Fishery Survey – Lake Nebagamon
Douglas County, 2005-2006
WBIC Code – 2865000

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April, 2008

Executive Summary

Between 1986 and 2005 Lake Nebagamon supported a dynamic assemblage of sport fish and popular fisheries for walleye, northern pike, smallmouth bass, bluegill and black crappie. Densities of walleye, northern pike and smallmouth bass were generally low (< 3 fish/acre) but within ranges commonly found in northern Wisconsin lakes. Recruitment and abundance of gamefish was variable. Although the strong 1988 and 1989 year-classes contributed to higher abundances of walleye in 1992 and 1994, comparatively weak recruitment after 1997 resulted in two-fold declines in abundance by 2005. Between 1994 and 2005, abundance of northern pike oscillated two-fold. Over the same time period relative abundance of smallmouth bass doubled, suggesting recruitment of this species increased as walleye declined. Although abundance of walleye and smallmouth bass appeared inversely related, reasons for the substantial variability of gamefish populations over the course of this investigation remain unclear.

Recreational fisheries for all species were variable and appeared positively related to species abundance. As abundance of walleye declined in 1994 and 2005, angler effort for walleye similarly declined, as did walleye catch and harvest. Likewise, increases in smallmouth bass abundance after 1994 were concurrent with three-fold increases in the angler effort and catch of this species and by 2005 smallmouth bass comprised a third of the gamefish catch. Catch rates and angler effort for smallmouth bass have increased across the ceded territory since 1994, suggesting trends in Lake Nebagamon are part of a larger trend of expanding smallmouth bass populations and sport fisheries region wide.

Management recommendations include; stocking of large fingerling walleye in alternate years, retaining the 15 in minimum length limit for walleye, conducting walleye stock assessments every 6 years and continuing work with local citizen and governmental groups to protect and enhance habitat, limit spread or introduction of exotic species, collect water quality data and plan for future lake management.

Introduction

Lake Nebagamon is a 914 acre drainage lake located in northeastern Douglas County, approximately 30 miles east of the cities of Superior and Duluth, MN (Figure 1). Major inlets to the lake include Minnesuing Creek and an unnamed tributary draining Steele and Little Steele Lake. Water exiting the lake eventually flows into Lake Superior through Nebagamon Creek and the Bois Brule River. Much of the lake's 41 sq mile watershed is forested and privately owned.

Lake Nebagamon has a maximum and mean depth of 56 and 20 ft, respectively. Water quality and clarity are fair and generally reflective of the lake's mesotrophic status. Chlorophyll-a and total phosphorous average 3.8 ug/l and 18.4ug/l, respectively (Self Help Monitoring 2005). The water is stained and subject to periodic algae blooms. Mid-summer secchi depths average 8 ft but seldom exceed depths of 10 ft or more. Littoral substrates are predominately sand and macrophytes are common. Located near the region's largest metropolitan areas, much of the lake's 10.8 miles of shoreline is developed. Concerns about deteriorating water quality prompted the construction of a sewer system in 1977 which encompasses the Village of Lake Nebagamon and residences on the lake's far north side (Cooper Engineering 1994). Rusty crayfish *Orconectes rusticus* and purple loosestrife *Lythrum salicaria* are the only exotic species known present.

Fisheries management activities have largely focused on periodic surveys, stocking, and habitat management. The first recorded lake survey occurred in 1936. In addition to an abundance of habitat from macrophytes and fallen trees, investigators at the time noted the lake's typically good water clarity was periodically reduced by algae blooms (Anonymous 1936). Periodic surveys from 1956 - 1974 found fish communities dominated by walleye *Sander vitreus*, northern pike *Esox lucius*, smallmouth bass *Micropterus dolomieui*, yellow perch *Perca flavescens*, black crappie *Pomoxis nigromaculatus* and white sucker *Catostomus commersoni*. Surveys since 1986 have largely entailed comprehensive assessments of walleye and northern pike.

Stockings dating back to 1934 have been varied. Stockings of various sunfishes (centrachidae) during the late 1930s likely stemmed from Mississippi River fish rescue and transfer operations (Becker 1983). Annual stockings of walleye from 1934 – 1963 were discontinued after a 1963 survey deemed continued stocking unnecessary (Weiher 1964). Two-story management through semiannual brown trout S*almo trutta* stockings from 1964 – 1971 was discontinued due to poor angler return (Pratt 1975). Walleye stockings resumed after a 1986 survey found below average walleye abundance (Kampa 1986). Although a subsequent assessment in 1994 suggested small and large fingerling stockings contributed to higher walleye abundance (Sand 1994), abundance remained below management objectives of 3 adult walleye/acre (Staggs et al. 1990). These findings prompted an expansion of stocking to include stockings of walleye fry in Minnesuing Creek, a tributary historically known to support significant spawning migrations of walleye from Lake Nebagamon (R.Cleary, WDNR – retired, personal communication). Between 1986 and 2005 a total of over three million walleye of various sizes were stocked (Table 1).

Habitat improvement efforts have primarily focused on the enhancement of walleye reproduction. In-lake spawning reefs were constructed in 1998 and 1999 and intensive beaver *castor canedensis* control was initiated in 1998 to insure free passage of walleye to high quality spawning habitats in Minnesuing Creek.

Lake Nebagamon supports a mixed fishery (sport and tribal) for walleye and popular sport fisheries for northern pike, black crappie and yellow perch (Sand 1994). Excluding walleye, sport harvest has been largely managed through statewide length and bag restrictions. Allocation of the mixed fishery is accomplished via spear quotas derived from annually adjusted safe harvest levels and corresponding angler bag limit reductions (Staggs et al. 1990). Angler bag limits since the onset of the tribal fishery in 1989 have largely ranged between two or three walleye per day. A 15 inch minimum length limit on walleye has been in effect since 1990.

A boat ramp in the Village of Lake Nebagamon provides the only public access with launching and parking facilities. Other public corridors include six undeveloped platted accesses and Wisconsin Department of Natural Resources (WDNR) frontage on Minnesuing Creek.

The objective of this report is to evaluate the status and management of the primary sport fishes in Lake Nebagamon.

Methods

Walleye stocks were surveyed by the WDNR in 1986, 1994, 1998 and 2005. Walleye were captured with fyke nets (4 x 6 ft frames, 0.5 in bar mesh) set in spawning areas immediately after ice out. Lead length varied but generally equaled the distance between shore and the 4-foot contour. Water temperatures ranged from 39 – 48 F. All walleye and gamefish captured incidentally to walleye were observed for fin-clips, sexed, and measured to the nearest 0.1 in total length (TL). For aging purposes, the second dorsal spine was sub-sampled from 10 walleye per in group, per sex. Walleye captured in 1986 were given a top caudal fin-clip prior to release. Marking was extended to all gamefish after 1986. Sexable walleye and unsexable walleye $\geq$ 15 in received either a pelvic or pectoral fin-clip which varied by year while immature walleye < 15 in received a top caudal fin-clip. Gamefish other than walleye received a top caudal fin-clip in 1994 and 1998 and a size specific fin-clip in 2005 (Hennessy 2002). All panfish captured in fyke nets after 1994 were measured to the nearest 0.1 in TL and released.

Shortly after marking a sufficient number of spawning walleye, a single night of electrofishing was conducted to estimate the adult stock. The entire shoreline was sampled utilizing a variable voltage pulsed DC boomshocker with two dippers in 1986 and variable voltage AC boomshockers with two dippers after 1986. Only walleye were collected in 1986 whereas all gamefish were collected in surveys thereafter. In all years, fish collected were processed identically to those handled during the previous netting period except 1986 when no further marking of walleye was conducted.

In 1994, and 1998 a second night of electrofishing was conducted in May to obtain quantitative estimates of total walleye abundance and relative abundance estimates of smallmouth and largemouth bass. Gamefish captured were measured, observed for finclips, and released. In 2005, three nights of electrofishing were conducted in May to obtain quantitative estimates of smallmouth and largemouth bass abundance. Gamefish captured during the initial two nights of electrofishing were processed and marked according to protocols used during the previous sampling periods. Gamefish captured on the third and final night of electrofishing in May were measured, observed for finclips, and released.

Fall electrofishing surveys (1986 – 2006) to determine the relative abundance of age-0 walleye (year-class strength) were conducted by the WDNR and the Great Lakes Indian Fish and Wildlife Commission (GLIFWC). Both agencies sampled the entire shoreline at night utilizing boomshockers with two men dipping. GLIFWC and WDNR utilized pulsed direct current (Pulsed DC) and alternating current (AC), respectively. All but one survey (1988) sampled the entire shoreline.

Stocking of small walleye fingerling in the spring of 2002 was evaluated the autumn following stocking and stocking of walleye fry in Minnesuing Creek was similarly evaluated in 2005. Fry and fingerlings were chemically marked with oxytetracycline (OTC) according to Brooks et al. (1994) at the Governor Thompson State Fish Hatchery prior to stocking. Otoliths from subsamples of age-0 walleye sacrificed during routine fall electrofishing surveys were viewed for marks (Jennings et al. 2005). In addition, stocking of fin-clipped large walleye fingerling in the fall of 1989 was evaluated in the spring of 1990. All age-1 walleye collected by electrofishing were observed for fin-clips and released. In all evaluations, the percentage of marked individuals was considered the stocked contribution. Survival was calculated by multiplying the estimated abundance of each year-class (Serns 1982) by the stocked contribution.

Population estimates for walleye in 1992 and 1997 were conducted by GLIFWC utilizing methodologies described by Ngu and Kmiecik (1993) and Rose et al. (1999). Abundance estimates for gamefish were calculated using the Chapman and Bailey modifications of the Petersen formula (Ricker 1975). For the purpose of this evaluation, adult walleye were defined as being $\geq$ 15 in or sexable, while adult northern pike were defined as all fish $\geq$ 12 in. Abundance estimates by length and age group for adult walleye and northern pike were obtained by proportioning length and age frequencies obtained with fyke nets to their estimated population abundance. The variance for these estimates was calculated using the formula:

$$var\ (p \cdot pe) = p^2 \cdot var(pe) + pe^2 \cdot var(p) - var(p) \cdot var(pe),\ \text{where}$$

var = variance

p = the proportion of fish sampled in length group

pe = population estimate for fish $\geq$ 10 in.

Walleye spines were cross-sectioned and viewed microscopically at 100X according to Margenau (1982). The microcomputer software FishCalc89 (FishCalc89 1989) was used to generate length and age distributions. Proportional (PSD) and relative (RSD) stock densities for all species were calculated according to Anderson and Gutreuter (1983). Walleye density and growth was compared to regional averages obtained from data sets compiled by WDNR Treaty Fisheries Assessment Unit for all ceded territory lakes surveyed since 1990. Kolmogorov Smirnov tests were used to detect changes in size structure over time and t-tests were used to detect differences between means. Statistical significance for all tests was $\acute{\alpha} = 0.05$.

Creel surveys were conducted from the first Saturday in May through 1 March during the 1994 – 1995 (1994) and 1998 – 1999 (1998) fishing seasons and from first Saturday in May through 5 March during the 2005 – 2006 (2005) fishing season. No surveys were conducted in November and early December due to thin ice and dangerous fishing conditions. Creel survey methods followed a stratified random design described by Rasmussen et al. (1998). Angler exploitation of adult walleye was estimated by dividing the projected number of fin-clipped walleye harvested during the course of the fishing season by the total number of marked walleye at large (Beard et al. 2003a).

Results

<u>Walleye.</u> Estimated abundance of adult walleye in all years suggests Lake Nebagamon supports a low density walleye population. Walleye density was the highest in 1992 (3.2 adults/acre), 6 years after the initiation of stocking in 1986. Walleye density in 2005 however, was similar to pre-stocking densities despite nearly 2 decades of near annual walleye stockings (2005 = 1.3 adults/acre, 1986 = 1.5 adults/acre; Figure 2). Walleye density in all years

was below management objectives of 3 adults/acre in all years except 1992. Relative to other ceded territory lakes, adult density in Lake Nebagamon (mean = 2.0 adults/acre, N = 6, SD = 0.72) has been less than lakes supported primarily through natural reproduction (mean = 3.9 adults/acre, N = 357, SD = 2.47) and similar to lakes supported primarily through stocking (mean = 1.9 adults/acre, N = 143, SD = 1.83).

Size structure of adult walleye was good but variable. Legal length walleye (≥15 in) comprised more than half the adult stock in all years and size structure shifted towards increasingly larger walleye between 1986 and 1998 (D = 0.15, P < 0.01). PSD increased from 61 in 1986 to 65 and 72 in 1994 and 1998, respectively. PSD in 2005 declined to 54 and size structure overall was not significantly different from 1986 (D = 0.07 P = 0.15). Two-fold increases in the abundance of walleye between 15 – 20 in were primarily responsible for larger size structures in 1994 and 1998. In all years, walleye ≥ 20 in were sparse and accounted for less than 12% of the adult stock. With the exception of higher abundances of small walleye in 1994, abundance of sublegal (≤15 in) walleye was stable (Figure 3).

In all years, male and female walleye initiated maturity at age 3 and age 4, respectively. Although walleye ages 4 - 6 accounted for more than half the adult stock in all years, recruitment was variable (Figure 4). Age 4 and age 5 walleye comprised 56% of the adult stock in 1986 whereas the strong cohorts of age 5 and age 6 walleye comprised 71% of the adult stock in 1994. Comparatively weak cohorts of age 3 – 6 walleye comprised 74% of the adult stock in 2005. Overall, age structure shifted towards younger age walleye. Walleye age 10 and older declined from 11% of the adult stock in 1986 to 4% of the adult stock in 2005. Average age of adult walleye over the same time period declined significantly ($\underline{t}$ = 4.84, df = 937, P <0.001). Average age of adult walleye in 1986 and 2005 was 6.2 and 5.4 years, respectively (1986, N = 527, SD = 2.68; 2005, N = 412, SD = 2.00).

The effect of stocking on adult cohorts was mixed. Strong and weak cohorts stemmed from both stocked and non-stocked year classes. Although large fingerling stocked in 1989 contributed 25% to the strong age 5 cohort in 1994 (Sand 1994), no stocking occurred in the year that produced the strong age 4 cohort in 1998. Conversely, a majority of the adult stock in 2005 consisted of relatively weak cohorts supplemented by stocking (Figure 4).

Walleye growth across years was variable and dimorphic. In most years, male walleye attained legal harvestable length (15 in) at age 5. In all years, females attained legal harvestable length by age 4 and on average, were larger than males at any given age. Disparate growth between sexes became increasingly noticeable with age. By gender, the largest walleye sampled were a 22.1 in (age 16) male captured in 1986 and a 27.8 in (age 14) female captured in 1994. Across years growth of both sexes was similar to the regional average, however male walleye tended to grow slowly after age 10 (Figure 5).

Fall electrofishing surveys from 1986 - 2006 indicate abundance of age-0 walleye was variable in both stocked and non-stocked years (Table 2). Relative abundance of age-0 walleye in stocked years ranged from 2.8 – 40.1 fish/mile. Natural reproduction occurred in all non-stocked years. Relative abundance of age-0 walleye in non-stocked years ranged from 0.8 – 28.9 fish/mile. Although on average the relative abundance of age-0 walleye in stocked years (mean = 19.7 fish/mile, N = 14, SD = 12.95) was 38% higher than non-stocked years (mean = 14.3 fish/mile, N = 4, SD = 12.45), differences were not significant ($\underline{t}$ = 0.74, df = 16, P = 0.47). Relative abundance of age-0 walleye in both stocked and non-stocked years was generally low, exceeding the ceded territory average for self sustaining lakes (≥ 33 age-0/mi) about once every seven years (Figure 6).

Survival of fry and fingerling (small and large) stockings was generally poor (Table 3). Survival appeared positively related to size at stocking with September stockings of large fingerling exhibiting a higher survival to the following May (6.9%) than June stockings of small fingerling (2.1%) and May stockings of fry (0.3%) to the following September. Survival rate had little effect on contribution, however. Contributions of small and large fingerling stockings were similar (19 - 21%) whereas the largest contribution (26%) resulted from fry stockings in Minnesuing Creek. Assuming stocked fry and small fingerling experienced the high overwinter mortality of large fingerling, fewer than 120 progeny from either stocking likely survived to age-1.

<u>Northern Pike.</u> Density of northern pike was variable (Figure 7). Estimated density of adult (≥ 12 in) northern pike ranged from a low of 1.2 fish/acre in 2005 to a high of 2.6 fish/acre in 1998. Northern pike were more abundant than walleye in 1998 but were less abundant than walleye in 1994 and 2005. Average density of northern pike (1.8 adults/acre, N = 3, SD = 0.72) and walleye (2.1 adults/acre, N = 6, SD = 0.73) has remained low suggesting the two species occupy the lake at relatively similar abundances and no one species is consistently dominant.

Northern pike size structure was fair. Northern pike < 21 in comprised between 49 - 78% of the adult stock in all years. Although PSD increased from 22 in 1994 to 51 in 2005, shifts in size structure across years were primarily attributable to three-fold variations in the abundance of fish < 23 in. Although northern pike > 23 in were sparse, abundance was stable and large fish (>36 in) were present in all years (Figure 8).

<u>Smallmouth and Largemouth Bass.</u> Relative abundance of smallmouth bass sampled electrofishing increased from 5.4 fish/mile in 1994 to 10.3 fish/mile and 9.7fish/mile in 1998 and 2005, respectively. Size structure between 1994 and 2005 improved (D = 0.25, P = 0.021). Relative abundance of legal length smallmouth bass (≥ 14 in) increased from 1.8 fish/mile in 1994 to 4.3 fish/mile in 2005 while RSD-14 increased from 34 to 44, respectively

(Figure 9). In all years, catch of smallmouth bass outnumbered largemouth bass by 30 to 1 or more. Estimated density of smallmouth bass (≥ 6 in) in 2005 was 1.3 fish/acre (95% CI = 0.9 fish/acre – 1.7 fish/acre).

Panfish. Panfish populations in 1998 and 2005 were similar. Rock bass and bluegill were the most common species captured in fyke nets followed by black crappie and yellow perch. Relative abundance of all species was low (< 2 fish/lift). Size structure of bluegill and black crappie was good. Quality size bluegill (≥ 6 in) comprised a majority (59 - 70%) of the species catch in both years. Preferred size bluegill (≥ 8 in) increased from 5 to 28 % of the catch in 1998 and 2005, respectively. In both years, a majority (57 – 64%) of the black crappie catch were preferred size (≥10 in) or larger (Figure 10).

Sport and Tribal Harvest. On average, anglers fished an estimated 17,140 hours (N =3, SD = 2,135) during the 1994, 1998 and 2005 fishing seasons. Across years, angler effort declined from 19,596 hours in 1994 to 15,725 hours in 2005. In all years, open water anglers accounted for two-thirds of the annual fishing effort.

Walleye were the most targeted gamefish species in all years, followed by northern pike, and smallmouth bass. Angler effort for walleye declined from 11,575 hours in 1994 to 6,855 hours in 2005 while angler effort for northern pike declined from 6,353 hours to 4,235 hours. Across years, smallmouth bass grew increasingly popular. Angler effort for smallmouth bass increased from 703 hours in 1994 to 3,385 hours in 2005. In all years, anglers targeting panfish accounted for 30% of the annual fishing effort and black crappie were the most targeted panfish species (Figure 11).

Walleye and northern pike comprised nearly 85% of the gamefish catch in 1994 and 1998. By 2005, the angler catch of gamefish was more equally distributed between walleye (36%), northern pike (24%) and smallmouth bass (40%). In all years, walleye were the most abundant species harvested followed by northern pike and smallmouth bass (Figure 12).

Catch and harvest of gamefish was variable across years, however. Angler catch of walleye declined from a high of 3,321 in 1994 to a low of 1,990 in 2005 while harvest declined from 966 to 389, respectively. Walleye between 15 - 20 in comprised 85% of the angler harvest or more and average length of walleye harvested was similar between years, ranging from 16.6 in (N = 131, SD = 1.54) in 1998 to 17.0 in (N = 305, SD = 2.50) in 1994. In all years angler exploitation of adult walleye was similar, ranging from a low of 12.6% in 1994 to a high of 14.9% in 1998 (mean = 13.8%, N = 3, SD = 0.64). (Table 4)

Angler catch and harvest of northern pike ranged from a high of 2,815 and 602 in 1998 to a low of 1,361 and 275 in 2005, respectively. The average length of northern pike harvested increased from 20.7 in (N= 158, SD = 3.87) in 1994 to 22.0 in (N = 62, SD = 3.37) in 2005, however northern pike < 23 in comprised at least two-thirds of the sport harvest in all years. Angler catch of smallmouth bass increased from 612 in 1994 to 2,218 in 2005. Anglers released greater than 90% of their catch in all years and as such harvests were low (Figure 12).

Angler effort for bluegill and black crappie varied less than 10% between 1994 and 2005 while angler effort for yellow perch declined 75% over the same time period. Bluegill and black crappie comprised more than 70% of the panfish catch and harvest in all years. At least two-thirds of the bluegill harvested annually exceeded 7 in while the majority of the black crappie harvested annually exceeded 10 in. Yellow perch accounted for nearly a third of the panfish catch and harvest in 1994 but became an increasingly minor portion of the sport fishery thereafter. Declines in the combined harvest of all species from 3,581 in 1994 to 2,468 in 2005 were primarily attributable to 95% declines in the harvest of yellow perch (Figure12).

Anglers accounted for nearly all of the walleye harvest in 1994, 1998 and 2005. Spearing accounted for less than 1% of the total walleye harvest in 1998 and 2005 and no spearing occurred in 1994. Since 1989 however, spear harvests of walleye ranged from a low of 8 in 2005 to a high of 223 in 2004 and on average, significant harvests (>100) occurred about once every three years (WDNR unpublished data, Brule; Figure 13). Given the average adult density of 2.0 walleye/acre, tribal exploitation in years with significant harvests likely ranged between 9 and 12%.

Discussion

Between 1986 and 2005 Lake Nebagamon supported a dynamic assemblage of sport fish and popular fisheries for walleye, northern pike, smallmouth bass, bluegill and black crappie. Densities of walleye, northern pike and smallmouth bass were generally low (< 3 fish/acre) but within ranges commonly found in northern Wisconsin lakes (Hansen and Hennessy 2006). Recruitment and abundance of gamefish was variable. Although the strong 1988 and 1989 year-classes contributed to higher abundances of walleye in 1992 and 1994, comparatively weak recruitment after 1997 resulted in two-fold declines in abundance by 2005. Between 1994 and 2005, abundance of northern pike oscillated two-fold. Over the same time period relative abundance of smallmouth bass doubled, suggesting recruitment of this species increased as walleye declined. Although abundance of walleye and smallmouth bass appeared inversely related, reasons for the substantial variability of gamefish populations over the course of this investigation remain unclear. Fish stocks are seldom static and typically exhibit wide temporal variation due to a host of biotic and abiotic factors including variable recruitment (Hansen et al. 1991), species interactions (Fayram et al. 2005), fishing mortality (Smith 1988), climatic conditions (Beard et al. 2003b) and habitat quality (Hoff 1991). Snow (1978) for instance, found annual abundance of northern pike in Murphy Flowage often fluctuated two-fold.

Likewise, Hansen et al. (1991) found abundance of walleye stocks fluctuated by as much as 65% on generally healthy self-sustaining lakes in northern Wisconsin. Despite low predator densities and changing predator assemblages over time, the low abundance and desirable size structure of panfish suggests Lake Nebagamon generally supports balanced fish communities (Anderson 1978).

Recreational fisheries for all species were variable and similar to the findings of Beard et al. (2003c) appeared positively related to species abundance. Angler catch and harvest of northern pike was highest in 1998, when this species was at its highest abundance. As abundance of walleye declined 1994 and 2005, angler effort for walleye similarly declined, as did walleye catch and harvest. Likewise, increases in smallmouth bass abundance after 1994 were concurrent with three-fold increases in the angler effort and catch of this species and by 2005 smallmouth bass comprised a third of the gamefish catch. Interestingly, catch rates and angler effort for smallmouth bass have increased across the ceded territory since 1994 (Hansen et al. 2006), suggesting trends in Lake Nebagamon are part of a larger trend of expanding smallmouth bass populations and sport fisheries region wide. Although smallmouth bass were more prevalent after 1994, anglers released more than 90% of their catch in all years and annual harvests were low. Walleye and northern pike were more heavily harvested however, sustaining average angler harvests of 700 walleye and 400 northern pike annually. Bluegill and black crappie dominated the angler catch and harvest of panfish in all years. Angler effort for bluegill and black crappie remained stable while angler effort for yellow perch declined 75% between 1994 and 2005. Similar declines in angler catch and harvest of yellow perch over the same period suggest abundance of this important sport and prey species declined (Forney 1974; Margenau et al. 1998).

The effectiveness of harvest management for gamefish stocks in Lake Nebagamon appears mixed. Although harvest regulations have maintained viable, self-sustaining gamefish populations, declining mean age of walleye and truncated size structures of walleye and northern pike suggest harvest may be limiting recruitment into larger size classes for these species. Angler exploitation of adult walleye averaged 14%. Pulses in spear harvests about once every three years likely result in total exploitation rates (sport and tribal) which range between 22 - 27% of the adult stock. Although these rates are generally within the biological optimum reported by Staggs (1990), it's reasonable to assume that selective angler harvest of legal length walleye (≥ 15in) combined with pulses in spear harvest have an impact on walleye size structure. Likewise, given the favorable morphology of Lake Nebagamon to produce large northern pike (Jacobsen 1992), the relatively small size structure observed in this investigation is evidence that harvest is limiting the ability of this species to reach larger sizes.

Impacts of stocking on walleye year-class strength and abundance were marginal. Although relative abundance of age-0 walleye in stocked years was higher than non-stocked years, differences were not statistically significant due to wide but similar variability in age-0 walleye abundance in both stocked and non-stocked years. Despite poor survival, all stockings evaluated during the course of this investigation contributed to year-class strength, however. Survival appeared positively related with size at stocking with large walleye fingerling exhibiting better survival than small fingerling or fry. Contributions of all stockings to year class strength were similar however, ranging from about 20% for both small and large fingerling to 26% for fry. Despite poor survival, fry stockings in Minnesuing creek resulted in a higher number of surviving progeny to fall than lake stockings of small fingerling. Although the effectiveness of fry stockings are variable (Kampa 1998), successful contributions are usually attributed to timing of stocking with periods of high zooplankton abundance (Priegel 1971). While the productive estuary environment of Minnesuing Creek would appear to provide more ideal rearing and feeding conditions than lake environments, reasons for the higher contribution of fry remain unclear. Nevertheless, contributions from all stockings were low, and these results suggest higher relative abundances of age-0 walleye in stocked years, though not significant, were in part due to stocking. These findings are consistent with Sand (1994) who found large fingerling stockings evaluated here also contributed to the adult stock, comprising 25% of the strong age-5 walleye cohort in 1994.

All walleye stockings appeared to supplement year-class strength, however, stocking evaluations indicate more than 70% of the lakes walleye production stems from natural reproduction. Likewise, the similar variability between walleye year-class strength in Lake Nebagamon with that of self-sustaining lakes across the ceded territory further suggests changes in walleye abundance overtime were primarily attributable to variable natural reproduction. These findings explain the lack of any consistent increase in walleye abundance since 1986 and suggest the low contributions from stocking were masked by highly variable natural recruitment.

Summary and Management Recommendations

1). Initiate alternate year stockings of fin-clipped large fingerling walleye at 10 fish/acre. Results of this investigation indicate survival of stocked walleye in Lake Nebagamon was positively related to size at stocking with large fingerling exhibiting a higher survival than small fingerling and fry. Although all stockings contributed to year-class strength, large fingerling stockings resulted in the highest number of survivors to age-1. Furthermore, large fingerling stocked in 1989 provided measurable contribution to the adult stock, comprising 25% of the strong age-5 cohort in 1994. Stockings of walleye fry in Minnesuing Creek out-performed lake stockings of small fingerling and should be considered for future evaluation if large fingerling quotas can not be met. Restrict all future stocking to alternate years and monitor trends in walleye recruitment through annual fall electrofishing inventories. Monitoring year-class strength in an equal number of stocked and non-stocked years will allow for more effective evaluation of future stocking success. In addition, the ability to monitor walleye recruitment in non-stocked years may be the most practical and upfront means of assessing the impacts of high harvest rates on walleye reproduction.

2). Retain the 15 in minimum length limit for walleye. Although truncated size structure and declining mean age of walleye stocks may be symptomatic of recruitment over-harvest, current harvest management of walleye has generally maintained a viable, self-sustaining population and resulted in total exploitation rates which are below the 35% TAC (Staggs 1990).

3). Conduct walleye stock assessments every six years as part of statewide lake monitoring rotation. The ability to conduct more frequent stock assessments will provide a unique opportunity to monitor potentially adverse effects of exploitation on adult walleye stocks and allow for evaluation of temporal effects of large fingerling stocking on walleye recruitment and abundance. An 18 in minimum length for walleye should be considered however, if future investigations indicate size and age structure further decline. Stocking alone failed to result in a consistent increase in walleye abundance and more conservative harvest regulations may be necessary to increase walleye abundance.

4). Continue habitat enhancement and shoreline protection efforts that focus on maintaining self-sustaining fish communities. Production of all sport fish in Lake Nebagamon is largely sustained through natural reproduction. The marginal performance of walleye stocking found during this investigation is a testament to the marginal sport fisheries which will result from further degradation of important spawning and nursery habitats.

5). Work with area residents, Douglas County Zoning, and the Village of Lake Nebagamon to create and adopt a lake management plan incorporating all phases of water resource and shoreland management. The plan should, 1) develop strategies for identifying, protecting and enhancing sensitive aquatic and shoreland habitats, 2) implement self-help water quality monitoring and provide mechanisms for control of satellite exotic infestations, and 3) provide an educational and interactive forum for environmentally sensitive shoreland living.

Acknowledgements

We are gratefully indebted to the many WDNR biologists, technicians, and creel clerks who helped in the collection of data used herein and to Terry Margenau for his constructive review of this report. Special thanks go to WDNR fish technician and creel clerk, Marty Kangas for his invaluable assistance with spring fish collections and for the courteous and professional manner he portrayed when contacting the numerous anglers who also provided information for this report. Special thanks also goes to the Lake Nebagamon Association for funding beaver control activities on Minnesuing Creek and to the local residents, businesses and clubs who so graciously assisted with spawning reef projects in 1998 and 1999. This report was written in memory of local resident and merchant Jan Follis, an advocate for healthy water resources who gratefully called the lake she loved, home.

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Table 1. Walleye stocking history, 1988 - 2004, Lake Nebagamon, Douglas County, Wisconsin.

Year	Fry	Small Fingerling	Large Fingerling	Total
1986		44,945		44,945
1987				
1988		45,012		45,012
1989		45,346	9,140	54,486
1990				
1991		14,600		14,600
1992		44,950		44,950
1993		45,100		45,100
1994				
1995		22,795		22,795
1996				
1997		45,700		45,700
1998				
1999		45,700		45,700
2000	500,000			500,000
2001	500,000	45,700		545,700
2002		45,700	300	46,000
2003	500,000		670	500,670
2004	610,000			610,000
2005	500,000			500,000
2006		40,118		
Total	2,610,000	485,666	10,110	3,065,658

Table 2. Relative abundance of YOY walleye in Lake Nebagamon, Douglas County, Wisconsin, 1986 - 2006. Number stocked represents the number of walleye stocked prior to electrofishing evaluations. Standard deviation in parenthesis.

Year	Number Stocked	Natural Catch/ Mile	Combined Catch/ Mile
1986	50,318		29.1
1988	45,012		35.4
1990		0.8	
1991	14,600		2.8
1992	44,950		19.3
1993	45,100		7.3
1994		28.9	
1995	22,795		40.1
1996		19.7	
1997	45,700		35.5
1998		7.9	
1999	45,700		25.7
2000	500,000		3.3
2001	545,700		
2002	45,700		24.0
2003	500,670		8.0
2004	610,000		9.2
2005	500,000		27.3
2006	40,118		9.1
	Mean:	14.3 (12.4)	19.7 (13.0)

Table 3. Summary of walleye stocking evaluations in Lake Nebagamon, Douglas County, Wisconsin, 1986 - 2006. Percent survival was the estimated number of survivors divided by the total number stocked x 100. Spring stockings of small fingerling and fry were evaluated the autumn following stocking. Fall stockings of large fingerling were evaluated the spring following stocking.

Year Class*	Number Stocked	Stocking Density (number/acre)	Size Class	Mean Length (in)	Mark Type	Estimated Year-class Abundance	Percent Stocked	Estimated Number of Survivors	Percent Survival
1989	9,140	10	Lg. Fng	6.9	Fin-clip	3,228	19.6	634	6.9
2002	45,700	50	Sm. Fng	1.4	OTC	5,129	18.9	972	2.1
2005	500,000	547	Fry	0.2	OTC	5,763	26.5	1,529	0.3

Table 4. Abundance and harvest of walleye by length group, 1994 - 2005, Lake Nebagamon, Douglas County, Wisconsin.

1994				
Length Interval	Estimated Abundance	Spear Harvest	Angler Harvest	Total Harvest
10.0 - 14.9	825	0	37	37
15.0 - 19.9	1,259	0	806	806
20.0 - 24.9	182	0	71	71
25.0+	65	0	17	17
Total:	2,331	0	931	931
1998				
Length Interval	Estimated Abundance	Spear Harvest	Angler Harvest	Total Harvest
10.0 - 14.9	465	4	0	4
15.0 - 19.9	1,138	14	693	707
20.0 - 24.9	53	0	31	31
25.0+	4	0	0	0
Total:	1,660	18	724	742
2005				
Length Interval	Estimated Abundance	Spear Harvest	Angler Harvest	Total Harvest
10.0 - 14.9	545	6	15	21
15.0 - 19.9	539	2	346	348
20.0 - 24.9	93	0	22	22
25.0+	9	0	6	6
Total:	1,186	8	389	397

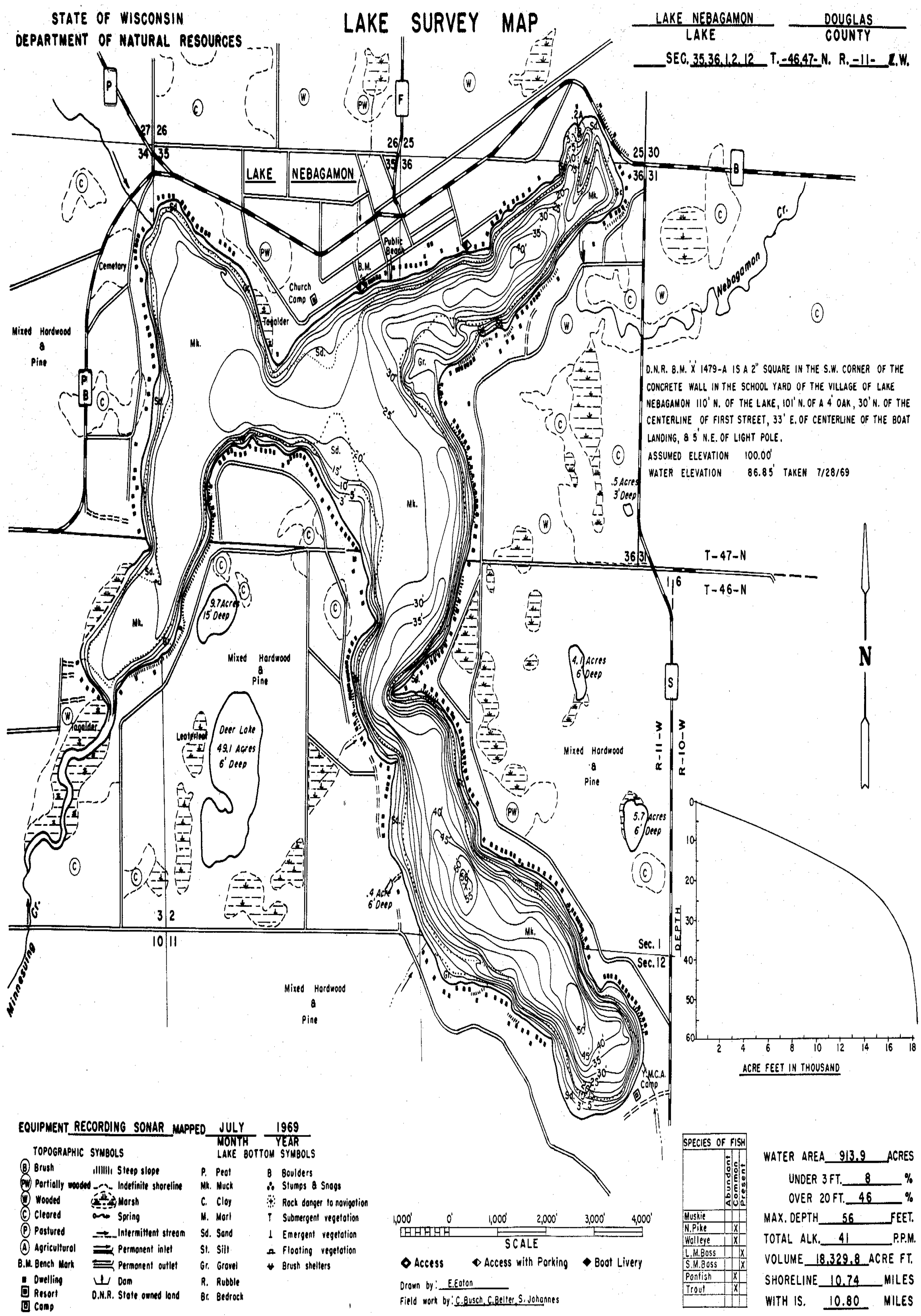

Figure 1. Lake Nebagamon, Douglas County, Wisconsin.

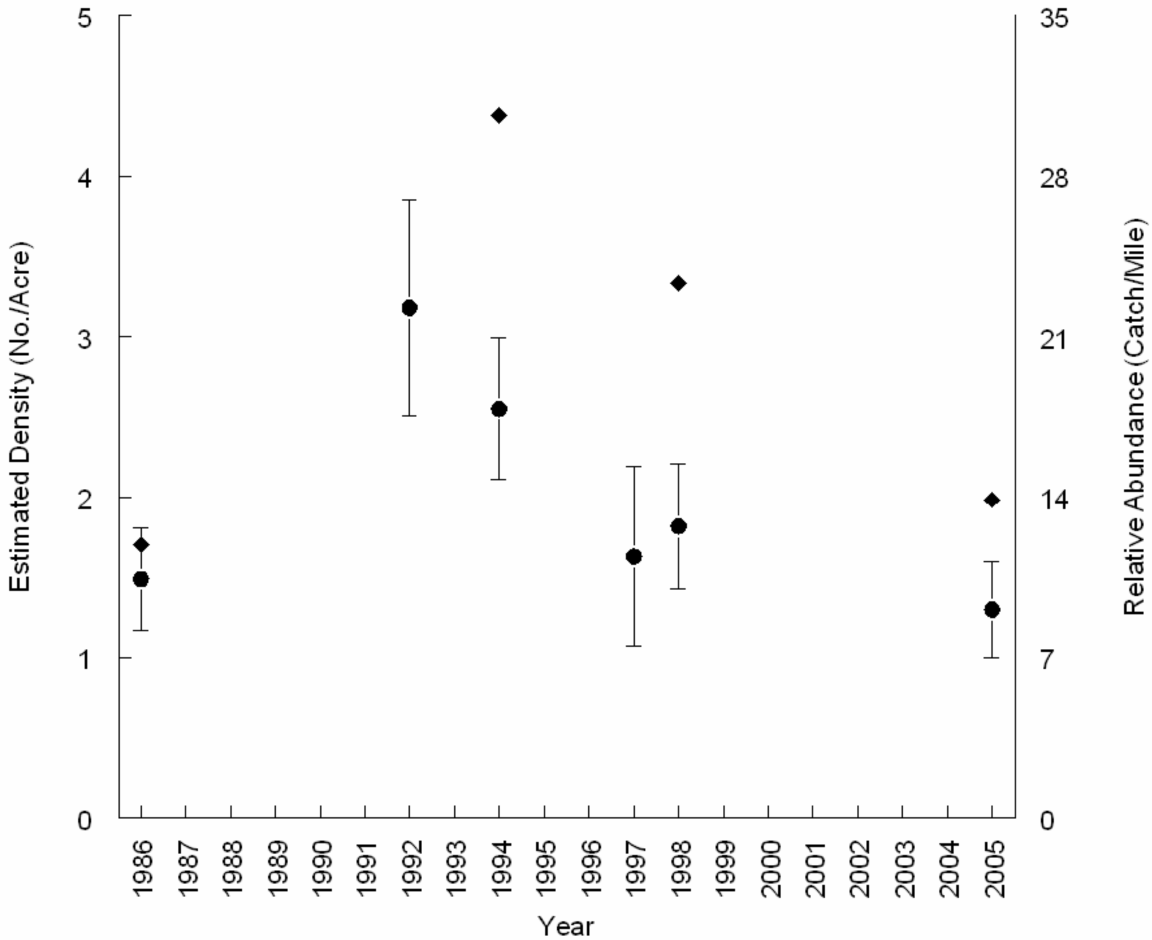

Figure 2. Estimated density and 95% confidence interval of adult walleye, 1986 - 2005, Lake Nebagamon, Douglas County, Wisconsin. Markers represent the relative abundance (catch/mile) of walleye sampled electrofishing.

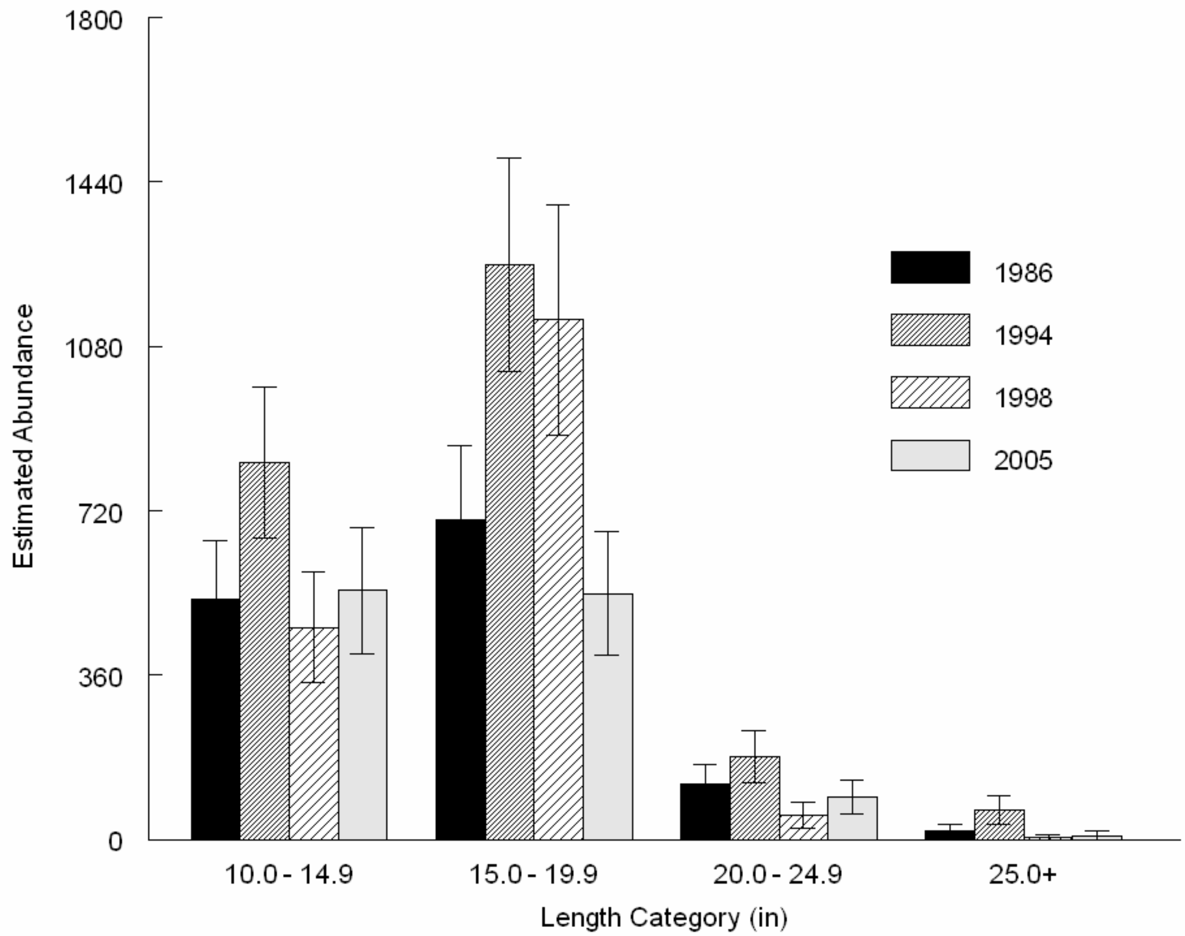

Figure 3. Estimated abundance of adult walleye by length, 1986 - 2005, Lake Nebagamon, Douglas County, Wisconsin. Error bars represent the 95% confidence interval of the estimated abundance.

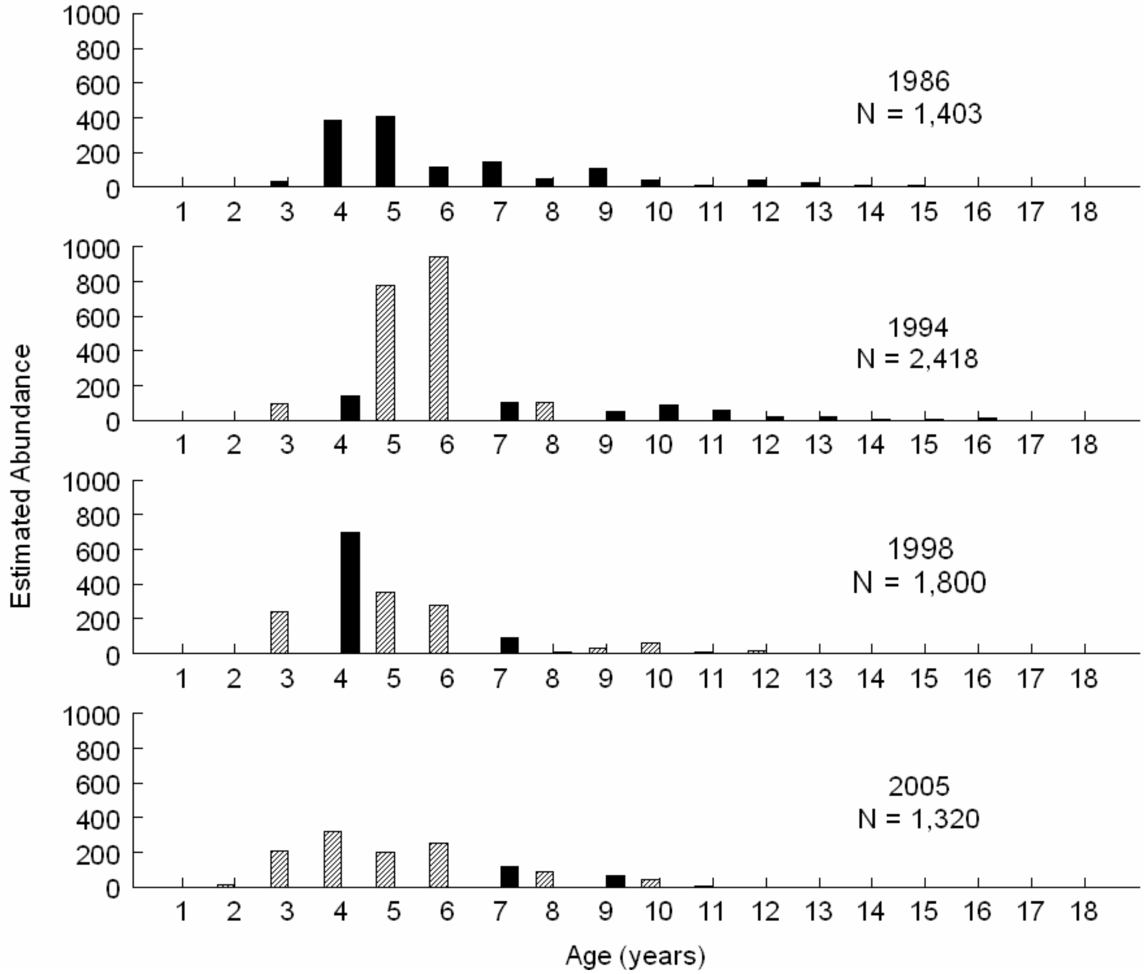

Figure 4. Age distributions of walleye, 1986 – 2005, Lake Nebagamon, Douglas County. Diagonal and solid bars represent cohorts stemming from stocked and non-stocked years, respectively.

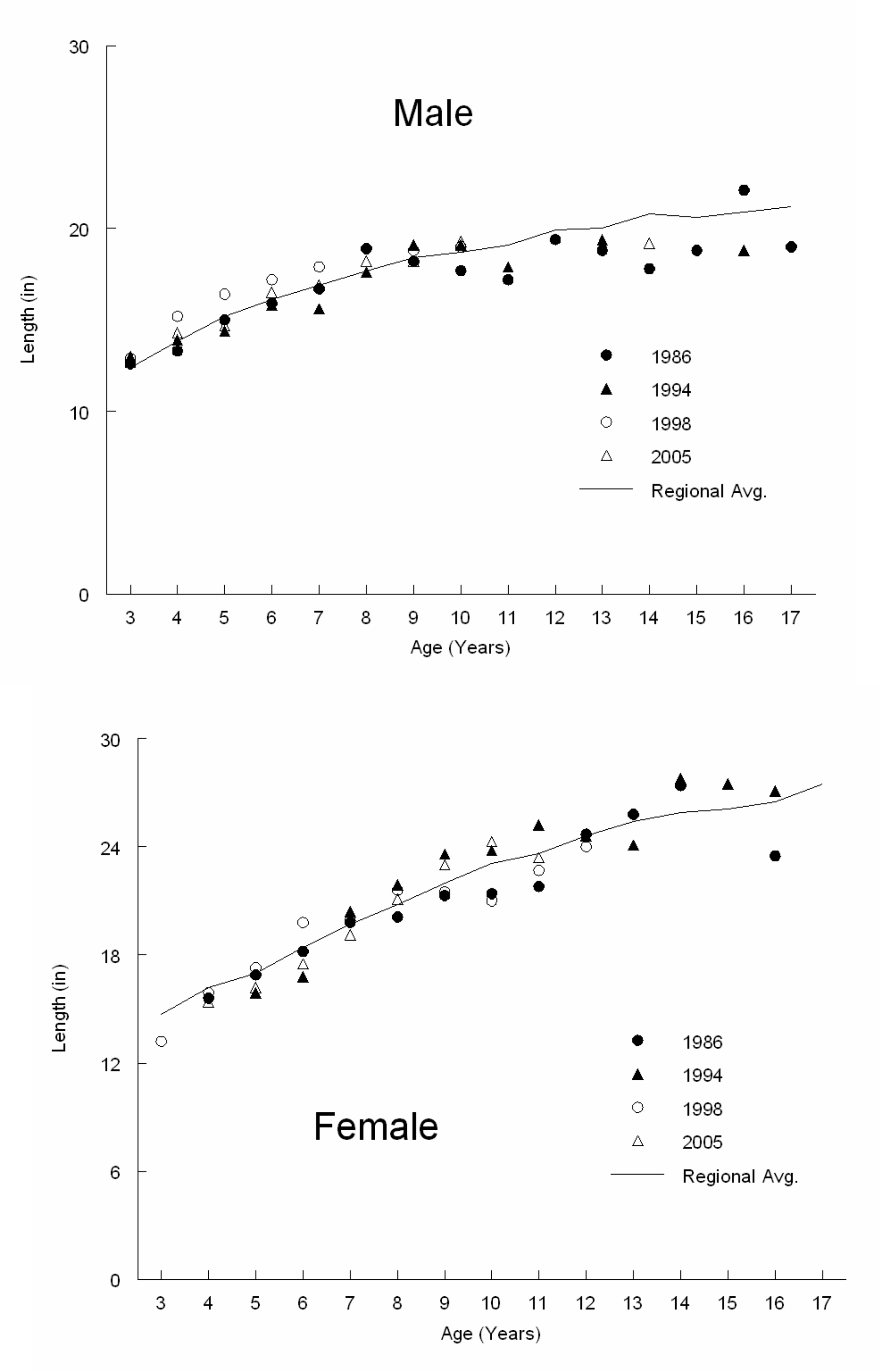

Figure 5. Length at age of walleye by gender, 1986 – 2005, Lake Nebagamon, Douglas County, Wisconsin.

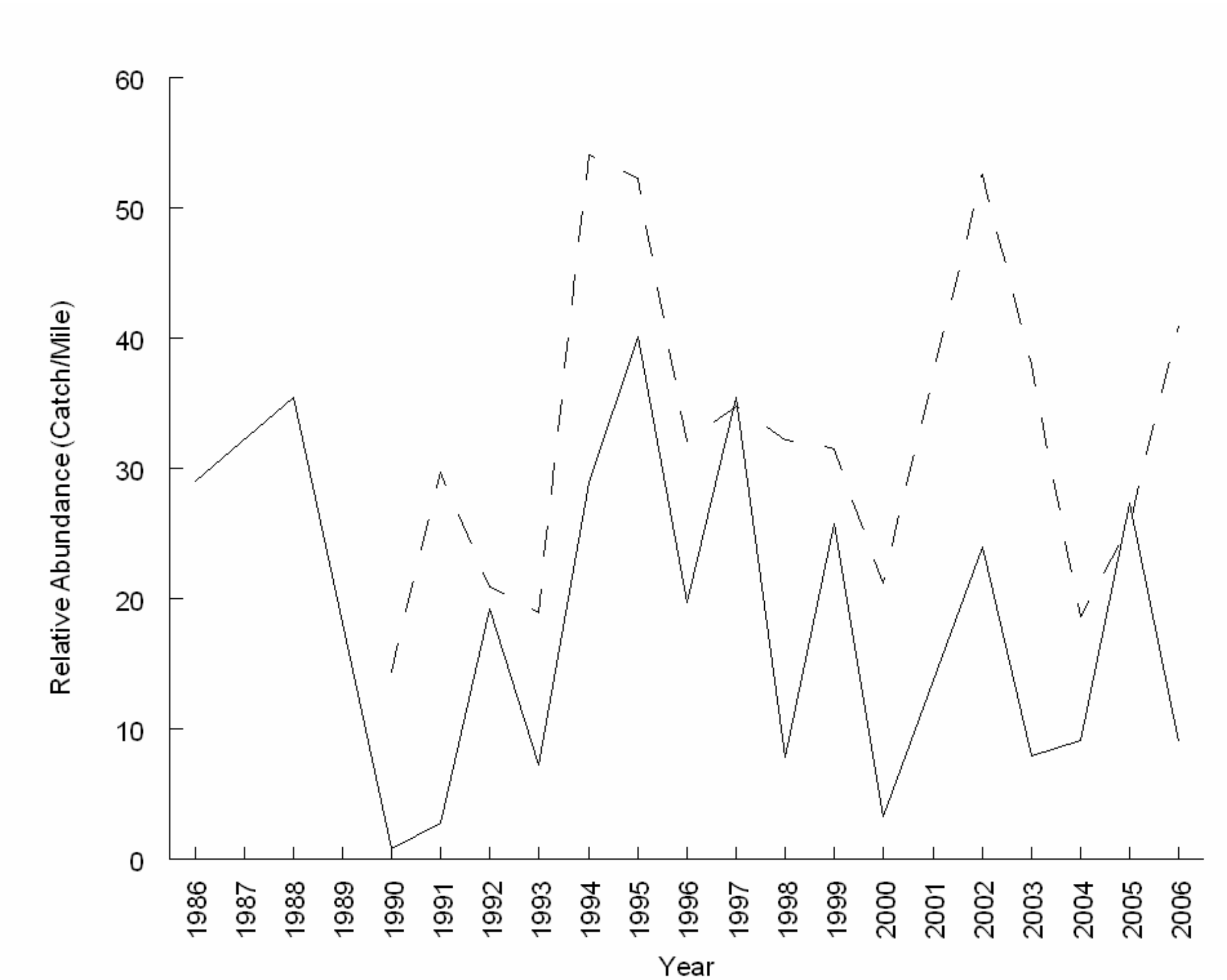

Figure 6. Comparison of the relative abundance (catch\mile) of age 0 walleye in Lake Nebagamon, Douglas County, Wisconsin (solid line) to ceded territory lakes primarily supported by natural reproduction (dotted line).

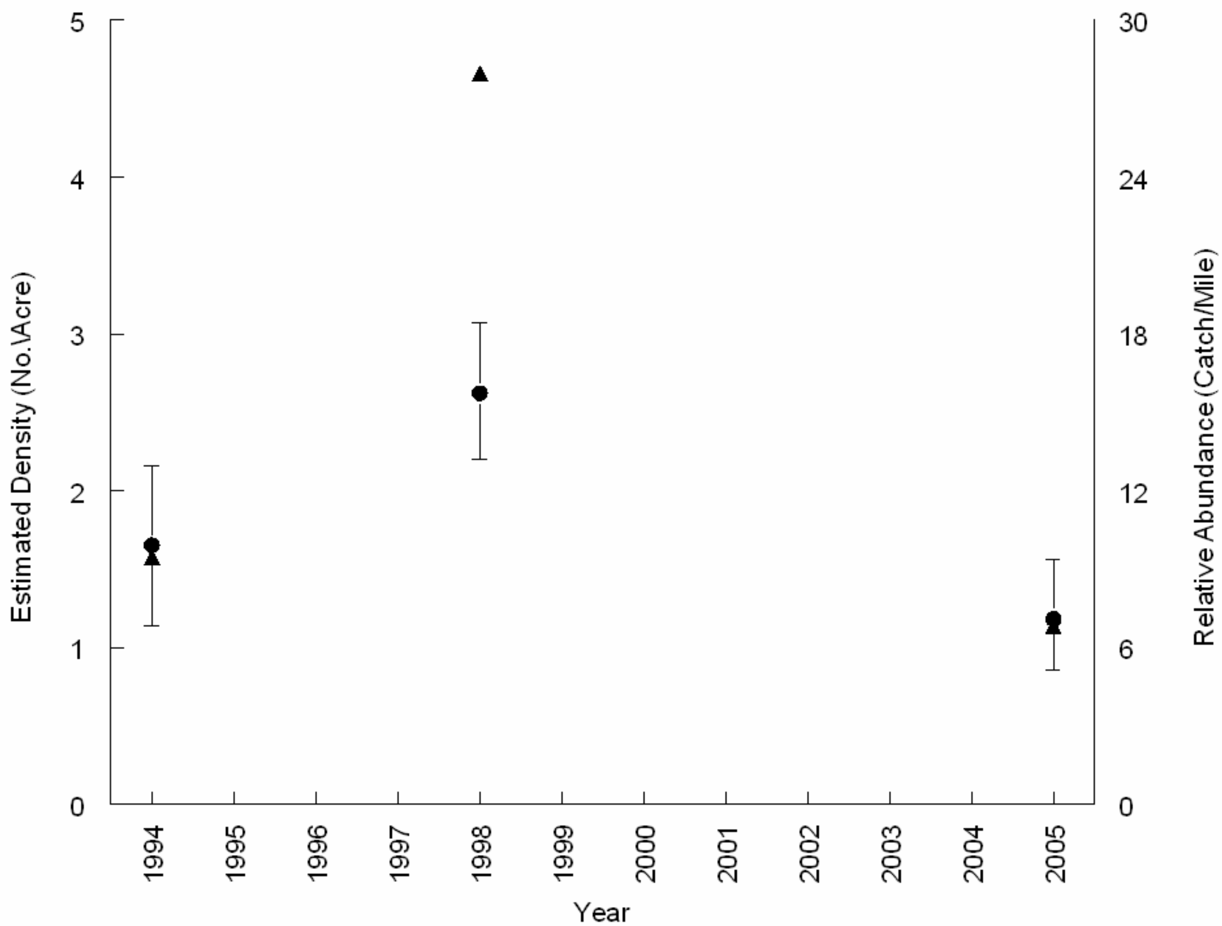

Figure 7. Estimated abundance and 95% confidence intervals of adult northern pike (≥12.0 in), 1986 - 2005, Lake Nebagamon, Douglas County, Wisconsin. Markers represent the relative abundance (catch/mile) of northern pike sampled electrofishing.

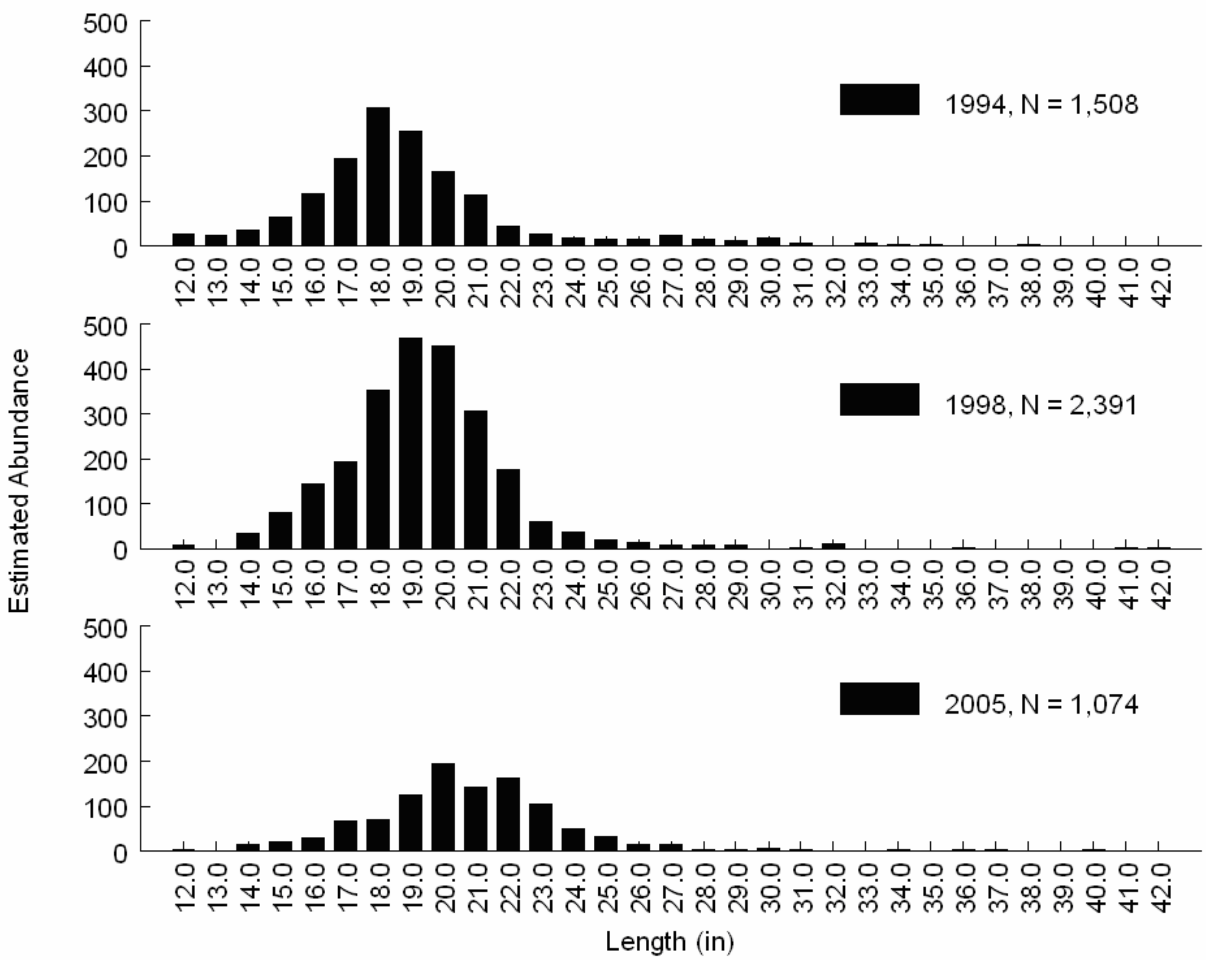

Figure 8. Estimated abundance of adult northern pike by length, 1994 – 2005, Lake Nebagamon, Douglas County, Wisconsin.

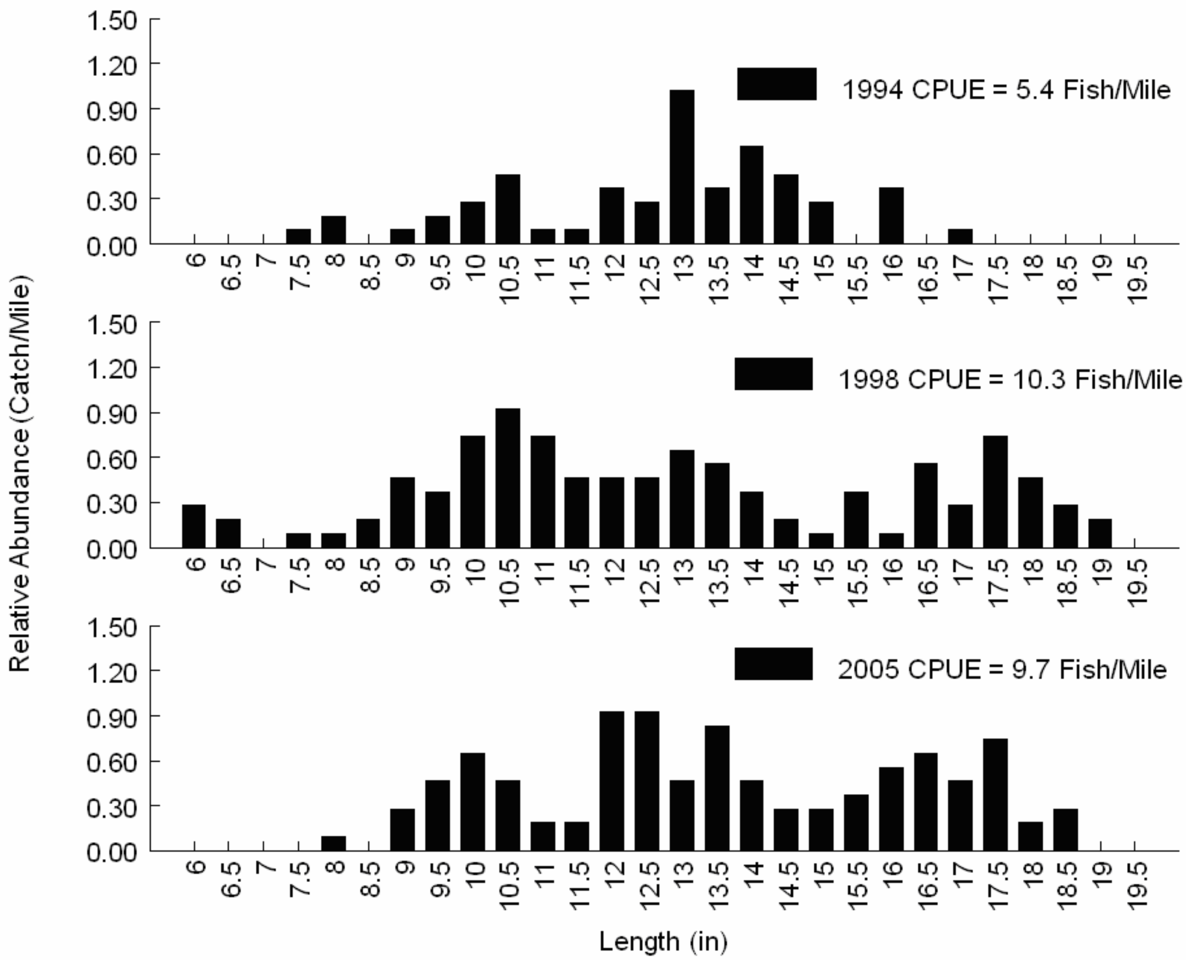

Figure 9. Relative abundance (catch/mile) of smallmouth bass by length, 1994 – 2005, Lake Nebagamon, Douglas County, Wisconsin.

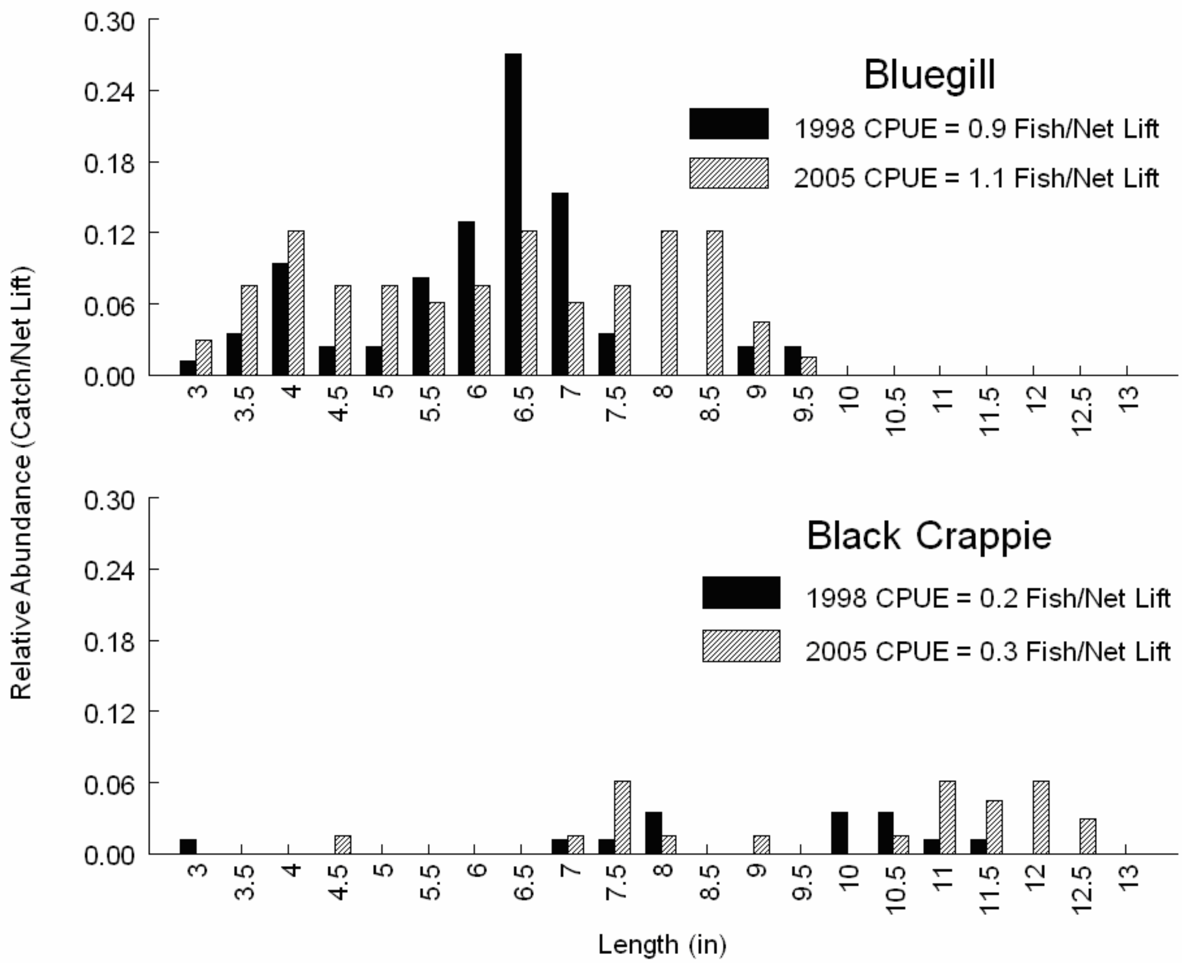

Figure 10. Relative abundance (catch/net lift) of bluegill and black crappie by length, 1998 and 2005, Lake Nebagamon, Douglas County, Wisconsin.

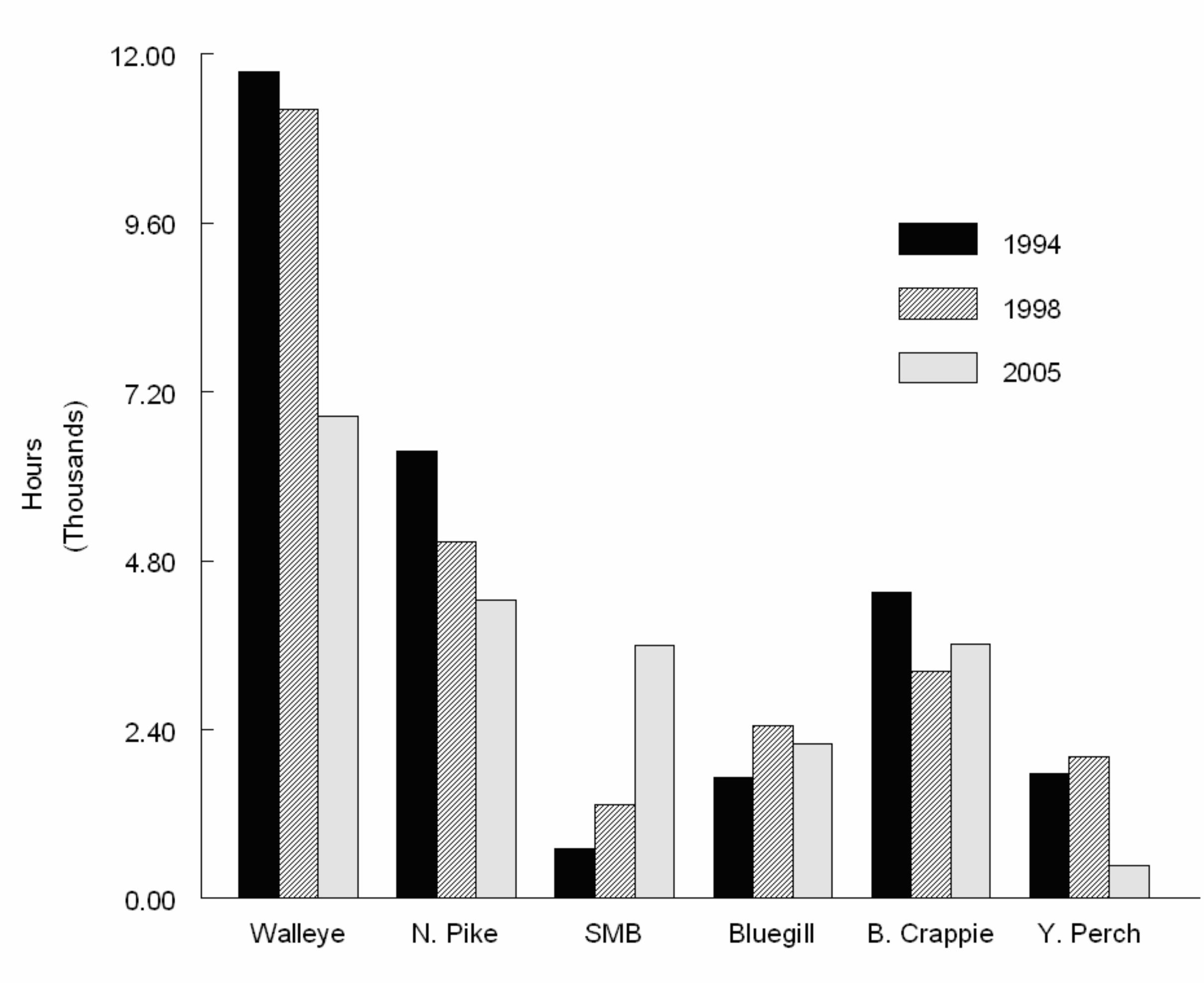

Figure 11. Directed fishing effort for sport fish, 1994 - 2005, Lake Nebagamon, Douglas County, Wisconsin.

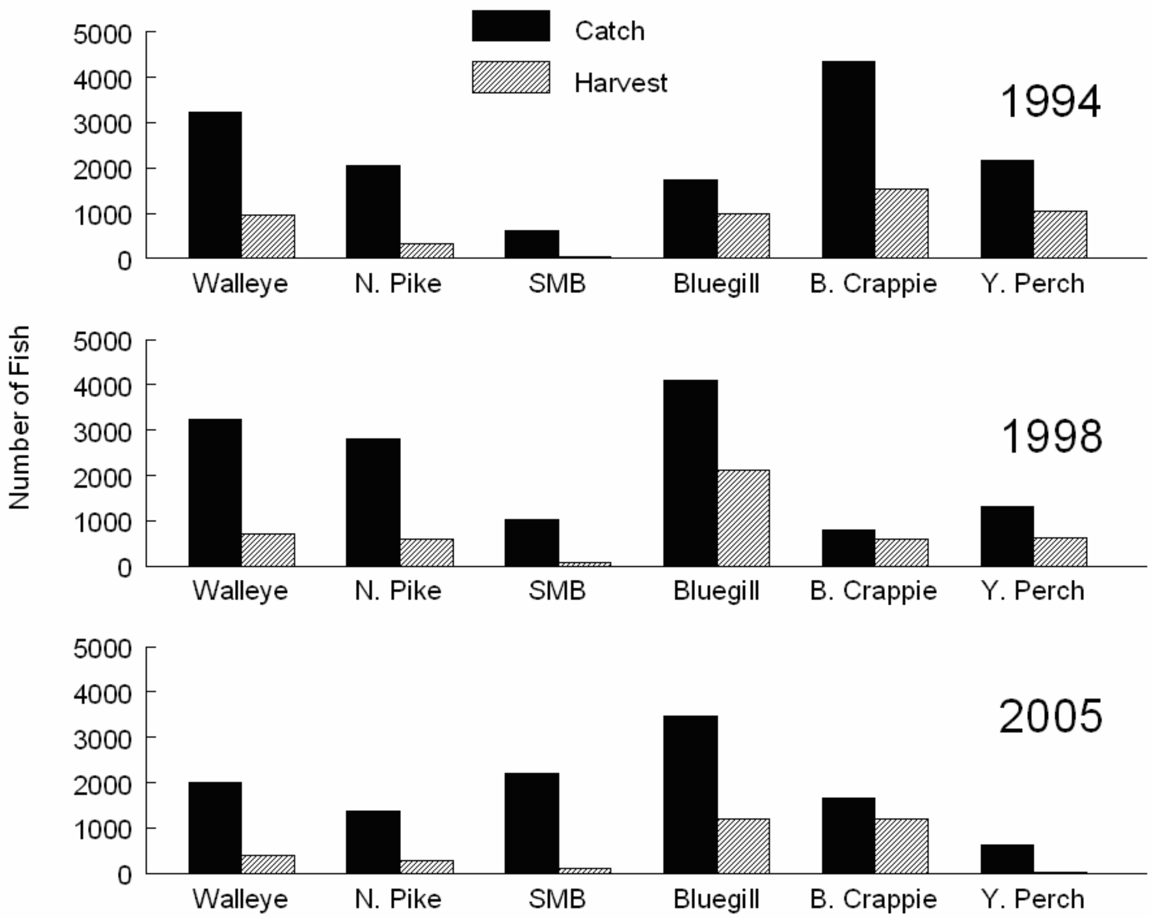

Figure 12. Catch and harvest of sport fish, 1994 - 2005, Lake Nebagamon, Douglas County, Wisconsin.

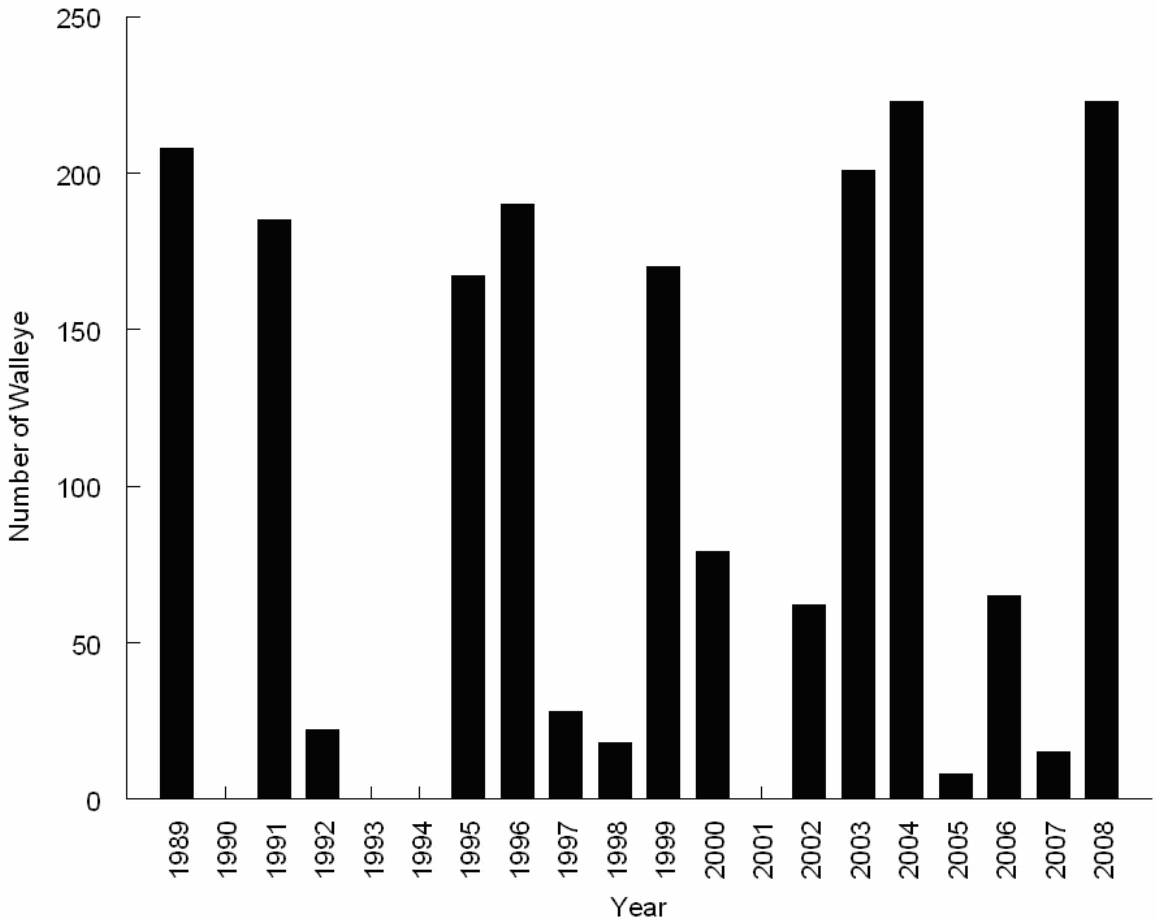

Figure 13. History of walleye spear harvests, 1989 - 2006, Lake Nebagamon, Douglas County, Wisconsin.