Population Trends of Walleye, Sauger, Yellow Perch and Double-crested Cormorants on Lake of the Woods, Minnesota

by

Tom Heinrich
Large Lake Specialist

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Introduction

Double-crested cormorants (*Phalacrocorax auritus*) are a native species in the Lake of the Woods area. In 1939, a commercial fisherman reported to Carlander (1939), "One fall a few years ago, 87 drowned cormorants were taken from one fyke net" on Lake of the Woods. The first attempt to count cormorants on the Minnesota portion of Lake of the Woods was done in 1956, when 130 nesting pairs were counted (K. Haws, MN-DNR Bemidji, pers. comm.). The cormorant population remained fairly stable through 1976 when 100 nesting pairs were counted. Starting in 1981, cormorant nests were counted at least every other year. These counts documented a rapid expansion in nesting cormorants through 1989, when the population peaked at 4,784 nesting pairs. The Lake of the Woods cormorant population has been fairly stable in Minnesota since 1989, ranging from 2,852 to 4,378 nesting pairs. The number of resident non-breeders and seasonal migrants has not been evaluated.

Counts were conducted on the Ontario portion of Lake of the Woods in 1983, 1984, 1986, 2000 and 2005. Not all sites were counted each year (T. Mosindy, OMNR Kenora, pers. comm.). It is substantially more difficult to locate every nesting colony in Ontario, as there are approximately 14,000 islands in 600,000 acres of water. Counts of nesting cormorants in Ontario have not been systematic, and did not capture the period of population expansion. The first count of nesting cormorants (1983) found 6,021 pairs. Subsequent counts were all lower than what was counted in 1983. The largest nesting colony in Ontario is located on the Three Sisters archipelago where counts have ranged from 1,775 (1986) to 4,531 (1983) pairs. This colony is significant as it is located only 2 miles from the Minnesota portion of Lake of the Woods. Ontario biologists feel that the cormorant population on the Ontario portion of Lake of the Woods is stable at between 3,100 and 6,000 nesting pairs. As in Minnesota, the number of non-breeders and migrants is not known.

Some local fisheries stakeholders, in both Ontario and Minnesota, have occasionally expressed concern that cormorants were negatively impacting the walleye and sauger populations of Lake of the Woods. Fishery managers from Ontario and Minnesota did not agree with these comments since walleye and sauger recruitment was consistent, harvest of walleye and sauger were at or above sustainable levels, and anglers were experiencing good catch rates.

As the continental cormorant population expanded through the 1990s, several studies were conducted that found cormorants did have a negative impact on the fish populations of several water bodies (Lantry et al. 2002, Rivers and Jacobson 2004, Rudstam *et al*. 2004). As results of these studies became public, local concern that the cormorants on Lake of the Woods were impacting the fish populations increased. In response to this concern, the Lake of the Woods County Board established a Cormorant Committee during the spring of 2006 to review potential solutions to the perceived cormorant problem. This report was produced to consolidate available information on trends in walleye, sauger, yellow perch and forage fish populations, in the Minnesota portion of Lake of the Woods, and to review if fishery trends could be correlated to changes in cormorant abundance.

Cormorant Abundance and Fish Consumption

Cormorant abundance has been monitored at least every other year, since 1981, on the Minnesota portion of Lake of the Woods through counts of nests. Figure 1 shows how cormorant abundance changed through the period of population expansion from 1976 to 1989. After 1989, the cormorant population stabilized (Figure 2). The low abundance documented in 1993 was due to an outbreak of Newcastle Disease during the winter of 1992-1993 (K. Haws. pers. comm.).

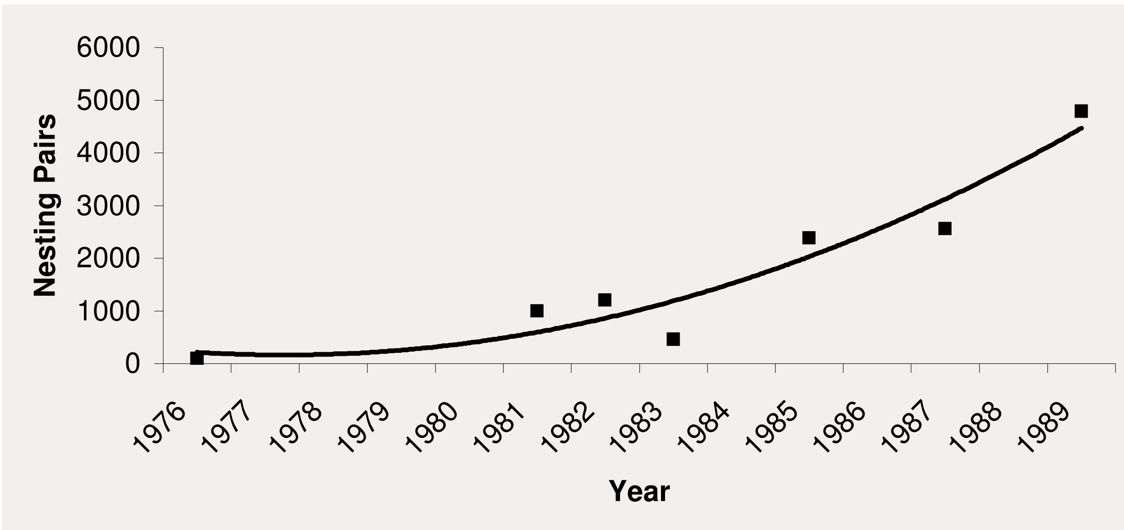

Figure 1. Counts of nesting pairs of cormorants on the Minnesota portion of Lake of the Woods, 1976-1989.

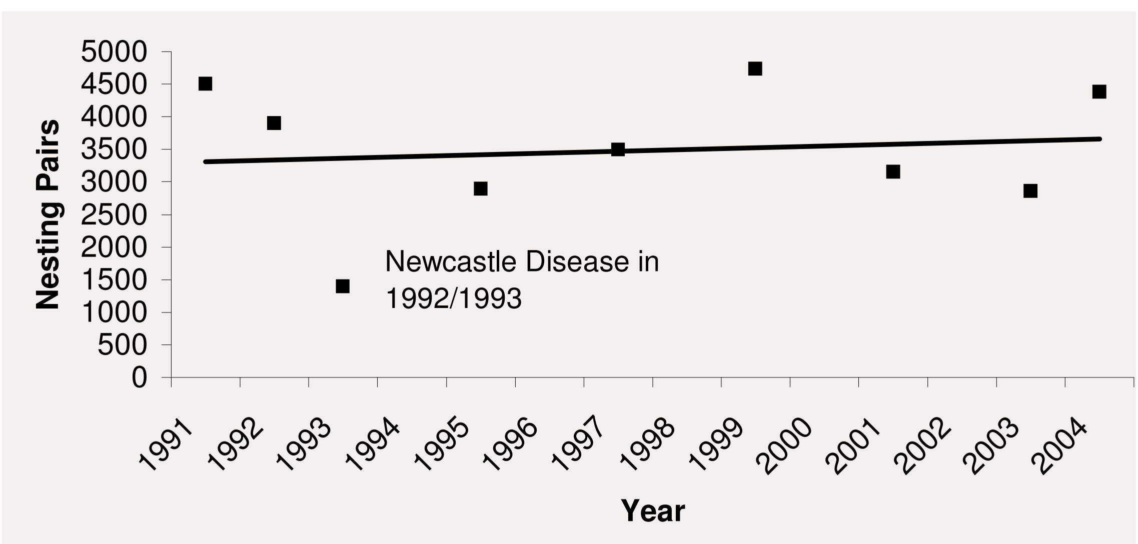

Figure 2. Nesting pairs of cormorants on the Minnesota portion of Lake of the Woods, 1991-2004.

The daily consumption of food items varies by the life stage of cormorants. Rivers and Jacobson (2004) assumed adult cormorants consumed 1 pound per day and chicks consumed 0.73 pounds per day. To calculate total consumption, the period of time cormorants spent in the area was divided into discrete periods based on the life stages of cormorants present. Rivers and Jacobson (2004) described the length of each period. The pre-chick period (before chicks were hatched) is 64 days, chick stage (after hatch, before chicks consumed at the adult rate), 42 days, and the post-chick stage (when chicks consumed at the adult rate), 52 days. Rivers and Jacobson (2004) reported that there were 1.9 chicks produced per nest on Leech Lake. Total consumption will be an underestimate because resident non-breeding and migratory cormorants on Lake of the Woods have not been counted. The number of adults (7,474) and chicks (7,100) is based on the mean number of cormorant nests from 1989 to 2004 (the period of stable cormorant abundance), excluding 1993. Assuming their entire diet was composed of fish the average annual consumption by cormorants over this period on Lake of the Woods was 1,767,848 pounds of fish, or 5.5 pounds per acre (Table 1). Rudstam *et al* (2004) reported that cormorants negatively impacted walleye (*Sander vitreus*) and yellow perch (*Perca flavescens*) populations of Oneida Lake at a consumption rate of 3.5 pounds per acre, and Rivers and Jacobson (2004) reported that a consumption rate of 11.8 pounds per acre caused walleye and yellow perch populations to decline on Leech Lake.

Table 1. Average annual fish consumption (pounds) by cormorants on the Minnesota portion of Lake of the Woods. Number of cormorants used is the mean number of adults from 1989 to 2004 (excluding 1993) and assuming 1.9 chicks per nest. The number of chicks produced was added to the number of adults in the post-chick period, when chicks fed at the adult rate.

Life Stage	Days in Period	Number of Adults	Pounds Consumed	Number of Chicks	Pounds Consumed	Total (Pounds)
Pre-chick	64	7,474	478,336	0	0	478,336
Chick	42	7,474	313,908	7,100	217,686	531,594
Post-chick	52	14,574	757,848	0	0	757,848
Total						1,767,778
Pounds per Acre (320,000 acres)						5.5

Lake of the Woods is shared between the State of Minnesota and the Canadian provinces of Ontario and Manitoba. No cormorants have been documented nesting on the Manitoba portion of Lake of the Woods, but biologists from Ontario feel that the Ontario nesting population of cormorants is stable at a level between 3,100 and 6,000 pairs. Assuming the higher figure, the Ontario population of cormorants is less than twice as high as the Minnesota population, while the Ontario portion of Lake of the Woods is approximately 600,000 acres, or almost two times larger than the Minnesota portion. While including the Ontario cormorant population would almost triple the total consumption of fish, the amount consumed per acre would change very little. For the purposes of this paper I am going to deal only with cormorants nesting in Minnesota.

Fish Recruitment

Fish recruitment is a very complex topic, and the specifics are beyond the scope of this paper. However, there are some generalities that should be highlighted. In general, mortality of young fish is very high but declines as the survivors get older. At some point on this continuum a bottleneck is passed and year class strength is established. As long as mortality sources are within a normal range, once year class strength is set, it should be possible to predict the abundance of future age classes based on the abundance of younger age classes. However, once year class strength has been established, any change in mortality would be expressed as a change in the relationship between the abundance of younger age classes and older age classes, and ultimately, the measure of year class strength. In the case of walleye and sauger (*Sander canadense*) on Lake of the Woods, this bottleneck occurs during their first summer, as year class strength can be predicted from data collected at the end of August. Conversely, summer sampling of young-of-year (YOY) yellow perch has not proven to be an effective way to predict yellow perch year class strength on Lake of the Woods.

Oneida Lake

Adult walleye and yellow perch populations on Oneida Lake declined through the 1990s, concurrent with cormorant population increases. The decline of adult walleye and yellow perch was attributed to increased mortality of sub-adult walleye (between age-1 and age-4) and yellow perch (between age-1 and age-3). After cormorants became established on Oneida Lake, the residuals between measured abundance and predicted abundance were all negative (see Figure 4, Rudstam et al. 2004). The only factor that could have caused the negative residuals was an increase in mortality between age-1 (the age that future abundance is estimated from) and age-3 or age-4. Age-1 abundance of both walleye and yellow perch during the period of the cormorant population increase was unchanged from earlier periods.

A cormorant diet study was conducted from 1995 through 2000 on Oneida Lake. This study found that between 40% (1995) and 81% (2000) of all cormorant prey items were walleye and yellow perch. Through the six years of the study, age-0 and age-1 walleye comprised 71% of all walleye eaten, while age-0 and age-1 yellow perch were 81% of all yellow perch consumed. Although the majority of walleye and yellow perch consumed by cormorants were age-0 and age-1, mortality at these ages appears to be compensatory. Consumption of the relatively small number of older walleye and yellow perch resulted in additive mortality and caused the decline in the walleye and yellow perch populations.

Leech Lake

Cormorant abundance increased from 1998 through 2004 on Leech Lake. Through the period of cormorant population increase, age-0 walleye and yellow perch abundance remained within the normal range, but the abundance of sub-adult walleye and yellow perch declined. Concurrent with the decline in the number of sub-adult walleye and yellow perch, the 2001 walleye year class was predicted to be very strong, while it actually turned out to be moderately weak. As on Oneida Lake, the overall abundance of age-0 walleye and yellow perch remain high, but high age-0 abundance has not resulted in strong year classes. Again, an increase in mortality between age-0 and recruitment to the gill net sample and year class strength index is likely.

Cormorant Control Results

Cormorant control measures have been undertaken on both Oneida Lake and Leech Lake. The target cormorant population on Oneida Lake has been set at no more than 100 resident adults and sub-adults, from 600+ individuals that had been using the lake. Cormorant control on Oneida Lake includes spring and fall hazing, egg oiling, nest destruction, killing of adults and exclusion devices. On Leech Lake the primary cormorant control measures are to reduce nesting habitat and to shoot adults. The goal is to reduce the number of nesting pairs from a high of 2,524 pairs to 500 pairs. Early indications on both lakes are that responses within the fish community are consistent with a reduction in mortality that could have been caused by cormorants.

Lake of the Woods Fish Assessment Tools

Two primary assessment tools are utilized to monitor percid populations on the Minnesota portion of Lake of the Woods. A standardized fall gill net assessment has been conducted annually since 1981. This assessment uses sites and methods established in a three-year survey conducted from 1968 to 1970. The period of fall gill net assessment overlaps the recent population change history of cormorants on Lake of the Woods. Products of the fall gill net survey include overall abundance, by species, and abundance of age classes, for species that are aged. From age class abundance, an index of year class strength can be generated. This year class strength index is useful for comparing the relative strength of year classes through time. For both walleye and sauger the year class strength index is based on the catch rate of age-2 through age-5 fish. This is important because on Oneida Lake it was found that the additional mortality causing the decline in the walleye population occurred after age-1, but before age-4. A weakness of the year class strength index is that it is a reflection of all sources of mortality. For instance, on Lake of the Woods anglers start to harvest walleye when they are 12 inches in length. Since age-2 walleye reach 12 inches in length during the fall, they are vulnerable to angler harvest for all four years in which their year class strength is measured. In this case, if angling were a major source of walleye mortality, changes in angling harvest would influence year class strength.

The second percid assessment tool is young-of-year (YOY) sampling conducted annually during July and August. YOY sampling is useful in predicting year class strength of both walleye and sauger. The most useful segment of YOY sampling is the trawling component, which is conducted in August. Though it has been conducted annually since 1983, seining has not yielded a useable predictive ability for walleye or sauger unless combined with trawling. The weakness of the trawl assessment is that it was not incorporated into sampling until 1990, after the cormorant population had stabilized on the Minnesota portion of the lake.

Lake of the Woods-Walleye

Overall walleye abundance in both Oneida Lake and Leech Lake declined during the period of cormorant abundance increase. Figure 3 shows how abundance of all age classes of walleye combined has varied on Lake of the Woods since 1968. Gill net catch per lift ranged from a low of 6.3 in 1982 to 26.6 in 1970. During the 1968 to 1970 study, walleye abundance increased sharply as a result of recruitment of the 1966 year class to the gill net sample. The 1966 year class of walleye is the strongest year class of walleye ever documented on Lake of the Woods (Figure 4). The line through Figure 3 shows that overall walleye abundance has not declined through time, and may have increased. Walleye year class strength has varied through time (Figure 4), but there is no increasing or decreasing trend in strength.

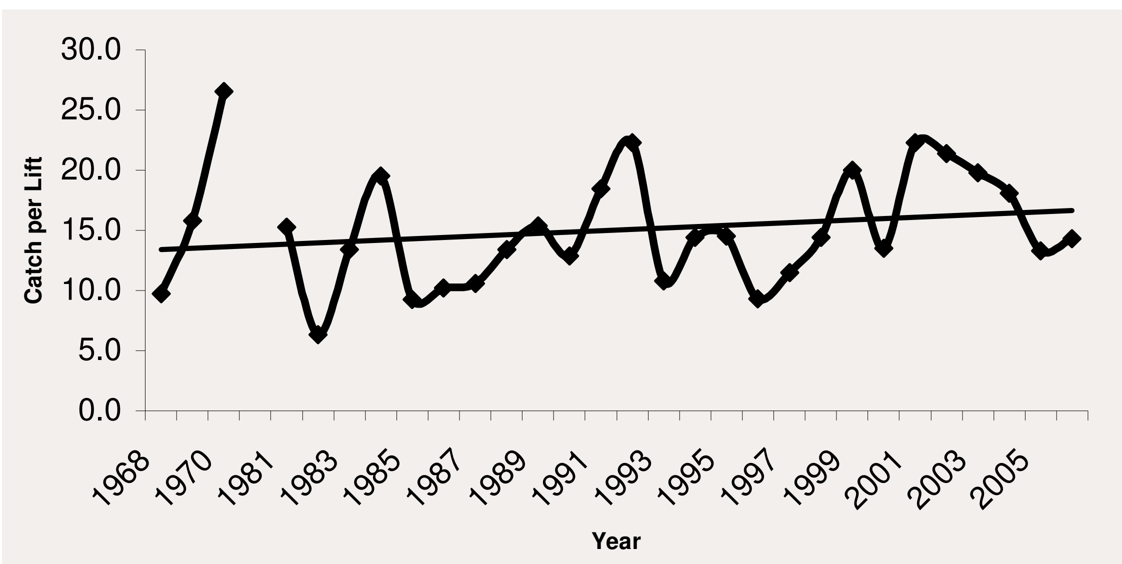

Figure 3. Walleye abundance (number of walleye per lift) as measured by standard experimental gill nets. The straight line through the points is the regression of abundance over time. Minnesota waters of Lake of the Woods. 1967-1970 and 1981-2006.

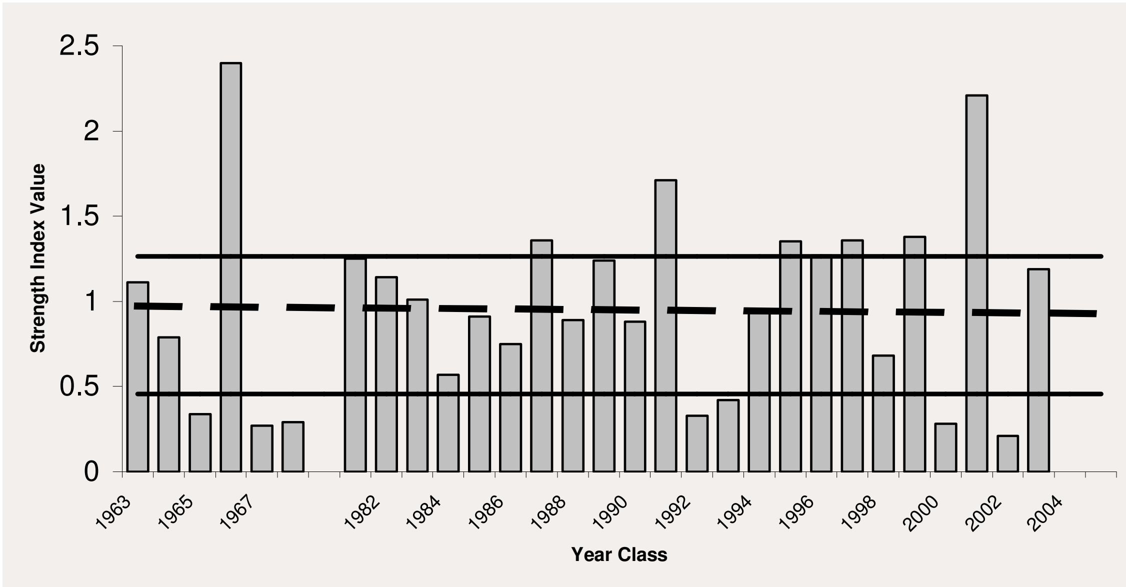

Figure 4. Walleye year class strength based on least squares means of natural log transformed age-2 to age-5 gill net CPUE, from fall gill net assessment. Solid horizontal lines are the first and third quartiles of the values and mark the bounds of strong and weak year classes. The dashed line is the change in year class strength through time.

Another way to look at recruitment is to try to predict the fall gill net catch rate of an age group from the catch rate at an earlier age. I used the ratio of gillnet CPUE at age-1 to age-2 and to age-3. Figure 5 shows that the ratio of age-2 walleye to age-1 walleye declined between 1983 and 2001. This suggests that mortality between age-1 and age-2 has increased through time. Conversely, Figure 6 suggests that the mortality rate between age-3 and age-1 has declined during the same time period.

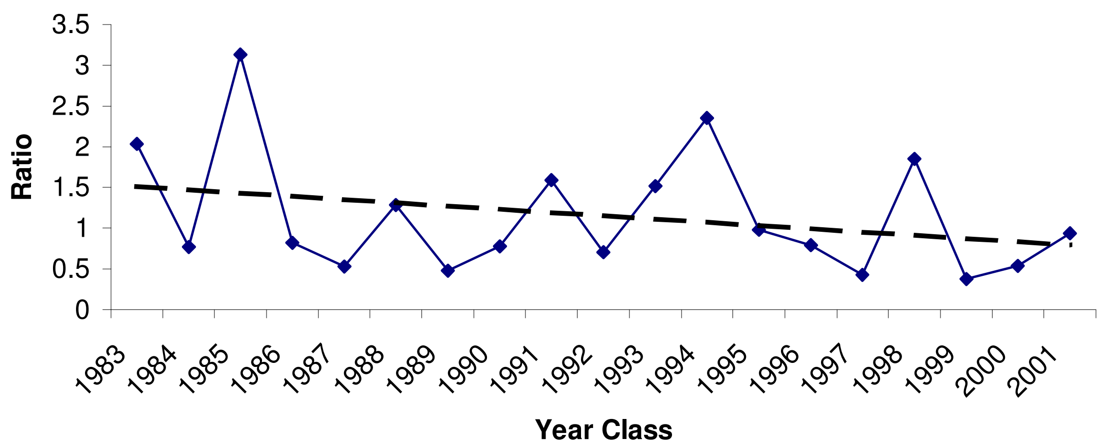

Figure 5. The ratio of the catch per unit of effort of age-1 to age-2 walleye, by year class. The dashed line through the points is the best fit trend line.

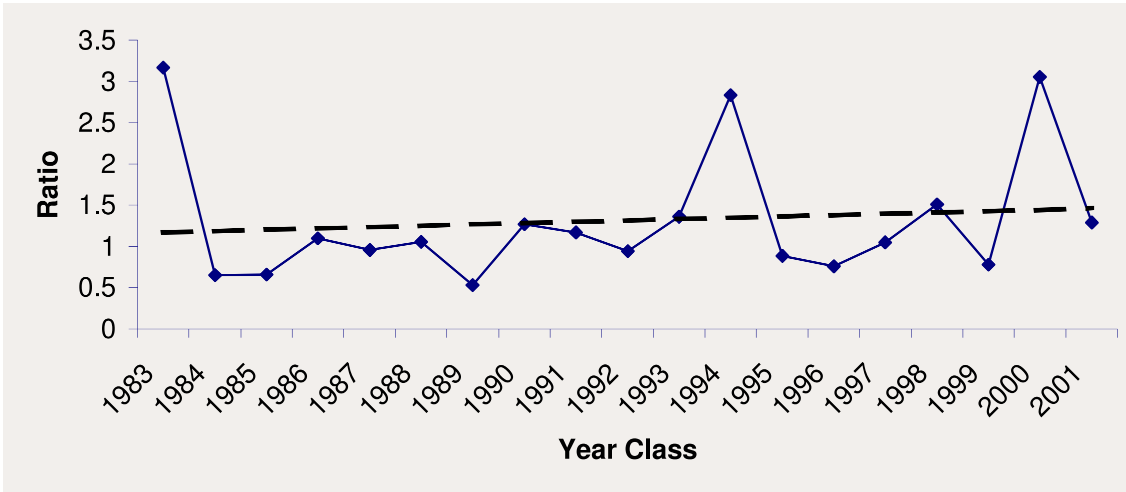

Figure 6. The ratio of the catch per unit of effort of age-1 to age-3 walleye, by year class. The dashed line through the points is the best fit trend line.

Sport harvest of walleye in the 1968 to 1970 survey averaged 462,000 pounds, which was in the same range of magnitude as sport walleye harvest in the 1980s (Figure 7). However, a commercial walleye fishery existed also through 1985. During the 1968 to 1970 period an additional 97,000 pounds of walleye were harvested commercially. An insignificant walleye harvest occurred through, what was at the time, a very small winter sport fishery. Total sport and commercial walleye harvest from 1968 to 1970 averaged 559,000 pounds. From 1981 through 1985, the walleye summer sport harvest averaged 202,000 pounds and an additional 154,000 pounds were harvested commercially. Additionally, approximately 37,000 pounds of walleye were harvested through a developing winter fishery, for a total harvest of 393,000 pounds. After 1985 commercial harvest was removed, but the summer and winter fisheries continued to expand. The average sport harvest, from all sources, from 2001 to 2005 was 660,000 pounds. Current total harvests exceed that from both the early 1980s, and the late 1960s.

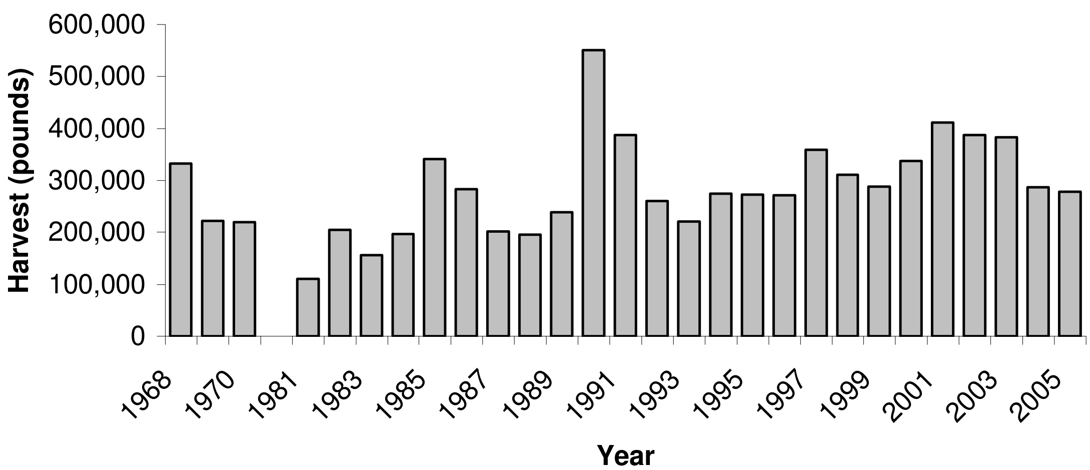

Figure 7. Summer sport fishery walleye harvest, Minnesota waters of Lake of the Woods, 1968 to 1970 and 1981 to 2005. Summer Lake of the Woods creel surveys.

Walleye harvest rates through the sport fishery are generally lower from 1998 through 2006 than in the previous periods (1968-1970, 1981-1984) (Figure 8). Release rates were not published from the surveys conducted from 1968 through 1970 or the surveys completed in 1981 through 1984, so comparison of release rates cannot be made. Observations by MN-DNR personnel indicate that very few walleye were released prior to implementation of experimental and special regulations forcing the release of some sizes.

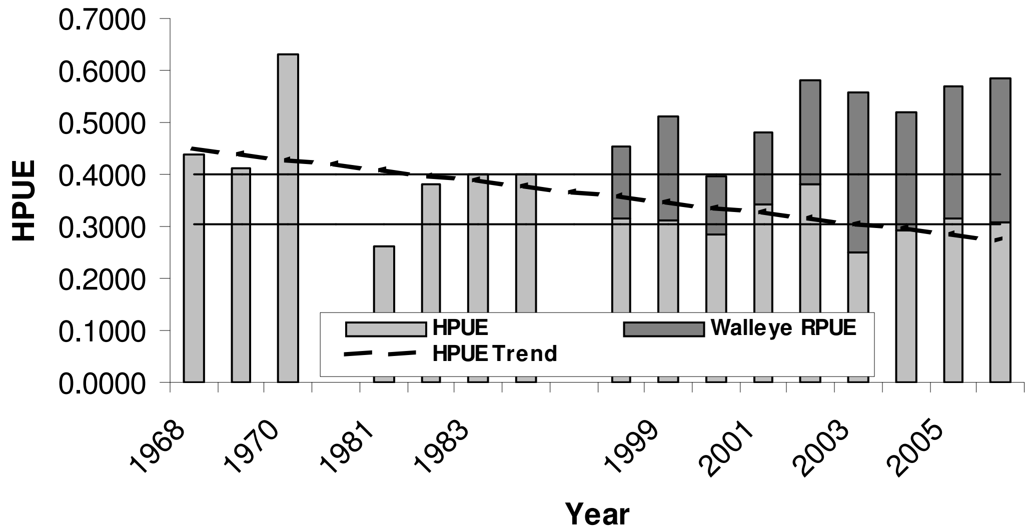

Figure 8. The number of walleye released per hour (RPUE) and harvested per hour (HPUE) from summer Lake of the Woods creel surveys. Horizontal lines are the first and third quartiles of the HPUE. Minnesota portion of Lake of the Woods.

Lake of the Woods Walleye Discussion

On both Oneida Lake and Leech Lake the overall abundance of walleye, as measured in annual sampling, declined as cormorant populations increased. On both lakes, it appeared that the decline in abundance was caused by increases in mortality between age-0 or age-1 and age-4 (Oneida Lake) or recruitment to the year class strength index (age-2 through age-5, Leech Lake). On Lake of the Woods there have been short-term declines in overall abundance, but abundance has rebounded following lows. Overall, the regression line through the gill net catch rates suggests an increasing trend in abundance, but the trend is not significant (p = 0.52).

The year class strength index, as used in Figure 4, is a very useful index as it reflects all sources of mortality that affect the year class through age-5. This is also a potential source of confounding factors. Walleye start to recruit to the sport fishery at age-2 and remain vulnerable through age-5. The increase in sport harvest documented since 1968 could increase mortality from age-2 through age-5. This would be manifested as declining year class strength through the period. Though a commercial fishery existed through 1985, this fishery was restricted by mesh size and minimum legal size. These restrictions did not allow female walleye to recruit to the commercial fishery until age-5 and male walleye recruited at age-6 (Schupp 1974). The commercial fishery therefore had very little effect on the year class strength index. A paired t-test between year class strength indices from the 1963 to 1968 year classes and the 1998 to 2003 year classes found no difference in mean strength between these periods (p = 0.57). The lack of change in year class strength index through time suggests that the increase in the cormorant population through the 1980s, and the increase in sport fishing harvest, did not significantly increase walleye mortality before age-5.

Figures 5 and 6 both suggest mortality changes between age-1 and age-2 (Figure 5) and age-1 and age-3 (Figure 6). However, Figure 5 suggests an increase in mortality rate while Figure 6 suggests a mortality rate decline. Neither regression is significant (p=0.21 age-1 to age-2, p=0.64 age-1 to age-3) so there is no significant change in mortality rate during the period presented.

Walleye sport fishing harvest rates (HPUE) have declined from 1968 through 2006 (Figure 8). Release rates were not reported before 1998. Sport fishing equipment has undergone many changes since 1968. Both commercial launches and private fishing boats have gotten larger. Electronic navigation and fish finding devices are more frequently used and have become more accurate and reliable. These changes should have increased catch rates. Paired one-tailed t-tests for mean HPUE between the 1968 to 1970 data set and the 1981 to 1983 series found the harvest rates were not significantly different (p=0.07). When the 1968 to 1970 data series is compared to 2004 to 2006, the HPUE in the earlier data series was found to be significantly higher than the later time series (p=0.05).

Not quantifiable from the available data is how angler behavior has affected catch and harvest. Anglers have generally become more release oriented recently, whereas in the late 1960s anglers were much more harvest oriented. The degree to which walleye that were released in the later surveys would have been harvested during the 1960 to 1970 period cannot be assessed. Schupp (1974) did report that anglers readily accepted walleye when they reached 12 inches in length. From 2004 to 2006 walleye recruited to the sport fishery when they reached 12 inches in length. This is unchanged from the earlier survey. A regulation, designed to reduce walleye harvest, was enacted prior to the summer 2005 fishing season. The regulation forced the return of all walleye between 19.5 and 28 inches in length and reduced the possession limit from 6 walleye to 4. Though this regulation would have affected HPUE in 2005 and 2006, earlier HPUE would have remained unaffected.

Lake of the Woods-Sauger

Information on sauger is somewhat more limited than walleye. Sauger were historically not a species of interest to the degree that walleye were, because they comprised a relatively small portion of sport and commercial harvests, and were felt to be relatively abundant.

Overall sauger abundance from 1968 to 1970 and 1981 to 2006 is presented in Figure 9. Sauger abundance has ranged from 4.5 sauger per lift (1981) to 20.1 per lift (2002). The regression line through annual abundance, as measured by fall gill nets assessment suggests stability in sauger abundance through time.

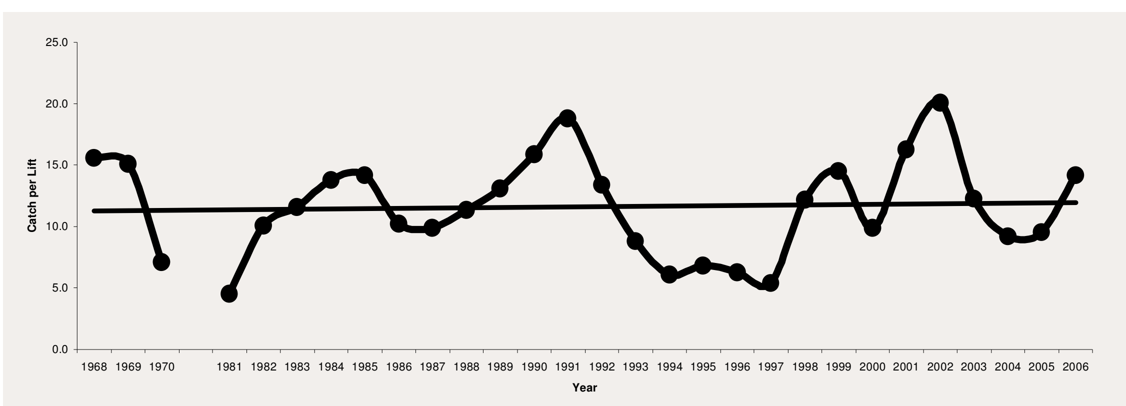

Figure 9. Sauger abundance (number of sauger per lift) as measured by standard experimental gill nets. The straight line through the points is the regression of abundance over time. Minnesota waters of Lake of the Woods. 1967-1970 and 1981-2006.

Sauger year class strength index values are available from 1982 to 2004 (Figure 10). Unlike walleye, sauger year class strength values are not available prior to the cormorant population expansion, but strengths through the expansion and after stabilization are available. There is not an increasing or decreasing trend in year class strength through time for sauger.

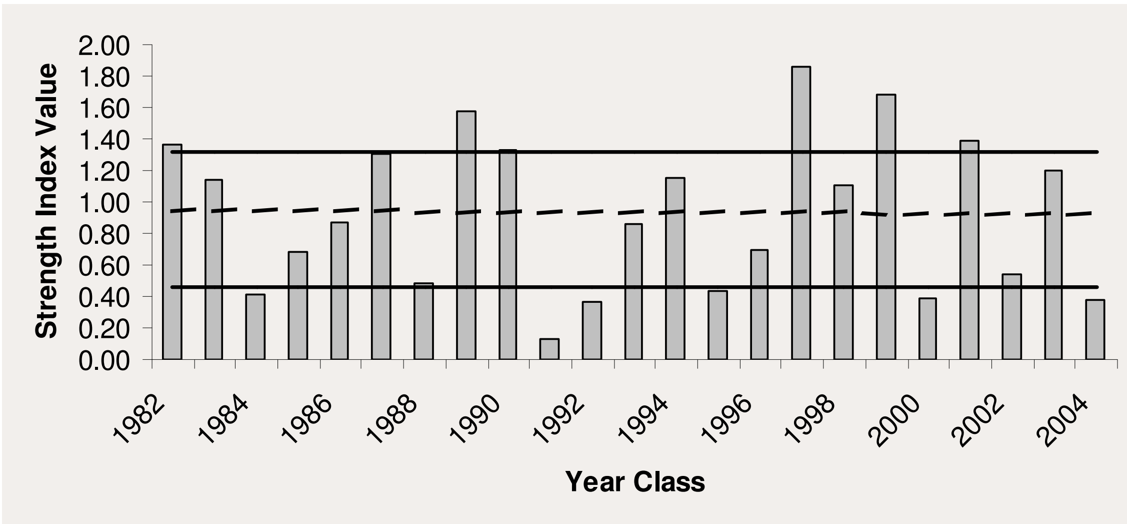

Figure 10. Sauger year class strength based on least squares means of natural log transformed age-2 to age-5 gill net CPUE, from fall gill net assessment. Solid horizontal lines are the first and third quartiles of the values and mark the bounds of strong and weak year classes. The dashed line is the trend in year class strength through time.

Sauger were historically less important to the commercial fishery than walleye. From 1968 to 1970 commercial sauger harvest averaged 15,800 pounds (Figure 11). In the five years prior to the removal of the commercial fishery from Lake of the Woods, commercial sauger harvest averaged 13,660 pounds. Sauger did not become a major component of the sport harvest until the winter fishery expanded. The winter fishery from 1968 through 1970 was very small and only 1,700 pounds of sauger were harvested annually. This fishery grew substantially through the 1970s and 1980 to where approximately 161,000 pounds of sauger were harvested during the winter of 1982. During the most recent five-year period (2001 to 2005), winter harvest of sauger averaged 250,000 pounds. Total sauger harvest averaged 48,000 pounds from 1968 through 1970, 192,000 pounds from 1981 through 1985 and 289,000 pounds from 2001 through 2005.Note that between 1981 and 1989 only two winter creel surveys were conducted. Blank years were filled with averages of preceding and succeeding years.

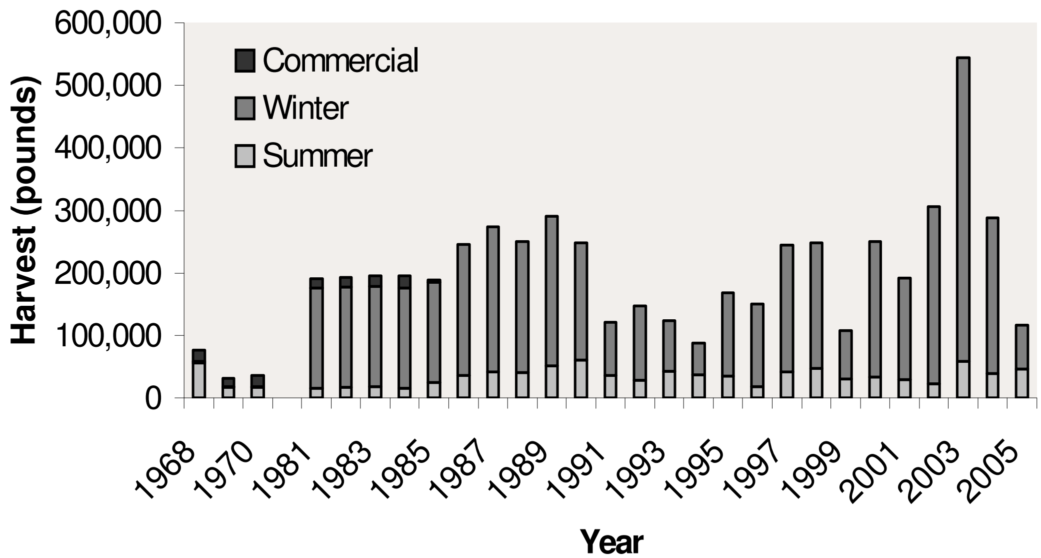

Figure 11. Total sauger harvest from 1968 to 1970 and 1981 to 2005. Note that in years without a winter creel survey, harvest estimates were made by averaging preceding and succeeding surveys. Summer creel surveys have been annual since 1981. Minnesota waters of Lake of the Woods.

Lake of the Woods Sauger Discussion

The harvest history of sauger on Lake of the Woods is very different than that of walleye. Walleye have been heavily harvested since the early 1900s. In contrast, intensive sauger harvest did not start until the establishment of the winter fishery in the early 1980s. As such, data from the 1968 to 1970 assessment reflect a very lightly exploited population. As the cormorant population expanded on Lake of the Woods through the 1980s the winter fishery also expanded. Additionally, from 1986 to 1996 a commercial fishery specifically targeting sauger existed just across the border on the Ontario portion of Lake of the Woods. The Ontario commercial fishery ended after 1996 due to concerns that the sauger population was showing signs of over-harvest in the early and mid 1990s (Anonymous 1998).

Since the start of the increase in harvest on sauger in the late 1970s and early 1980s, the sauger population has remained stable. Overall abundance and year class strength do not show significant increasing or decreasing trends (p=0.92, abundance, p=0.96, year class strength). A significant decline in the sauger population took place from 1991 through 1997. The high sauger abundance in 1991 was likely the result of the moderately strong to strong year classes produced in 1987, 1989 and 1990. The rapid decline in overall sauger abundance after 1991, despite the presence of the strong year classes, can be attributed to the combined effects of the winter sport fishery in Minnesota and the sauger targeting commercial fishery in Ontario. With the elimination of the commercial fishery, the sauger population rebounded.

Lake of the Woods-Yellow Perch and Other Forage Species

Yellow perch are not a major component of the sport fishery on the Minnesota portion of Lake of the Woods. Until recently winter anglers would frequently discard yellow perch onto the ice rather than release them. Strong year classes are occasionally produced. When perch grow to 10 inches or longer most anglers accept them. Angler and sport harvest during the 1968 to 1970 survey averaged 30,000 pounds per year During the early 1980s, yellow perch harvest was only 7,000 pounds, but in the 1997 to 2003 period yellow perch harvest averaged 56,000 pounds.

Figure 12 shows that yellow perch abundance has varied widely since 1968. Catch per lift has varied from 6.0 (1968) to 29.9 (1984) per lift. The 1968 to 1970 assessment was a period of very low yellow perch abundance. Generally, low periods of abundance have been followed by sharp increases in abundance. Figure 12 suggests that overall yellow perch is increasing. This apparent trend is likely strongly influenced by the low abundance in the 1968 to 1970 survey and the relatively high abundance documented from 2001 to 2003. The increase in yellow perch abundance since 1968 is a significant trend (p=0.02).

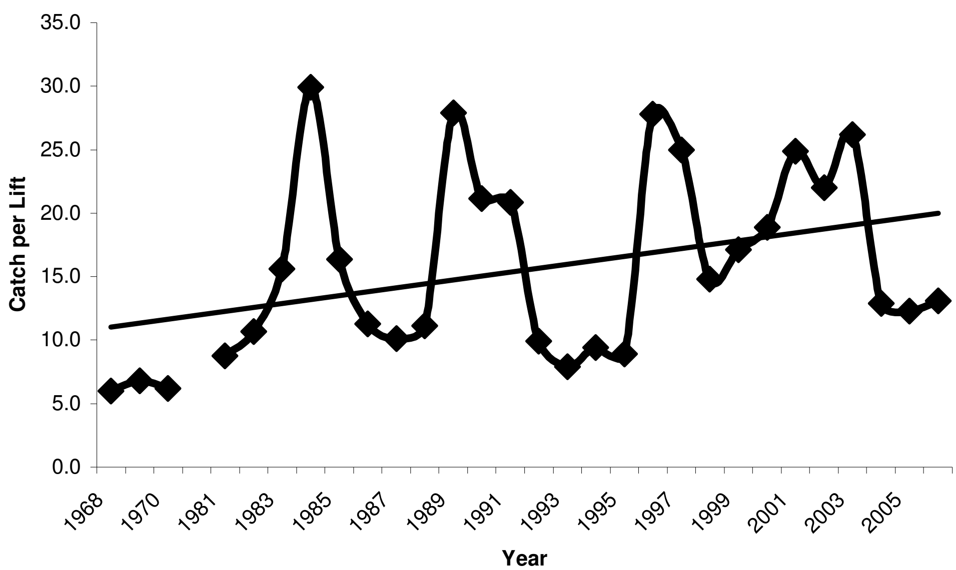

Figure 12. Yellow perch abundance (number of yellow perch per lift) as measured by standard experimental gill nets. The straight line through the points is the regression of abundance over time. Minnesota waters of Lake of the Woods, 1967-1970 and 1981-2006.

Yellow perch have been aged since 1990, so year class strength information is more limited than it is for walleye and sauger. The period for which yellow perch year class strength is available is entirely within the period of cormorant population stability. Yellow perch year class strength has been quite stable since 1989, with only two weak and three strong year classes (Figure 13). The trend line through year class strength suggests that year classes have been getting stronger since 1989, though the trend is not significant (p=0.56).

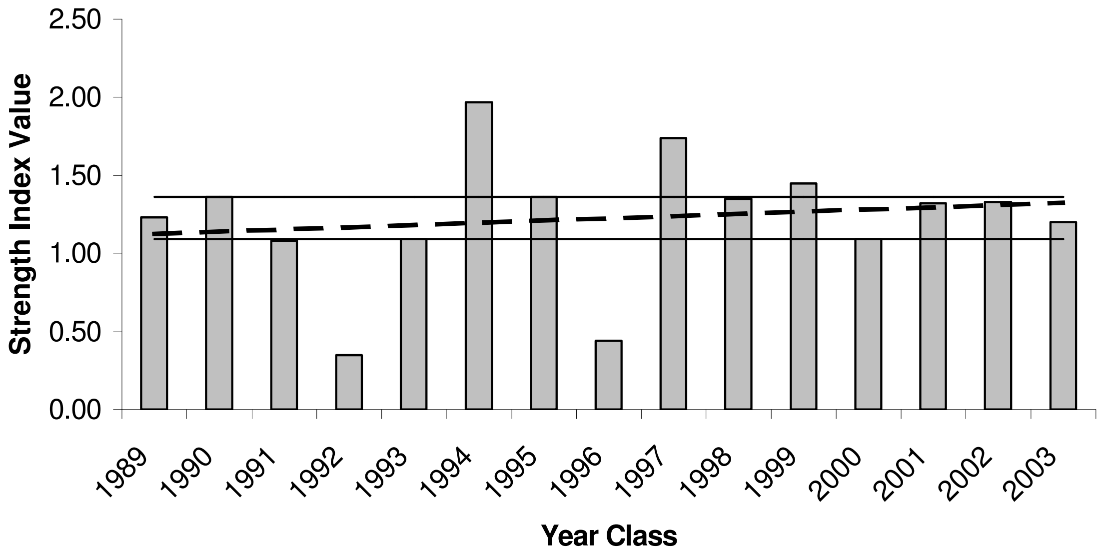

Figure 13. Yellow perch year class strength based on least squares means of natural log transformed age-2 to age-5 gill net CPUE, from fall gill net assessment. Solid horizontal lines are the first and third quartiles of the values and mark the bounds of strong and weak year classes. The dashed line is the trend in year class strength through time.

Age-0 and age-1 yellow perch are major forage items for walleye and sauger on Lake of the Woods. The abundance of forage species, including yellow perch, has been measured through trawling since 1991 (trawling has been conducted since 1989, but sites were standardized since 1991, with minor modifications in 1995). In addition to forage species, the abundance of age-0 walleye and sauger is measured. Figure 14 shows how the overall abundance of forage species, expressed as biomass per trawling hour, has varied since 1991. Catch rates (number per hour reported in annual Lake of the Woods Large Lake Survey Reports) were converted to biomass by multiplying by the mean weight (g) of each species and life stage sampled.

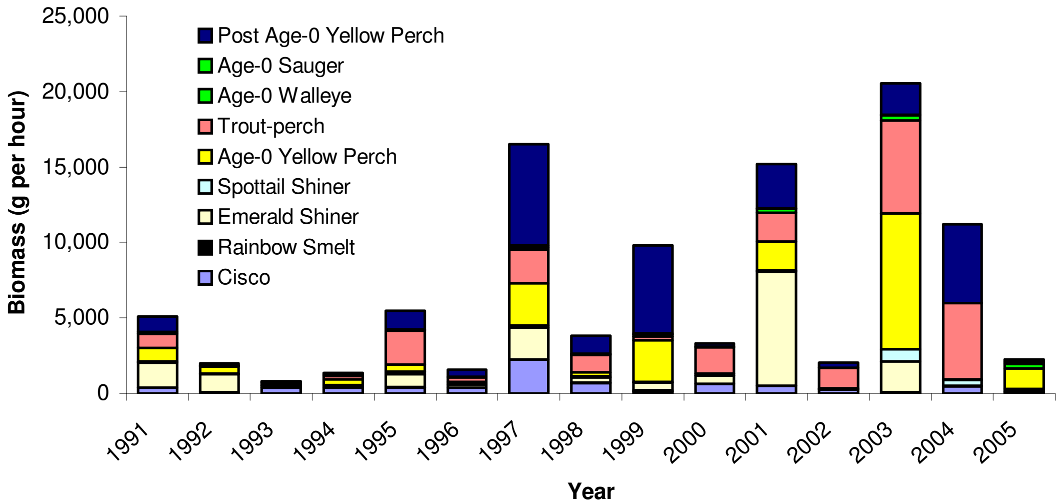

Figure 14. Biomass of trawl sampled species. Biomass is the mass (g) sampled per trawling hour. Minnesota waters of Lake of the Woods.

Figure 14 shows that the overall abundance of forage items varies widely by year. The variability is not caused by variation in abundance of any species, but rather by all species and life stages in the sample. For example, age-0 yellow perch have ranged from being the largest single component of the sample in 2003 to being virtually undetected in 2004 (CV=171). Even in years when overall forage abundance is high, some life stages and species that frequently comprise a large portion of the sample can be present at very low abundance. Other major species in the sample such as emerald shiner (*Notropis atherinoides*) and trout-perch (*Percopsis omiscomaycus*) have had similar ranges of abundance. In general, coefficients of variation were quite high for all species and life stages sampled in the trawling program. The species with the lowest coefficient of variation in the trawling sample were age-0 walleye (CV=108) and age-0 sauger (CV=103). Age-0 walleye and sauger are a very small component of the overall biomass sampled.

Summary

The focus of this paper is to describe trends in walleye, sauger, yellow perch and forage fish populations and to test if any trends could be correlated to changes (increases) in cormorant abundance. Overall abundance of walleye, sauger and yellow perch is available from 1968 to 1970, and then annually since 1981. This period encompasses the entire range of changes in the cormorant population on the Minnesota portion of Lake of the Woods, from before population expansion, through the expansion in the 1980s, and through 13 years of population stability. If increased cormorant abundance caused an increase in additive mortality on walleye, sauger or yellow perch, the increased mortality would be expressed as high abundance in the late 1960s, declining abundance through the 1980s and stable abundance, though at a lower level than during the 1960s, to the present time. There is no declining trend in abundance in any of the three species. Due to the lack of a declining trend in abundance, it is highly improbable that the present level of cormorant abundance has negatively impacted the walleye, sauger or yellow perch populations on Lake of the Woods.

Year class strength indices are available for walleye and sauger. Walleye strength indices are available through the entire range of the cormorant population change, while sauger strength indices are available only from just prior to the cormorant population expansion. Since the greatest potential influence by cormorants on walleye and sauger populations would occur either before, or just as, these species have their strength indices scored, any additional mortality during early life would be reflected as lower year class strength indices. Though the strongest walleye year class produced during the period of this evaluation was produced while cormorants were present at very low levels, three weak and two moderate year classes were also produced during this period. Also, the second and third strongest year classes produced since 1963 (1991 and 2001) were produced after the cormorant population had expanded and stabilized. The trend in strength of year classes produced since 1963 is flat. There is no evidence in the year class strength indices to suggest that cormorants have been causing additive mortality to the walleye and sauger year classes on the Minnesota portion of Lake of the Woods.

Trawl data is only available since the cormorant population has stabilized and is therefore not useful to evaluate if forage item abundance has been negatively impacted by cormorants. It does however show that age-0 walleye and sauger are an extremely small component of the fish community, and may indicate why cormorants have not affected walleye and sauger population on Lake of the Woods. Other fish species of similar size are much more abundant than age-0 walleye and sauger. Since cormorants are an opportunistic feeder (Anonymous 2005), they are likely foraging on other species simply because they are more likely to encounter them.

Of all indicators examined for negative trends through time (due to increasing mortality) the only two that suggest increased mortality are predicting age-2 walleye abundance from age-1 abundance (Figure 5) and the decline in sport fishing CPUE. Predicting the gill net assessment abundance of age-2 walleye from the gill net abundance of age-1 walleye is problematic because neither age-1 nor age-2 walleye are fully recruited to the gill net sample. Since they are not fully recruited, and recruitment is based on size, any changes in growth would be reflected as differences in perceived abundance. In any case, the trend suggesting a decline in the number of age-2 walleye per age-1 walleye is not significant. Also, the trend of increasing number of age-3 walleye per age-1 walleye (Figure 6) through time is counter intuitive if the trend suggested by Figure 5 were real.

The significant decrease in walleye sport harvest rate since the 1968 to1970 survey may have several causes. Annual gill net sampling does not suggest a decline in abundance of the walleye population, so the cause is likely a change within the sport fishery. The increasing size of boats and greater sophistication of electronics should serve to increase angler catch, and thereby, harvest rates, through the period. Overall harvest has increased, but this increase in harvest has been driven by increased participation in the sport fishery. Currently the sport fishery alone is harvesting more walleye than were harvested by the combined sport and commercial fisheries during the 1968 to 1970 study. The larger annual harvest through a greater number of anglers simply leaves fewer fish per angler. Another potential cause is changing values within the fishery. Release rates were not reported for the 1968 to 1970 study, but anglers are currently more open to releasing walleye that they would have harvested during the earlier study. For instance, during the summer of 2006 the harvest rate was 0.31 walleye per hour and the release rate was 0.28 walleye per hour, for a total catch rate of 0.59 walleye per hour. Schupp (1974) reported that anglers started to harvest walleye when they reached 12 inches in length. If walleye that were shorter than 12 inches are removed from the release rate found in 2006, the release rate becomes 0.16 walleye per hour. It is likely that these fish would have been harvested during the 1968 to 1970 study. If this assumption is correct the harvest rate in 2006 would have been 0.47 walleye per hour and would have exceeded the harvest rate in two of the three years of the 1968 to 1970 study.

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