark for strong reproduction in a self-sustaining population (mean 0.22%, range 0.02-0.60). More recently hatch rates have also been estimated for other Minnesota lakes as part of a study evaluating fry densities in Walleye egg-take lakes (Table 2; Dale Logsdon, personal communication). These data demonstrate Walleye hatch rates observed in Leech Lake are similar to other large Minnesota Walleye populations. Generally, marking rates increase with stocking density because higher stocking density is the same as higher marking effort in mark-recapture studies. Higher densities of stocked fry and total fry have not translated to stronger year classes.

Young-of-year Walleye catch rates exceeded the long-term averages for seining, trawling and electrofishing in 2014, but mean lengths were always between the long-term average and lower quartile ranges. Young-of year Yellow Perch catch rates were below the long-term averages for seining and trawling in 2014 and growth rates were near or above upper quartile ranges.

Electrofishing catch rates have the potential to index Walleye year class strength. This is because a strong relationship is evident between year class strength and average length of YOY Walleye sampled electrofishing (Figure 11). A similar relationship has been observed on Lake Vermillion (D. Williams, MN DNR, personal communication). This relationship underscores the influence first-year growth has on eventual recruitment to the fishery and highlights the potential utility of fall electrofishing when assessing recruitment in the future.

Overall, numbers of YOY Walleye sampled via trawling and gill netting in 2014 indicate a predicted YCS that will exceed the management plan objective of 1.35. Assuming the YCS values for all three incomplete year classes remain above 1.35, YCS values will have exceeded the objective range in 8 of the past 10 years. No year classes had YCS values below the 25th percentile range which is considered poor. The current management plan objective is to exceed the threshold of 1.35 in two of four consecutive years. Year classes that have values below the 25th percentile allow for prey populations such as Yellow Perch to increase in number after high predation pressure by an average or strong Walleye year class.

While stocking efforts have increased total fry density, recruitment has been limited by natural trade-offs associated with density, and increased stocking rates have not resulted in more young Walleye recruiting to the fishery. A curve-linear and/or declining relationship between total fry density and recruitment suggests density-dependent effects are structuring recruitment to age-3. Competition between YOY fish for food and space increases as total fry density increases; however, the trade-off is slower growth rates. This is important because overwinter survival for YOY Walleye is a significant bottleneck that is highly correlated to size (Toreys and Coble 1979; Copeland and Carline 1998; Pratt and Fox 2002). Thus, larger YOY are more likely to survive their first winter and smaller YOY are more likely to succumb to mortality, and activities that reduce first-year growth, such as stocking, will inherently reduce the likelihood for individual survival. This explains why higher stocking levels have not resulted in stronger year classes of Walleye. First-year growth is also temperature-dependent (Neuheimer and Taggart 2007; Venturelli et al. 2010), and longer and warmer summers can buffer but not negate the effect of higher fry densities on growth. Lastly, another important consideration when contemplating appropriate fry densities is the prey population. Juvenile Walleye, whether stocked or naturally produced, that do not survive and recruit to the fishery must consume prey until mortality occurs.

Consequently, elevated fry densities not only fail to increase recruitment because of density-dependent limitations, but also exert added and unnecessary demand on the prey base.

Due to the high degree of variability in YOY Walleye survival, forecasting recruitment (i.e. year class strength) based on YOY metrics will inherently be accompanied by uncertainty. For example, variability exists among Minnesota's ten largest Walleye lakes as to which YOY Walleye sampling methods are the best predictor of ensuing YCS. Fall electrofishing catch rate is the best gear on Cass, Kabetogama, Rainy, and Vermillion lakes to predict YCS. Conversely, trawling has been the best gear on Lake of the Woods, Leech, Mille Lacs, and Winnibigoshish lakes. Upper Red Lake is the only lake where seining is the best gear to predict Walleye YCS, and all three gears are good predictors on Lake Pepin. Therefore, while over 30 years of annual survey work has determined the best gear(s) for predicting Walleye YCS in each of these systems, no estimate is without variability from year to year or lake to lake because of the dynamic mortality processes that influence recruitment. Furthermore, changes in lake ecology, such as the introduction of an invasive species, have the potential to alter these predictive relationships.

Future management decisions should consider actions that optimize YOY growth and recruitment potential while minimizing effects on the prey base. Lower fry densities have the highest potential for strong year classes during longer, warmer summers but also the greatest risk for weak year classes during cool, short summers. The management plan objective of establishing YCS values that exceed the long-term average in only two of four consecutive years have the goal of predation relief and minimizing density dependent effects on juvenile Walleye. In short, the "boom-bust" potential of a year class observed in the past appears to be strongly tied to fry density and growing season. Conversely, recruitment also decreases as fry densities increase above 600 total fry/LA, regardless of growing season length. This is because food, space, and other resources become increasingly limited as more young Walleyes compete with each other. Current Walleye regulations have resulted in a more stable adult population and therefore more consistent fry production. This has resulted in less recruitment variability, especially in recent years as the adult population has stabilized. Although climatological variables will always influence YCS, employing adaptive management strategies that result in increased fry densities should only be considered if the weight of evidence suggests it is appropriate.

GILLNET SURVEY

Introduction

Gillnet surveys on Leech Lake have been completed annually between early and mid-September starting in 1983. Gillnets are the most effective tool for assessing the four target species (Walleye, Yellow Perch, Northern Pike, and Cisco). However, information on other species is also collected. Since 1983, four nets have been set at standard locations within each major bay (Wingate and Schupp 1984). Four nets were added in the central area of the main basin (Pelican Island) in 1984 for a total of 36 net sets per year. Data collected with gillnets measure trends in population metrics, such as relative abundance, spawner stock biomass, age- and size-structure, growth rates, mortality rates, and recruitment. Gillnet catch rates are also used to establish population management goals that can be quantitatively evaluated over time.

Methods

Standard experimental gillnet were set at 36 sites throughout the lake from early through mid-September. Experimental nets (50-ft. panels of 0.75, 1.00, 1.25, 1.5, and 2.0-inch bar mesh; 250-ft. total net length) are used to reduce size-selective biases encountered when using nets of a single mesh size. Standardized methods include net design, net location, net orientation, and time of year. Four gillnets were set in each of 9 different areas (Figure 14). Western bay sets included net stations 1-16 and main lake sets included net stations 17-36. While most data are summarized lake wide, differences in catch rates, growth, and spawner stock between the main lake and western bays result in these data to be summarized both by basin and lake wide.

All fish captured were identified to species, measured (TL, mm), and weighed (g). Sex and maturity data were recorded for all Walleye, Yellow Perch, Cisco, and Northern Pike when possible. Data were recorded separately for each of the five mesh sizes within each net. Weights and lengths were converted from metric units to English units.

Ages were estimated using sagittal otoliths from all Walleye collected. Otoliths have been used to age Walleye since 1990. Cleithera were removed from a sub-sample of ten Northern Pike per 25-mm length intervals from each basin. Cleithera have been used to age Northern Pike since 1990. Otoliths were removed from a sub-sample of five Yellow Perch, per sex and per mesh panel, from each net. Otoliths have been used to age Yellow Perch since 2001. In most cases, sub-sampling for Yellow Perch otolith collection only occurred within the 0.75 and 1.00-inch mesh sizes. Otoliths were removed from a sub-sample of ten Cisco per 25 mm length group per basin. Cisco ages were determined starting in 2008. Age assignment was basin-specific for each species because differences observed in population metrics among basin types, particularly growth rate (Schupp 1978).

Size structure for Walleye, Yellow Perch, and Northern Pike was summarized using Proportional Stock Density (PSD; Anderson 1976) and Relative Stock Density (RSD; Gabelhouse 1984) indices. These indices are a length-categorization system developed by fisheries biologists to quantify the size structure of fish populations. It represents the proportion of fish in a sample longer than a specific length, and deliberately excludes smaller individuals that are poorly sampled by the gear. The lengths analyzed for Walleye were ≥15 and ≥20 inches, excluding those less than 10 inches. The lengths analyzed for Yellow Perch were ≥8 and ≥10 inches, excluding those less than 5 inches. The lengths analyzed for Northern Pike were ≥21 and ≥28 inches, excluding those less than 14 inches. Growth rates were compared for Walleye, Yellow Perch, and Northern Pike between the current year assessed and the long-term mean.

Walleye condition was assessed using relative weight (*Wr*), which compares the weight of a fish relative to its length (Murphy et al. 1990). Spawner stock biomass of mature females was estimated using Qabg (Anderson 1998). The length and age at which an individual has a 50% chance of being mature was estimated for Walleye and Yellow Perch (Gangl and Pereira 2003). These two biological performance indicators (BPI) are sensitive to changes in population mortality, which can be indicative of overharvest (Gangl and Pereira 2003) or other stressors (Schultz et al. 2013). The other BPI indicator calculated included female length at age-3(Gangl and Pereira 2003).

Results

Standard experimental gillnet were set at 36 sites from September 7-19, 2014, sampling 21 different species. Consistent with past surveys, overall gill net catch rates for all species combined were higher for the western bays than the main lake sets (Table 6). Of the four target species, catch rates for Walleye and Cisco are typically higher in the main lake sets, while catch rates for Yellow Perch and Northern Pike are typically higher in the western bays (Figure 15). Past trends held true for three of these four species in 2014 excluding Northern Pike, which had higher catch rates in the main lake. Long-term gillnet catch rates for all species are summarized in Appendix 1.

Walleye

A total of 321 Walleye were sampled in gillnets. An overall catch rate of 8.9 (fish/net) and 14.3 (pounds/net), was similar to 2013 (Figures 16 and 17). This is higher than the long-term averages of 7.8 (fish/net) and 9.5 (pounds/net). Previous catch rates ranged from 4.6 fish/net (1993) to 13.4 fish/net (1988), and 5.3 pounds/net (1983) to 18.4 pounds/net (2007). The 2014 catch rate exceeded the 2011-2015 management objective of 8.5 fish/net (Figure 18); 8.5 is the 75th percentile of the long-term data set (1983-2010).

Consistent with long-term trends, catch rates were higher in the main lake (12.6 fish/net) compared to the western bays (4.3 fish/net) (Table 6, Figure 15). Of all Walleye sampled, 79% were from the main lake, while 21% were from the western bays. By sampling strata, catch rates ranged from 0.3 fish/net (Steamboat Bay) to 22.3 fish/net (Portage Bay).

Total length of Walleye sampled ranged from 6 to 26 inches (Table 8; Figure 19) and ages ranged from 0 to 21 years old (Table 9; Figure 20). The 2011 and 2012 year classes made up 38% of all Walleye sampled. The percentage of Walleye sampled that were ≥15.0 inches (PSD-Q) was 67%, while the percentage sampled that were ≥20 (RSD-P) was 22% (Figure 21). Forty-two percent of Walleye sampled in 2014 were shorter than 15 inches, which is below the 2011-2015 management plan objective range of 45-65% (Figure 22). The average lengths of age-1 through age-4 Walleye were 9.5, 12.5, 15.6, and 17.5 inches, respectively (Figure 23).

Most males were mature by 15 inches and age-3, while most females were mature by 18 inches and age-4 (Tables 8 and 9). Condition (*Wr*) in 2014 was 82.7, and has been below the long-term average (84.0) for the past eight years (Figure 24). Spawner stock biomass of mature female Walleye was estimated to be 2.51 pounds/acre, which exceeds the 2011-2015 management plan objective range of 1.50-2.00 pounds/acre and was the highest estimate observed to date (Figure 25).

The catch rate of age-3 Walleyes in 2014 was 1.7 (2011 year class), which was slightly under the upper quartile range for all catch rates observed since 1980 (Figure 26). Catch rates of age-3 Walleyes have exceeded the long-term average (1.3) in five of seven years since 2005. Female length at age-3 (15.4 inches) was slightly below the threshold of 15.6 inches (Figure 27). Female length at 50% maturity in 2014 (17.44 inches) was slightly above the threshold of 17.40 inches. Female age at 50% maturity in 2014 (3.90 years) was slightly below the threshold of 3.95 years.

Yellow Perch

A total of 501 Yellow Perch were sampled in gillnets. An overall catch rate of 13.9 (fish/net) and 2.2 (pounds/net) was similar to 2013 (Figures 16 and 17), but lower than the long-term averages of 21.1(fish/net) and 4.9 (pounds/net). Previous catch rates ranged from 12.1 fish/net (2013) to 37.7 fish/net (1995), and 2.5 pounds/net (2013) to 8.1 pounds/net (1995). The 2014 catch rate was below the 2011-2015 management objective of 16.3 fish/net (Figure 18); 16.3 is the 25th percentile of the long-term data set (1983-2010).

Consistent with long-term trends, the catch rate in 2014 was higher in the western bays (24.6 fish/net) compared to the main lake (5.4 fish/net) (Table 6, Figure 15). Of Yellow Perch sampled, 78% were from the western bays, while 22% were from the main lake. By sampling strata, catch rates ranged from 0.8 fish/net (Stony, Ottertail, Pine, and Goose) to 40.8 fish/net (Steamboat Bay).

Total length of Yellow Perch sampled ranged from 3 to 12 inches (Table 8; Figure 19) and ages ranged from 1 to 14 years old (Table 9; Figure 20). The 2011 year class made up 51% of all Yellow Perch sampled, meaning a strong year class appears to be entering the fishery. Of all Yellow Perch sampled, 21% were ≥8 inches, 9% were ≥9 inches, and 4% were ≥10 inches. The percentage sampled that were ≥8.0 inches (RSD-Q) was 20%, compared to the management plan objective of 30% (Figure 21). Neither of the size structure objectives in the 2011-2015 management plan was met in 2014. The average lengths of age-1 through age-4 Yellow Perch were 3.4, 5.4, 6.1, and 7.5 inches, respectively (Figure 28).
Length and age of female Yellow Perch at 50% sexual maturity were 6.5 inches and 2.5 years. All males were mature by 5 inches and age-3, while all females were mature by 7 inches and age-4 (Tables 8 and 9). Males tend to reach sexual maturity before they are effectively sampled by gillnets.

The catch rate of age-3 Yellow Perch in 2014 was 7.2 (2011 year class), which was the same as the upper quartile range for all catch rates observed since 1983 (Figure 29). Catch rates of age-3 Yellow Perch have been below the long-term average (5.4 fish/net) for three of the past four year classes (2008-2011). Female length at age-3 (6.3 inches) was below the long-term average of 6.5 inches and has had a declining trend since 2006 when growth rates peaked presumably in response to cormorant predation.

Northern Pike

A total of 165 Northern Pike were sampled in gillnets. The overall catch rate was 4.6 (fish/net) and 9.9 (pounds/net). This was similar to 2013 (Figures 16 and 17), but lower than the long-term averages of 4.8 (fish/net) and 11.5 (pounds/net). Previous catch rates ranged from 3.6 fish/net (1993) to 6.2 fish/net (1995), and 7.9 pounds/net (1984) to 19.0 pounds/net (1995). The 2014 catch rate was above the 2011-2015 management objective of 4.1 fish/net (Figure 18); 4.1 is the 25th percentile of the long-term data set (1983-2010).

Although catch rates have been higher in the western bays than the main lake since 2000, the catch rate in 2014 was higher in the main lake (5.1 fish/net) compared to the western bays (3.9 fish/net) (Table 6, Figure 15). Of all Northern Pike sampled, 62% were from the main lake, while 38%

were from the western bays. By sampling strata, catch rates ranged from 2.0 fish/net (Walker Bay) to 8.3 fish/net (Boy/Headquarters Bay).

Total length of Northern Pike sampled ranged from 11 to 34 inches (Table 8; Figure 19) and ages ranged from 1 to 9 years old (Table 9; Figure 20). The 2010 and 2011 year classes made up 47% of all Northern Pike sampled. Of all Northern Pike sampled, 56% were 20 inches or longer, 13% were 25 inches or longer, and 4% were 30 inches or longer. The percentage of Northern Pike sampled in 2014 that were ≥21 inches (RSD-Q) was 49%, compared to the management plan objective of 43% (Figure 21). Both of the Northern Pike size structure objectives in the 2011-2015 management plan were met in 2014. The average lengths of age-1 through age-4 Northern Pike were 14.5, 17.0, 19.7, and 22.1 inches, respectively (Figure 30).

All males were mature by 14 inches and age-2, while all females were mature by 16 inches and age-2 (Tables 8 and 9). The catch rate of age-3 Northern Pike in 2014 was 1.1 fish/net, which was similar to the long-term average of 1.3 (Figure 31). Catch rates of age-3 Northern Pike have been between the upper and lower quartile ranges for seven consecutive year classes (2005-2011), indicating stable recruitment.

Cisco (Tullibee)

A total of 144 cisco were sampled in gillnets. The overall catch rate was 4.0 (fish/net) and 5.4 (pounds/net). This was up slightly from 2013 (Figures 16 and 17). The number/net was lower than the long-term average of 5.3 (fish/net), but pounds/net was higher than the long-term average of 2.8 (pounds/net) due to primarily large adults being sampled in 2014. Previous catch rates ranged from 0.6 fish/net (2006) to 18.5 fish/net (1987), and 0.2 pounds/net (2006) to 7.2 pounds/net (1985).

Catch rates were higher in the main lake than the western bays. The catch rate in the main lake was 6.5 fish/net while the catch rate in the western bays was 0.9 fish/net (Table 6, Figure 15). Of all Cisco sampled, 90% were from the main lake, while 10% were from the western bays. By sampling strata, catch rates ranged from 0.0 fish/net (Steamboat Bay) to 11.8 fish/net (Main Basin North).

Cisco sampled ranged from 7 to 18 inches (Table 8; Figure 19) and 2 to 10 years old (Table 9, Figure 20). Several year classes were well represented in the 2014 sample, with the 2006, 2007, 2008, 2011, and 2012 year classes each making up from 13 to 22 % of all year classes sampled. Of all Cisco sampled 82% were 10 inches or longer and 58% were 15 inches or longer. Mean lengths of age-2 through age-5 fish were 8.7, 12.2, 13.9, and 14.7 inches, respectively. All males and females were mature by 9 inches and age-3 (Tables 8 and 9). Since cisco aging began in 2008, the 2007 and 2008 year classes have been the most frequently sampled (Figure 32). Individuals from all year classes since 2001 have been sampled, indicating consistent recruitment.

Other Species

Other species sampled in 2014 included Black Crappie, Bluegill, Bowfin, Brown Bullhead (*Ameiurus nebulosus*), Burbot, Muskellunge, Pumpkinseed, Rock Bass, White Sucker, and Yellow Bullhead (*Ictalurus natalis*), are not effectively sampled by gill nets or are present in low numbers (Table 4). Species not sampled in 2014 that have been previously sampled include Black Bullhead (*Ameiurus melas*), Lake Whitefish, Largemouth Bass, Shorthead Redhorse, Smallmouth Bass, and Tiger Muskellunge (*Esox masquinongy x Esox lucius*; Appendix 1).

Discussion

Catch rates of Walleye remained above the long-term average for the eighth consecutive year and overall Walleye biomass sampled (lbs/net) has increased steadily since 2004. Conversely, catch rates of Yellow Perch have had a decreasing trend for seven years and the 2014 catch rate was the second lowest observed since the large lake program began in 1983. Catch rates of Northern Pike continued to remain between quartile ranges. Cisco catch rates were between quartile ranges in terms of fish/net; however, catch rates in terms of pounds/net exceeded the upper quartile due to the high proportion of larger individuals sampled.

Biological performance indicators (BPIs), or population response metrics, were developed to monitor exploitation of Minnesota's large lake Walleye populations (Gangl and Pereira 2003). Exceedance of BPI threshold levels can indicate overharvest or, more precisely, increased mortality. Two of the initial signs of increased mortality are increased growth and earlier maturity rates (Rose et al. 1999). During 2000-2010, the average female length at age-3 and female length and age at 50% maturity, indicated cause for concern (Figure 27). Schultz et al. (2013) found statistical differences in Walleye recruitment, growth, and maturity among the 1992–1997, 1998–2004, and 2005–2011 time periods, which represent pre-colonization, population buildup, and the management eras of the double-crested cormorant population. The differences in these metrics across these respective time periods were suggested Walleye population responses to increased mortality, and some of these metrics were strongly associated with changes in cormorant abundance. Similar percid population responses were observed on Lake Huron (Fielder 2008, 2010). As of 2014, female mean length at age-3, length at 50% maturity, and age at 50% maturity have declined below their respective thresholds and become similar to the long-term averages. Therefore, Walleye population metrics, which are indexed by the BPIs, have all returned to levels similar to long-term averages.

The metrics for Walleye associated with the 2011-2015 Leech Lake Management Plan (Schultz 2010a) were within or above management objectives for all objectives except the proportion of Walleye shorter than fifteen inches. The consistency in the Walleye population since 2005 suggests a positive response to current management actions. The protected slot limit on Walleye has successfully protected mature females and has increased the reproductive capacity of the population. Walleye recruitment has also become less variable since 2007, as indicated by the catch rate of age-3 Walleye remaining above the long-term average in five of the seven years between 2005 and 2011. This is similar to post-regulation recruitment patterns observed on Upper Red Lake (Kennedy 2013) and Lake Winnibigoshish (Schultz and Staples 2010a). Density is an important factor regulating growth, maturity, and recruitment (Spangler et al. 1977; Muth and Wolfert 1986; Schueller et al. 2005). Changes in the Walleye population have led to considerable improvements to the recreational fishery as indicated by summer creel surveys conducted during

2008-2011, 2014 (Schultz 2009; Schultz 2010b; Vondra and Schultz 2011, Ward and Schultz 2012, Stevens 2014). Overall, Walleye metrics indicate the population has fully recovered, while some metrics indicate the population density has exceeded those levels to the detriment of the prey base.

Statewide declines in Yellow Perch have been observed and suspected causes include increases in predation by gamefish, increases in competition at early life stages by insectivores such as bluegills, and near shore spawning habitat loss, among others (Bethke and Staples 2015). Specific causes of recent declines in Yellow Perch abundance in Leech Lake are unclear, but elevated predation by juvenile and adult Walleye and increases in total harvest of Yellow Perch by winter anglers are both suspected. Recent Walleye year classes have consistently been near or above the long-term average in terms of strength, which has resulted in a consistent high forage demand by juvenile Walleye. Pierce et al (2006) documented density-dependent responses in both Walleye and Yellow Perch populations with changes in Walleye stocking rates and that Walleye predation associated with differing stocking rates was a plausible explanation for most changes observed in the prey base. This is because juvenile Walleye have higher metabolic rates and energy demand, on a per-pound basis they consume more than adult Walleye (Kitchell et al. 1977; Hartman and Margraf 1992; Madon and Culver 1993). Furthermore, management actions that can elevate juvenile Walleye densities may lead to reduced Walleye growth (Forney 1976; Pierce et al. 2006; Kampa and Hatzenbeler 2009), reduced Walleye recruitment (Fayram et al. 2005; Jacobson and Anderson 2007; Hansen et al. 2012), and exert unnecessary predation pressure on Yellow Perch (Nielsen 1980; Lyons and Magnuson 1987; Knight et al 2004; Pierce et al. 2006). Recent steps taken to reduce predation pressure on Yellow Perch include a reduced Walleye fry stocking rate and increased angler harvest through regulation relaxation. An above average Yellow Perch catch rate for the 2011 year class indicates the first strong year class potentially has been produced since 2007. Above average year classes of Yellow Perch had been produced annually from 2003 through 2007.

Record Yellow Perch harvest by anglers was documented during the 2010 angling season, with winter angling making a significant contribution for the first time in the creel history (Schultz and Vondra 2011). Winter creel surveys are proposed in two of the next three winters in addition to summer surveys proposed in 2016 and 2017 should quantify this further. Although many anglers continue to perceive cormorant consumption of Yellow Perch to have a significant influence on recruitment, consumption by cormorants has been reduced by 90% relative to 2004 levels and are similar to pre-2000 levels (Schultz et al. 2013).

Increases in Northern Pike density, particularly increases in ‘hammer handle’ sized pike, are currently being observed statewide (B Bethke, MN DNR, personal communication). . These trends have resulted in proposals to statewide regulations and concerns by anglers. Despite statewide trends, Northern Pike catch rates have varied by less than three fish/net since 1983, indicating a stable population on Leech Lake. Catch rates of age-3 Northern Pike have also only varied between 0.4 and 2.4 (fish/net). Similar to walleye and yellow perch, northern pike in Leech Lake tend to grow slightly faster in the main lake than in the western bays.

Peaks in cisco catch rates are often highly variable, and typically are associated with strong year classes of age-1 and/or age-2 fish. Juvenile Cisco can comprise larger proportions of predator diets when large year classes are present, thereby providing predation relief to Yellow Perch (Forney

1974) and other prey species (Schultz et al. 2013). Cisco populations are often limited by thermal regimes. As a coldwater species Cisco require elevated oxygen levels. During warm summers oxygen levels particularly in the shallower, windswept main lake basin will decrease due to the reduced ability of water to retain oxygen at higher temperatures. In addition, as coldwater species such as Cisco become physiological stressed by warmer temperatures oxygen demand is increased (Pörtner 2001; Pörtner and Knust 2007). In instances such as this without sufficient thermal refuge Cisco can be subject to episodes of summer kill. Consequently, the cisco population in Leech Lake is constrained by summer climate trends particularly in the main basin where oxygen-rich coldwater habitat is limited but spawning habitat is abundant. This has the potential for impacts on other species, specifically the growth rates of predatory species.

OTHER WORK

Water Quality

Water samples were collected at stations one (Walker Bay) and five (Stony Point) on July 28, 2014. The Minnesota Department of Agriculture Chemistry Laboratory in St. Paul, Minnesota analyzed the samples collected for total phosphorus, conductivity, chlorophyll a, pH, total alkalinity and total dissolved solids.

When looking at the long-term data set collected by the MNDNR, there has been no apparent change in water quality since the inception of the Large Lake Program (Table 10). Water clarity data is available from the University of Minnesota Remote Sensing and Geospatial Analysis Laboratory and Water Resources Center (2014). Water quality monitoring data is also available from the Minnesota Pollution Control Agency (2014).

In general, Walker Bay is less productive with greater water clarity than the main lake (Stony Point site). Walker, Kabekona, and Agency bay sample sites exceed 100 feet deep and stratify annually around early to mid-July (Figures 33-37). Stratification refers to a substantial change in temperature commonly referred to as the thermocline. The location off Stony Point, similar to Portage, Sucker, Boy, and Headquarters bays, rarely exceed 30 feet and do not stratify. This means the water temperature and oxygen levels are very similar throughout the entire water column.

Aquatic Invasive Species (AIS)

A survey of Leech Lake boat harbors in 2004 found established beds of Eurasian water milfoil (EWM; *Myriophyllum spicatum*) in several harbors between Stony and Rogers points and were immediately treated with aquatic herbicide. Since 2004 harbors have been annually checked for EWM by DNR personnel and treated when necessary. Extensive searches have only discovered rooted EWM outside of harbors at one location, in Miller Bay on the south side of the main lake, and treatments have resulted in the eradication of EWM from some harbors. However, this invasive species continues to be discovered in new harbors throughout the lake.

The DNR Division of Ecological and Water Resources (EWR) conducted site inspections on 175 harbors on the lake in July and August of 2014. Fourteen harbors were found to have Eurasian Water milfoil. Although permission to treat all 14 harbors was sought, it was only granted from 11 harbor owners or associations. A total of 7.8 acres were treated on October 2, 2014 (Figure 38). Inspection and treatment plans for 2015 remain consistent with what is specified in the Leech Lake Management Plan. Inspection and treatment plans beyond 2015 will have to be coordinated with EWR and included in the 2016-2020 management plan. EWM is now considered widespread throughout the main basin harbors, and appears to be establishing itself in open areas of the main lake despite annual treatments.

While conducting EWM harbor searches during 2009 curly-leaf pondweed (CLP) (*Potamogeton crispus*) was identified and removed from a harbor near Whipholt Beach. This is not the first occurrence of CLP, as it has been previously documented in the Leech Lake River embayment near Federal Dam. Like EWM, CLP can be an aggressive invasive aquatic plant and DNR personnel will continue to monitor CLP presence in Leech Lake.

Rusty crayfish (*Orconectes rusticus*) are a nonnative species of crayfish native to the Ohio River drainage basin and were first sampled by the DNR in the late 1980s. Staff began recording the number of rusty and native crayfish entangled per gill net during the annual gill net assessment in 2002 after rusty crayfish numbers had expanded (Figure 39). Yellow Perch appear to have a strong influence on Rusty Crayfish abundance, as an inverse relationship exists between the two species (Figure 40).

The DNR Division of Ecological and Water Resources spent 1,842 hours conducting 4,767 watercraft inspections at Shingobee, Federal Dam, Walker City Park, Stony Point, Erickson's Landing, Sugar Point, and Sucker Bay accesses in 2014. Preliminary 2015 plans include a similar schedule; however, new nearby infestations could result in schedule adjustments. The Cass County SWCD also contributed significant watercraft inspection hours on area lakes.

Double-Crested Cormorant management

The 2014 spring and fall double-crested cormorant (*Phalacrocorax auritus*) numbers were 2,517 and 602, respectively (Figures 41-42). A total of 1,698 adults were removed during 2014, bringing the overall total to 23,496 birds culled since work began in 2005 and making Leech Lake the largest single management site in the U.S. (S. Mortensen, LLBO Division of Resource Management, personal communication). The DNR continues to annually contribute $33,000 in funding for cormorant management. In a study conducted from 2004-2011, Schultz et al. (2013) concluded that total feeding effort and fish consumption was reduced by nearly 90%. In 2004, the cormorant population consumed 16.81 pounds/acre and by 2011 total fish consumption was reduced to 1.61 pounds/acre. Respectively, average fledged and nestling diets were comprised of Yellow Perch (61.0% and 77.4%), Cisco spp. (12.3% and 9.4%), minnows *Notropis* spp. (9.9% and 2.2%), Trout-perch *Percopsis omiscomaycus* (4.1% and 0.4%), and Walleye (4.6% and 3.6%), though considerable seasonal and temporal variability was observed.

Modeling also determined the predation potential on juvenile walleye by cormorants was high enough during 2000-2004 to impact walleye recruitment (Schultz et al. 2013). The 2000-2005 year classes of Walleye were five of the worst seven year classes observed since 1983, and this trend was most prevalent in the main lake basin where cormorants fed almost exclusively. Statistical differences were observed in walleye recruitment, growth, and maturity rates and yellow perch growth rates among the 1992–1997, 1998–2004, and 2005–2011 time periods. These time periods represented the pre-colonization, colonization and expansion, and cormorant management eras. The differences in these metrics across these respective time periods were indicators of a population response to increased mortality (Gangl and Pereira 2003; Fielder 2008).

Zooplankton Sampling

In 2014, zooplankton were sampled monthly at five locations from mid-May through mid-October. Sampling stations included sites in Walker Bay, Kabekona Bay, Agency Bay, Stony Point (Main Lake), and Five Mile Point (Portage Bay). The sites selected were the deepest locations in each respective area. After locating each site and holding the boat with the motors with the stern into the wind, a net with a 30 cm mouth diameter and 80 μm mesh was lowered so that the bucket of the net was approximately 0.5 meters from the bottom. The net was raised at 0.5 to 1 meters per second to the surface. The sample was rinsed from the bucket into a plastic bottle and preserved with 100% reagent alcohol.

The DNR Division of Ecological and Water Resources Biology Lab processed the samples. Samples were prepared in the lab by filtering them through 80 μm mesh and rinsing specimens into a graduated beaker. Water was added to a volume that provided at least 150-200 organisms per 5 ml aliquot. The beaker was swirled to ensure thorough mixing. A 5 ml aliquot was withdrawn from each sample using a bulb pipet and transferred to a counting grid. Individual zooplankters were identified to the lowest taxonomic group possible, counted, and measured using a dissecting microscope and a computerized analysis system. Density (number/liter), biomass (μg/liter), percent composition by number and weight, mean length (mm), mean weight (μg) and total count of each taxon identified was generated by an analysis system and recorded in the DNR zooplankton database (J. Hirsch, DNR).

The number and biomass of zooplankton sampled at each of the five sites throughout 2014 was variable and without discernible trends (Table 11, Figure 43). The number of zooplankton sampled ranged from 22/liter in Walker Bay to 37/liter in Portage Bay. The biomass of zooplankton sampled ranged from 74 (µg/liter) in Kabekona Bay to 102 in Portage Bay. The overall diversity of taxa sampled was high for lakes in this region, with 19 species identified (Table 12).
No spiny waterflea (*Bythotrephes longimanus*) or zebra mussel (*Dreissena polymorpha*) veliger's were found in any of the samples. When spiny waterflea are present, small cladocerans commonly decline or disappear (Yan and Pawson 1997). Most individual taxa identified were typical of lakes in this region; however two somewhat rare species have been sampled in each of the past three years. One was *Daphnia longiremis*, which is a cold/deep water daphnia which spends most of its life below the thermocline. Other regional lakes this species has been sampled include Cass, Ten Mile, and Carlos. The other rare species sampled was a large copepod *Limnocalanus macrurus*, which is a glacial relict. This species has only been sampled in the large deep lakes in the state, such as Lake of the Woods, Rainy, Namakan and Sand Point Lakes. These are two species we will closely monitor when assessing how climate change, AIS, and other influences affect the lake.

Data in 2014 indicate a similar overall density (number/liter) and biomass (μg/liter) were sampled at most stations and during most months, when compared with 2013. However, densities and biomass were substantially higher in 2012 (Figure 44). Species diversity was similar between years with 20 species being sampled in 2012, while 19 species were sampled in both 2013 and 2014. Over the past three years, the density sampled in Portage Bay and at Stony Point has been consistently higher than the other three sites.

Walleye Regulation Changes

Prior to 2005 Leech Lake Walleye regulations were consistent with statewide regulations. Following a formal regulation review and public input process in 2004, an 18-26" protected slot limit (PSL), bag of 4, with one fish over 26" allowed in possession, was implemented in May 2005. The objective was to protect Walleye spawning stock and promote natural reproduction. A formal review of this regulation occurred in 2010 as part of the Leech Lake Management Planning Process, which resulted in strong support for the continuation of the regulation. As an outcome of this review, criteria were established in the 2011-2015 Management Plan for relaxing the protected slot under certain predetermined conditions. Exceedance of the spawner stock biomass objective range of 1.5 – 2.0 pounds/acre for two consecutive years would initiate consideration for relaxing the 18-26" PSL to a 20-26" PSL (bag and possession limit unchanged). These criteria were met in 2012 and 2103 (Figure 25). Following a formal regulation review and public input process in the fall and winter of 2013-2014, a 20-26" PSL (bag and possession limit unchanged), was implemented in May 2014. Criteria now state that if estimates of mature female Walleye biomass fall below 1.50 pounds/acre for two consecutive years, the DNR will implement alternative regulations designed to increase spawner biomass to within management goals. Special summer and winter creel surveys occurred in 2014 to quantify regulation change effects on catch and harvest (Stevens and Ward 2015). Regularly scheduled creel surveys are planned for 2016 and 2017.

SUMMARY

Recent management actions have allowed for improvements in the Leech Lake Walleye population. Benchmarks used to evaluate the success of the 2011-2015 management plan included a standing stock biomass of mature females maintained at 1.5-2.0 pounds/acre, an increase in the Walleye gillnet catch rate to at least 8.5 fish/net, between 45% and 65% of Walleye sampled in gillnets being shorter than 15.0 inches, and Walleye year classes having a measured strength of the long-term average (50^{th} percentile) or higher during any two of four consecutive years. The estimated spawner biomass in 2014 was 2.5 pounds per acre and exceeded the management objective range for the third consecutive year. The gillnet catch rate of 8.9 fish/net exceeded the management objective and was above the long-term average for the eighth consecutive year. Of the Walleye sampled in gillnets, 42% were shorter than 15.0 inches. This percentage is slightly below the management objective range of 45-65% and indicates a higher proportion of larger individuals were sampled. Similar to the 2010-2013 year classes, the 2014 year class has a predicted relative strength above the long-term average and the management plan objective.

The 2010, 2011, and 2012 Walleye year classes will provide anglers harvest opportunities throughout 2015. The Walleye regulation (PSL 18-26") that was in place from 2005-2013 contributed to improved fishing quality by increasing the number of older, larger Walleye in the population for anglers to catch. This has been reflected by overall higher Walleye catch rates in the summer creel surveys during 2008-2011 and 2014, when compared to the 2004-2005 summer creel surveys. The new Walleye regulation (PSL 20-26", bag and possession limit unchanged) resulted in about 25% of angler-caught Walleye being protected, compared to 30-35% under the previous regulation.

The strength of the 2014 Walleye year class will depend largely on winter survival. Median length of the YOY Walleye sampled during September electrofishing was 5.86 inches, indicating below average growth was accrued by greater than 50% of the cohort. However, above average air temperatures in October may have extended the 2014 growing season. Of the seven year classes produced from 2005-2011, four exceeded the upper quartile range and were considered strong, one was between quartile ranges and considered average, while two were below the lower quartile range and considered poor. The 2012-2014 year classes are predicted to remain between quartile ranges based on age-0, age-1, and age-2 catch rates thus far.

Current Walleye regulations have resulted in a more stable adult population and therefore more consistent fry production. This has resulted in less recruitment variability, especially in recent years as the adult population has stabilized. The number of wild fry that has been produced annually since 2007 has averaged 363 fry/LA (range 108-779 fry/LA). Walleye fry densities ranging from 300-600 fry/LA have resulted in the greatest number of individuals recruiting thus far; the 2012-2014 year class observations are still incomplete. Wild fry production will continue to vary with environmental conditions, and this variability is both normal and beneficial to the long-term maintenance of the fishery, which includes the prey base. Given the relatively consistent range in wild fry production following build-up of spawner biomass, the observed density-dependent relationships between total fry density, growth and recruitment, and the evidence implicating cormorants as strong contributor to population declines in the early 2000's, continued stockings are no longer warranted. Planning efforts beginning February, 2015 should define how and when stocking should be most appropriately used as a management tool in the future.

Cormorant management efforts since 2005 benefitted juvenile Walleye and Yellow Perch survival and led to short-term increases of Yellow Perch. High angler harvest and Walleye predation are suspected causes of the current declining trend in Yellow Perch abundance; the latter theory is supported by the consistently lower condition values of adult Walleye since 2007 and various previously explanations.

In addition to the improvements to the Walleye population, Leech Lake continues to support numerous sportfish populations that appear relatively healthy or unchanged, and remains a destination for many anglers pursuing quality multi-species angling opportunities. Northern pike abundance exceeds the management objective, and size structure indices suggest a relatively balanced population. Yellow perch catch rates have had a declining trend for the past seven years, and size structure objectives both fell below management objectives in 2014 for the first time since 2007. However, a strong 2011 Yellow Perch year class was observed and should begin to contribute to the fishery by 2016. Anglers frequently report catching quality bluegill and black crappie. Leech Lake continues to be a destination for several Largemouth Bass, Muskellunge, and Walleye fishing tournaments each year.

Although the monitoring and treatment of Eurasian water milfoil (EWM) has likely slowed the spread of this invasive plant, it continues to be found at new locations around the lake each year in both harbors and areas of the main lake proper. Constant awareness by users and property owners alike is paramount to prevent further spread and establishment of EWM to new locations, as well as the spread of other AIS to new waters.

RECOMMENDATIONS

Leech Lake supports a diverse fish population and maintains good water quality. However, human development continues to expand throughout the area and, as more people relocate to this area and recreate on and around Leech Lake, the opportunities for further effects from human activities will continue to increase. Habitat protection measures should continue to be a priority to ensure the ecological resilience of Leech Lake is not compromised. This can be done through scrutinizing development proposals within the entire Leech Lake River watershed. Projects that are approved should use techniques that minimize impacts to the resource. Landowners within the watershed should be encouraged to use Best Management Practices (BMPs), especially along the lakeshore. The vegetation study that began in 2002 was completed in 2005, and the information obtained will further our understanding of fish habitats and identify areas to focus future protection efforts on based on species presence and abundance. A future vegetation study to assess changes in species presence and abundance should be a priority. A future shoreline habitat survey, similar to Wilcox (1979), to evaluate changes in shoreline substrates and spawning areas should also be a priority.

A comprehensive list of sensitive shoreline that is prone to development was drafted to prioritize conservation action, particularly on new developments. In addition, these landowners should be contacted and made aware of options such as conservation easements. Efforts such as these provide the best opportunities to sustain the quality resources that Leech Lake provides.

Education and communication efforts are extremely valuable in changing attitudes and perceptions about what does or does not impact ecosystem health. Participation by individuals representing various groups and organizations through the Leech Lake Management Planning Process assists in disseminating annual fish survey information to their respective organizations. Other forms of public engagement that will continue to be pursued include volunteers, media outlets, Leech Lake Updates, etc.

Continued monitoring and treatment of harbors with Eurasian water milfoil is planned for 2015. Additional educational contacts should be made to those that use the harbors, with increased effort during high use periods. Cooperation of the harbor owners is critical. Similar efforts are needed to prevent the introduction of other exotic species, such as zebra mussels or spiny waterflea, which have already established in other Minnesota systems. Attendance of a DNR volunteer boat inspector training session, participating on the Cass County Invasive Species Task Force, increased boat inspections at public accesses, requiring all watercraft participating in fishing tournaments to have an AIS inspection, increased AIS signage at public accesses, and educating those staying at resorts are all measures that are being taken to slow the spread of invasive species.

Annual monitoring of fish populations and water quality analyses should continue. The next Muskellunge egg collection and put-back stocking event is scheduled for 2017. The next lakewide survey to monitor Centrarchid populations (Bluegill, Black Crappie, and Largemouth Bass) is scheduled for spring 2015. Double-Crested Cormorant management efforts should continue as prescribed by the management plan for this species. Finally, to completely evaluate the full capacity of Walleye reproduction and recruitment since cormorant management was implemented in 2005, stocking blanks (years where no stocking occurs) should be pursued.

Continued summer and winter creel surveys as frequently as possible will assist in monitoring changes in pressure, catch, catch rates, harvest, and harvest rates for all species. Guide diaries were pursued as a surrogate for creel surveys during years in which creel surveys were not scheduled. Poor overall participation resulted in a sample size that was inappropriate for statistical comparisons during the trial year in 2011.

Many of the above action items were outlined in the Leech Lake Management Plan, 2011-2015 (Schultz 2010a).

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TABLES

Table 1. The number of Walleye stocked in Leech Lake from 1922 through 2014.

Year	Adult	Yearling	Fingerling	Fryling	Fry
1922-1945	890	-	-	-	171,038,212
1946	50	-	-	-	-
1947	-	-	-	-	-
1948	-	-	87,583	-	-
1949	-	-	123,854	-	-
1950	-	66	26,464	-	-
1951	197	-	54,050	-	-
1952	-	-	62,564	-	-
1953	-	-	34,191	-	-
1954	283	-	173,483	-	-
1955	145	-	25,064	-	-
1956	6	-	9,625	-	-
1957	666	-	5,576	-	-
1958	12	-	-	-	-
1959	-	-	10,472	-	-
1960-1961	-	-	-	-	-
1962	653	1,101	15,439	-	-
1963	-	6	10,396	-	-
1964	-	-	23,148	-	-
1965	-	-	34,380	-	-
1966	-	-	11,815	-	-
1967	-	-	44,863	-	-
1968	-	-	7,387	-	-
1969	-	5	140	-	-
1970	22	-	31,603	-	-
1971	-	-	-	-	-
1972	120	-	2,660	-	-
1973	1	10	18,554	-	-
1974	50	-	2,505	-	-
1975	-	-	26,560	-	-
1976-1979	-	-	-	-	-
1980	-	-	49,650	-	-
1981	-	-	5,300	-	-
1982	270	-	34,067	-	-
1983	-	818	-	-	2,000,000
1984	-	-	12,250	-	400,000
1985	4	110	7,150	-	100,000
1986	-	-	1,790	-	2,500,000
1987	-	-	112	-	-
1988-2004	-	-	-	-	-
2005	-	-	-	-	7,562,115
2006	-	-	-	206,084	22,032,452
2007	-	-	-	-	7,523,670
2008	-	-	-	-	22,166,808
2009	-	-	-	-	22,669,368
2010	-	-	-	-	22,501,356
2011	-	-	-	-	22,021,332
2012					7,501,632
2013					7,527,478
2014	-	-	-	-	7,500,512

Table 2. Summary of Walleye fry stocking for five Minnesota lakes, 1999-2014 and Leech Lake, 2005-2014. SSB refers to spawner stock biomass estimated from gillnet catches of mature female Walleye the previous fall.

		SSB	Amount	YOY	Hatch	Fry per LA	
Lake	Year	(lbs/A)	Stocked/LA	Marked (%)	Rate (%)	Wild	Total
Leech	2005	1.91	130	39	0.22	203	334
	2006	1.04	380	86	0.12	61	440
	2007	1.67	129	23	0.54	432	561
	2008	2.13	382	55	0.31	317	699
	2009	1.32	391	50	0.60	385	775
	2010	1.49	388	57	0.40	290	678
	2011	1.67	380	69	0.21	172	552
	2012	1.82	129	14	0.89	779	908
	2013	2.28	130	23	0.38	422	552
	2014	2.21	129	54	0.10	108	237
	Mean	1.75	257	47	0.38	317	574
Red	1999	0.08	522	86	0.60	86	607
	2001	0.59	400	70	0.16	174	574
	2003	0.33	414	97	0.02	11	425
	2004	3.68	127	9	0.18	1325	1452
	2005	1.05	49	14	0.15	290	339
	Mean	1.15	302	55	0.22	377	679
Ottertail	2008	0.99	153	29	0.48	373	526
	2009	1.02	600	56	0.56	467	1067
	2010	1.77	733	72	0.20	277	1010
	2011	2.65	820	67	0.18	406	1226
	2012	0.97	1728	67	1.11	854	2582
	2013	1.42	586	64	0.26	329	915
	Mean	1.47	770	59	0.46	451	1221
Woman	2007	1.49	2448	73	0.88	896	3344
	2008	1.41	1516	60	1.01	1014	2530
	2009	1.23	580	83	0.15	117	697
	2010	0.35	995	97	0.26	28	1023
	2011	1.11	1002	96	0.06	41	1043
	2012	0.70	1350	71	0.95	551	1901
	2013	1.33	584	97	0.02	21	605
	Mean	1.09	1211	82	0.47	381	1592
Winnibigoshish	2009	1.98	623	83	0.06	132	755
	2010	2.02	514	88	0.04	72	586
	2011	2.48	693	74	0.10	239	932
	2012	1.75	133	49	0.08	140	272
	2013	2.69	1038	4	8.16	22246	23285
	Mean	2.18	600	60	1.69	4566	5166
Vermillion	2010	1.24	400	37	0.70	666	1066
	2011	0.90	1000	60	0.97	665	1665
	2012	1.98	773	62	0.27	474	1247
	2013	2.01	773	12	2.85	5533	6306
	Mean	1.53	737	43	1.20	602	2571

Table 3. Seine catch rates (CPUE, number/haul) of all species and ages captured, Leech Lake, 2014.

Species	Age	Total number	Number measured	Mean length (inches)	Length (inches) Min	Max	Catch rates num/haul	num/acre
Johnny Darter	All	8	0	N/A	N/A	N/A	0.4	1.3
Black Crappie	YOY	9	9	1.34	0.87	1.50	0.5	1.5
Bluntnose Minnow	All	12	0	N/A	N/A	N/A	0.6	1.9
Emerald Shiner	All	27	0	N/A	N/A	N/A	1.4	4.4
Fathead Minnow	All	1	0	N/A	N/A	N/A	0.1	0.2
Largemouth Bass	YOY	584	112	1.59	1.18	2.20	29.2	94.2
Logperch	All	50	0	N/A	N/A	N/A	2.5	8.1
Longnose Dace	All	9	0	N/A	N/A	N/A	0.5	1.5
Mimic Shiner	All	1,869	0	N/A	N/A	N/A	93.5	301.5
Spotfin Shiner	All	113	0	N/A	N/A	N/A	5.7	18.2
Tullibee (Cisco)	YOY	3	3	2.49	2.20	2.72	0.2	0.5
Walleye	YOY	782	214	3.37	1.93	4.25	39.1	126.1
Walleye	≥1	16	16	6.88	5.94	8.07	0.8	2.6
Yellow Perch	YOY	1,832	417	1.63	1.18	1.97	91.6	295.5
Yellow Perch	≥1	281	218	3.13	2.36	6.30	14.1	45.3

Table 4. Trawl catch rates (CPUE, number/hour) of all species and ages captured, Leech Lake, 2014.

Species	Age	Total number	Number measured	Mean length (inches)	Length range (inches) Min	Max	Catch rates num/haul	num/hour
Johnny Darter	All	4	0	N/A	N/A	N/A	0.2	2.4
Black Crappie	YOY	1	1	2.32	2.32	2.32	0.1	0.6
Bluntnose Minnow	All	70	0	N/A	N/A	N/A	3.5	42.0
Burbot	YOY	1	0	N/A	N/A	N/A	0.1	0.6
Golden Shiner	All	1	0	N/A	N/A	N/A	0.1	0.6
Largemouth Bass	YOY	26	26	2.87	2.05	3.5	1.3	15.6
Logperch	All	206	0	N/A	N/A	N/A	10.3	123.6
Mimic Shiner	All	62	0	N/A	N/A	N/A	3.1	37.2
Northern Pike	All	3	3	21.67	20.12	23.62	0.2	1.8
Pumpkinseed	All	1	1	3.54	3.54	3.54	0.1	0.6
Smallmouth Bass	YOY	41	41	1.86	1.3	2.56	2.1	24.6
Spotfin Shiner	All	226	0	N/A	N/A	N/A	11.3	135.6
Spottail Shiner	All	224	0	N/A	N/A	N/A	11.2	134.4
Tadpole Madtom	All	16	0	N/A	N/A	N/A	0.8	9.6
Trout-Perch	All	1	0	N/A	N/A	N/A	0.1	0.6
Tullibee (Cisco)	YOY	1	1	2.91	2.91	2.91	0.1	0.6
Walleye	YOY	593	301	4.74	2.76	6.26	29.7	355.8
Walleye	≥1	96	82	10.21	6.54	22.13	4.8	57.6
White Sucker	All	15	0	N/A	N/A	N/A	0.8	9.0
Yellow Perch	YOY	4,629	311	1.95	1.46	2.44	231.5	2,777.4
Yellow Perch	≥1	5,502	468	3.93	2.48	12.05	275.1	3,301.2

Table 5. Catch-per-effort (CPE) of young-of-year walleye in selected gears and associated year class strength (YCS) indices. Estimates are incomplete until Walleye are fully recruited at age-3.

				Year Class Strength (Pereira)		
Year Class	Trawl CPE (fish/hour)	Gillnet CPE (fish/net)	Electrofishing CPE (fish/hour)	Observed (q-adj)	Eq. 1 Predicted	Eq. 2 Predicted
1983		0.22		1.96		
1984		0.36		1.20		
1985		0.03		1.49		
1986		0.08		2.18		
1987	49	0.11		1.06		
1988	128	1.81		2.30		
1989	62	0.06		1.10		
1990	72	0.03		1.20		
1991	58	0.47		1.64		
1992	103	0.00		0.71		
1993	16	0.00		0.30		
1994	493	0.08		2.29		
1995	183	0.51		1.81		
1996	262	0.14		1.42		
1997	5	0.29		1.89		
1998	139	0.47		1.11		
1999	348	0.56		1.31		
2000	28	0.14		0.73		
2001	103	0.69		1.04		
2002	38	0.31		1.04		
2003	27	0.08		0.61		
2004	3	0.00		0.47		
2005	247	0.03	60	1.33		
2006	240	0.69	35	1.88		
2007	31	1.47	27	1.78		
2008	508	0.00	42	1.38		
2009	153	0.03	164	1.23		
2010	80	0.03	56	1.66		
2011	40	0.03	175	1.47		
2012	**148**	**0.47**	**237**	**1.76**	**1.35±0.19**	**1.63±0.21**
2013	**346**	**0.06**	**88**	**1.81**	**1.68±0.33**	**1.46±0.28**
2014	**356**	**0.06**	**109**		**1.69±0.34**	**1.46±0.28**
Mean	152	0.29	99	1.39		

Equation 1: YCS = (0.00163*trawl CPE) + 1.11148; R-sq = 0.19

Equation 2: YCS = (0.42158*trawl CPE) + (1.99048*gillnet CPE) + 0.33500; R-sq = 0.43

Table 6. Gillnet catch-per-effort (fish/net) summary by species and basin for Leech Lake, 2014.

	Western Bays			Main Lake			Whole Lake	
		1983-2014			1983-2014			1983-2014
Species	2014	Mean	#	2014	Mean	#	2014	Mean
Black bullhead	0.0	8.6	#	0.0	2.1	#	0.0	5.0
Black crappie	0.1	0.3	#	0.7	0.5	#	0.4	0.4
Bluegill	0.1	0.7	#	0.1	0.3	#	0.1	0.5
Bowfin	0.0	0.1	#	0.1	0.0	#	0.1	0.1
Brown bullhead	0.2	1.9	#	0.1	1.1	#	0.1	1.5
Burbot	0.1	0.0	#	0.2	0.1	#	0.1	0.1
Hybrid sunfish	0.0	0.0	#	0.0	0.0	#	0.0	0.0
Lake whitefish	0.0	0.1	#	0.0	0.0	#	0.0	0.1
Largemouth bass	0.0	0.1	#	0.0	0.1	#	0.0	0.1
Muskellunge	0.1	0.0	#	0.1	0.0	#	0.1	0.0
Northern pike	3.9	5.3	#	5.1	4.4	#	4.6	4.8
Pumpkinseed	0.4	1.0	#	0.2	0.5	#	0.3	0.8
Rock bass	1.4	3.0	#	0.2	0.3	#	0.8	1.5
Shorthead redhorse	0.0	0.0	#	0.0	0.0	#	0.0	0.0
Smallmouth bass	0.0	0.0	#	0.0	0.0	#	0.0	0.0
Tiger muskellunge	0.0	0.0	#	0.0	0.0	#	0.0	0.0
Tulibee/cisco	0.9	4.6	#	6.5	6.0	#	4.0	5.3
Walleye	4.3	5.7	#	12.6	9.4	#	8.9	7.8
White sucker	1.5	1.3	#	0.8	1.6	#	1.1	1.5
Yellow bullhead	0.2	2.1	#	0.5	0.9	#	0.4	1.5
Yellow perch	24.6	25.6	#	5.4	17.5	#	13.9	21.1

Table 7. Length-frequency distribution of all species sampled in experimental gillnet sets, Leech Lake, 2014.

Length	Black Crappie	Bluegill	Bowfin	Brown Bullhead	Burbot	Muskellunge	Northern Pike	Pumpkinseed	Rock Bass	Tadpole Madtom	Cisco	Walleye	White Sucker	Yellow Bullhead	Yellow Perch
3								2		4					1
4								1	1						7
5		1						5	5						175
6		1						1	1			2			157
7	2								4		1	3			56
8	4							1	5		17	12	4	1	60
9	2								7		7	27	2	1	26
10	4								4		2	21	1	6	13
11	1						1				4	13	3	2	5
12	1			1			1				19	14	4	2	1
13	1			2	1		3				5	26	1	1	
14				2			8				5	17	2		
15							10				20	21	3		
16					2		6				43	26	7		
17							16				20	26	10		
18							10				1	33	2		
19							18					20			
20							14					11			
21			1				16					14			
22			1		1		20					15			
23							13					9			
24							8					7			
25						2	3					3			
26							7					1			
27							1								
28							3								
29															
30							3								
31							2								
32															
33							1								
34							1								
35															
≥36															
Total	15	2	2	5	4	2	165	10	27	4	144	321	39	13	501
Min. length	7	6	22	12	14	25	12	4	5	2	8	7	9	9	3
Max. length	13	6	22	14	22	26	34	8	11	2	18	26	19	13	12
Mean length	10	6	22	14	17	26	21	5	8	2	14	16	15	11	7

Table 8. Length- frequency distribution of immature (I) and mature (M) Walleye, Yellow Perch, Northern Pike, and Cisco, by sex from gill nets in Leech Lake, 2014.

	Walleye				Yellow Perch				Northern Pike				Cisco			
	F		M		F		M		F		M		F		M	
Length	I	M	I	M	I	M	I	M	I	M	I	M	I	M	I	M
0																
1																
2																
3								1								
4					1			6								
5					70	9		96								
6			2		37	43		77								
7	2		1			42		14							1	
8	7		5			49		11					5		8	
9	13		14			22		4								3
10	11		10			9		4						1		1
11	4		9			3		2			1			2		2
12	6		8			1					1			8		11
13	19		7								1	2		2		3
14	8		5	4					4			4		1		4
15	9			12					1	4		5		5		15
16	8			18						4		2		15		28
17	9	3		14						9		7		13		7
18		17		16						2		8		1		
19		11		9						4		14				
20		5		6						5		9				
21		8		6						5		11				
22		9		6						14		6				
23		9								10		3				
24		7								6		2				
25		3								3						
26		1								7						
27										1						
28										3						
29																
30										3						
31										2						
32																
33										1						
34										1						
35																
≥36																
Total	96	73	61	91	108	178	0	215	5	84	3	73	5	48	9	74

Table 9. Age- frequency distribution of immature (I) and mature (M) Walleye, Yellow Perch, Northern Pike, and Cisco, by sex from gill nets in Leech Lake, 2014.

	Walleye				Yellow Perch				Northern Pike				Cisco			
	F		M		F		M		F		M		F		M	
Age	I	M	I	M	I	M	I	M	I	M	I	M	I	M	I	M
0			2													
1	30		27					1	5	4	3	10				
2	27		31	2	35	2		33		12		7	5	7	9	3
3	36	1	1	22	73	62		123		21		18		11		9
4	3	19		22		64		34		21		17				7
5		9		10		32		5		14		12		1		13
6		8		7		7		4		5		6		20		4
7		7		7		9		7		4		3		7		24
8		16		9		2		6						6		12
9		7		6				1		3				4		1
10		4		2												1
11		1		1												
12				1												
13		1														
14								1								
15																
16																
17																
18				1												
19																
20																
21				1												
Total	96	73	61	91	108	178	0	215	5	84	3	73	5	56	9	74

Table 10. Mean chlorophyll-a (Chlor-a), total phosphorous (Total P), pH, alkalinity, total dissolved solids (TDS), Secchi depth, and mean calculated trophic state index (TSI) by basin, Leech Lake, 1984-2014.

	Main Lake								Western Bays							
Year	Station	Chlor-a (ppb)	Total P (ppm)	pH	Alkalinity (ppm)	TDS (ppm)	Secchi (ft.)	Mean TSI	Station	Chlor-a (ppb)	Total P (ppm)	pH	Alkalinity (ppm)	TDS (ppm)	Secchi (ft.)	Mean TSI
1984		4.0	0.022	-	133	169	-	-		4.0	0.011	-	132	147	-	-
1985		-	-	-	-	-	-	-		-	-	-	-	-	-	-
1986	7	3.0	0.011	8.5	134	158	4.7	-	1	3.0	0.006	8.6	135	160	9.3	-
1987	7	3.0	0.014	8.4	131	154	3.9	-	1	4.0	0.014	8.5	147	153	8.2	-
1988	5	3.0	0.031	7.9	133	169	7.7	-	1	3.0	0.017	8.0	46	377	7.9	-
1989	5	3.0	0.017	7.9	132	172	7.6	-	1	3.0	0.008	8.5	128	176	9.8	-
1990	3	3.0	0.015	8.6	130	168	7.3	-	1	3.0	0.015	8.4	130	164	12.2	-
1991	5	1.0	0.020	8.5	127	180	7.7	-	1	1.0	<0.005	8.6	126	172	7.9	-
1992	5	2.0	0.016	8.4	139	178	11.4	-	1	3.0	0.010	8.5	139	168	13.2	-
1993	5	6.4	0.013	8.6	140	156	8.5	-	1	4.9	0.014	8.6	128	180	13.0	-
1994	5	5.5	0.023	8.6	138	170	6.0	-	1	2.9	0.016	8.7	140	168	8.0	-
1995	7	11.9	0.018	8.6	136	192	8.9	-	1	6.5	0.012	8.7	136	180	11.5	-
1996	7	3.1	0.055	8.5	133	176	8.9	-	1	2.4	0.020	8.7	136	224	10.6	-
1997	7	3.1	0.041	8.5	132	172	9.9	-	1	4.4	0.044	8.6	133	192	13.6	-
1998	3	6.5	0.028	8.6	131	152	-	-	1	4.2	0.029	8.7	133	172	-	-
1999	5	5.1	0.028	8.6	129	172	7.5	49	1	3.8	0.025	8.6	135	180	13.0	45
2000	3	4.2	0.028	8.5	139	180	6.0	49	6	2.4	0.019	8.6	138	176	17.2	41
2001	3	5.6	0.033	8.7	125	170	7.0	49	6	4.0	0.016	8.8	126	168	11.0	43
2002	3	5.4	0.020	8.7	133	164	6.5	49	6	4.1	0.020	8.8	136	176	11.0	44
2003	3	7.2	0.020	8.4	139	160	6.5	50	6	4.1	0.010	8.6	140	160	11.0	44
2004	3	3.4	0.013	8.5	143	176	9.0	44	6	2.4	0.010	8.7	146	176	13.1	40
2005	3	4.4	0.016	8.6	143	172	5.0	50	6	3.7	0.016	8.6	141	176	8.5	45
2006	3	8.4	0.016	8.5	140	148	6.0	51	6	4.2	0.010	8.5	135	144	10.0	44
2007	3	8.9	0.019	8.5	144	168	8.2	48	6	3.6	0.011	8.6	143	168	10.5	42
2008	5	3.4	0.013	0.9	146	172	6.5	39	1	5.2	0.012	8.5	148	168	10.5	38
2009	5	7.6	0.019	8.4	143	188	-	49	1	5.1	0.011	8.4	148	196	-	43
2010	5	7.0	0.017	8.5	144	188	6	43	1	3.4	0.012	8.6	143	188	11.0	36
2011[1]		-	-	-	-	-	-	-		-	-	-	-	-	-	-
2012	5	7.3	0.030	8.2	141	188	6.5	45	1	4.5	0.024	8.4	140	180	10.5	40
2013	5	8.7	0.023	8.5	142	152	7.2	44	1	5.8	0.011	8.4	141	140	10.9	37
2014	5	7.6	0.024	8.5	144	196	8.0	43	1	4.7	0.018	8.5	145	166	13.0	38
Mean		5.3	0.022	8.2	137	171	7.2	47		3.8	0.016	8.6	134	179	11.0	41

[1] water quality data was not collected in 2011 due to state shutdown from July 1-20.

Table 11. Density (number/liter) and biomass (µg/liter) of zooplankton sampled by month at the five standardized zooplankton sites on Leech Lake in 2014.

Date	Unit	Walker Bay	Agency Bay	Portage Bay	Kabekona Bay	Stony Point	Average
5/16/14	(#/L)	10	16	22	18	18	17
	(µg/L)	41	69	71	31	40	50
5/28/14	(#/L)	11	10	28	54	26	26
	(µg/L)	39	55	93	95	96	76
6/11/14	(#/L)	29	31	42	36	28	33
	(µg/L)	123	151	193	105	135	142
7/14/14	(#/L)	21	31	29	18	21	24
	(µg/L)	96	178	77	43	49	89
8/13/14	(#/L)	28	22	82	31	62	45
	(µg/L)	79	84	150	81	103	99
9/12/14	(#/L)	36	30	39	35	33	34
	(µg/L)	118	78	75	68	65	81
10/9/14	(#/L)	19	30	19	25	22	23
	(µg/L)	96	81	57	93	93	84
Average	(#/L)	22	24	37	31	30	29
	(µg/L)	85	99	102	74	83	91

Table 12. The overall density (number/liter) of zooplankton at each of the five sample sites, by species, Leech Lake 2014.

Taxa	Walker Bay	Agency Bay	Portage Bay	Kabekona Bay	Stony Point	Station Average
Copepods:						
Nauplii	4.2	3.5	5.1	8.3	4.8	5.2
Copepodites	2.4	3.2	4.3	5.9	3.5	3.8
Diaptomidae	5.8	6.3	3.3	2.8	3.2	4.3
Epischura lacustris	0.2	0.3	0.2	0.3	0.5	0.3
Limnocalanus macrurus	0.3	0.5				0.4
Mesocyclops edax	1.9	0.9	1.7	1.2	1.2	1.4
Diacyclops bicuspidatus thomasi	2.4	2.4	3.6	6.1	4.3	3.8
Tropocyclops prasinus mexicanus	2.6	1.7	4.1	2.1	3.2	2.7
Cladocerans:						
Daphnia galeata mendotae	1.3	1.9	4.4	1.6	2.9	2.4
Daphnia longiremis		0.5		0.5	0.1	0.3
Daphnia pulicaria	0.2	0.2	0.5	0.6	0.2	0.3
Daphnia retrocurva	1.5	1.9	5.4	2.5	2.1	2.7
Bosmina sp.	1.2	2.1	3.0	0.6	2.0	1.8
Eubosmina coregoni	0.7	0.4	1.6	0.3	2.0	1.0
Chydorus sphaericus	0.7	1.0	2.3	1.5	3.2	1.7
Holopedium gibberum	0.2	0.4	0.3	0.4		0.3
Diaphanosoma birgei	1.0	0.4	1.7	0.5	2.2	1.2
Eurycercus lamellatus					0.1	0.1
Ceriodaphnia sp.	0.2	0.2	5.6	0.2	2.9	1.8
Total	26.8	27.6	46.8	35.2	38.5	35.5

FIGURES

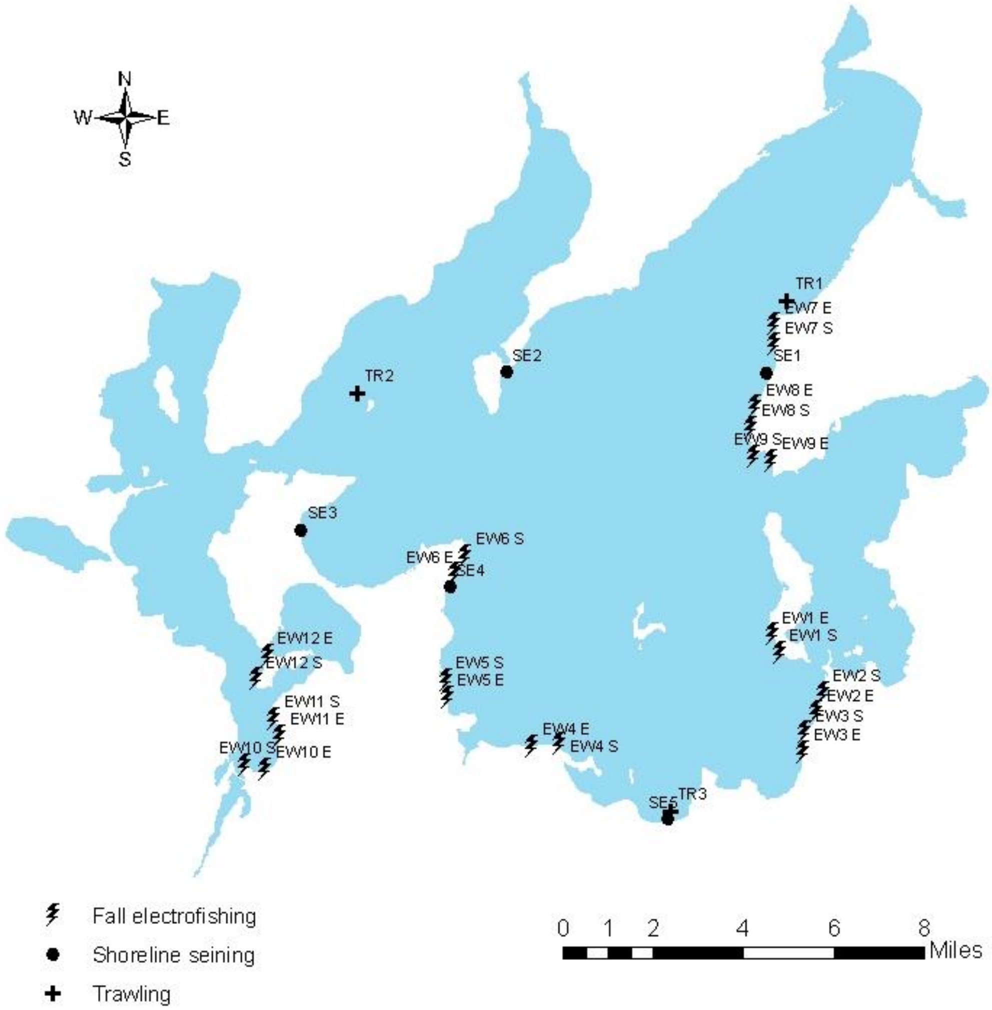

Figure 1. Long-term sampling stations targeting young-of-year Walleye and Yellow Perch in Leech Lake.

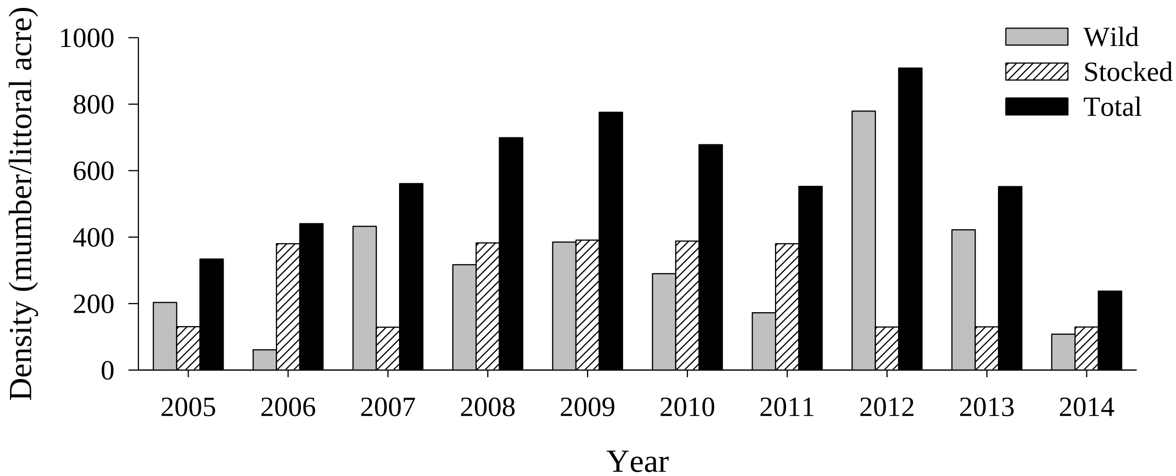

Figure 2. The Walleye fry density (fry/littoral acre) estimated with OTC marking for stocked and naturally produced Walleye fry in Leech Lake, 2005-2014.

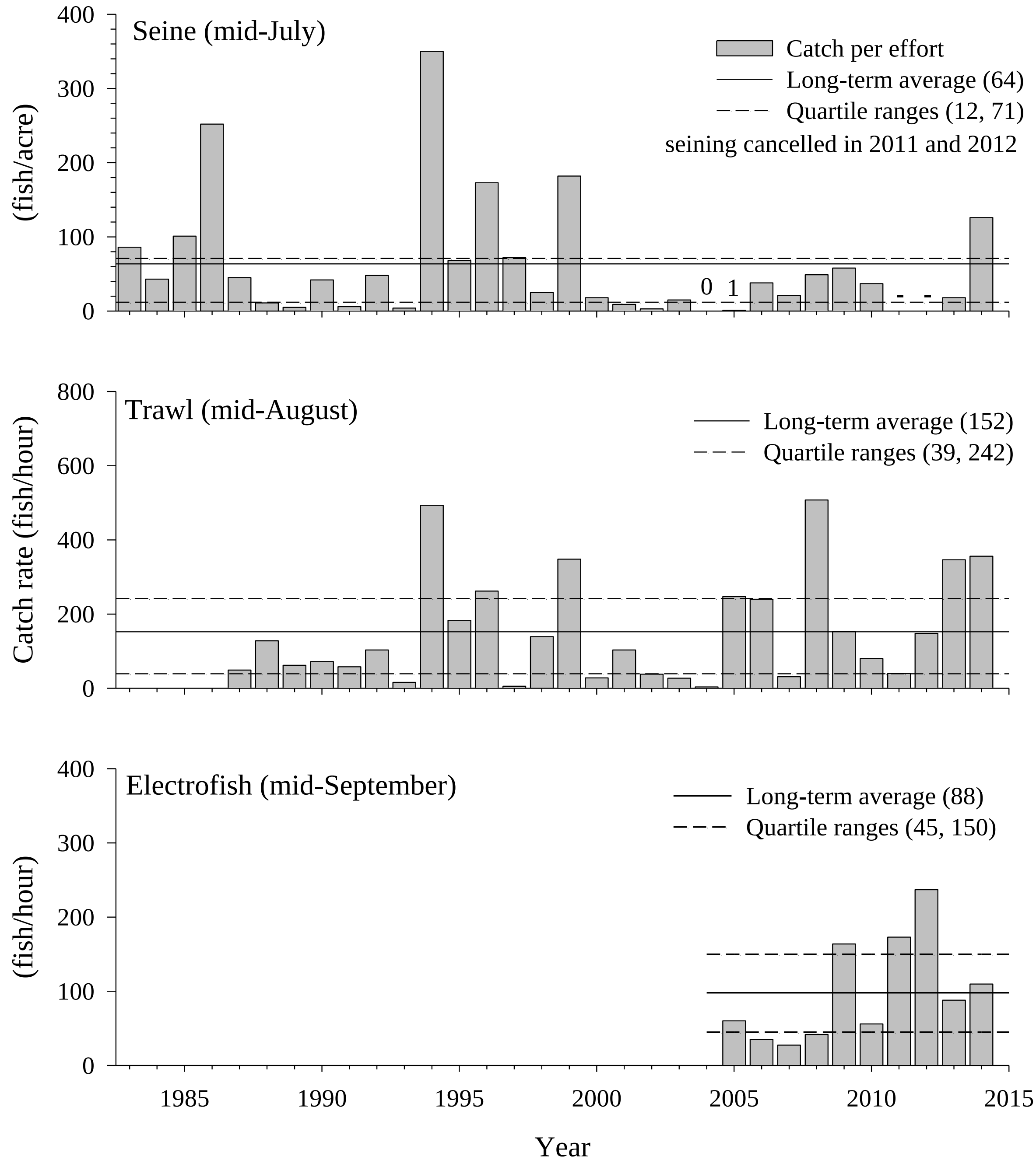

Figure 3. Catch-per-effort (bars) and long-term averages (lines) of young-of-year (YOY) Walleye sampled seining (top), trawling (middle), and electrofishing (bottom), Leech Lake, 1983-2014.

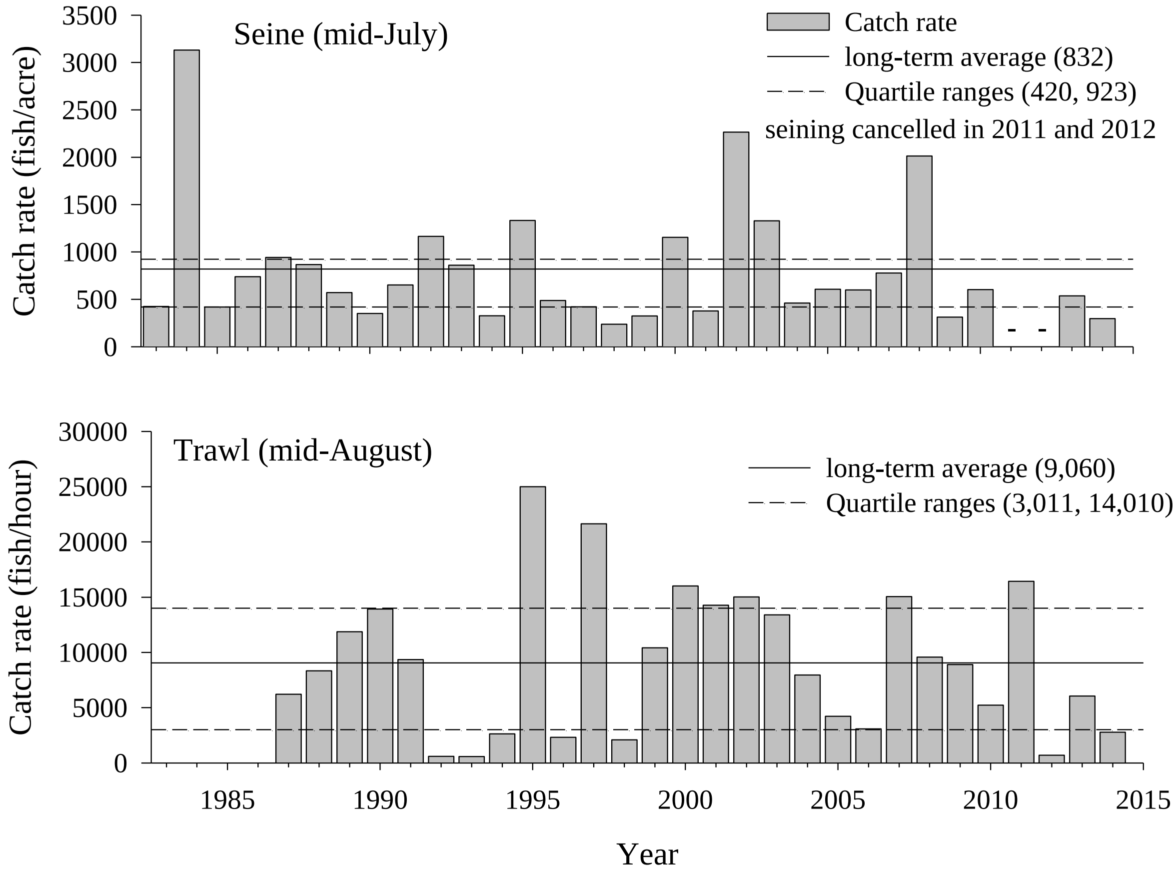

Figure 4. Catch-per-effort (bars) and long-term averages (lines) of young-of-year (YOY) Yellow Perch sampled at standardized seining and trawling locations, Leech Lake, 1983-2014.

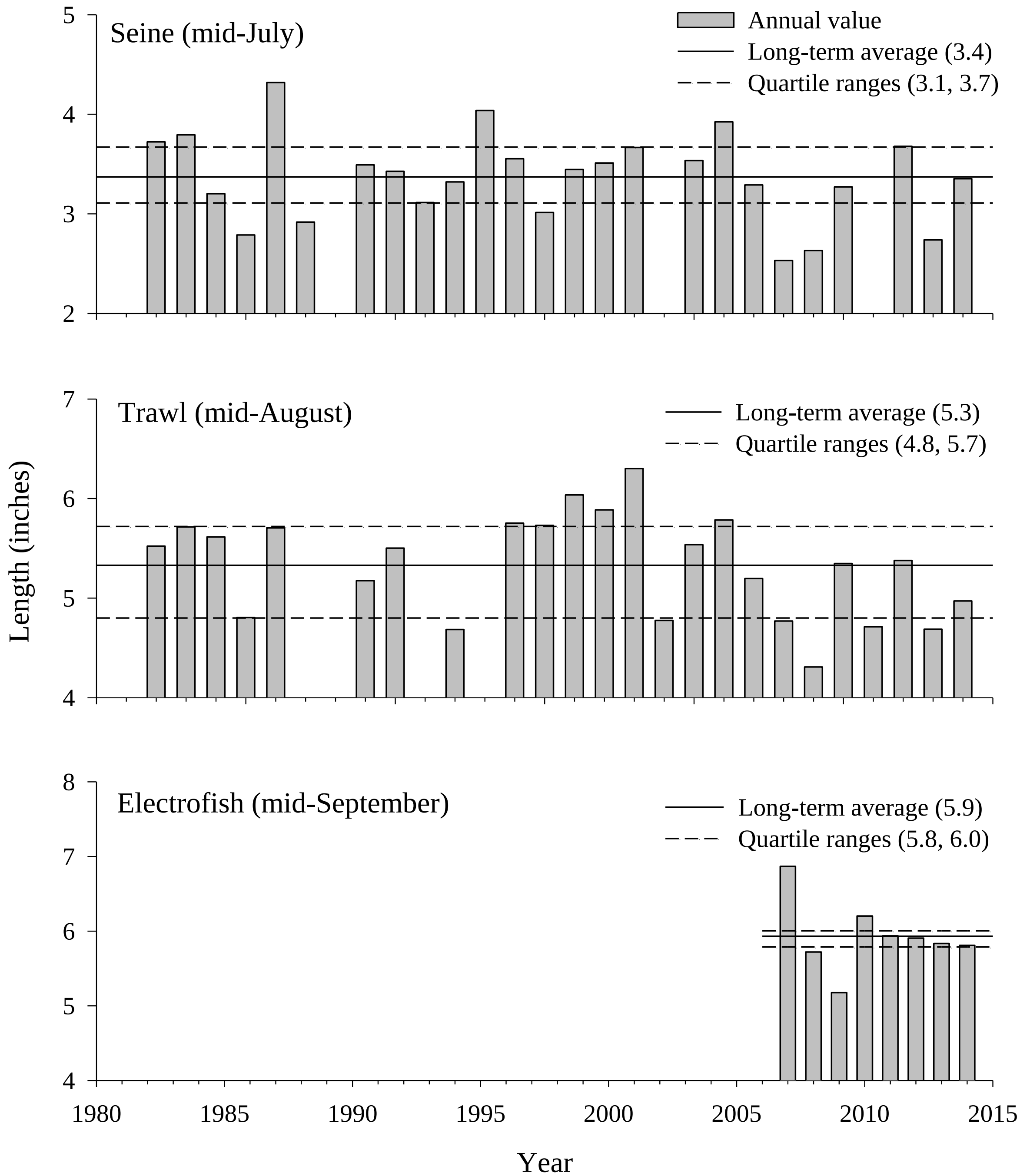

Figure 5. Average annual growth rates of young-of-year (YOY) Walleye sampled seining (top), trawling (middle), and electrofishing (bottom) in Leech Lake, 1987-2014. Growth rates are standardized by Julian Weeks 28-29 (seining), 33-34 (trawling), and 37-38 (electrofishing).

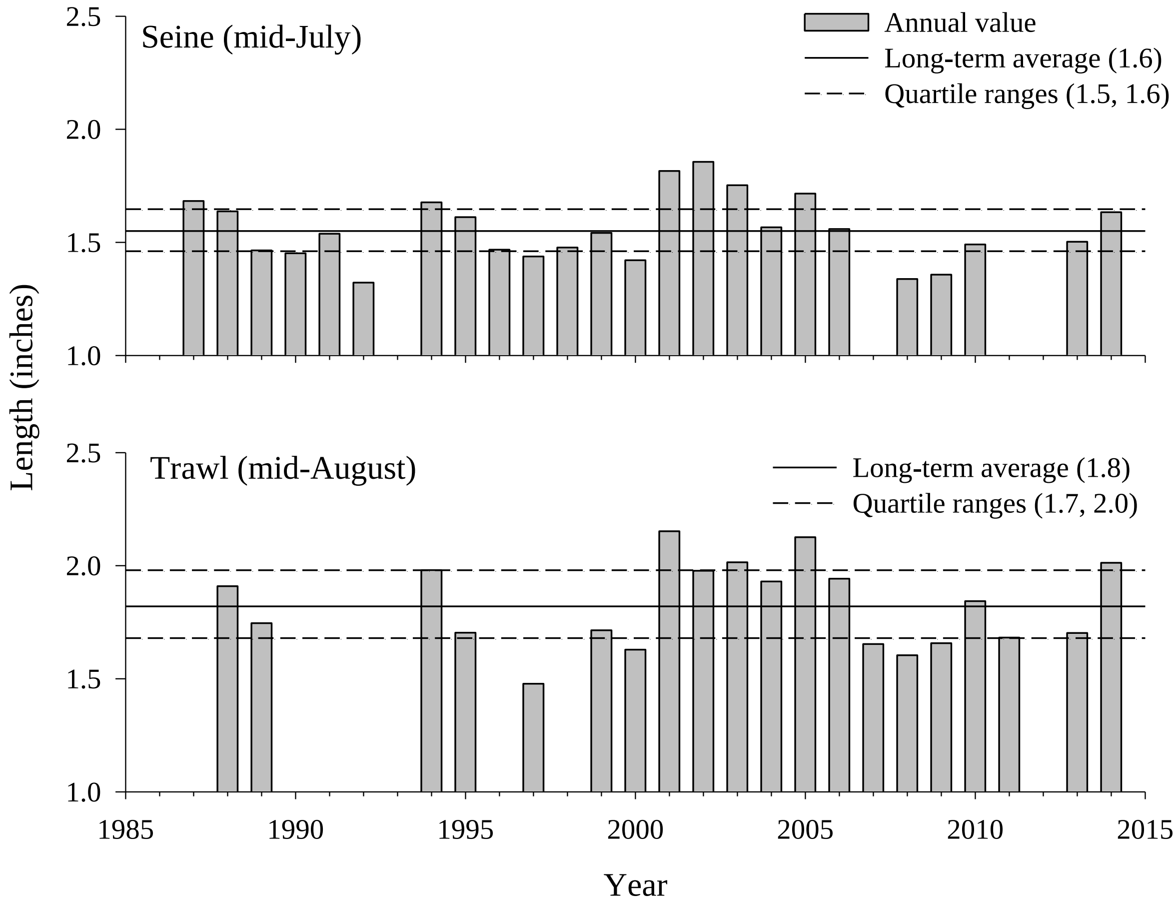

Figure 6. Average annual growth rates of young-of-year (YOY) Yellow Perch sampled seining (top) and trawling (bottom) in Leech Lake, 1987-2014. Growth rates are standardized by Julian Weeks 28-29 for seining and 33-34 for trawling.

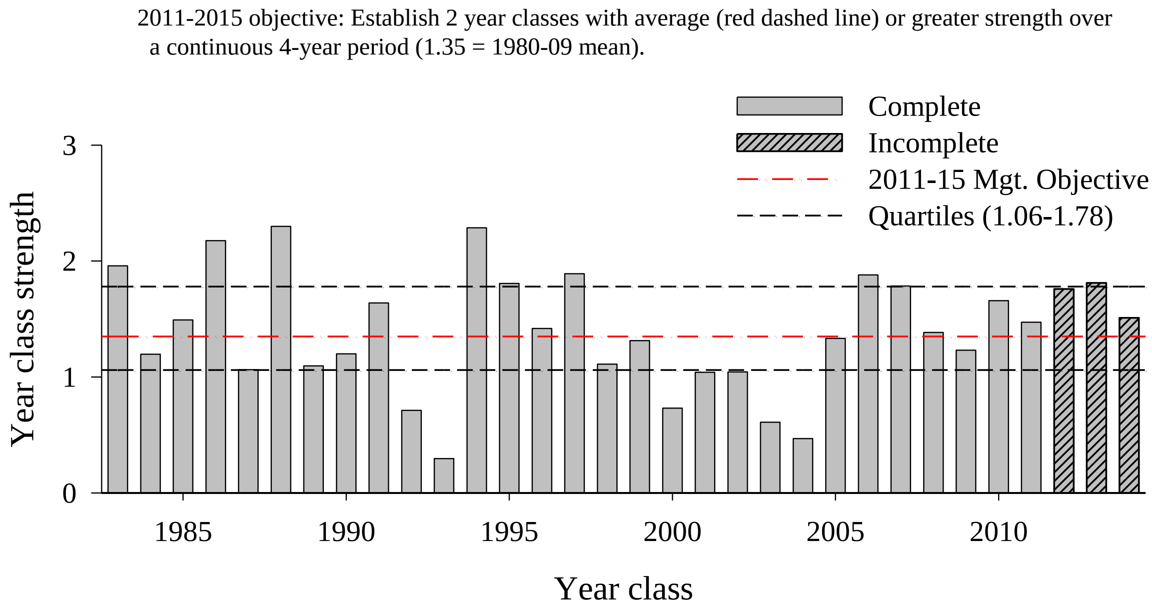

Figure 7. Walleye year class strength index relative to the 2011-2015 Leech Lake Management Plan objective for Walleye recruitment (Schultz 2010a).

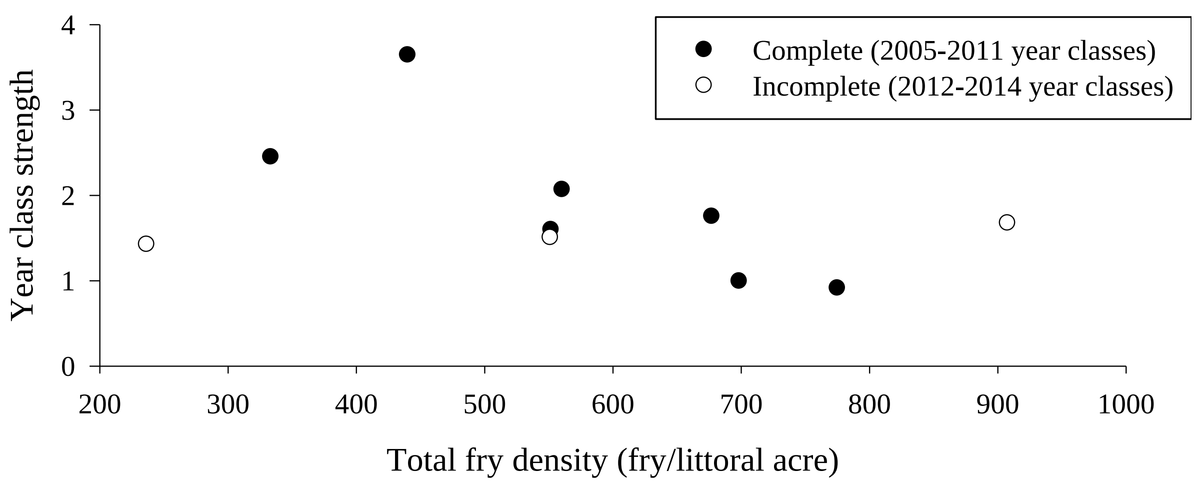

Figure 8. Total Walleye fry density (fry/littoral acre) estimated with OTC marking and the resulting year class strength index at Leech Lake. The number of fry stocked for a specific year class is also indicated.

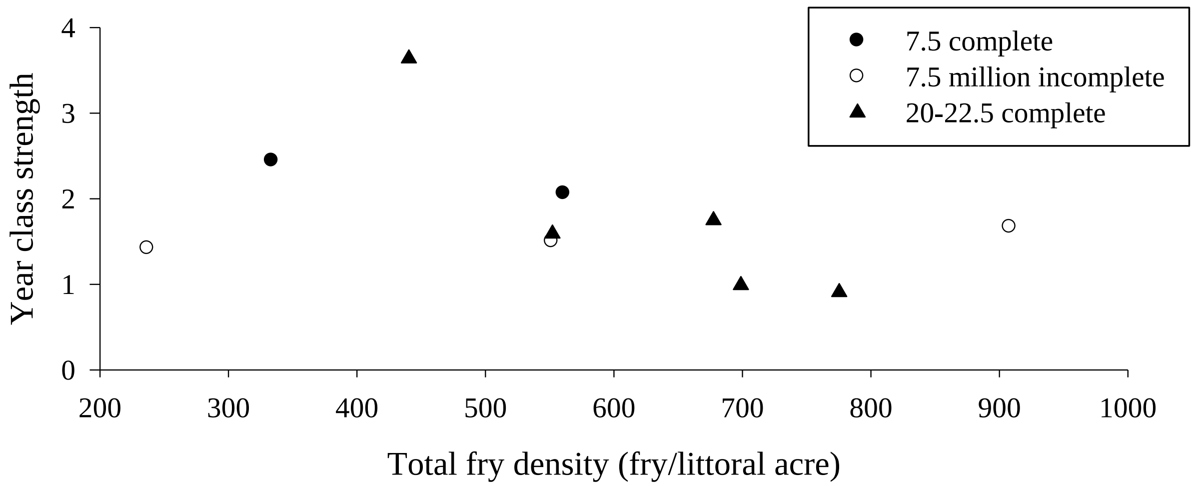

Figure 9. Total Walleye fry density (fry/littoral acre) estimated with OTC marking and the resulting year class strength index at Leech Lake. The number of fry stocked for a specific year class is also indicated.

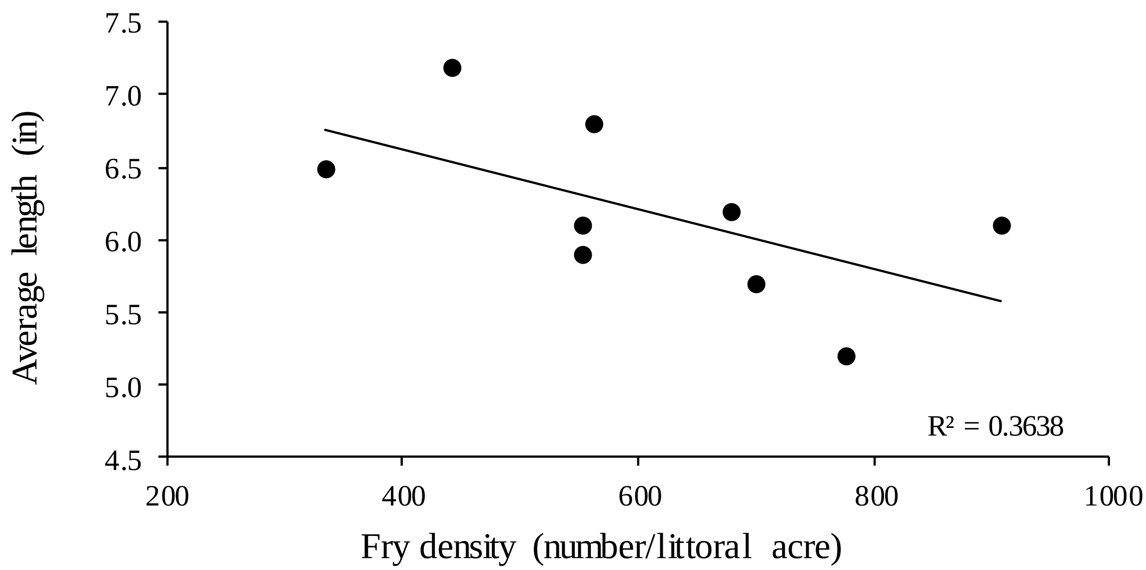

Figure 10. The total Walleye fry density (fry/littoral acre) estimated with OTC marking and the average length (in) of young-of-year Walleye sampled by electrofishing in mid-September at Leech Lake, 2005-2014.

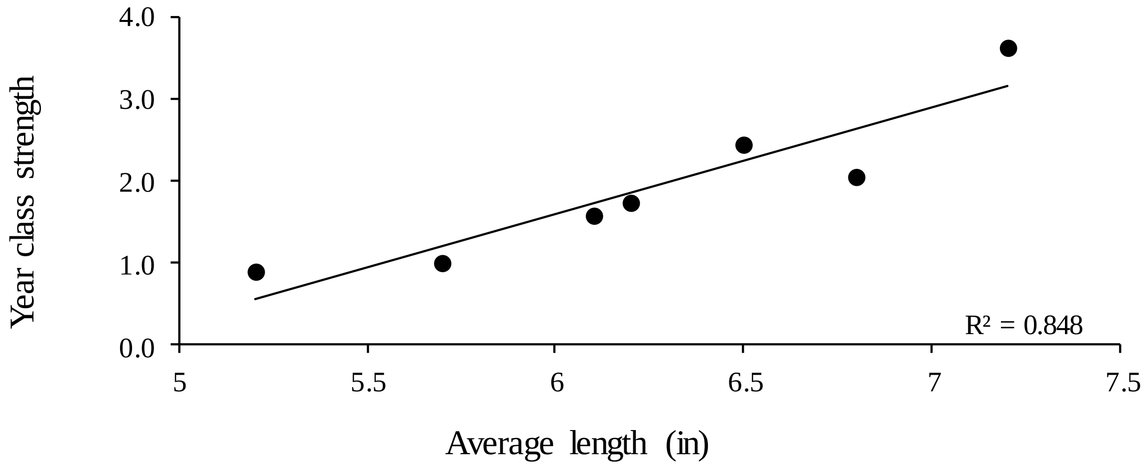

Figure 11. The average length (in) of young-of-year Walleye sampled by electrofishing in mid-September and the resulting Walleye year class strength in Leech Lake. These data represent fully recruited year classes (2005-2011).

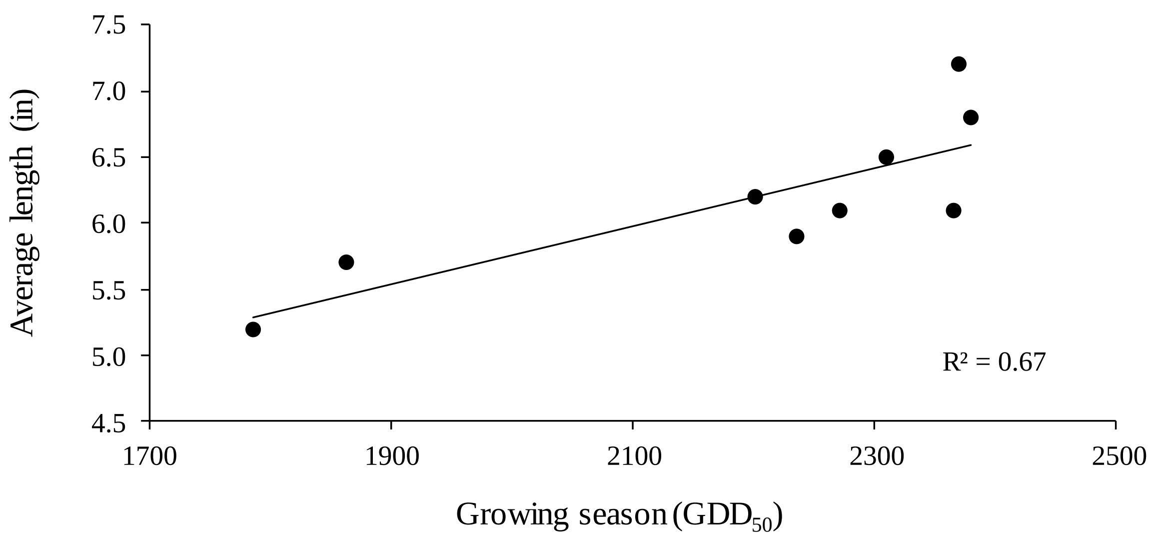

Figure 12. Growing degree days (GDD_{50}) and the average length (in) of young-of-year Walleye sampled by electrofishing in mid-September at Leech Lake, 2005-2014.

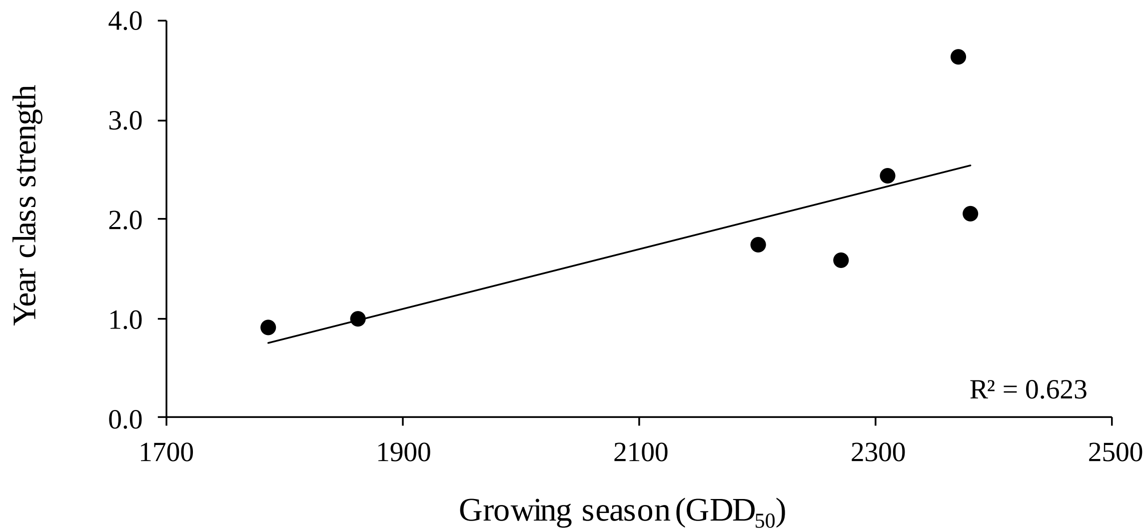

Figure 13. Growing degree days (GDD_{50}) and the resulting observed Walleye year class strength in Leech Lake. These data represent fully recruited year classes (2005-2011).

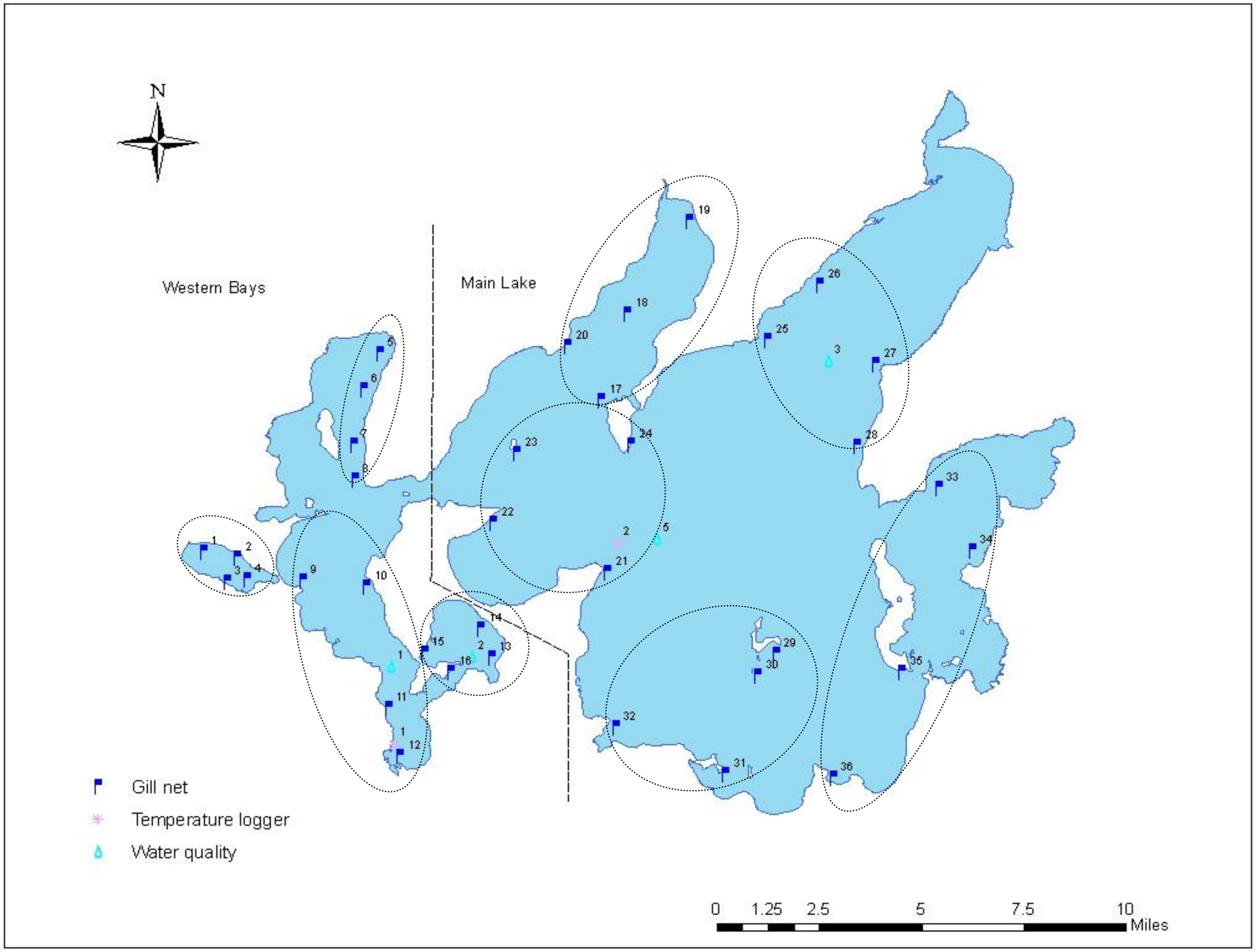

Figure 14. Gillnet (flags), temperature loggers (dots) and water quality (droplets) sampling locations on Leech Lake. Dotted circles represent gillnet sampling strata.

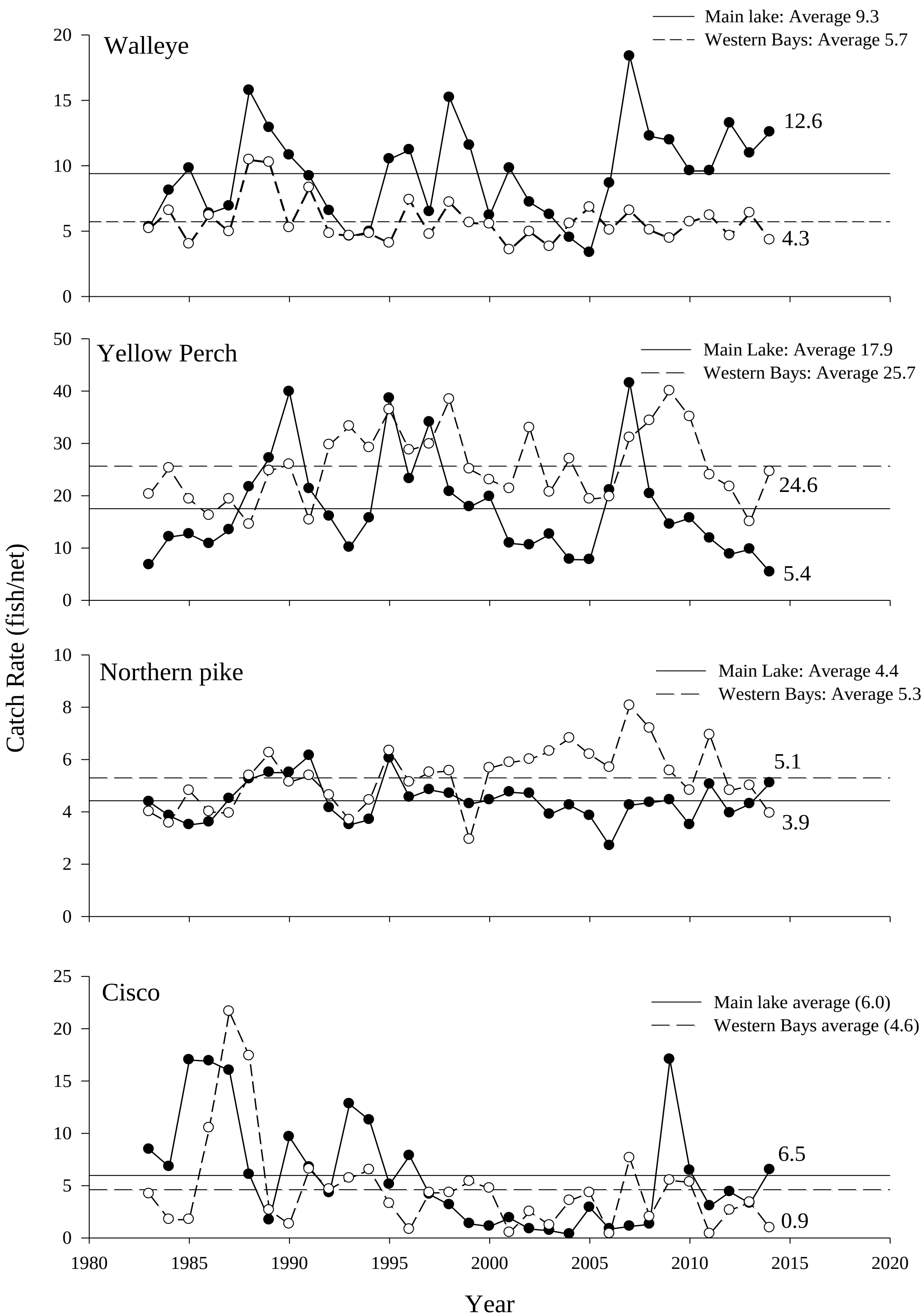

Figure 15. Basin-specific gillnet catch rates (fish/net) of selected species in Leech Lake, 1983-2014. Horizontal lines represent respective long-term averages.

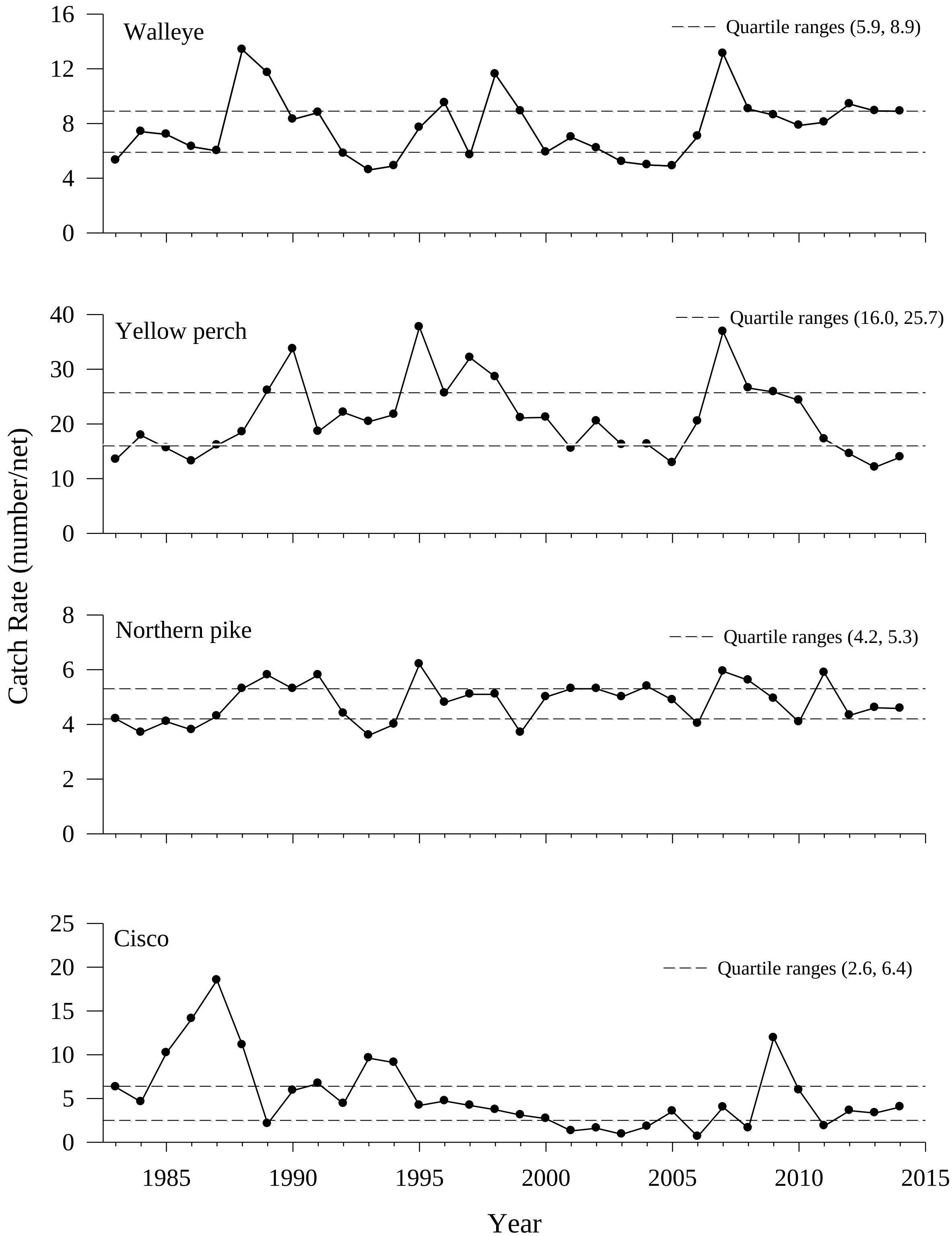

Figure 16. Gillnet catch rates (number/net) of selected species in Leech Lake, 1983-2014. Horizontal lines represent respective upper (3rd) and lower (1st) quartiles.

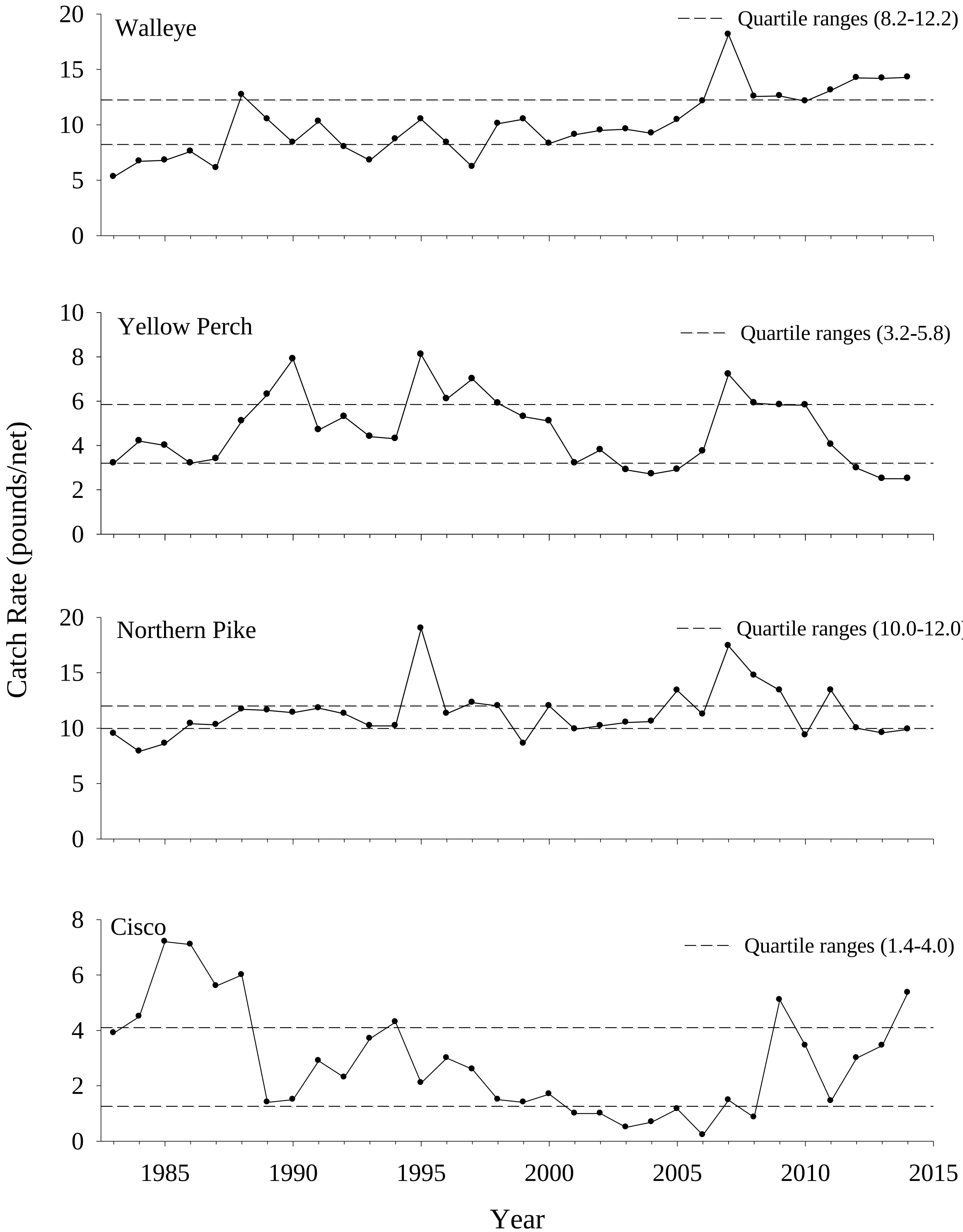

Figure 17. Gillnet catch rates (pounds/net) of selected species in Leech Lake, 1983-2014. Horizontal lines represent respective upper (3rd) and lower (1st) quartiles.

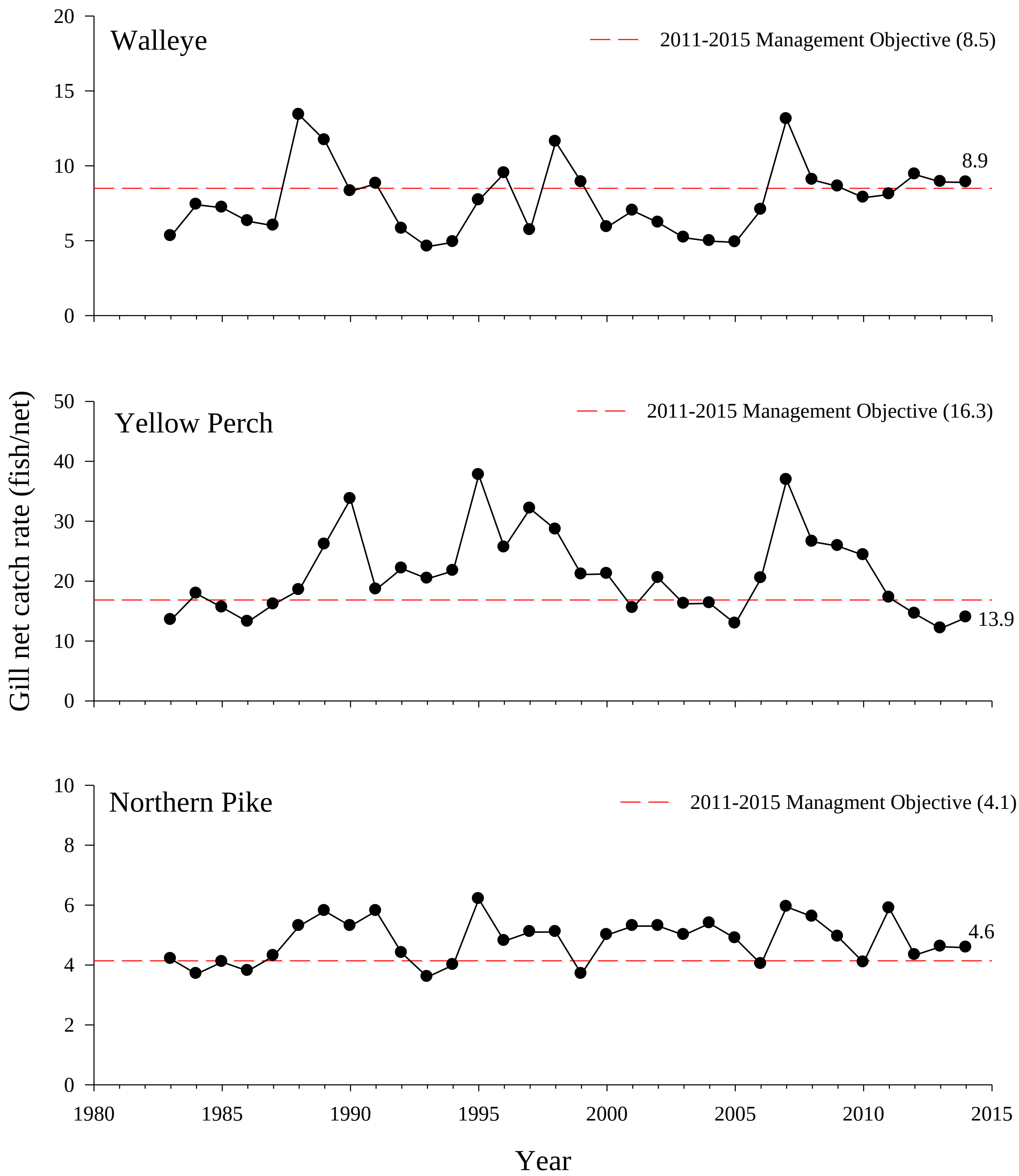

Figure 18. Gill net catch rates of Walleye, Yellow Perch, and Northern Pike compared to 2011-2015 Leech Lake Management Plan objectives (Schultz 2010a).

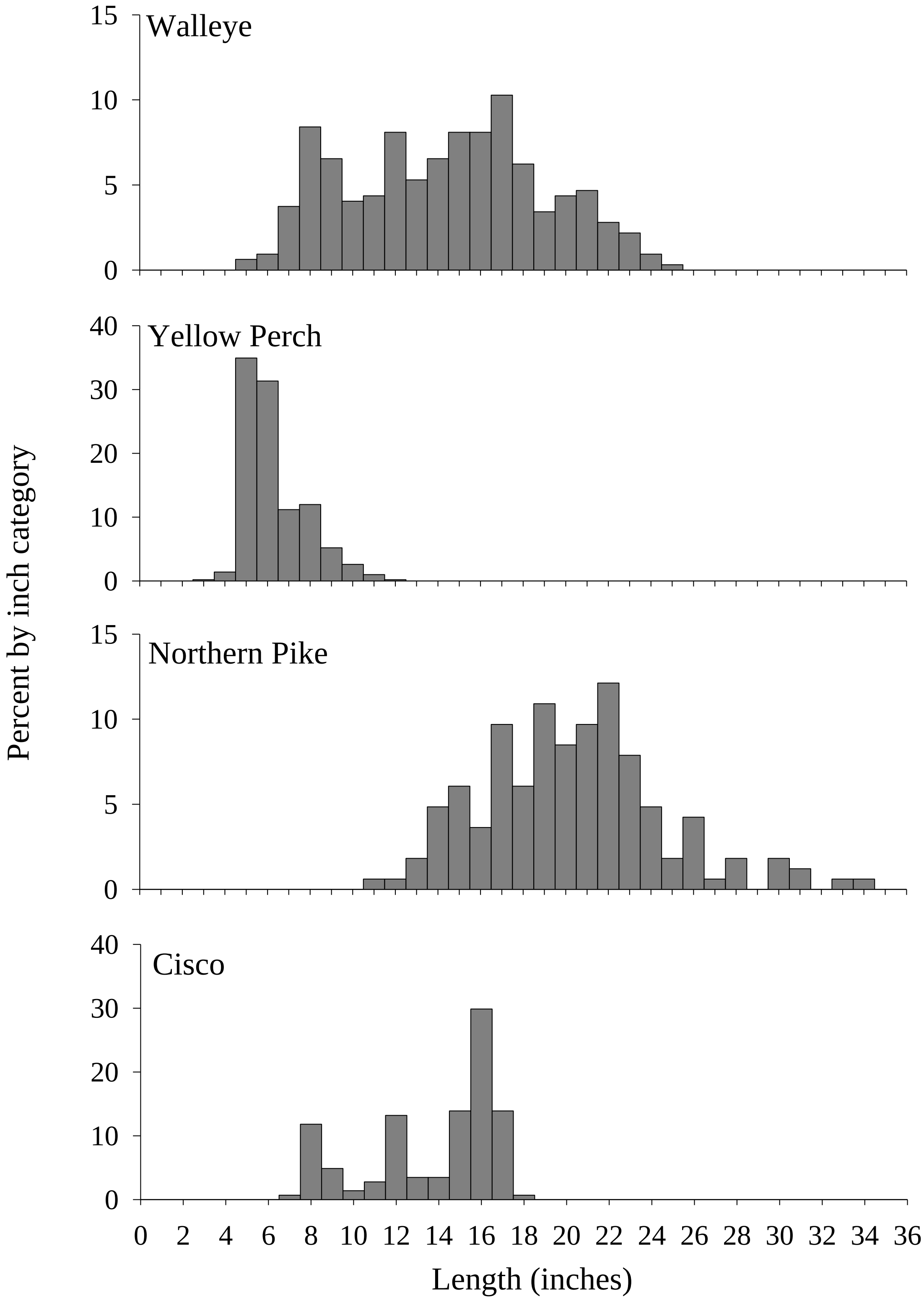

Figure 19. Length frequency distribution for Walleye, Yellow Perch, Northern Pike, and Cisco sampled with gillnets in Leech Lake, 2014.

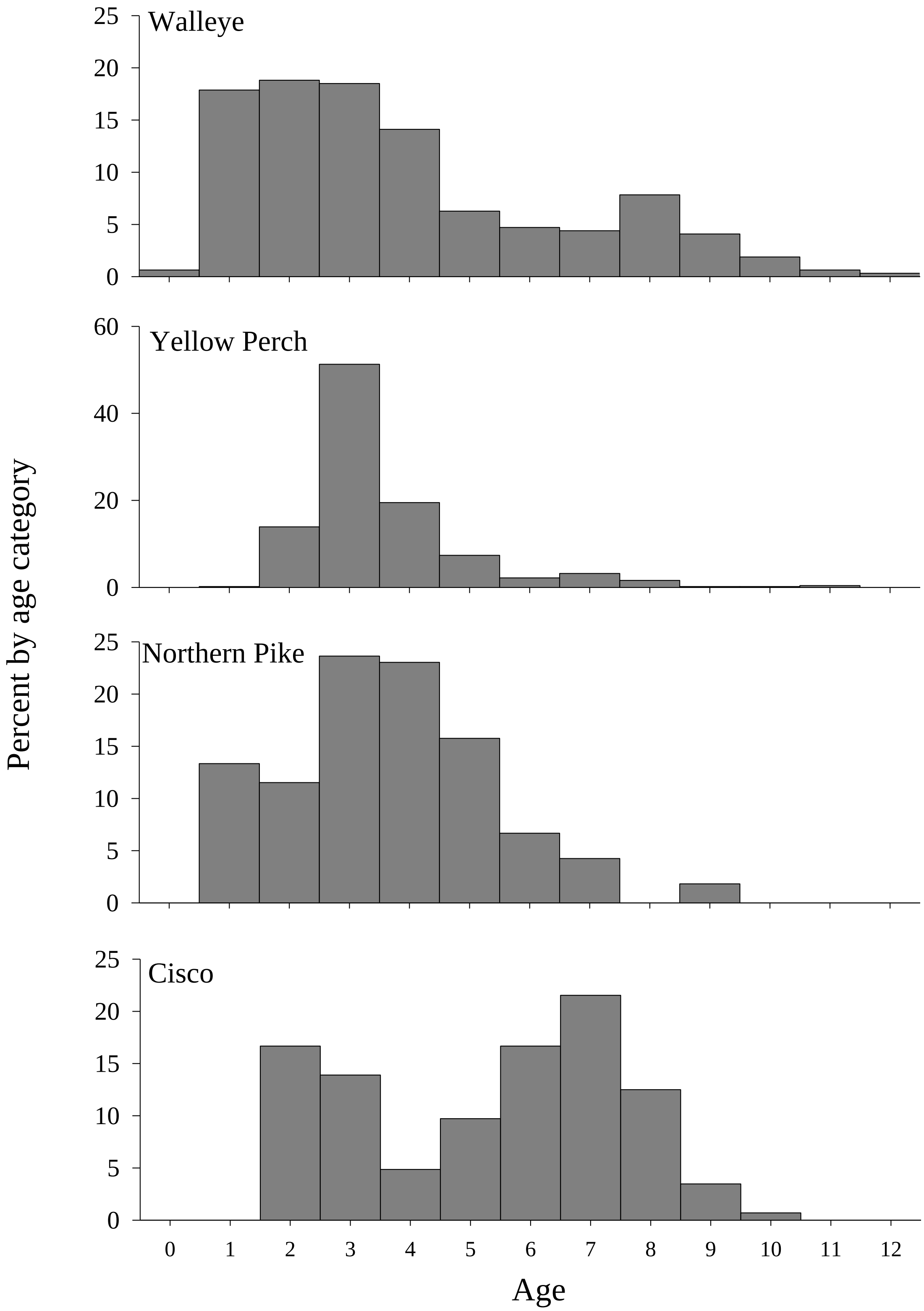

Figure 20. Age frequency distribution for Walleye, Yellow Perch, Northern Pike, and Cisco sampled with gillnets in Leech Lake, 2014. Three Walleye with between ages 13 and 21 are not represented in this figure.

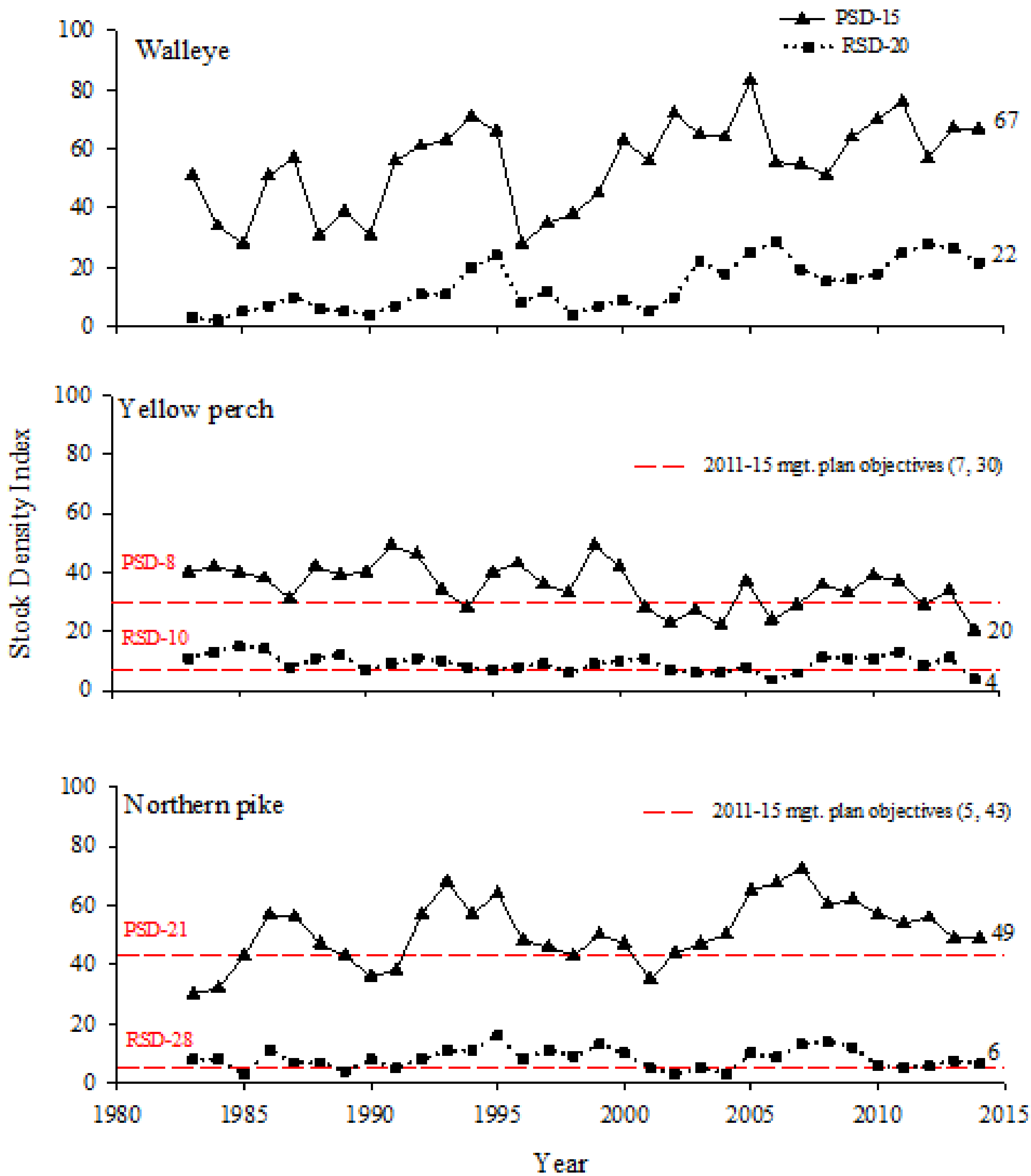

Figure 21. Size structure indices for Walleye, Yellow Perch and Northern Pike relative to the 2011-2015 Leech Lake Management Plan (Schultz 2010a).

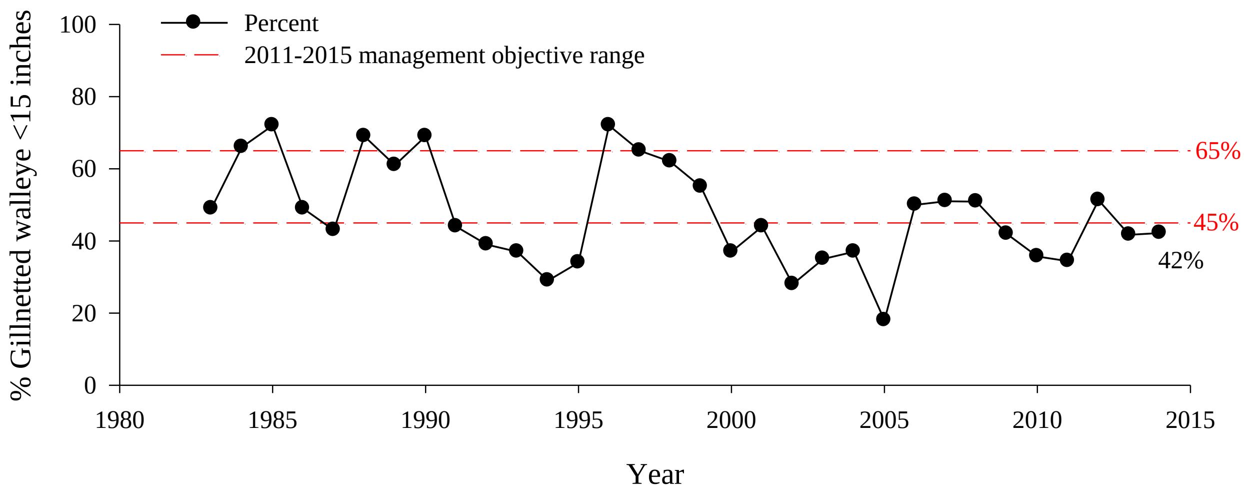

Figure 22. Proportion of gill net sampled walleye shorter than 15 inches relative to 2011-2015 Leech Lake Management Plan objectives (Schultz 2010a).

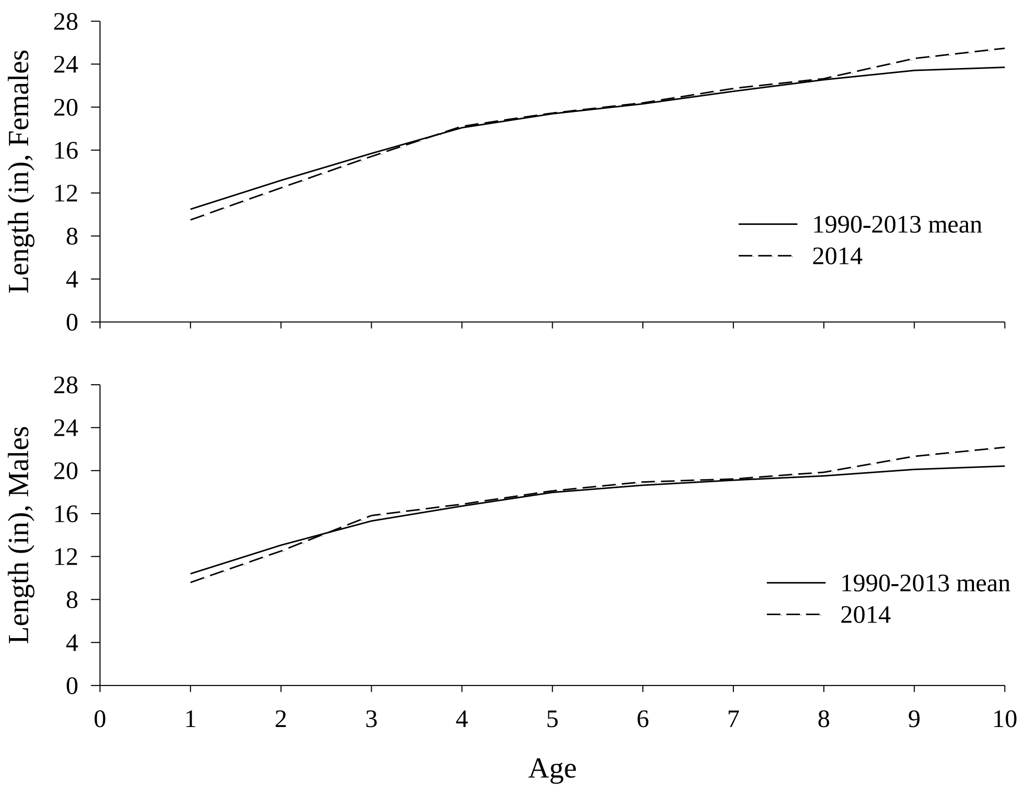

Figure 23. Mean length at capture by age for Walleye sampled in experimental gillnets in Leech Lake, 1990-2014. Mean lengths from 2014 are compared to the 1990-2013 average.

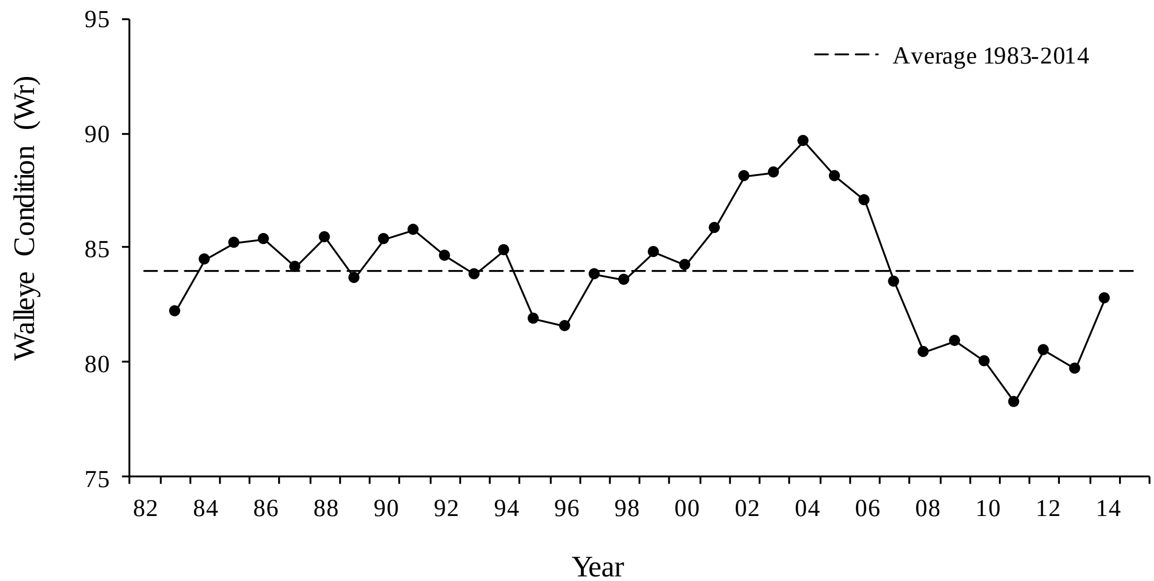

Figure 24. Annual mean condition (*Wr*) of Walleye sampled in experimental gillnets in Leech Lake, 1983-2014.

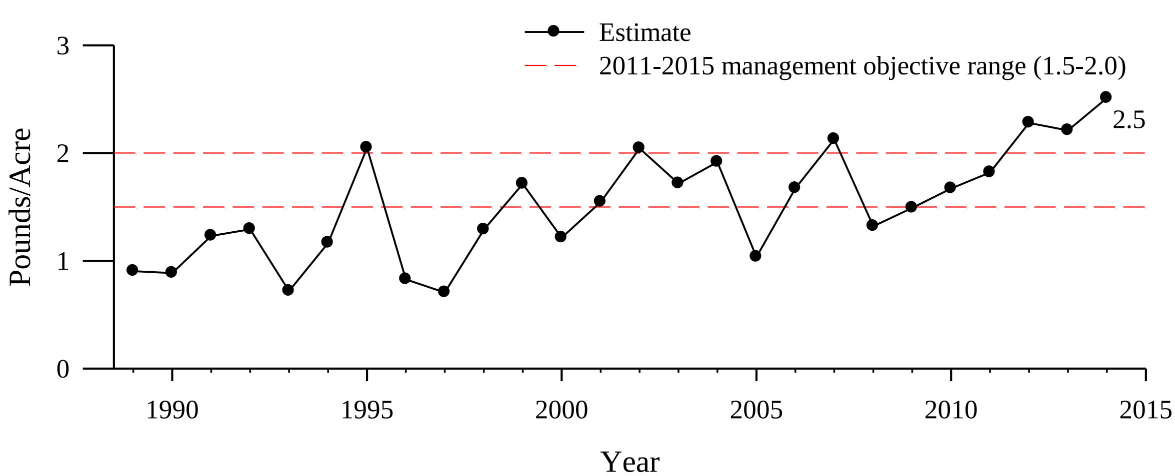

Figure 25. Estimated biomass (pounds/acre) of mature female Walleye in Leech Lake, 1989-2014. Horizontal dashed lines depict the current management objective range of 1.5-2.0 pounds/acre (Schultz 2010a).

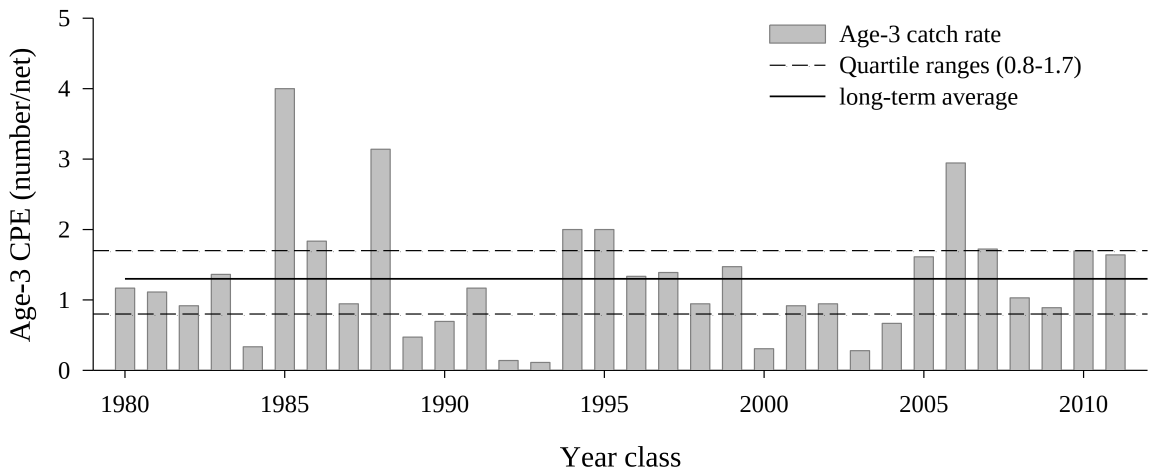

Figure 26. Catch rate (number/net) of all age-3 Walleye with gillnets in Leech Lake, 1980-2011.

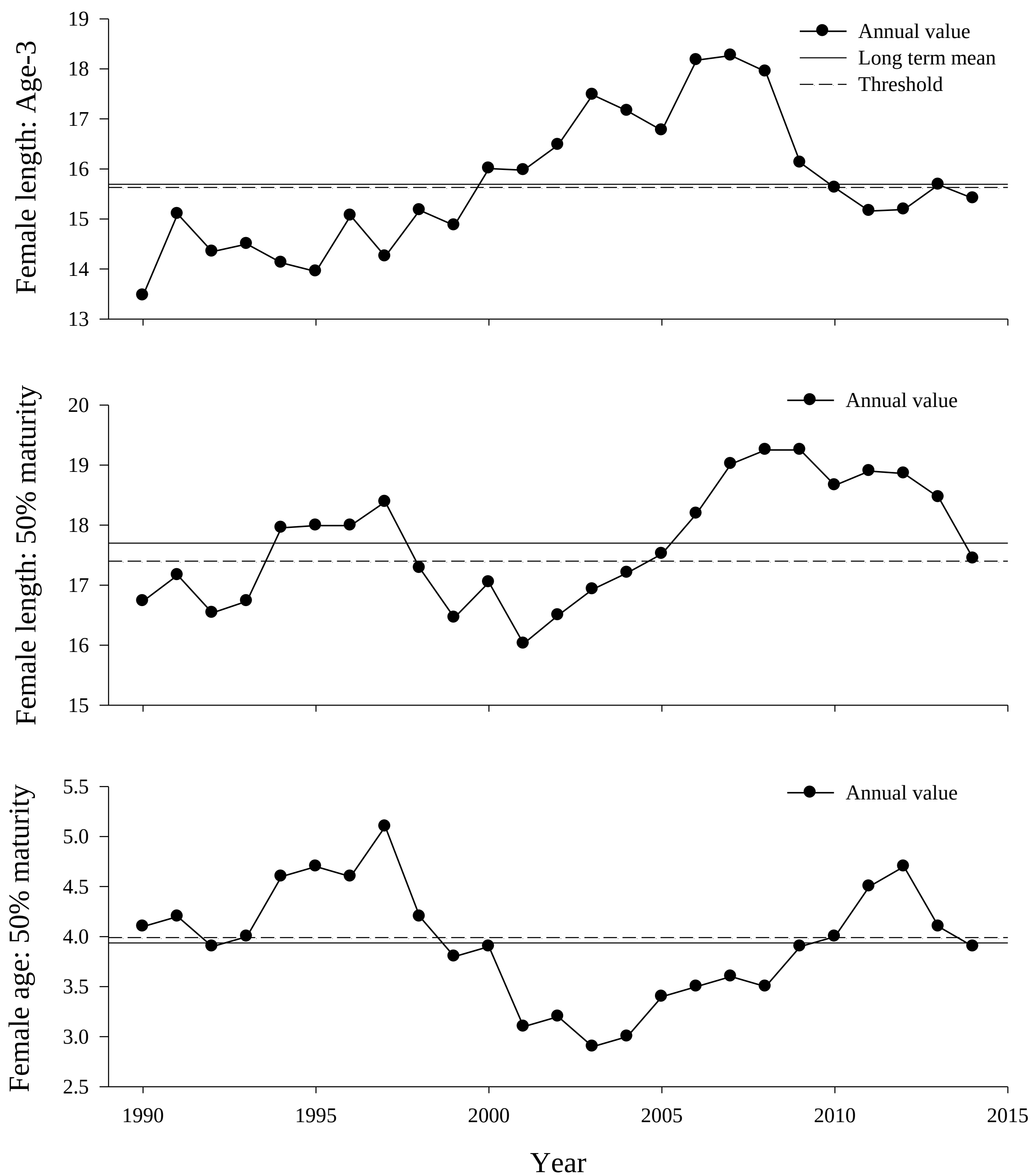

Figure 27. Female Walleye length at age-3 (top), length at 50% maturity (middle) and age at 50% maturity sampled with experimental gillnets in Leech Lake, 1990-2014. Values above the threshold (dashed line) for female length at age-3 indicate a potential population stress response, while values below the thresholds for female length and age at 50% maturity indicate a potential population stress response.

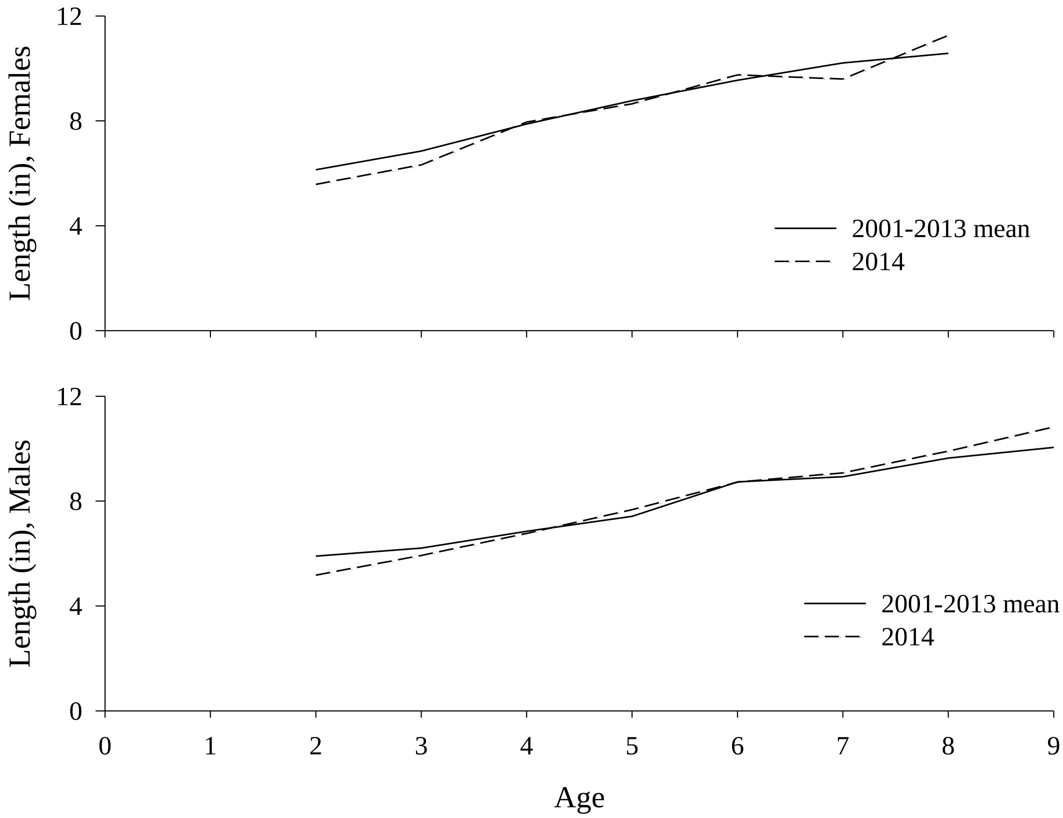

Figure 28. Mean length at capture by age for Yellow Perch sampled in experimental gillnets in Leech Lake, 2001-2014. Mean lengths from 2014 are compared to the 2001-2013 average.

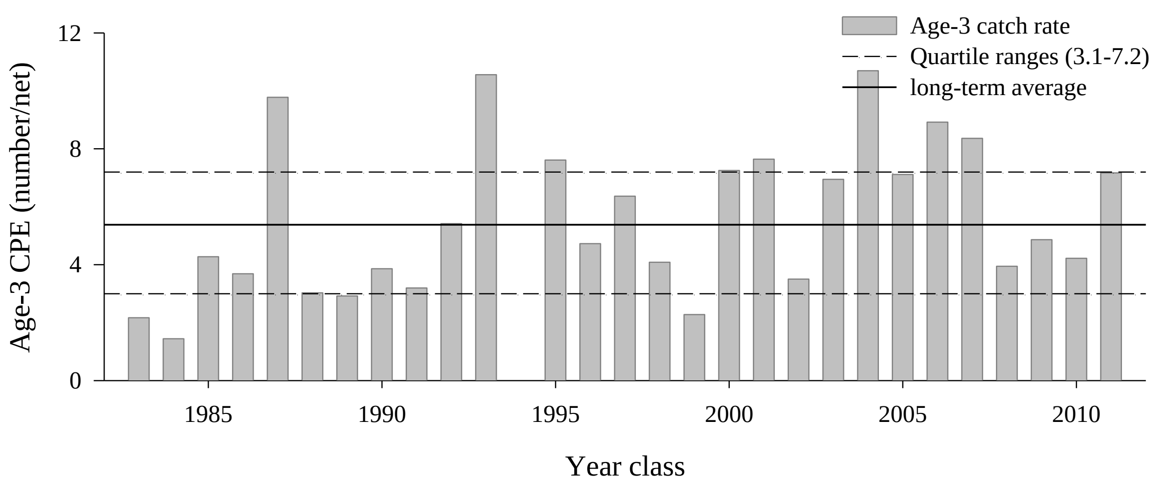

Figure 29. Catch rate (number/net) of age-3 Yellow Perch with gillnets in Leech Lake, 1983-2011.

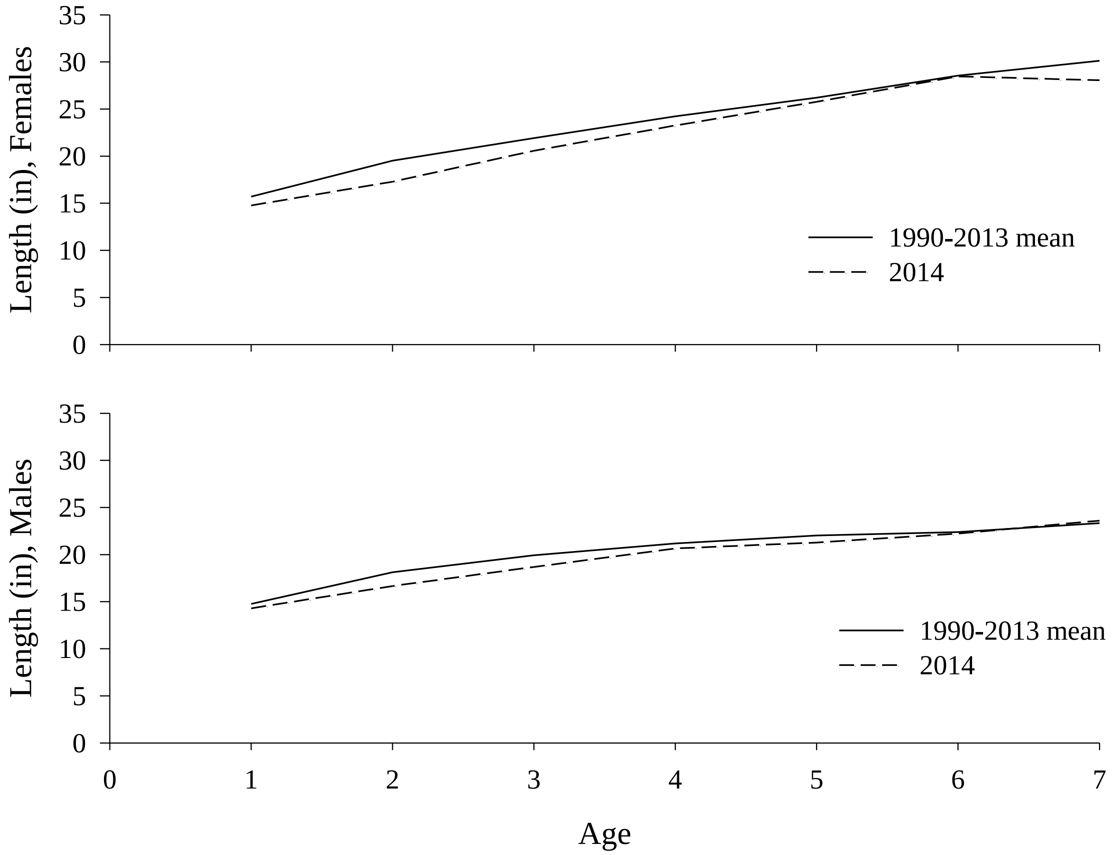

Figure 30. Mean length at capture by age for Northern Pike sampled in experimental gillnets in Leech Lake, 1990-2014. Mean lengths from 2014 are compared to the 1990-2013 average.

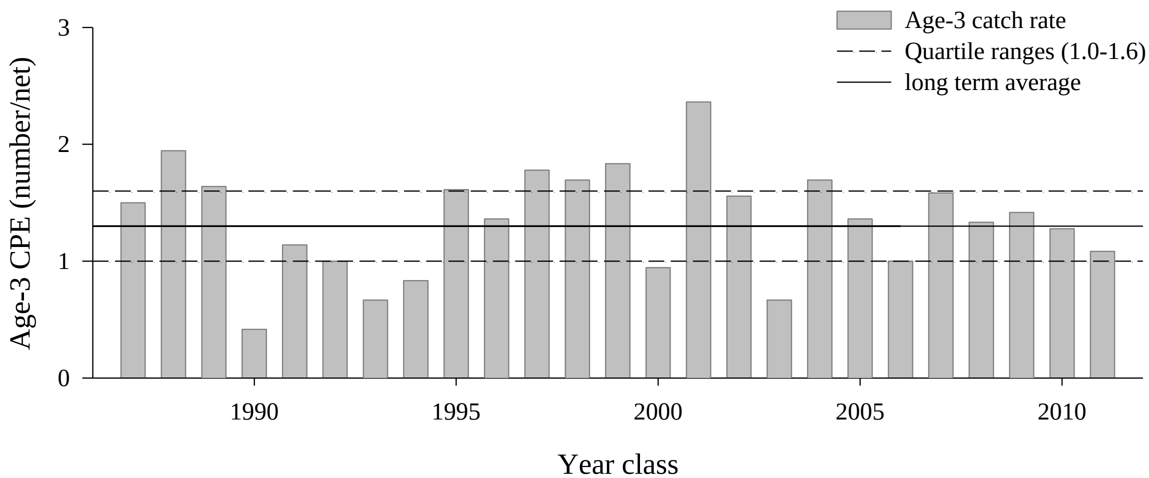

Figure 31. Catch rate (number/net) of age-3 Northern Pike with gillnets in Leech Lake, 1987-2011.

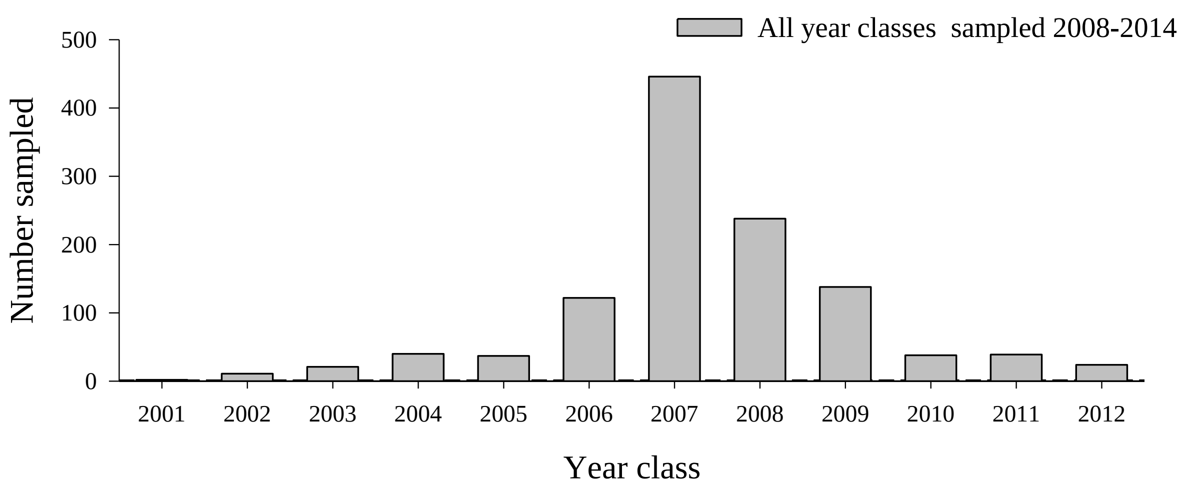

Figure 32. Number of aged Cisco sampled by year class with gill nets in Leech Lake, 2008-2014.

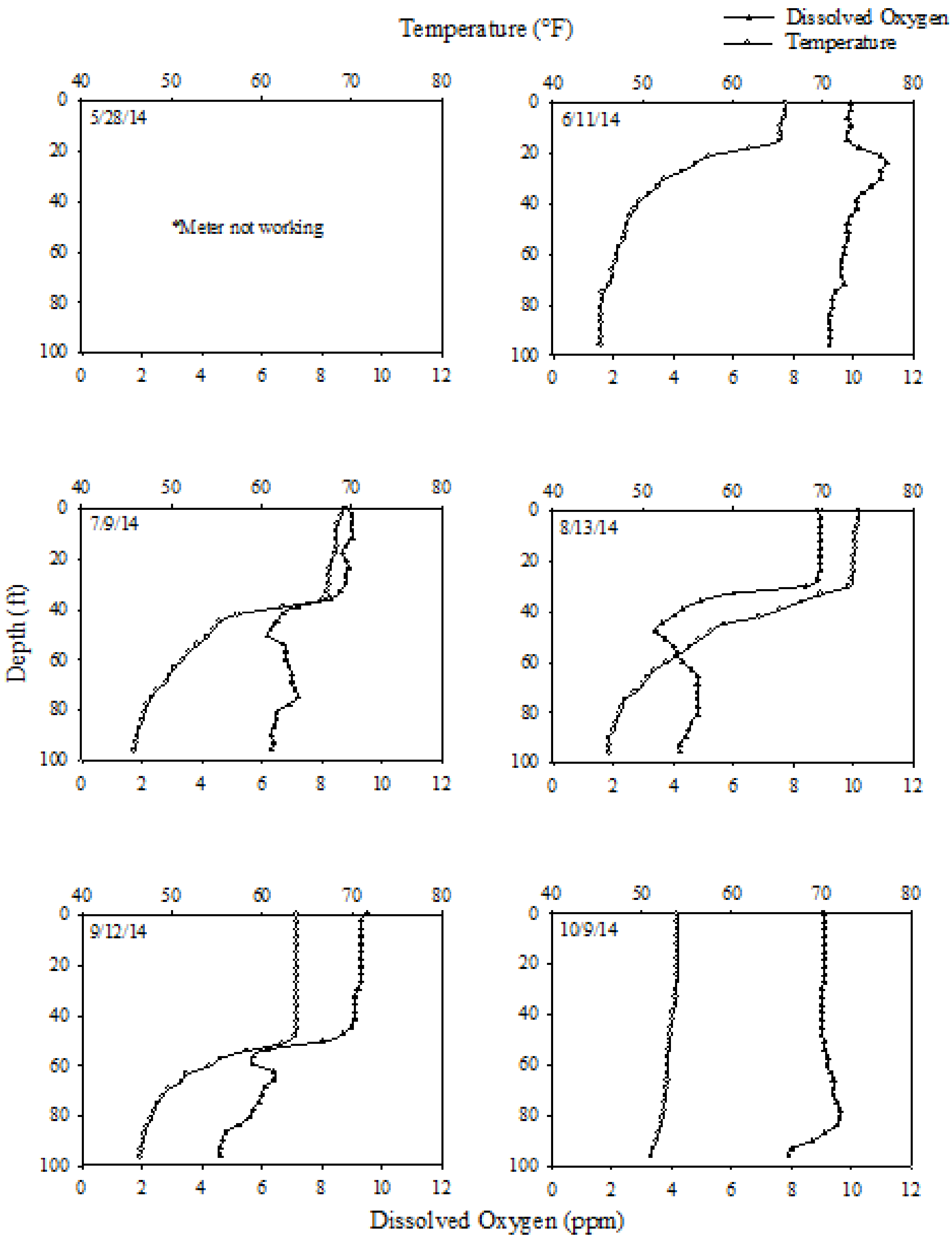

Figure 33. Monthly temperature and oxygen profiles from Walker Bay (WQ1), Leech Lake, from mid-June through mid-October, 2014.

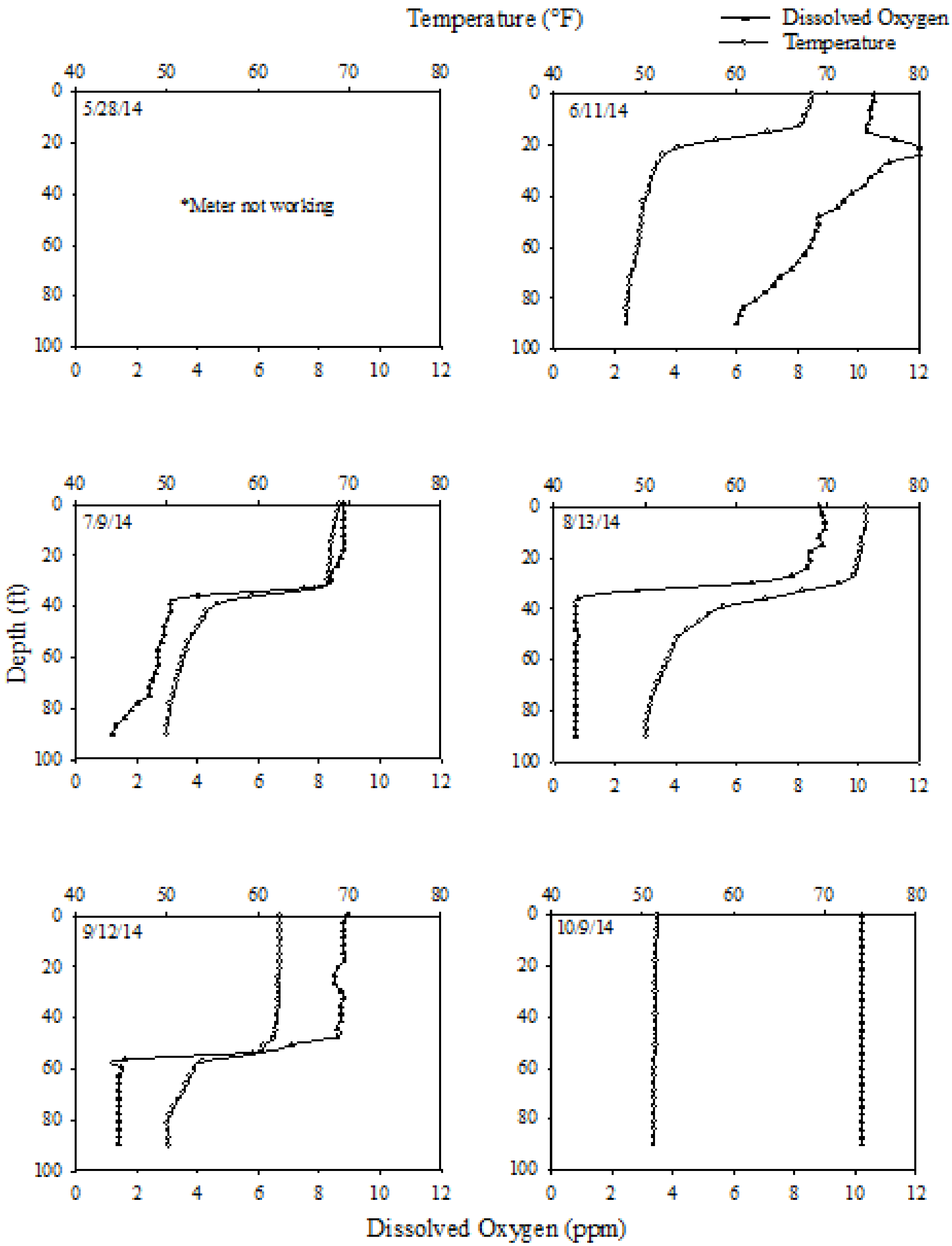

Figure 34. Monthly temperature and oxygen profiles from Agency Bay (WQ2), Leech Lake, from mid-June through mid-October, 2014.

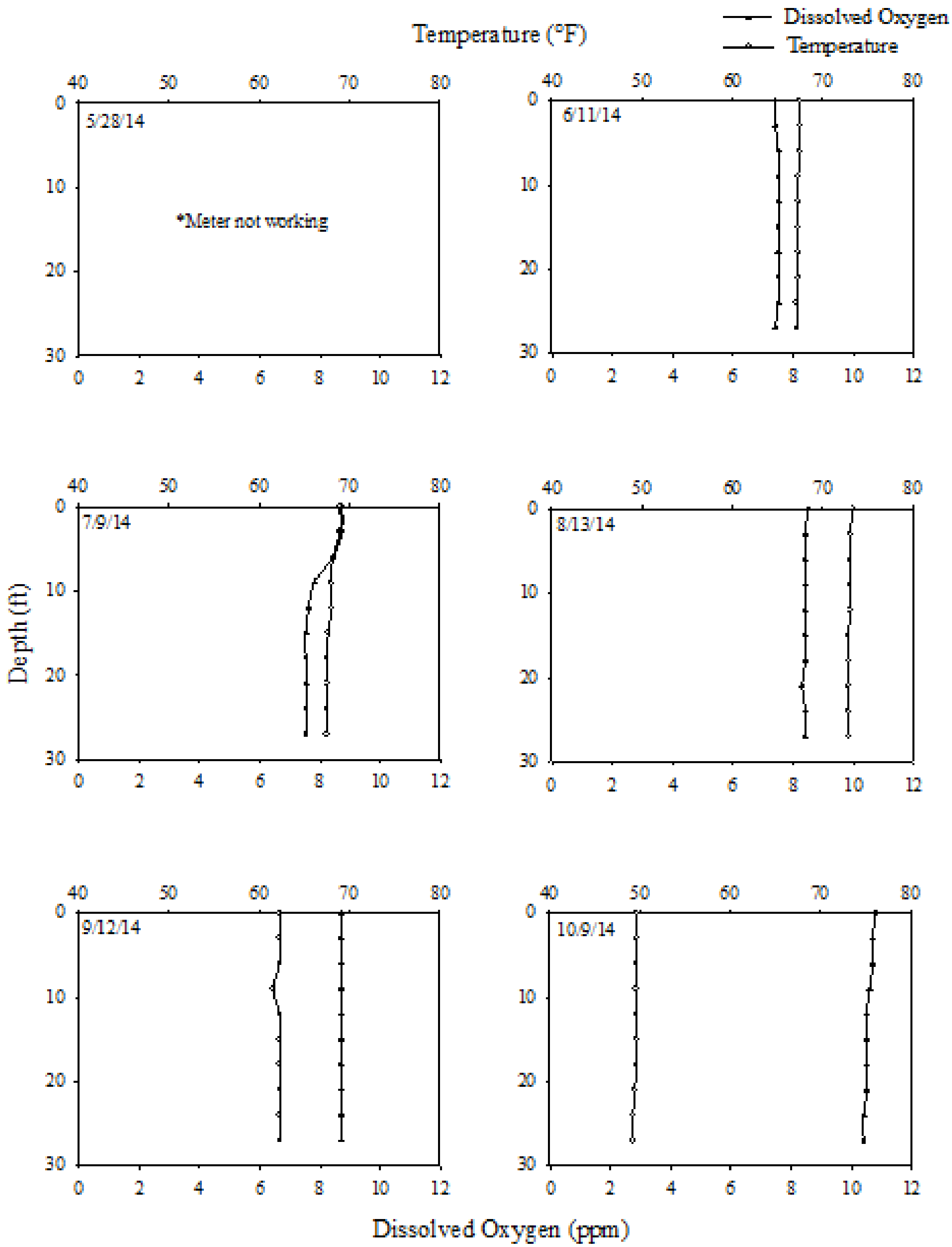

Figure 35. Monthly temperature and oxygen profiles from Portage Bay (WQ3), Leech Lake, from mid-June through mid-October, 2014.

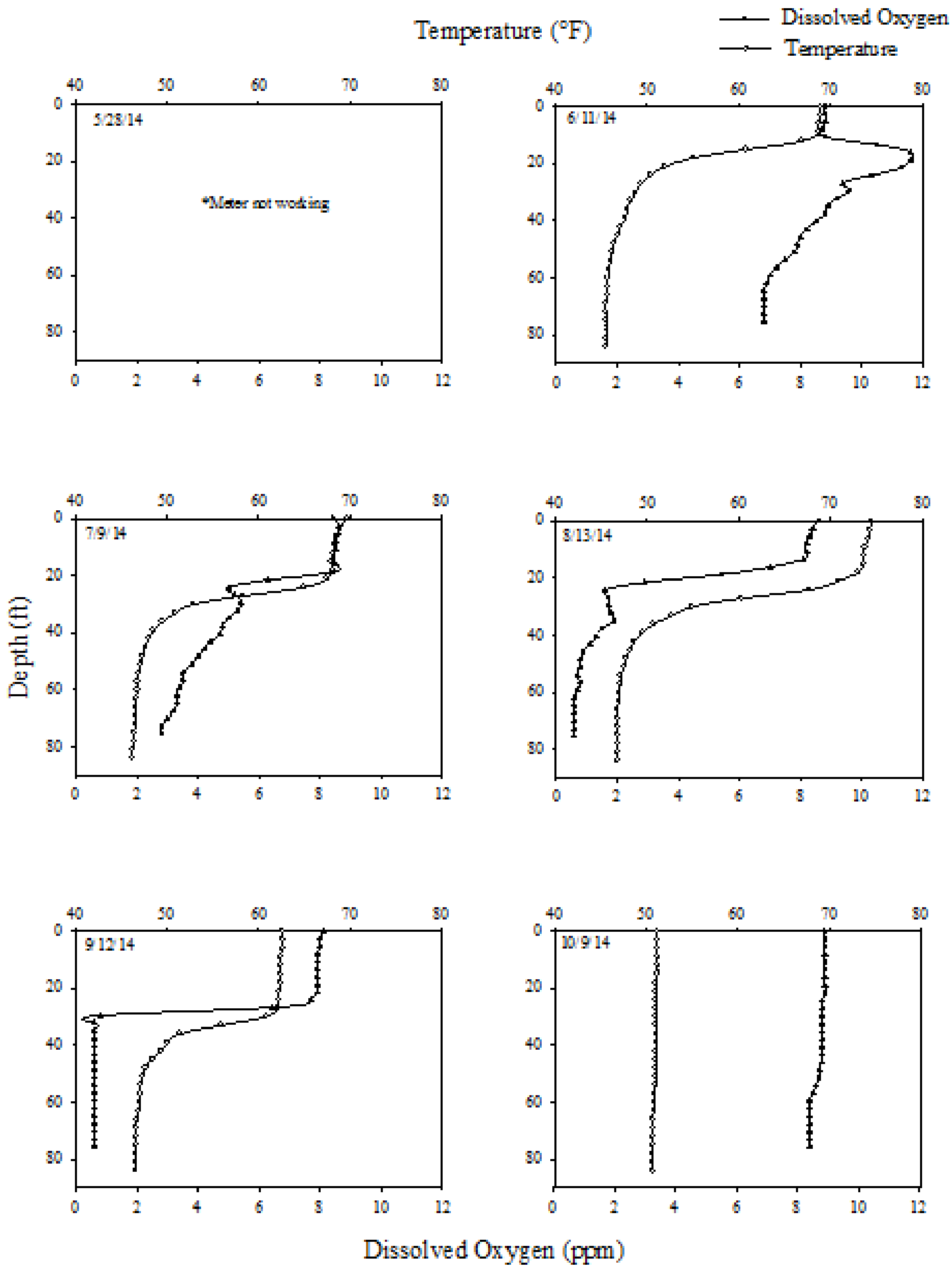

Figure 36. Monthly temperature and oxygen profiles from Kabekona Bay (WQ4), Leech Lake, in Leech Lake from mid-June through mid-October, 2014.

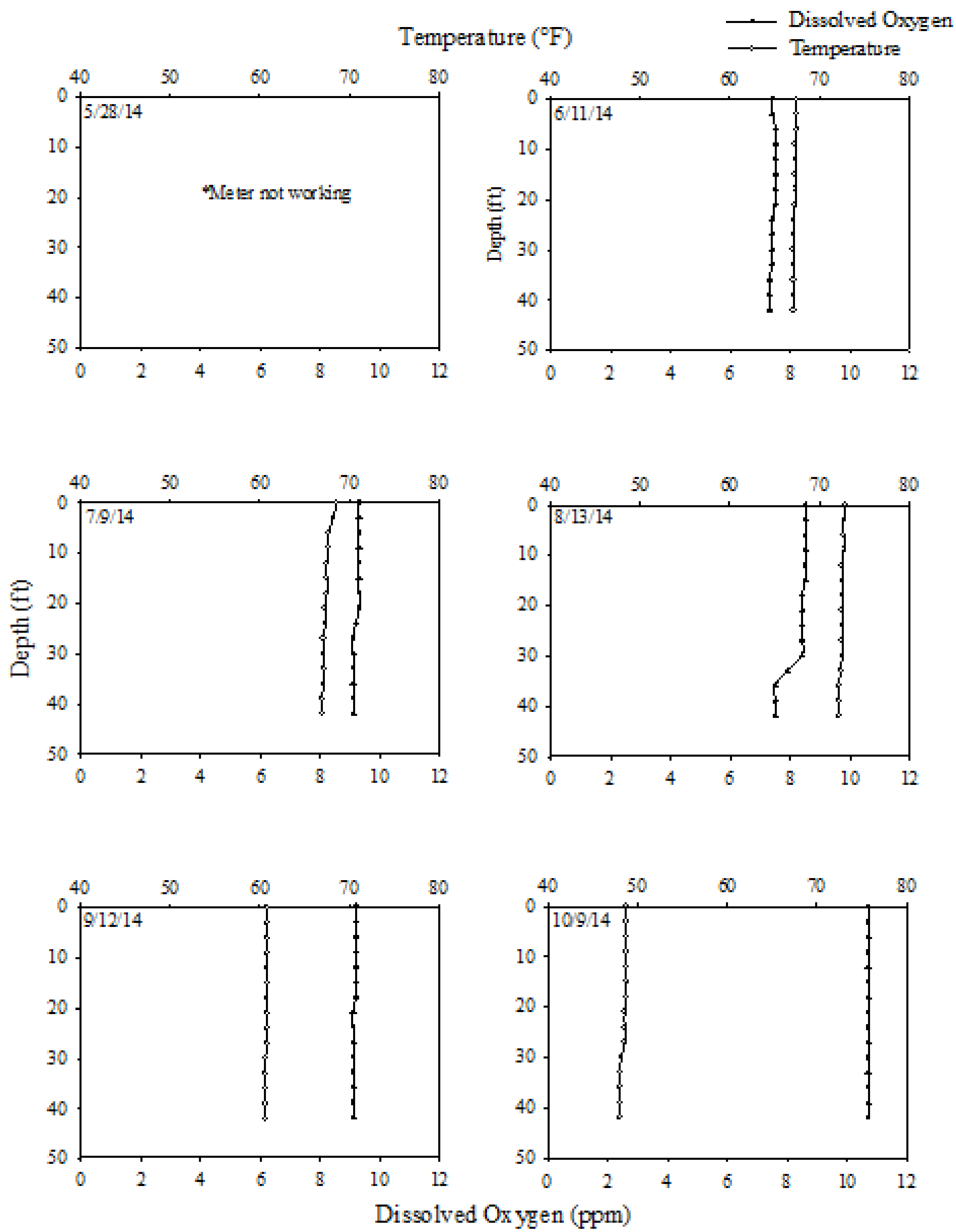

Figure 37. Monthly temperature and oxygen profiles from the Main Basin (WQ5), Leech Lake, from mid-June through mid-October, 2014.

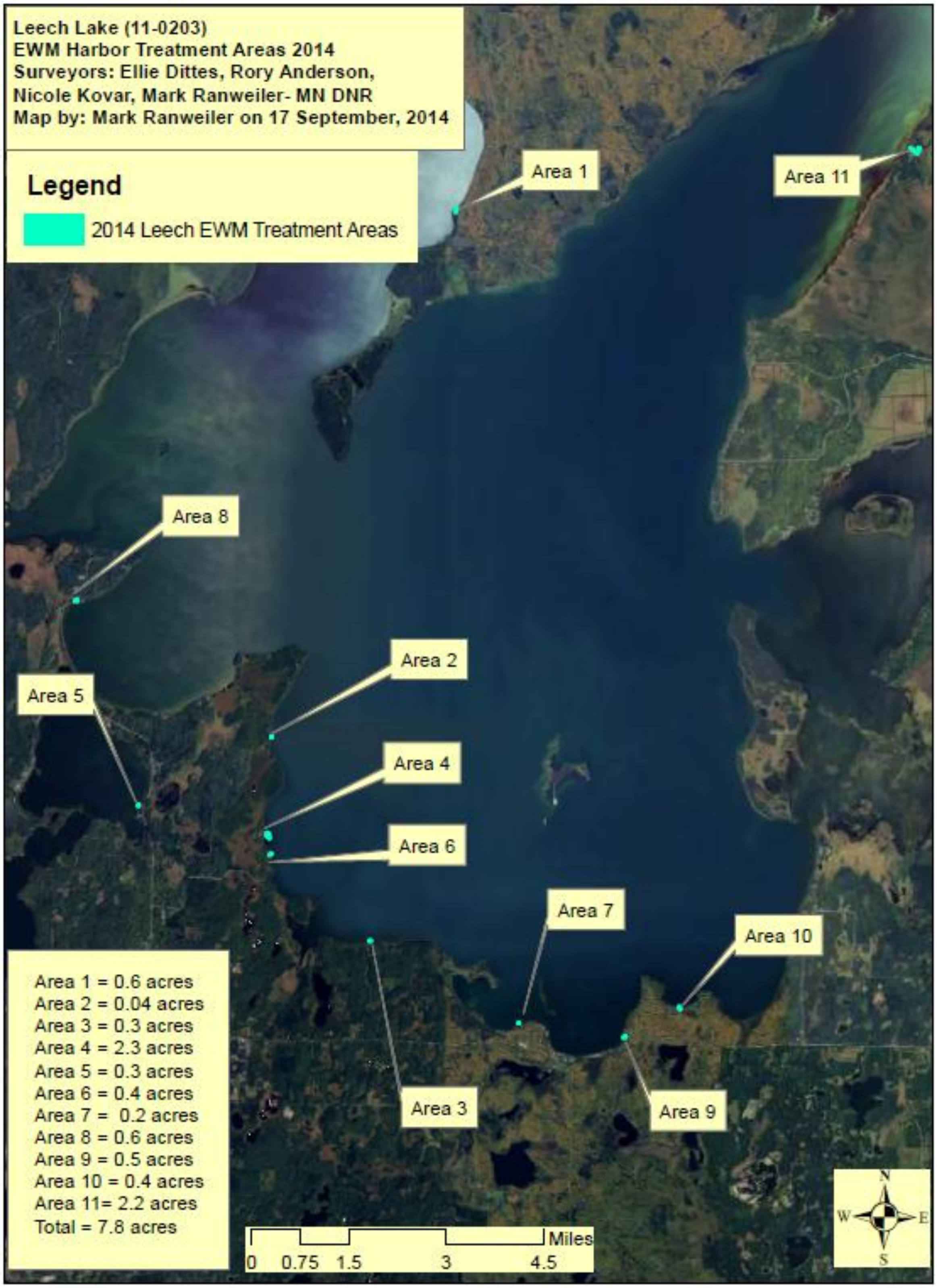

Figure 38. Areas on Leech Lake where boat harbors were treated for Eurasian watermilfoil in 2014.

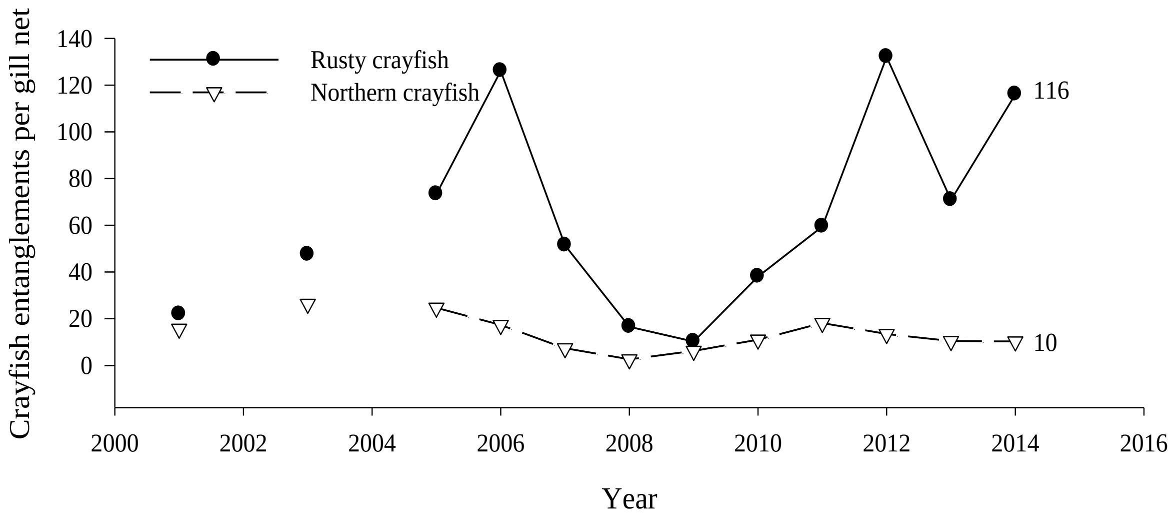

Figure 39. Crayfish entanglement rates (number/net) in gill nets, 2001-2014 as an index of relative abundance. Numbers were not recorded in 2000, 2002, or 2004.

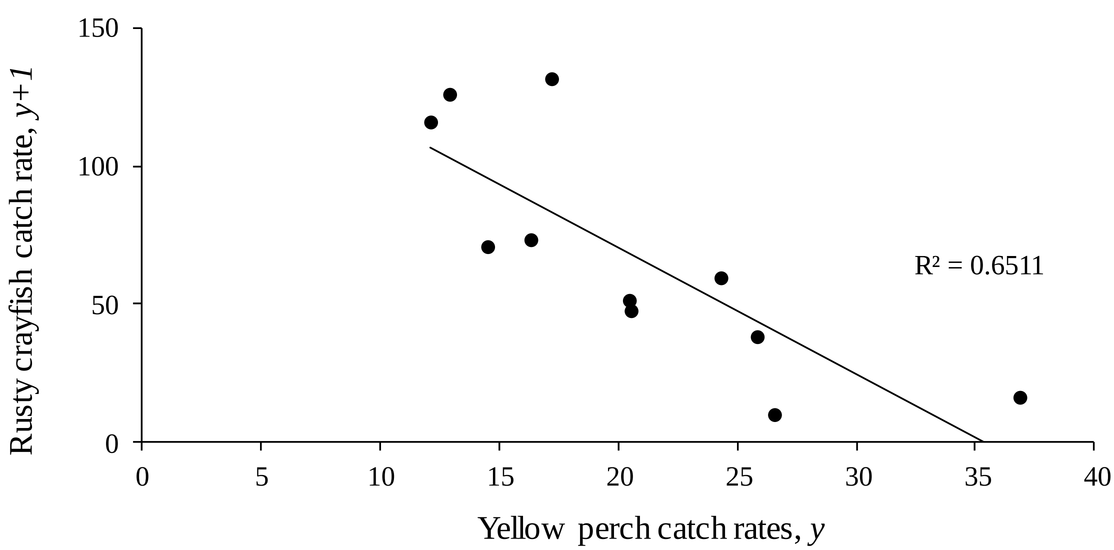

Figure 40. Yellow Perch catch rates (number/net) in year *y* and rusty crayfish entanglement rates (number/net) the following year (*y+1*) in Leech Lake, 2001-2013.

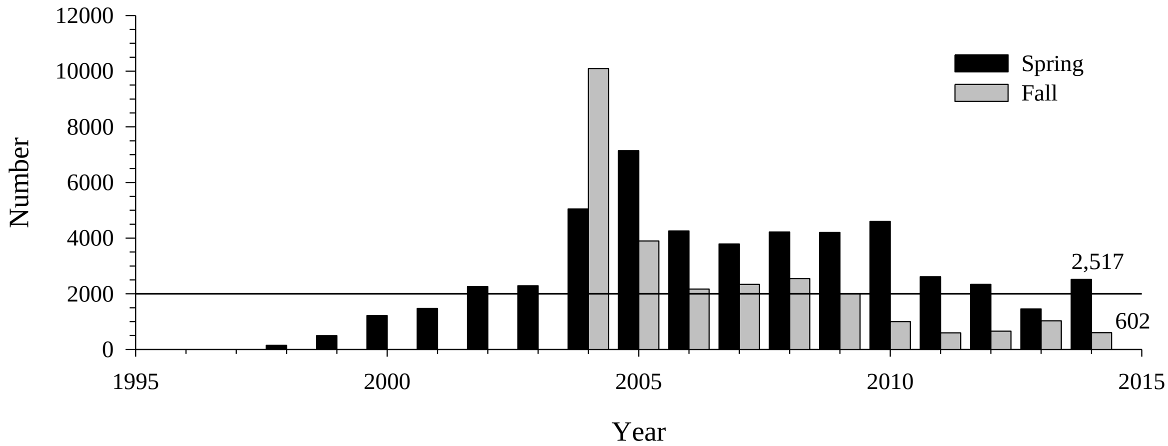

Figure 41. Spring and fall Double-Crested Cormorant numbers on Leech Lake, 1998-2014. The line depicts the current fall population goal of 2,000 birds ([500 nesting pairs x 2 adults] + 2 offspring/nest). (S. Mortensen, Division of Resource Management, Leech Lake Band of Ojibwe, personal communication).

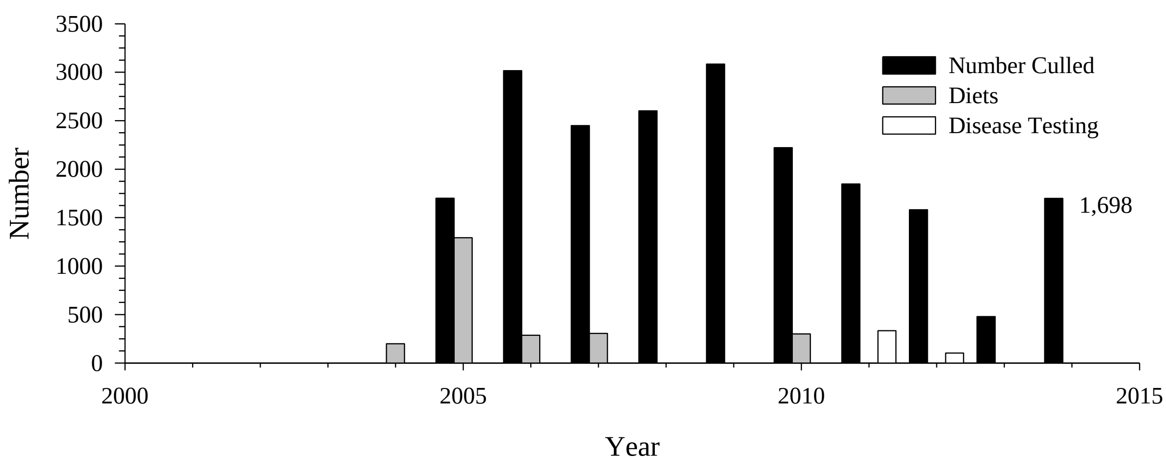

Figure 42. The number of Double-Crested Cormorants culled on Leech Lake, 2000-2014. The number of additional birds culled for diet and disease testing is also indicated. (S. Mortensen, Division of Resource Management, Leech Lake Band of Ojibwe, personal communication).

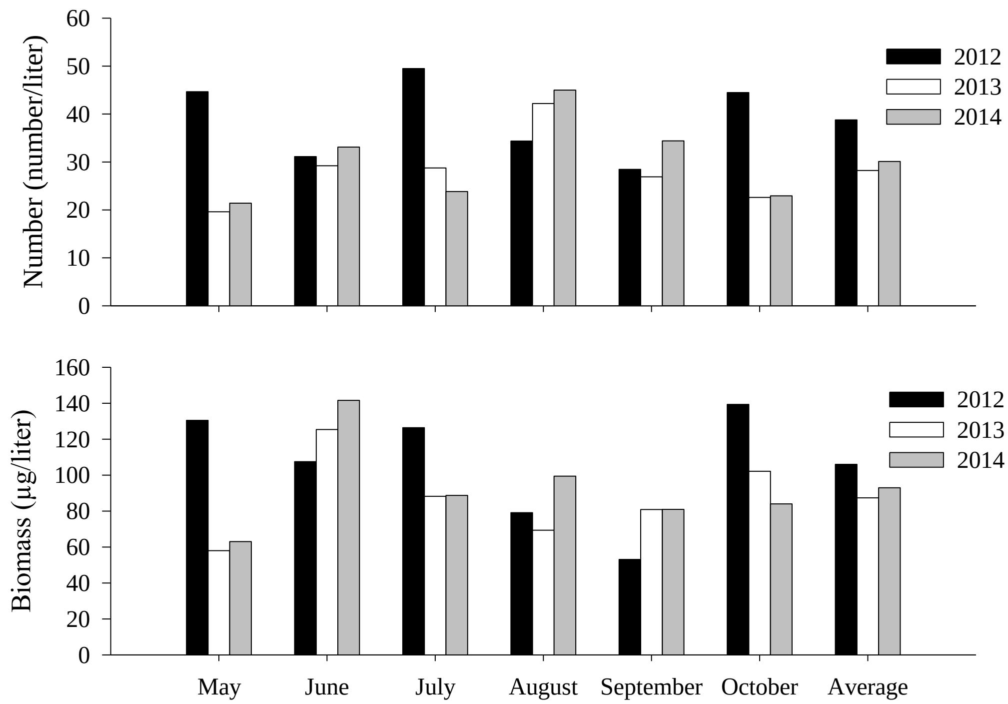

Figure 43. Density (number/liter) and biomass (µg/liter) of zooplankton sampled from May through at the five standardized zooplankton sites on Leech Lake in 2014.

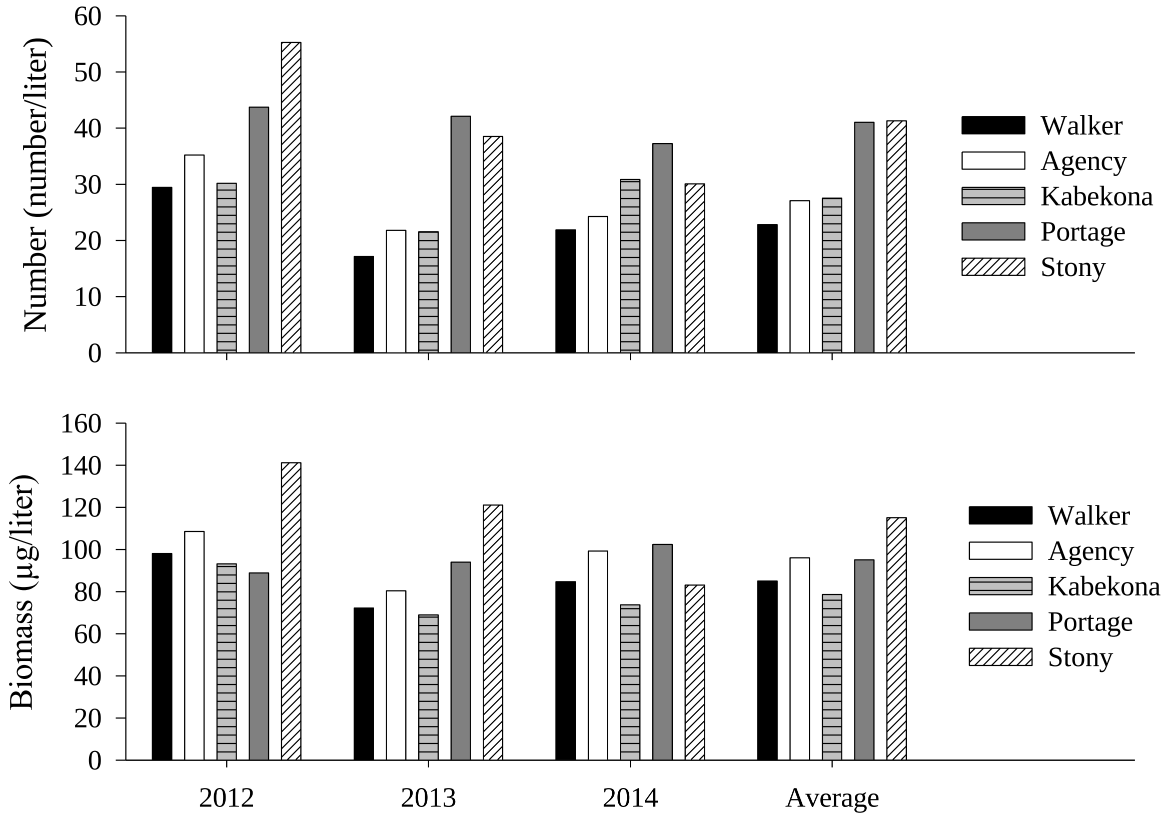

Figure 44. Density (number/liter) and biomass (µg/liter) of zooplankton sampled from May through at the five standardized zooplankton sites on Leech Lake in 2014.

APPENDIX

Table A1. Gillnet catch-per-effort (fish/net) by species for Leech Lake, 1983-2014.

	Year											
Species	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Black bullhead	11.3	9.7	13.8	8.0	11.2	15.1	21.3	11.6	16.5	9.8	4.3	3.9
Black crappie	0.1	0.5	0.2	0.3	0.3	0.4	0.3	0.3	0.5	0.2	0.2	0.2
Bluegill	0.0	0.1	0.0	0.2	0.1	0.1	0.6	0.3	0.1	0.4	0.3	0.2
Bowfin	0.0	0.0	0.1	0.0	0.1	0.2	0.0	0.0	0.0	0.1	0.0	0.0
Brown bullhead	2.5	1.1	0.6	0.8	1.1	0.9	1.8	0.9	3.1	1.5	1.7	2.2
Burbot	0.1	0.1	0.1	0.2	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.1
Hybrid sunfish	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lake whitefish	0.2	0.2	0.0	0.0	0.1	0.2	0.0	0.0	0.4	0.0	0.0	0.1
Largemouth bass	0.1	0.0	0.0	0.0	0.1	0.1	0.4	0.0	0.1	0.0	0.0	0.0
Muskellunge	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	0.0	0.1	0.0
Northern pike	4.2	3.7	4.1	3.8	4.3	5.3	5.8	5.3	5.8	4.4	3.6	4.0
Pumpkinseed	0.1	0.3	0.3	0.2	0.3	0.7	1.1	1.6	1.0	1.1	0.5	0.4
Rock bass	0.5	1.3	2.1	1.1	0.4	0.9	2.3	2.7	2.1	1.1	2.1	1.2
Shorthead redhorse	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Smallmouth bass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tiger muskellunge	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tullibee/cisco	6.3	4.6	10.2	14.1	18.5	11.1	2.1	5.9	6.7	4.4	9.6	9.1
Walleye	5.3	7.4	7.2	6.3	6.0	13.4	11.7	8.3	8.8	5.8	4.6	4.9
White sucker	1.3	1.8	1.8	1.1	2.4	2.6	2.1	2.1	1.8	2.0	1.6	1.9
Yellow bullhead	1.1	0.4	1.4	1.0	1.3	2.2	1.9	0.9	3.4	1.4	1.7	2.7
Yellow perch	13.5	17.9	15.6	13.2	16.1	18.5	26.1	33.7	18.6	22.1	20.4	21.7
Total fish/set	46.6	49.1	57.3	50.2	62.1	71.5	78.0	73.9	69.1	54.4	50.8	52.6
Total sets	32	36	36	36	36	36	36	36	36	36	36	36

Table A1 continued. Gillnet catch-per-effort (fish/net) by species for Leech Lake, 1983-2014.

	Year											
Species	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Black bullhead	0.9	0.7	1.5	2.5	1.8	0.5	0.7	1.2	1.3	4.3	3.5	1.4
Black crappie	0.1	0.1	0.1	0.2	0.3	0.2	0.4	0.3	0.6	0.3	0.4	0.6
Bluegill	0.1	0.1	0.1	0.2	0.1	0.6	0.6	1.0	0.5	0.8	2.1	1.1
Bowfin	0.0	0.0	0.0	0.1	0.3	0.2	0.1	0.1	0.0	0.1	0.0	0.0
Brown bullhead	0.9	0.6	0.7	1.3	3.3	2.1	2.1	0.9	0.9	1.6	4.1	2.0
Burbot	0.1	0.0	0.0	0.1	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0
Hybrid sunfish	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lake whitefish	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Largemouth bass	0.0	0.1	0.0	0.2	0.1	0.0	0.1	0.3	0.3	0.1	0.0	0.1
Muskellunge	0.1	0.0	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Northern pike	6.2	4.8	5.1	5.1	3.7	5.0	5.3	5.3	5.0	5.4	4.9	4.0
Pumpkinseed	0.2	0.5	1.1	0.7	0.4	0.4	1.1	1.1	1.6	0.8	2.1	0.6
Rock bass	2.7	2.9	2.0	2.3	1.8	0.9	1.9	1.2	1.3	2.0	0.6	0.5
Shorthead redhorse	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Smallmouth bass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tiger muskellunge	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tullibee/cisco	4.2	4.7	4.2	3.7	3.1	2.7	1.3	1.6	0.9	1.8	3.5	0.6
Walleye	7.7	9.5	5.7	11.6	8.9	5.9	7.0	6.2	5.2	5.0	4.9	7.1
White sucker	3.1	2.0	1.2	2.0	1.2	0.9	1.2	1.3	1.4	0.8	0.9	1.9
Yellow bullhead	0.4	0.3	0.9	0.8	0.9	0.4	0.5	1.6	1.3	2.7	2.6	1.7
Yellow perch	37.7	25.6	32.1	28.6	21.1	21.2	15.5	20.5	16.2	16.3	12.9	20.5
Total fish/set	64.6	52.0	55.1	59.3	47.0	41.1	37.7	42.6	36.3	41.9	42.4	42.3
Total sets	35	36	35	36	36	35	36	36	36	36	36	36

Table A1 continued. Gillnet catch-per-effort (fish/net) by species for Leech Lake, 1983-2014.

	Year												Quartiles	
Species	2007	2008	2009	2010	2011	2012	2013	2014	Min	Max	Median	Mean	First	Third
Black bullhead	1.9	1.1	0.3	0.3	0.2	0.0	0.0	0.0	0.0	21.3	1.8	5.0	0.7	9.7
Black crappie	1.7	0.9	1.1	0.6	0.5	0.2	0.9	0.4	0.1	1.7	0.3	0.4	0.2	0.5
Bluegill	1.1	1.2	1.1	0.6	0.7	0.3	1.2	0.1	0.0	2.1	0.3	0.5	0.1	0.7
Bowfin	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.0	0.3	0.1	0.1	0.0	0.1
Brown bullhead	4.3	2.0	0.6	1.9	0.6	0.3	0.2	0.1	0.1	4.3	1.2	1.5	0.7	2.0
Burbot	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.1	0.1	0.0	0.1
Hybrid sunfish	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lake whitefish	0.0	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.4	0.0	0.1	0.0	0.1
Largemouth bass	0.2	0.1	0.1	0.1	0.1	0.4	0.1	0.0	0.0	0.4	0.1	0.1	0.0	0.1
Muskellunge	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.1	0.0	0.3	0.0	0.0	0.0	0.1
Northern pike	5.9	5.6	4.9	4.1	5.9	4.3	4.6	4.6	3.6	6.2	4.9	4.8	4.2	5.3
Pumpkinseed	1.3	1.5	0.7	0.3	0.3	0.4	1.4	0.3	0.1	2.1	0.7	0.8	0.3	1.1
Rock bass	1.3	2.4	2.2	1.0	1.3	0.8	1.4	0.8	0.4	2.9	1.3	1.5	1.0	2.1
Shorthead redhorse	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Smallmouth bass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tiger muskellunge	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tullibee/cisco	4.0	1.6	11.9	5.9	1.9	3.6	3.3	4.0	0.6	18.5	4.1	5.3	2.5	6.4
Walleye	13.1	9.1	8.6	7.9	8.1	9.4	8.9	8.9	4.6	13.4	7.6	7.8	5.9	8.9
White sucker	0.7	0.6	1.1	0.6	1.1	1.5	0.9	1.1	0.6	3.1	1.4	1.5	1.1	1.9
Yellow bullhead	4.2	2.6	1.4	2.8	1.0	0.6	0.4	0.4	0.3	4.2	1.3	1.5	0.8	2.0
Yellow perch	36.9	26.6	25.8	24.3	17.2	14.5	12.1	13.9	12.1	37.7	20.4	21.1	15.9	25.7
Total fish/set	77.0	55.3	60.1	50.6	39.1	36.4	35.6	34.7	34.7	78.0	50.7	52.1	42.2	59.5
Total sets	36	36	36	36	36	36	36	36						