Fishery Survey - Diamond Lake, Bayfield County, 2003-2004 WBIC Code - 2897100

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Executive Summary

The fisheries of Diamond Lake (Bayfield County) were surveyed during 2003 and 2004. Survey objectives were to obtain an estimate of the walleye, largemouth and smallmouth bass populations, along with sport and tribal use of these species. Sampling followed standardized Treaty Assessment protocol and included spring fyke netting, spring and fall electroshocking, and a creel survey. Results indicated adult walleye abundance ($\geq$ 15 in and sexable fish) was 2.0 adults/acre, similar to previous surveys on Diamond Lake and the Bayfield/Douglas County average for stocked walleye lakes, but below the statewide management objective of 3.0 adults/acre. The walleye size structure has been variable between survey periods but has consistently included high mean lengths. The length frequency distribution of walleye indicates change over time that is likely due to fluctuations in stocking strategy and failure of several year classes. While low levels of natural reproduction may be present, stocking has driven the system since 1986. The success of the northern pike regulation (minimum length limit of 32 in and a bag limit of 1 fish per day) has been mixed. The more restrictive regulation has reduced harvest of northern pike and increased relative abundance, however mean length and size structure have declined. The effects of the 32 in minimum length regulation on Diamond Lake should continue to be scrutinized in future survey years. Largemouth bass densities and mean length have increased which may be related to the increased angler directed effort toward largemouth bass. Smallmouth bass populations have remained stable in comparison with previous surveys. Bluegill populations have increased in abundance and decreased in mean length when compared to previous surveys. Angling pressure during the 2003-2004 fishing season was 4.8 hr/acre (the lowest recorded for Bayfield and Douglas County creel surveys), of which a high majority (94%) was during the open water period. Creel survey results indicated walleye and largemouth bass were the most sought after gamefish species (25.2% and 21.3% respectively of directed effort) by anglers in 2002. There

was no angler harvest of walleye during the creel survey. Estimated exploitation (sport angling plus tribal spearing) of walleye ≥ 15 in was 12.9% in 2003-2004. Tribal spearers harvested 86 walleye averaging 18.9 in. Management recommendations include, 1) Maintaining existing walleye regulations and increase stocking frequency from biannually to annually in an attempt to increase densities, 2) Retain the northern pike 32 in minimum length limit with a bag limit of one fish until the results of the 2006 surveys are examined, 3) Attempt to control overabundant bluegill populations through increased predator densities, 4) Work with local residents, associations and groups to develop a lake management plan that addresses fisheries management goals, habitat protection and rehabilitation as well as education of users and riparian residents.

Introduction

Diamond Lake is a 341 acre drainage lake near the headwaters of Eighteen Mile Creek in Bayfield County. Diamond Lake is a low range mesotrophic lake with clear water, has private riparian ownership along the entire lake with the exception of the public access on the southern end of the lake and is a popular recreational lake in the area. Diamond Lake has a maximum depth of 83 feet and a total alkalinity of 33 mg/l. Average summer secchi disk depth trophic state index (TSI) value for the deep hole on Diamond Lake was 41.4 (SD = 2.4, N = 40), for the time period between 1992 and 2003. Average summer chlorophyll-a and total phosphorus TSI values for the deep hole on Diamond Lake were 41.3 (SD = 3.5, N = 20) and 47.1 (SD = 3.4, N = 23) for the time period between 1994 and 2003. TSI indices are used to evaluate the trophic state or nutrient condition of lakes. The data on Diamond Lake indicate the nutrient condition was near the division line between oligotrophic and mesotrophic condition.

Diamond Lake has a diverse fishery consisting of walleye *Sander vitreus*, northern pike *Esox lucius*, largemouth bass *Micropterus salmoides*, smallmouth bass *M. dolomieui*, bluegill *Lepomis macrochirus*, pumpkinseed *L. gibbosus*, green sunfish *L. cyanellus*, rock bass *Ambloplites rupestris*, black crappie *Pomoxis nigromaculatus*, yellow perch *Perca flavescens*, white sucker *Catostomus commersoni*, yellow bullhead *Ictalurus natalis*, rainbow smelt *Osmerus mordax*, mottled sculpin *Cottus bairdi*, creek chub *Semotilus atromaculatus*, common shiner *Notropis cornutlus*, tadpole madtom *Noturus gyrinus*, and central mudminnow *Umbra limi*. Cisco *Coregonus artedii* were also present historically but have not been sampled since 1969.

Historic management of Diamond Lake has included fishery surveys, stocking, and various length and bag regulations. Historic surveys for walleye occurred in 1990 and 1996 utilizing Wisconsin Department of Natural Resources (WDNR) standardized treaty protocols (Hennessey 2002). Walleye surveys were also conducted in 1968, 1971 and 1975 to evaluate

the success of walleye stocking using a different sampling protocol, i.e. electrofishing and netting to capture walleye to determine year class strength. These historic walleye surveys did not include population estimates.

Diamond Lake has a long stocking history (Table 1). Walleye have been the only species stocked since 1969. Prior to 1969 the majority of the stocking involved rainbow trout and largemouth bass and to a lesser extent northern pike, smallmouth bass and brown trout. Rainbow, brown and brook trout were stocked from 1959 to 1968 in an attempt to create a two-story fishery. Survey results from 1968 found few trout and little carry over into subsequent years from stocking; at that time trout stocking was discontinued and walleye stocking was initiated (Weiher 1972). Walleye stocking began in 1969 and was intended to establish a self-sustaining fishery that might exercise biological control over an abundant but slow growing bluegill population. Prior to 1969 there had been only a remnant walleye population (Pratt 1976). Walleye stocking was discontinued in 1980 due to evidence of natural reproduction and a decline of black crappie and bluegill (Schram 1981). The first walleye population estimate occurred in 1990 and found that six walleye year classes were produced naturally after stocking had been discontinued. However, after the six naturally reproduced year classes of walleye there were 5 years with no evidence of natural reproduction and bluegill abundance had reached levels that were comparable to levels prior to walleye stocking (Kampa and Sand 1991). Kampa and Sand (1991) found this perplexing and speculated that Diamond Lake did not have habitat conditions conducive to walleye reproduction since walleye were present in the lake for many years prior to stocking even though their numbers were just detectable. However, the six year classes of naturally reproduced walleye seemed to diminish this argument. The authors also speculated that the presence of smelt in Diamond Lake might have also been a factor, suggesting that smelt could be significant predators on early life history stages of walleye.

Whether environmental conditions or smelt predation acted alone or in concert in walleye declines in Diamond Lake was unknown.

Walleye fishing regulations have changed over time in Diamond Lake. There was no minimum length limit for walleye until 1990 when a 15 in minimum length limit was instituted statewide. In 2000, the 15 in minimum length limit remained on Diamond Lake and an additional slot limit from 20 inches to 28 inches was instituted; only one walleye over 28 inches was allowed. The slot limit was proposed because natural recruitment was low and the population was dependent on stocking, and past survival and growth of stocked fish had been excellent (Scholl 1998).

Northern pike regulations also changed over time in Diamond Lake. There was no minimum length and a bag limit of 5 northern pike until 1995 when a 32 in minimum length limit and a bag limit of one was implemented. The more restrictive northern pike regulation was implemented in an attempt to produce a higher quality northern pike fishery and encouraged by information which indicated presence of a smelt and cisco forage base, good growth rates and good thermal conditions for northern pike (Scholl 1994).

Recent management has focused on walleye stocking, regulation changes, public outreach and education and habitat protection. The objective of the 2003-2004 survey was to determine the status of the walleye, largemouth and smallmouth bass populations, along with sport and tribal use of these species. More specifically, we were interested in determining population abundance, growth, size structure and harvest of walleye, largemouth and smallmouth bass. We also hoped to determine some population parameters of other important game and panfish in Diamond Lake.

Methods

Diamond Lake was sampled during 2003-2004 following the Wisconsin Department of Natural Resources comprehensive treat assessment protocol (Hennessey 2002). This sampling included spring fyke netting and electroshocking to estimate walleye, bass (both largemouth and smallmouth) and northern pike abundance, late June fyke netting for panfish abundance, August mini-fyke netting for non-game fish, fall electroshocking to estimate year class strength of walleye young-of-the-year (YOY), and a creel survey (both open water and ice). Mini-fyke netting and fall electroshocking also followed protocols of Wisconsin's statewide baseline monitoring program (Stewart 2001).

Walleye were captured for marking in the spring shortly after ice out with fyke nets. Each fish was measured (total length; inches and tenths) and fin-clipped. Adult (mature) walleyes were defined as all fish for which sex could be determined and all fish 15 in or longer. Adult walleyes were given a lake-specific mark. Walleyes of unknown sex less than 15 inches in length were classified as juveniles (immature) and were marked with a different lake-specific fin clip. Marking effort was based on a goal for total marks of 10% of the anticipated spawning population estimate. To estimate adult abundance, walleyes were recaptured 1-2 days after netting. Because the interval between marking and recapture was short, electrofishing of the entire shoreline was conducted to ensure equal vulnerability of marked and unmarked walleyes to capture. All walleyes in the recapture run were measured and examined for marks. All unmarked walleyes were given the appropriate mark so that a total population estimate could be estimated. To estimate total walleye abundance, a second electrofishing recapture run was conducted 2 weeks after the first recapture run. Again, the entire shoreline of the lake was electrofished. Population estimates were calculated with the Chapman modification of the Petersen Estimator using the equation:

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

where N is the population estimate, M is the total number of marked fish in the lake, C is the total number of fish captured in the recapture sample, and R is the total number of marked fish captured. The Chapman Modification method is used because simple Petersen Estimates tend to overestimate population sizes when R is relatively small (Ricker 1975). Abundance and variance were estimated by the total for walleye that were ≥ 15 in and sexable.

Largemouth and smallmouth bass encountered during fyke netting and subsequent electroshocking runs (adult and total walleye) were marked. Bass ≥ 12.0 in were given the same primary (adult) fin-clip given to walleye for that lake. Bass 8.0-11.9 in were given the secondary (juvenile) fin-clip for the lake. Recaptures were made during electroshocking runs made during mid-late May. The entire shoreline of the lake was sampled. Four electroshocking surveys were conducted. The first electroshocking run was conducted within a week of pulling the fyke nets. The second run was conducted approximately two weeks after the first electroshocking run. Third and fourth electroshocking runs were conducted at approximately weekly intervals thereafter. Bass populations were estimated after both the third and fourth runs. Population estimates were calculated using the Chapman modification of the Petersen estimator, as described above for walleye population estimates. Abundance and variance were estimated by the total for both largemouth and smallmouth bass that were ≥ 8 inches. The recapture run yielding the lowest coefficient of variation is the population estimate reported. Both largemouth and smallmouth bass were not targeted in the 1990 survey which did not include second, third or fourth electrofishing periods. The results presented are derived from 1996 and 2003 surveys. In 1996 population estimates for largemouth and smallmouth bass were determined from the fourth electroshocking survey. Population estimates for largemouth and smallmouth bass in 2003 were derived from the third and fourth

electroshocking surveys, respectively. Size structure and catch per unit effort (CPUE: the number of largemouth or smallmouth bass caught/hour of electroshocking) were derived from the first through fourth electroshocking surveys.

Walleye age and growth were determined from dorsal spine cross sections viewed microscopically at 100X (Margenau 1982). Age and growth of other fish species were determined by viewing acetate scale impressions under a 30X microfilm projector. Growth rates for all species were compared to an 18 county regional mean (Northern Region) using the Fisheres and Habitat database. Size structure quality of species sampled was determined using the indices proportional (PSD) and relative (RSD) stock densities (Anderson and Gutreuter 1983). The PSD and RSD value for a species is the number of fish of a specified length and longer divided by the number of fish of stock length or longer, the result multiplied by 100 (Appendix Table 1). Changes in population size structure were determined using Kolmogorov-Smirnov tests.

Creel surveys used a random stratified roving access design (Beard et al. 1997; Rasmussen et al. 1998). The survey was stratified by month and day-type (weekend / holiday or weekday), and the creel clerk conducted interviews at random within these strata. The survey was conducted on all weekends and holidays, and a randomly chosen two or three weekdays. Only completed-trip interview information was used in the analysis. The clerk recorded effort, catch, harvest, and targeted species from anglers completing their fishing trip. The clerk also measured harvested fish and examined them for fin-clips.

Results

Total survey effort in 2003 included 32 fyke net lifts targeting spawning gamefish. In June a second fyke-netting period targeted spawning panfish and included 15 fyke net lifts. A total of 12 mini-fyke net lifts targeting non-game fish were completed in August. Five

electroshocking surveys of the entire shoreline totaling 7.6 hours in spring (first through fourth recapture surveys) and 1.7 hours in fall (walleye recruitment survey) were conducted.

Walleye. Adult walleye abundance ($\geq$ 15 inches and sexable fish) was 667 (CV = 0.15; 2.0 adults/acre) in 2003 for Diamond Lake. The density of adult walleye in Diamond Lake decreased from 1990 to 1996 and was similar from 1996 to 2003. However, values for all three sampling years remain within the 95% confidence intervals (Figure 1). Length of walleye captured in fyke nets in 1990, 1996 and 2003 suggests significant shifts in size structure during the three sampling periods (1990 vs. 1996, $D = 0.47$, $P < 0.0001$: 1996 vs. 2003, $D = 0.43$, $P < 0.0001$; Figure 2). The length frequency distribution of walleye indicates change over time that is likely due to fluctuations in stocking strategy and failure of several year classes. Nevertheless, mean length for sexable walleye was high and ranged from 21.2 (SD = 2.14, N = 201), to 22.7 (SD = 4.34, N = 227), to 20.7 (SD = 2.73, N = 275) inches for survey years 1990, 1996, and 2003. Proportional stock density (PSD) values of 92 to 100 during the sampling years supported the contention of a quality size structure of the walleye population. Similarly, RSD-20 values ranging from 56 to 75 indicated in all sampling years at least 50% of mature walleye were over 20 inches in length.

Age of adult walleye sampled during the 2003 survey ranged from III to XVII. Male and female walleye first reached maturity at III and V, respectively. Age V walleye accounted for 59% of the adult stock. Age distribution data from 1990, 1996, and 2003 indicate naturally reproduced year classes from 1980 to 1984 and natural reproduction year class failures from 1985 to 2003 suggesting the walleye population has been supported largely by stocking since 1985 (Figure 3). No walleye were sampled in 2003 that would have been from nonstocked years. Not unexpectedly, age composition of walleye sampled in fyke nets differed for all years sampled (Figure 3). Growth rates for both sexes remained relatively consistent for all survey years. In 1990 and 1996 growth rates were above NOR regional averages with the

exception of ages XI through XIV which were slightly lower than region averages. In 2003 growth rates were above NOR regional averages (Figure 4). Walleye growth was dimorphic, female and male walleye reaching 15 inches sometime during the third and fourth growing season, respectively.

There were no YOY (young-of-year) walleye found in Diamond Lake in 2003. The average walleye YOY/mile was 3.3 (SD = 5.4, N = 11) for surveys completed from 1989 to 2004. Oxytetracycline (OTC) marking was used to mark YOY walleye fingerlings that were stocked in 1998, 2000 and 2004 to determine contribution of stocked walleye that were collected in fall surveys. OTC marks were found in 41%, 100% and 100% of YOY walleye collected in 1998, 2000 and 2004, respectively.

Northern Pike. Northern pike were the second most abundant predator in Diamond Lake, though their relative abundance was low. Catch per unit effort of northern pike (CPUE; the number of northern pike caught with each fyke net lift) increased from 0.9 to 1.8 to 3.0 from 1990 to 1996 to 2003. Mean lengths of northern pike decreased from 22.8 in (SD = 5.66, N = 30), 22.5 in (SD = 4.89, N = 72) to 19.5 in (SD = 4.78, N = 100) for survey years 1990, 1996 and 2003. PSD and RSD-28 indicated a declining size structure for northern pike. PSD for spring fyke netting samples were 73, 65 and 43 for 1990, 1996 and 2003. RSD-28 was 23, 21 and 4 for 1990, 1996 and 2003. Collectively, mean length, stock densities and percent length frequency indicate a decrease in length in three consecutive survey periods (Figure 5).

Largemouth Bass. Largemouth bass abundance ($\geq$ 8 inches) in Diamond Lake increased from 108 (CV = 0.24; 0.3 fish/acre) to 457 (CV = 0.21; 1.3 fish/acre) for 1996 and 2003. In addition, since 1996 the largemouth bass size structure has shifted to larger fish (Figure 6). The average length of largemouth bass increased from 9.8 in (SD = 4.29, N = 95) to 12.1 in (SD = 3.59, N = 221) from 1996 to 2003. The PSD remained similar between

1996 and 2003 and was 70 and 69, while RSD-15 increased slightly from 26 to 28. The proportional and relative stock densities indicate the shift in average length was due to a higher number of fish below the stock size of 8 in sampled in 1996. Growth of largemouth bass was consistent among survey years 1990, 1996 and 2003 and average compared to NOR region averages (Figure 7).

Smallmouth Bass. Smallmouth bass abundance (≥ 8 inches) in Diamond Lake remained similar from 140 (CV = 0.35; 0.41 fish/acre) to 136 (CV = 0.23; 0.40 fish/acre) for 1996 and 2003. Since 1996 the smallmouth bass size structure has remained stable (Figure 8). The average length of smallmouth bass increased from 9.8 in (SD = 4.14, N = 66) to 11.2 in (SD = 3.20, N = 77) from 1996 to 2003. PSD and RSD-14 values have also remained stable; 57 to 57, and 23 to 24 respectively, for 1996 and 2003. Density, average length and stock densities all indicate a stable smallmouth bass population in Diamond Lake. Growth of smallmouth bass was consistent among survey years and slightly below average when compared to growth of NOR region averages (Figure 9).

Panfish and other species. Bluegill were the most abundant panfish species sampled in Diamond Lake during the panfish fyke netting survey. Bluegill average length increased from 4.5 in (SD = 1.13, N = 951) to 5.3 in (SD = 1.01, N = 2,342) from 1990 to 1996. In 2003 average length decreased to 4.1 in (SD = 1.03, N = 2,087) and was the lowest mean length for the three panfish netting periods surveyed. Bluegill length frequency indicated a declining size structure (Figure 10). PSD increased and then decreased from 10 to 25 to 8 in panfish fyke netting surveys in 1990, 1996, and 2003 respectively. RSD-8 was less than one for all three surveys. CPUE increased from 78 to 130 to 139 for panfish fyke net surveys in 1990, 1996 and 2003 respectively. Relative abundance and growth data from surveys in 1968, 1975, 1990 and 1996 indicate a possible negative relationship between bluegill abundance and growth, and below average growth when compared to NOR region averages (Figure 11).

Black crappie was the second most abundant panfish sampled. The largest sample of black crappie was obtained by spring fyke netting (N = 1,232). PSD and RSD-10 values of 42 and 8 indicate a below average size structure for black crappie. Rock bass was the third most abundant panfish surveyed. The largest sample of rock bass was obtained by panfish netting (N = 68). PSD and RSD-9 values of 49 and 14 indicate an average size structure for rock bass. PSD and RSD-10 values of 1 and 0 indicated a poor size structure for yellow perch during spring fyke netting (N = 200). Pumpkinseed was sampled at the highest number during panfish netting (N = 46) and had PSD and RSD-8 values of 24 and 0 indicating a poor size structure.

Smelt were sampled during the spring fyke netting survey (N = 1,081) which indicated the continued presence of the invasive species. Mean length of measured smelt was 5.0 in (SD = 0.45, N = 221). The length frequency suggests the presence of at least two year classes (Figure 12).

Sport and Tribal Fishery. Anglers fished an estimated 1,635 hours (4.8 hrs/acre) during the 2003-2004 season in Diamond Lake, which is much lower than the average of 22.6 hrs/acre for Bayfield and Douglas County walleye lakes (WDNR unpublished data, Brule field office). The projected fishing pressure (4.8 hrs/acre) was the lowest recorded for creel surveys in Bayfield and Douglas County walleye lakes. Open water anglers accounted for 94% of all fishing effort. The directed effort, i.e. effort targeted toward a specific fish, was highest for walleye (25.2%). The most sought after panfish species was bluegill, with 12.4% of the directed effort. Fishing pressure has declined since 1990. The open water fishing pressure (hrs/acre) was 14.9, 13.0 and 4.5 for 1990, 1996 and 2003 respectively.

Walleye were the most sought after gamefish species in Diamond Lake by sport anglers, however no walleye were harvested in 2003-2004. An estimated 28 walleye were caught, all in the open water season. This represented a decline compared to previous surveys

and likely a result of reduced fishing pressure and a more restrictive regulation change that went into effect in 2000. Tribal harvest accounted for 86 walleye in 2003 (Krueger 2004). Walleye harvested ranged from 13.0 to 25.5 in. Tribal harvest represented 100% of the combined total harvest (sport angling plus tribal spearing) and 12.9% of the total stock. The mean length of tribally harvested walleye was 18.9 in (SD = 1.98, N = 86) and 2% were < 15 in. Male and female walleye represented 79% and 19% of the total tribal harvest, respectively. The remaining 2% were walleye of unknown sex. Total walleye exploitation (sport and tribal) increased from 16.1% to 25.4% from 1990 to 1996. In 2003 total walleye exploitation decreased to 12.9%.

The second most sought after gamefish species by anglers was largemouth bass with 21.3% of the directed effort. The directed effort for largemouth bass has increased from 0% to 4.2% to 23.3% in 1990, 1996 and 2003 respectively, and may be related to the 400% increase in density from 1996 to 2003. In the open water season of 2003 an estimated 536 largemouth bass were caught, 9 of which were harvested. Smallmouth bass was the fourth most sought after gamefish in 2003 on Diamond Lake with 12.9% of directed effort. An estimated 182 smallmouth were caught and no recorded harvest occurred. Directed effort, catch and harvest decreased for smallmouth bass from 1996 to 2003.

Northern pike were the third most sought after gamefish in 2003-2004 on Diamond Lake with 15.0% of directed effort. Estimated catch of northern pike was 232 with a recorded harvest of 2 fish. Directed effort for northern pike decreased from 18.5% to 15.0% from 1996 to 2003. Northern pike estimated catch decreased from 746 to 232 and estimated harvest decreased from 8 to 2 fish from 1996 to 2003. Mean length of harvested northern pike was 32.6 and 34.7 inches in 1996 and 2003 respectively. Estimated catch of northern pike decreased by 321% while relative abundance increased by 167% from 1996 to 2003.

Anglers pursuing panfish fished an estimated 521 hours and accounted for 23% of the total directed angling effort for the 2003-2004 open water and winter seasons combined. Harvest and average length of harvested bluegill decreased from 382 to 304 and 6.6 to 5.9 inches, respectively from 1996-1997 to 2003-2004. Black crappie harvest increased from 47 to 406 from 1996-1997 to 2003-2004. Average length of harvested black crappie declined from 11.5 to 8.6 inches during the same time period. Yellow perch and rock bass were minor components of the panfish fishery in both 1996-1997 and 2003-2004.

Discussion

Diamond Lake has supported and continues to support a diverse fish community and popular sport fishery. With the exception of walleye, good natural reproduction supports all species. Harvest management aimed at protecting adult walleye and northern pike has been largely successful.

Results from the 2003-2004 survey suggest that the objectives of the regulation change for walleye that included a minimum length limit of 15 inches and a protected slot length limit of 20 to 28 inches, with only one walleye over 28 inches allowed has been successful in protecting adult walleye. Overall harvest of walleye decreased from both 1993 and 1996 surveys and was a result of regulation change and decreased fishing pressure. Interestingly no angler harvest of walleye was recorded for both the open water and ice fishing seasons in 2003 and 2004. Caution must be used when comparing the creel survey data due to the observation that small sample size (few interviews) may lead to large variance and poor confidence interval coverage for harvest rate estimates (Newman et al. 1997). Size structure of walleye has remained excellent and walleye densities have remained relatively stable and are similar to Bayfield and Douglas County stocked lake average of 2.2 adult walleye/acre (SD = 0.82, N = 9) but below objectives of 3.0 adults/acre for ceded territory lakes managed for walleye (Staggs

et al. 1990). Although walleye densities have remained stable the main source of recruitment has changed since the mid-1980s. Percent distribution by ages for 2003 displays the missing year classes that are from years where no stocking occurred. While low levels of natural reproduction may be present, stocking has driven the system since 1986.

The success of the northern pike regulation (minimum length limit of 32 inches and a bag limit of 1 fish per day) has been mixed. The more restrictive regulation has reduced harvest of northern pike and increased relative abundance, however mean length and size structure have declined. Fisheries surveys in 2003 sampled one northern pike > 32 in, and the creel survey in 2003-2004 recorded one harvested northern pike that was 34.7 in. Nevertheless, a PSD value of 43 for Diamond Lake in 2003 is higher than that reported for small northern Wisconsin lakes of 30 (Margenau et al. 1998). Benike (2004) found that Largon Lake in Polk County, Wisconsin, took eight years for the 32 in minimum length regulation to produce significant differences in northern pike size structure. Considering that Diamond Lake is less productive than Largon Lake it may take longer to produce measurable benefits in size structure. The effects of the 32 in minimum length regulation on Diamond Lake should continue to be scrutinized in future survey years. Surveys are scheduled to be conducted in 2006 and 2009 and should provide a more definitive answer regarding the effectiveness of the 32 in minimum length regulation.

Largemouth bass densities and mean length have increased from 1996 to 2003 and were likely responsible for the increase in angler directed effort. Largemouth bass was the second most sought after fish (21%) by anglers. Interestingly, no directed effort for largemouth bass was recorded by creel surveys in 1990 and only 4% of directed effort by anglers was recorded in creel surveys from 1996. Smallmouth bass population densities and mean length have remained stable since 1996. Directed effort by anglers toward smallmouth bass has declined since 1990 and in 2003 had the lowest amount of directed effort of all gamefish.

Bluegill was the most abundant and most popular among anglers of the panfish species in Diamond Lake. Data from past surveys on Diamond Lake indicate that higher abundance in bluegill populations leads to slower growth. A similar negative correlation of bluegill growth and density was observed on six Wisconsin lakes (Weiner and Hanneman 1982). Tomcko and Pierce (2001) indicated that secchi depth and maximum depth were negatively correlated with bluegill length at ages I-VI. The slightly oligotrophic condition of Diamond Lake therefore could be correlated with slow bluegill growth. The density dependent growth of bluegill in Diamond Lake was identified as a potential problem in past surveys and as a result an attempt was made to increase the predator base and decrease bluegill abundance. The success of increasing predator abundance to control over abundant bluegill populations has been limited to date. However, Snow and Staggs (1994), noted a positive correlation between bluegill growth and walleye CPE in northern Wisconsin lakes, and substantial predation by walleyes on bluegills has been documented in simple communities (Beard 1982; Schneider 1995; Schnieder and Breck 1997). Adult walleyes are capable of preying on bluegills as large as 5 inches (Schneider and Breck 1997); consequently, a predation effect may occur beyond age 1. A potential tool to increase bluegill growth may be to increase walleye abundance. Angler exploitation may also be a factor in the abundant and mainly small bluegill population in Diamond Lake (Coble 1988). Decreasing angler harvest of large bluegill may be another potential tool for increasing the average size of bluegill. Yellow perch and rock bass are likely the lake's only native panfish species (Becker 1983). Bluegill, green sunfish, and black crappie are not known to be endemic to Lake Superior basin and their presence is likely the result of wide spread fish introductions throughout the century (Becker 1983). It plausible therefore, Diamond Lake lacks physical, biological and chemical characteristics necessary to support stable populations of non-native centrachid panfish. It is also plausible these species are

nothing more than a diversion of energy away from species more adapted to regional climatic and environmental conditions.

The effect of smelt on the fishery in Diamond Lake is not clearly understood. Yellow perch recruitment declined in Crystal Lake, Vilas County, Wisconsin after the exotic rainbow smelt increased in abundance. Exploitation competition between age-0 perch and smelt may reduce the likelihood of strong year-classes of yellow perch when year classes of rainbow smelt occur (Hrabik et al. 2001). In addition, rainbow smelt may have had some effect on the extirpation of cisco from Diamond Lake. Rainbow smelt were first sampled in Diamond Lake in 1967 while the last known sampling of cisco was 1969. Rainbow smelt have had similar negative interactions with cisco/herring in other waters (Anderson and Smith 1971; Loftus and Hulsman 1986). Rainbow smelt were introduced into the Horsetooth Reservoir, Colorado to increase prey availability for walleye in 1983. Within six years of smelt being introduced walleye growth improved by 50% and zooplankton levels were reduced from 40-80 organisms/L to less than 1.0 organism/L, and a switch occurred in zooplankton species composition (Johnson and Goettl 1999). The literature suggests that smelt can have significant impact on zooplankton communities and growth rates of walleye. Whether or not these impacts or other unknown impacts are being realized on Diamond Lake has yet to be found.

Summary and Management Recommendations

1. Walleye abundance in Diamond Lake is similar to stocked walleye lakes in Bayfield and Douglas Counties, but below ceded territory management objectives for walleye lakes. The current protected slot limit for walleye has been effective in protecting adult fish and should be maintained in light of the lakes current dependence on stocking for a majority of recruitment. Annual walleye stocking should be explored as a means to increase walleye

density, and potentially provide control of over abundant and slow growing bluegill populations.

2. Northern pike relative abundance has increased since the more restrictive regulation was implemented; however the hypothesized effect of producing larger northern pike has not yet been realized. The 32 in minimum length limit with a bag limit of one fish should remain at least until the results of the 2006 surveys are examined.
3. Bluegill remain in high abundance and exhibit slow growth. There are several potential directions to be explored. Explore the possibility of annual walleye stocking to increase predator abundance. In 1990, when walleye abundance was higher, bluegill abundance was lower and growth higher. Based on the low projected angling pressure in 2003-2004 for Diamond Lake, excessive bluegill mortality or cropping by anglers of the population is considered unlikely, however if predator abundance increases are not effective, more restrictive panfish regulations may need to be considered.
4. Work with local residents, the Diamond Lake Association, the Cable Area Chamber of Commerce and the WDNR lake grants program to create and adopt a lake management plan. 1) develop management objectives for fisheries including goals for densities and size structures for the various fish species found in the lake, 2) develop strategies for protecting and enhancing sensitive aquatic and shoreline habitats, 3) formally establish exotic species survey and control programs targeting satellite infestations, 4) provide educational and participation forum for environmentally sensitive shoreline living, 5) identify uses and user groups to facilitate all recreational uses on the lake, 6) continue water quality monitoring through the self help lake monitoring program. No amount of regulation or voluntary catch and release practices will change the need for healthy aquatic environments. Although water quality remains high, habitat loss, declining shoreline aesthetics, and exotic introductions are warning signs of cultural disturbances that are degrading ecosystem

health. Currently, smelt are the only known exotic that has been identified in Diamond Lake and much of the shoreline remains in a natural condition. Preserving and enhancing the ecosystem vigilance for exotic species must continue and shoreline restoration projects in areas that are currently lacking buffers should be explored. Preventing the spread of exotics and enhancing habitat through restoration projects, as well as preserving the existing habitat will be far more beneficial than losing what is currently present and relying on stocking and artificial habitat improvements to maintain the fishery and ecosystem as a whole.

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Table 1. Stocking history for Diamond Lake, Bayfield County.

Year	Species	Number Stocked	Age/Size
1933	Walleye	225,508	Fry
	Largemouth Bass	255	Fingerling
1934	Walleye	85,512	Fry
1935	Largemouth Bass	880	Fingerling
1939	Largemouth Bass	600	Fingerling
1940	Largemouth Bass	1,000	Fingerling
1944	Largemouth Bass	2,020	Fingerling
1945	Largemouth Bass	3,000	Fingerling
1946	Largemouth Bass	1,200	Fingerling
1947	Largemouth Bass	550	Fingerling
1949	Largemouth Bass	1,000	Fingerling
1950	Largemouth Bass	3,000	Fingerling
	Northern Pike	100,000	Fry
1951	Northern Pike	49,000	Fry
1952	Largemouth Bass	6,000	Fingerling
	Northern Pike	71,000	Fry
1955	Smallmouth Bass	3,500	Fingerling
1959	Rainbow Trout	10,000	Yearling
	Rainbow Trout	2,650	Fingerling
1960	Rainbow Trout	4,028	Yearling
	Rainbow Trout	5,000	Fingerling
	Brook Trout	450	Adults
1961	Rainbow Trout	6,500	Yearling
1962	Rainbow Trout	1,500	Yearling
	Brown Trout	2,500	Yearling
1963	Rainbow Trout	3,500	Yearling
1964	Rainbow Trout	1,500	Yearling
1965	Rainbow Trout	1,500	Yearling
1966	Rainbow Trout	1,500	Yearling
1967	Rainbow Trout	3,000	Yearling
1968	Rainbow Trout	1,500	Yearling
1969	Walleye	26,800	Fingerling
1970	Walleye	5,600	Fingerling
1971	Walleye	5,600	Fingerling
1972	Walleye	8,000	Fingerling
1973	Walleye	16,590	Fingerling
1975	Walleye	18,075	Fingerling
1976	Walleye	18,000	Fingerling
1977	Walleye	48,040	Fingerling
1978	Walleye	32,076	Fingerling
1979	Walleye	32,584	Fingerling
1991	Walleye	3,000	Fingerling
1992	Walleye	25,575	Fingerling
1994	Walleye	21,287	Fingerling
1996	Walleye	17,050	Fingerling
1998	Walleye	17,050	Fingerling
2000	Walleye	17,050	Fingerling
2002	Walleye	17,050	Fingerling
2004	Walleye	17,061	Fingerling

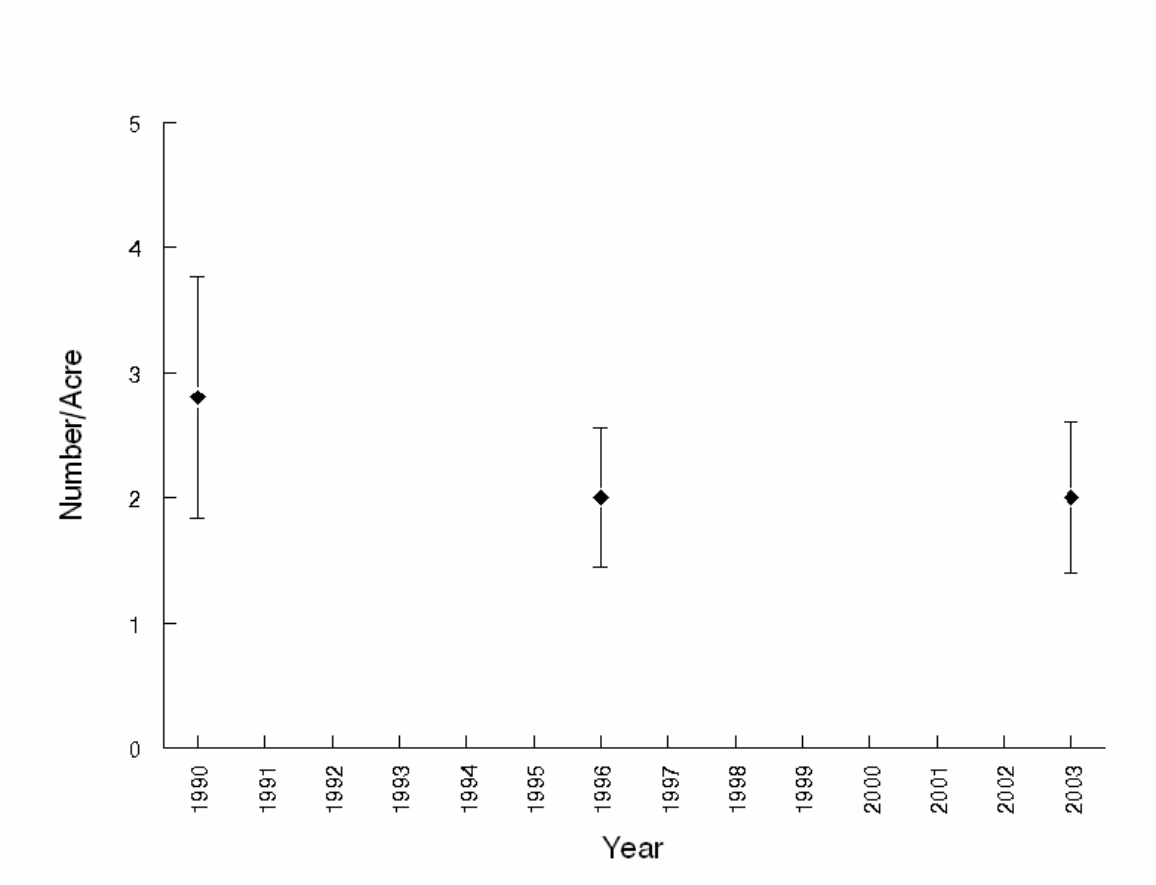

Figure 1. Number of adult walleye ≥ 15 in and sexable (number/acre ± 95% confidence intervals) by year in Diamond Lake, Bayfield County, Wisconsin.

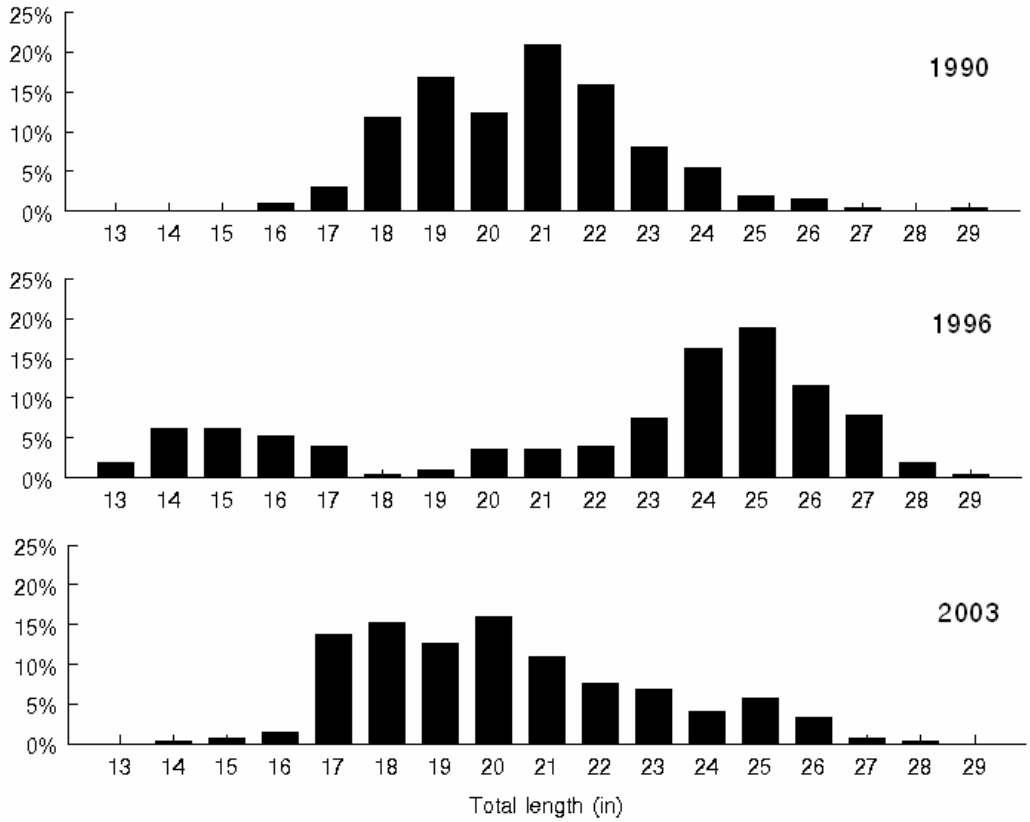

Figure 2. Percentage length frequency of fyke net catches for walleye by length interval in Diamond Lake, Bayfield County, Wisconsin.

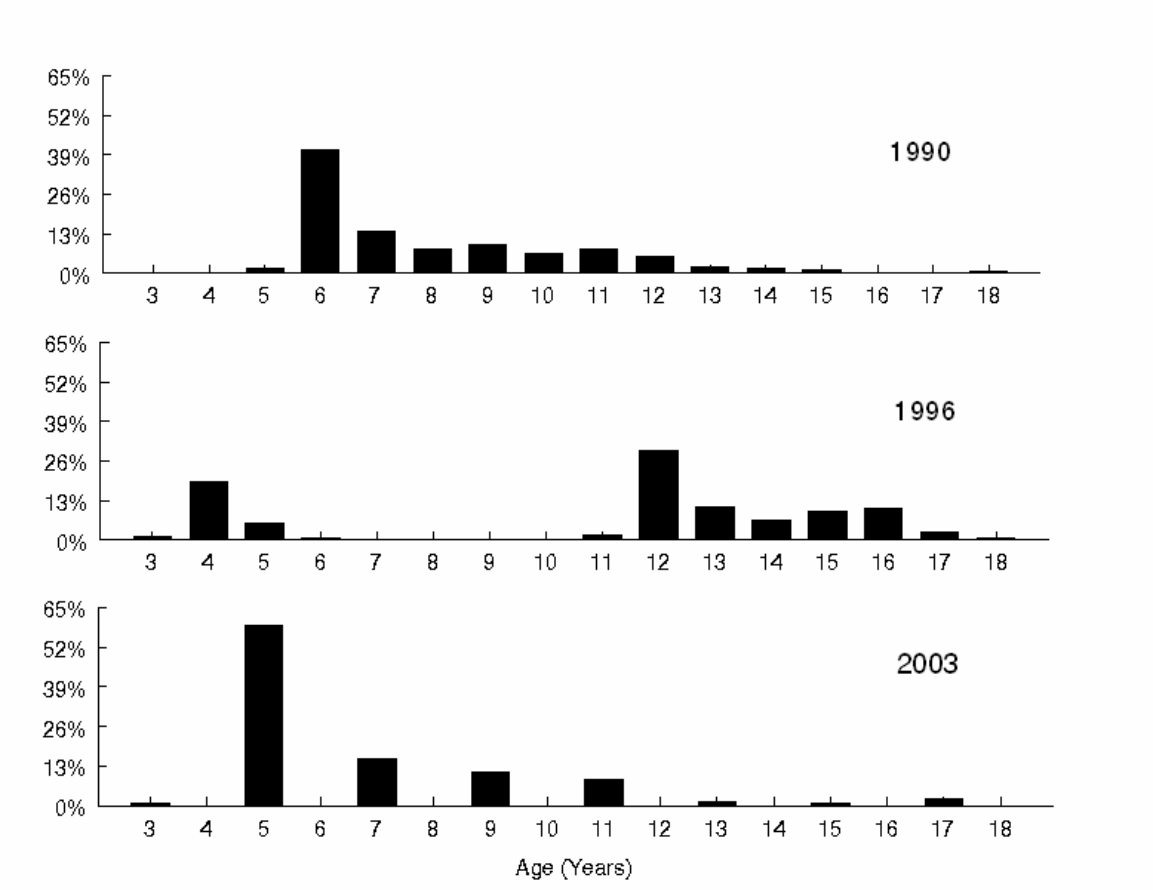

Figure 3. Percentage distribution by age of walleye in Diamond Lake, Bayfield County, Wisconsin.

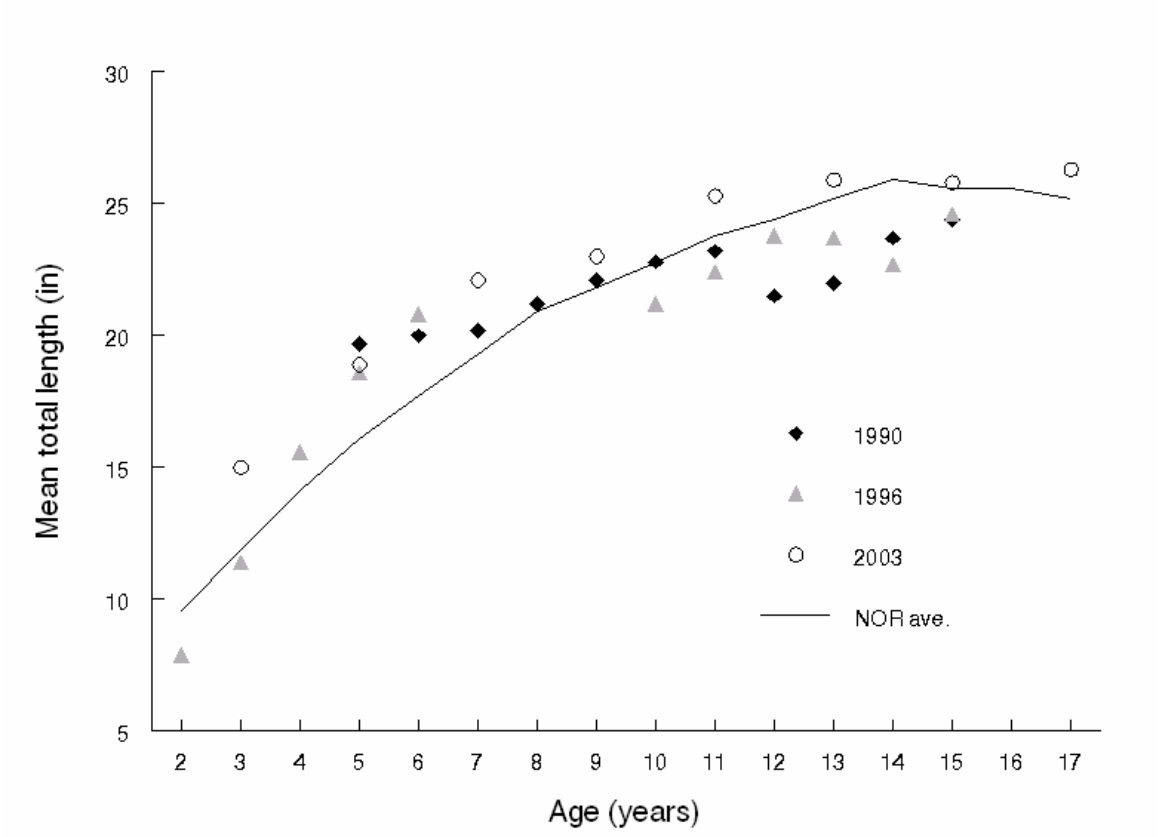

Figure 4. Age at length of walleye in Diamond Lake, Bayfield County, Wisconsin.

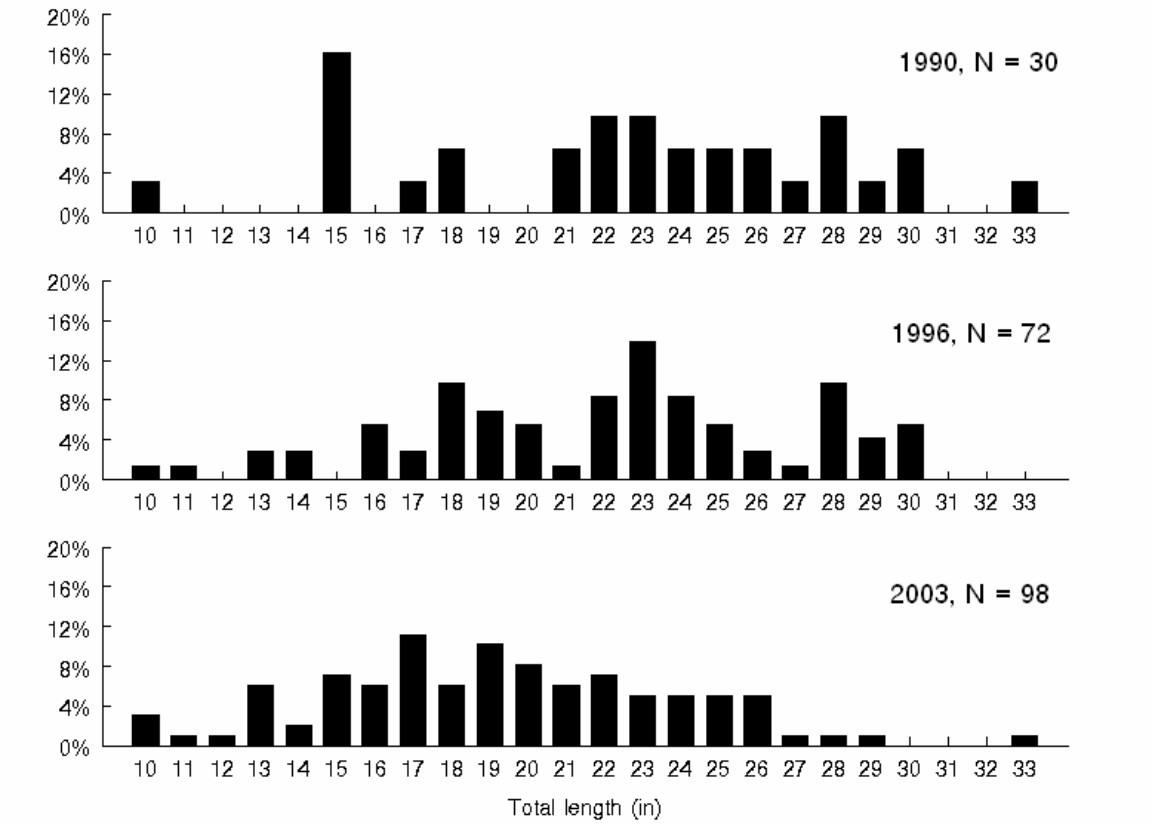

Figure 5. Percent length frequency of northern pike in Diamond Lake, Bayfield County, Wisconsin.

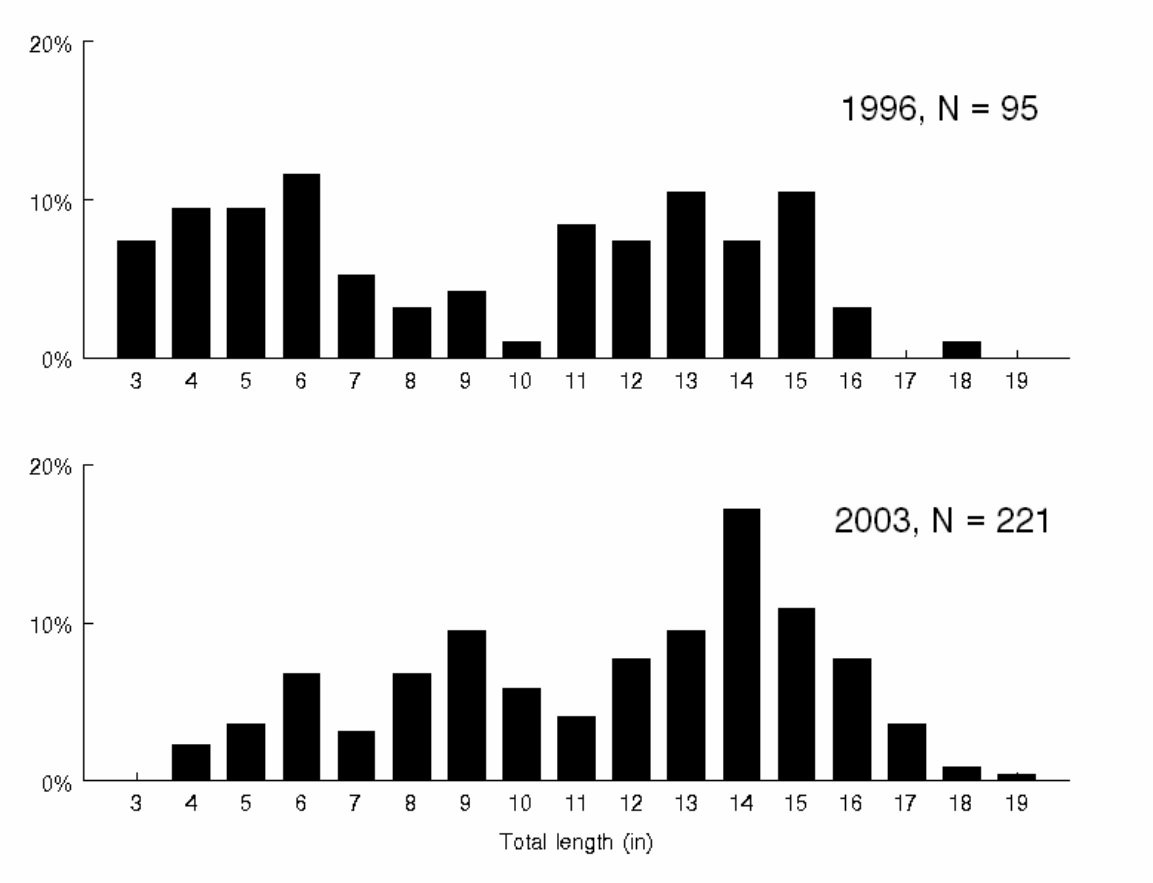

Figure 6. Percent length frequency of largemouth bass in Diamond Lake, Bayfield County, Wisconsin.

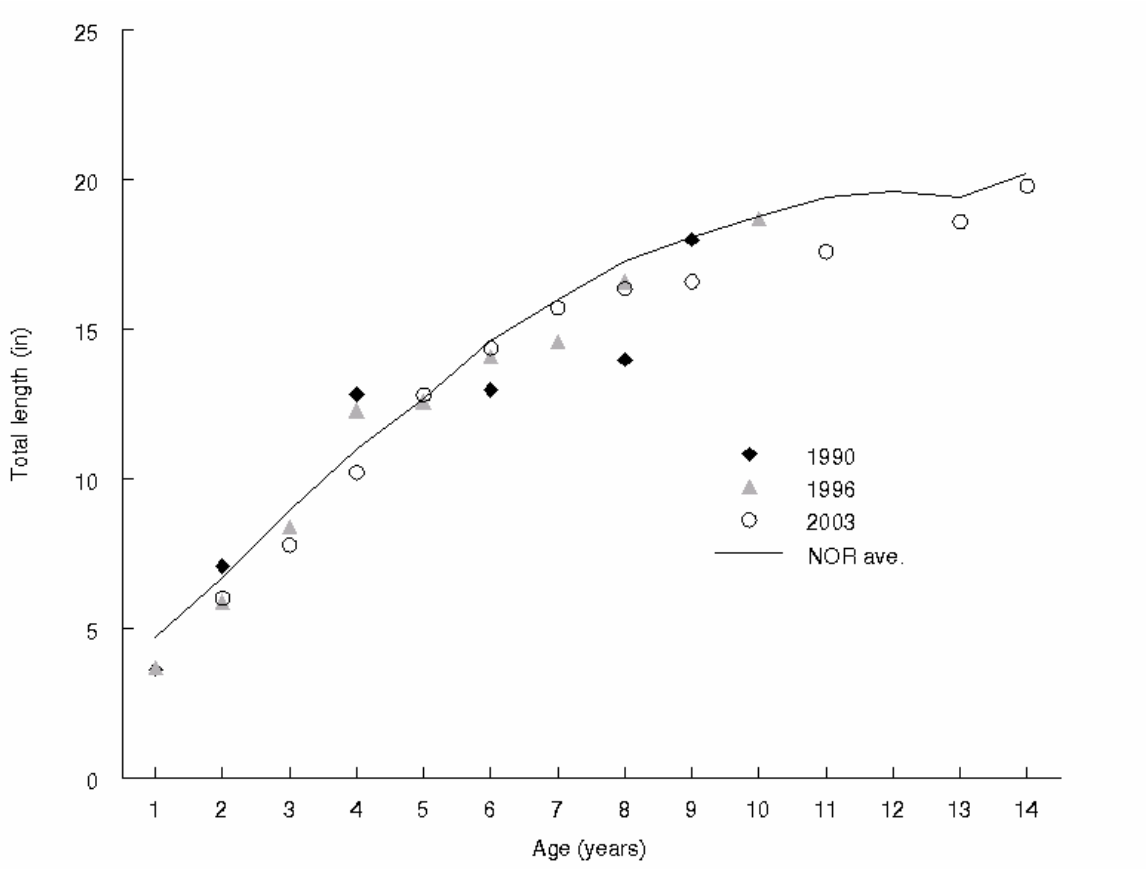

Figure 7. Length at age of largemouth bass in Diamond Lake, Bayfield County, Wisconsin.

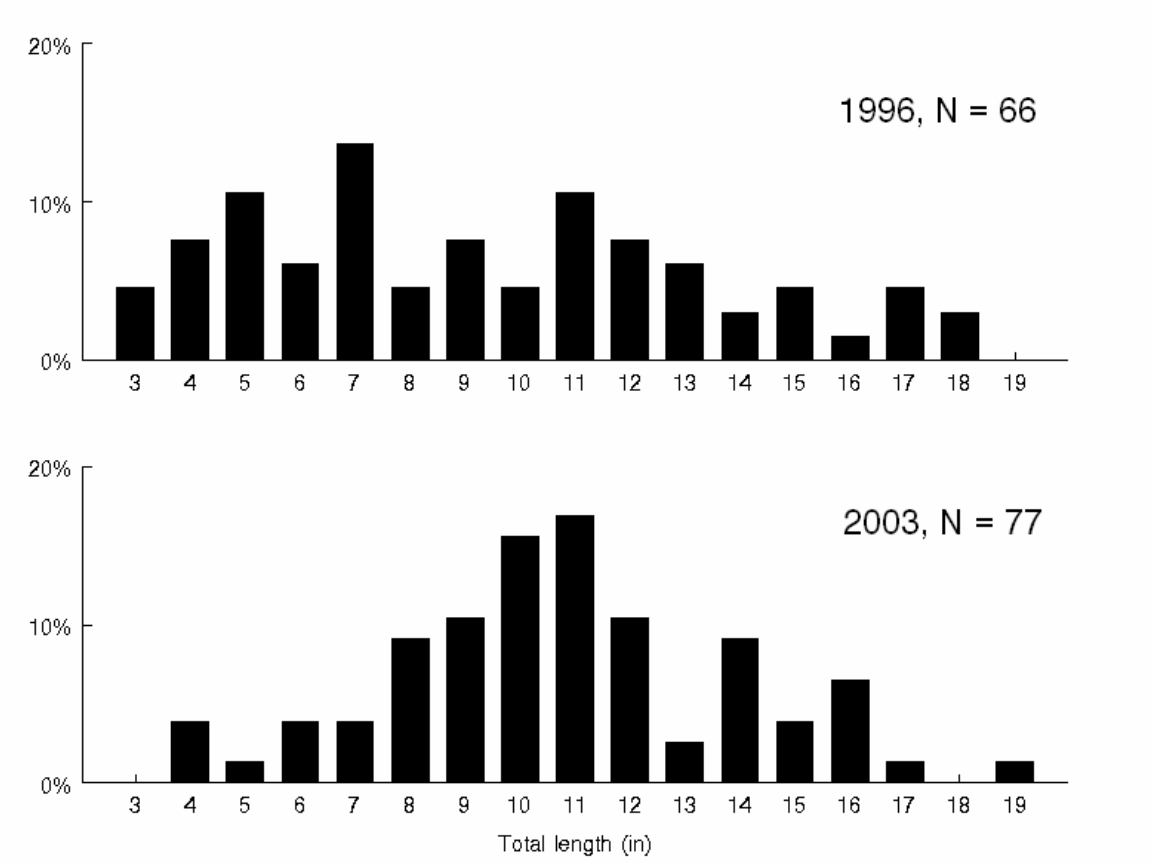

Figure 8. Percent length frequency of smallmouth bass in Diamond Lake, Bayfield County, Wisconsin.

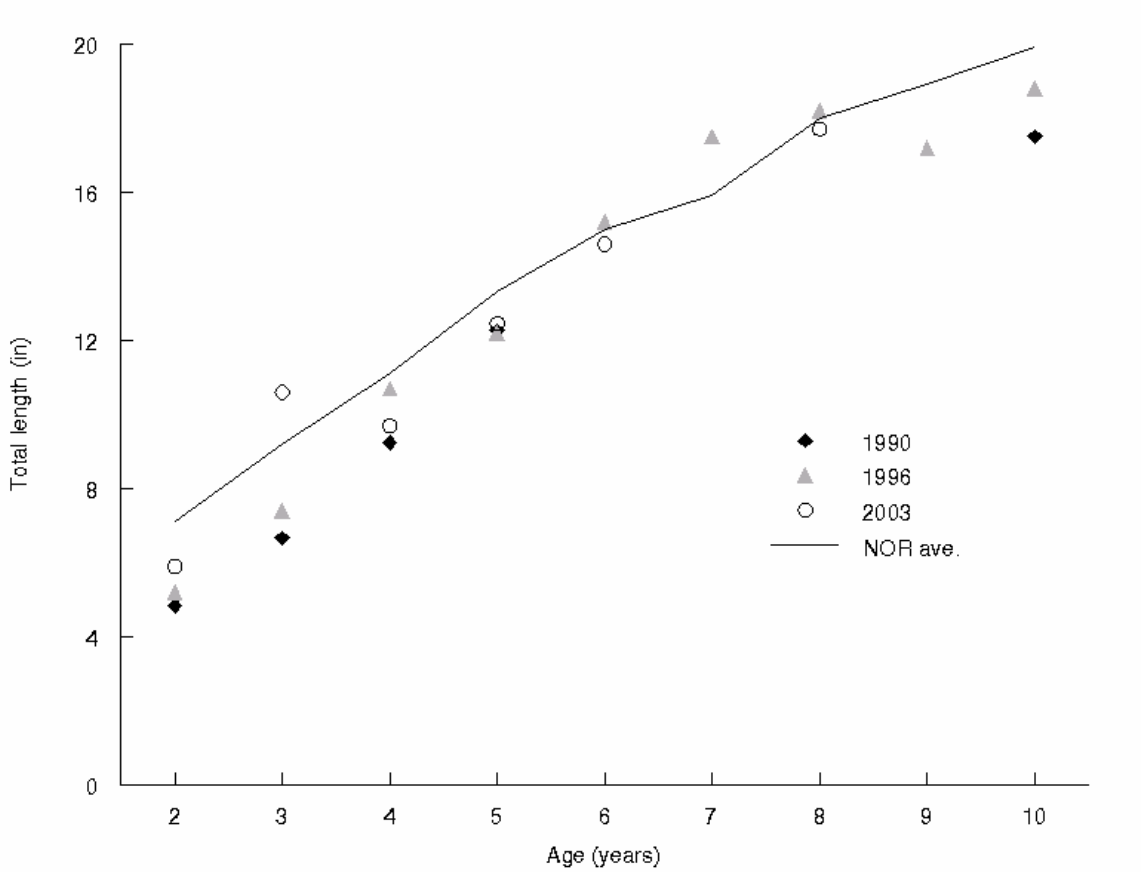

Figure 9. Age at length of smallmouth bass in Diamond Lake, Bayfield County, Wisconsin.

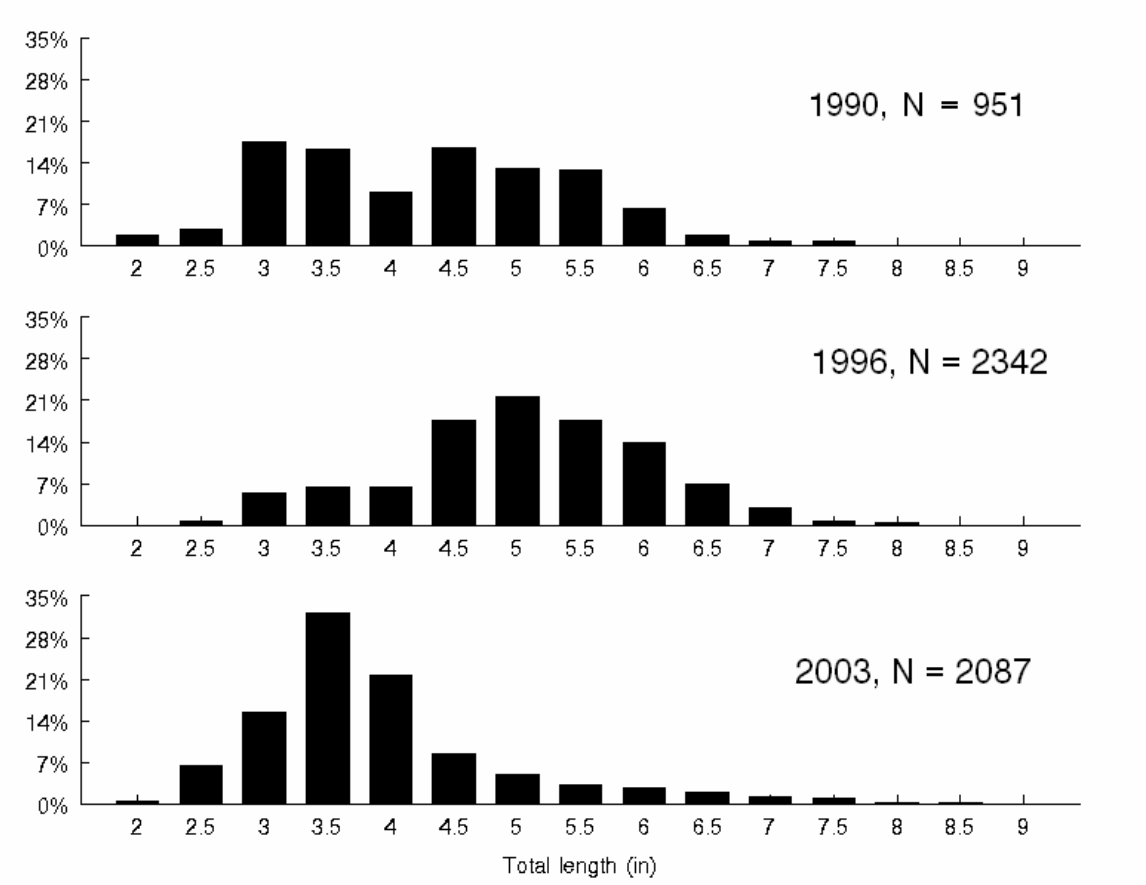

Figure 10. Percentage length frequency of bluegill in Diamond Lake, Bayfield County, Wisconsin.

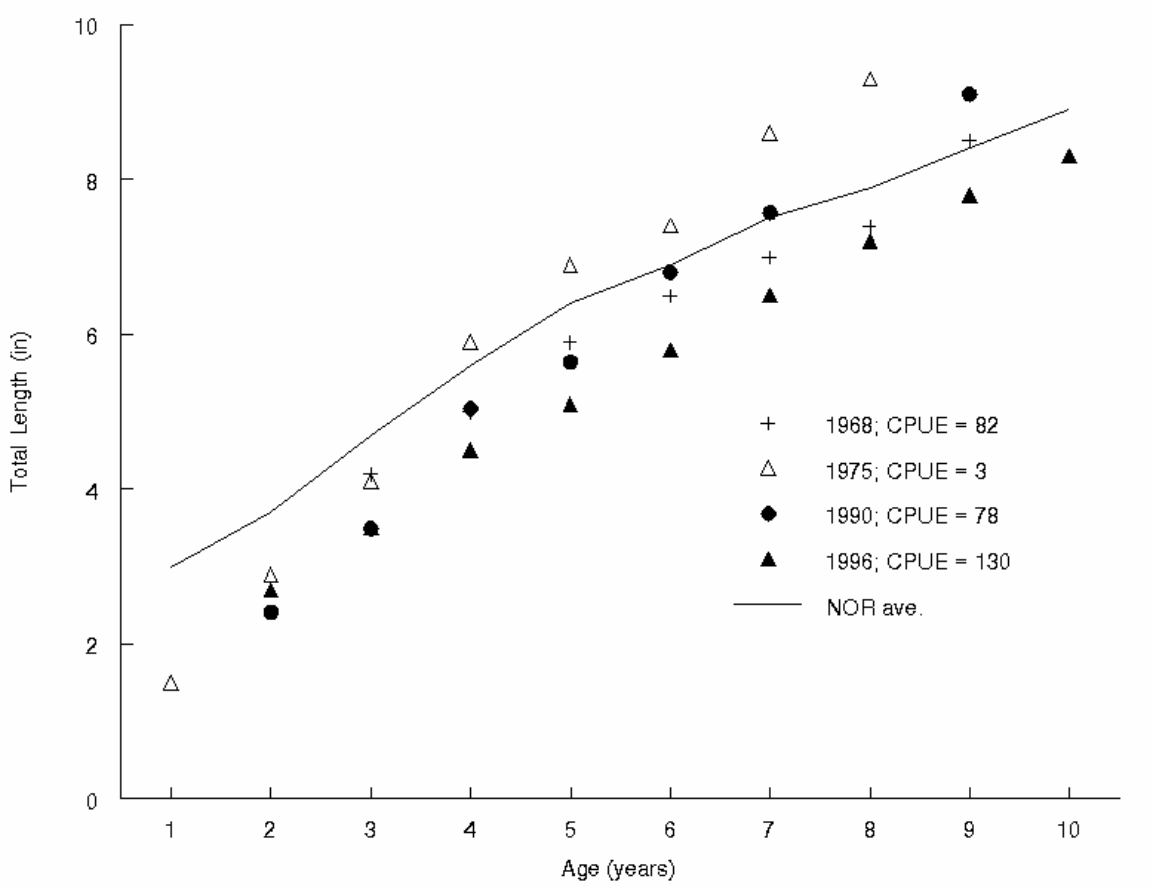

Figure 11. Age at length for bluegill with corresponding CPUE values for Diamond Lake, Bayfield County, Wisconsin.

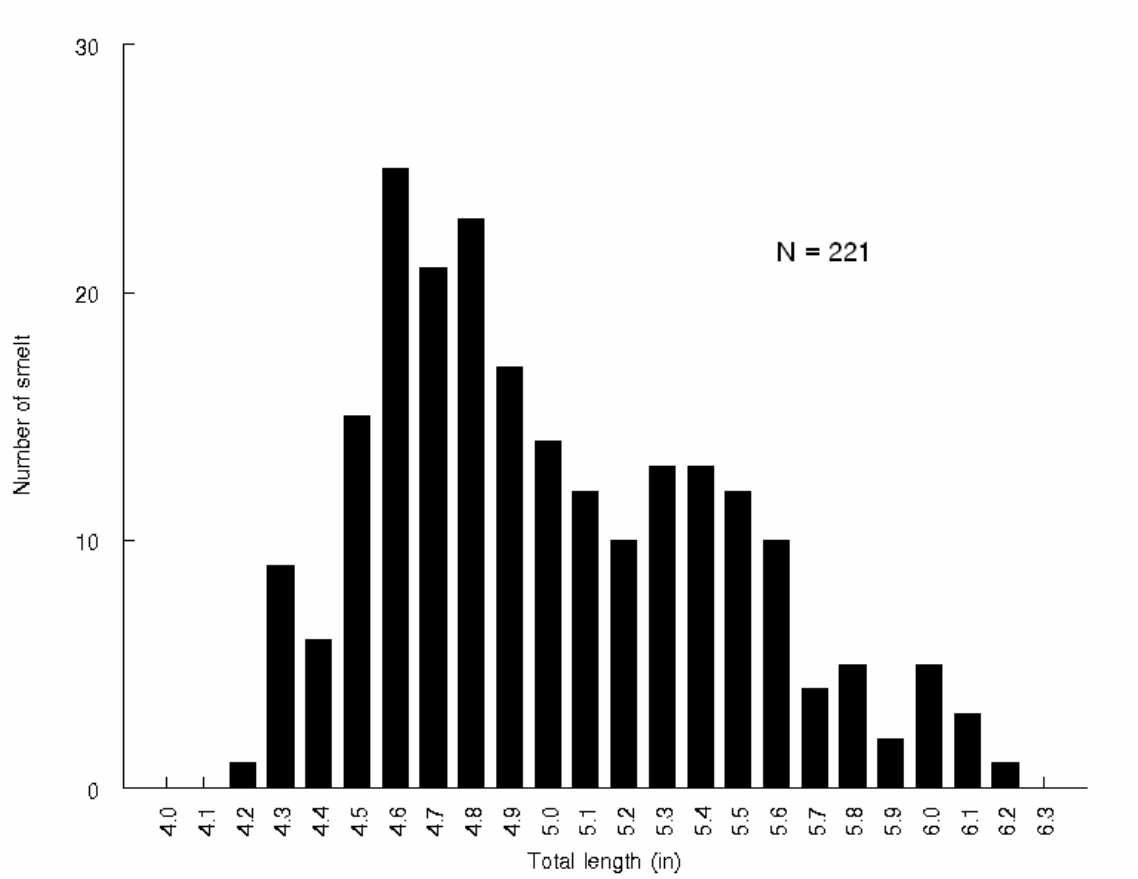

Figure 12. Length frequency of rainbow smelt in Diamond Lake, Bayfield County, Wisconsin.

Appendix

Table 1. Proportional and relative stock density values.

Species	Stock Size (in)	Quality Size (in)	Preferred Size (in)
Black Crappie	5	8	10
Bluegill	3	6	8
Largemouth Bass	8	12	15
Northern Pike	14	21	28
Pumpkinseed	3	6	8
Rock Bass	4	7	9
Smallmouth Bass	7	11	14
Walleye	10	15	20
Yellow Perch	5	8	10