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RR2096 September 2011

Habitat and Fish Community Changes in the Michigan Waters of Green Bay 1989–2005

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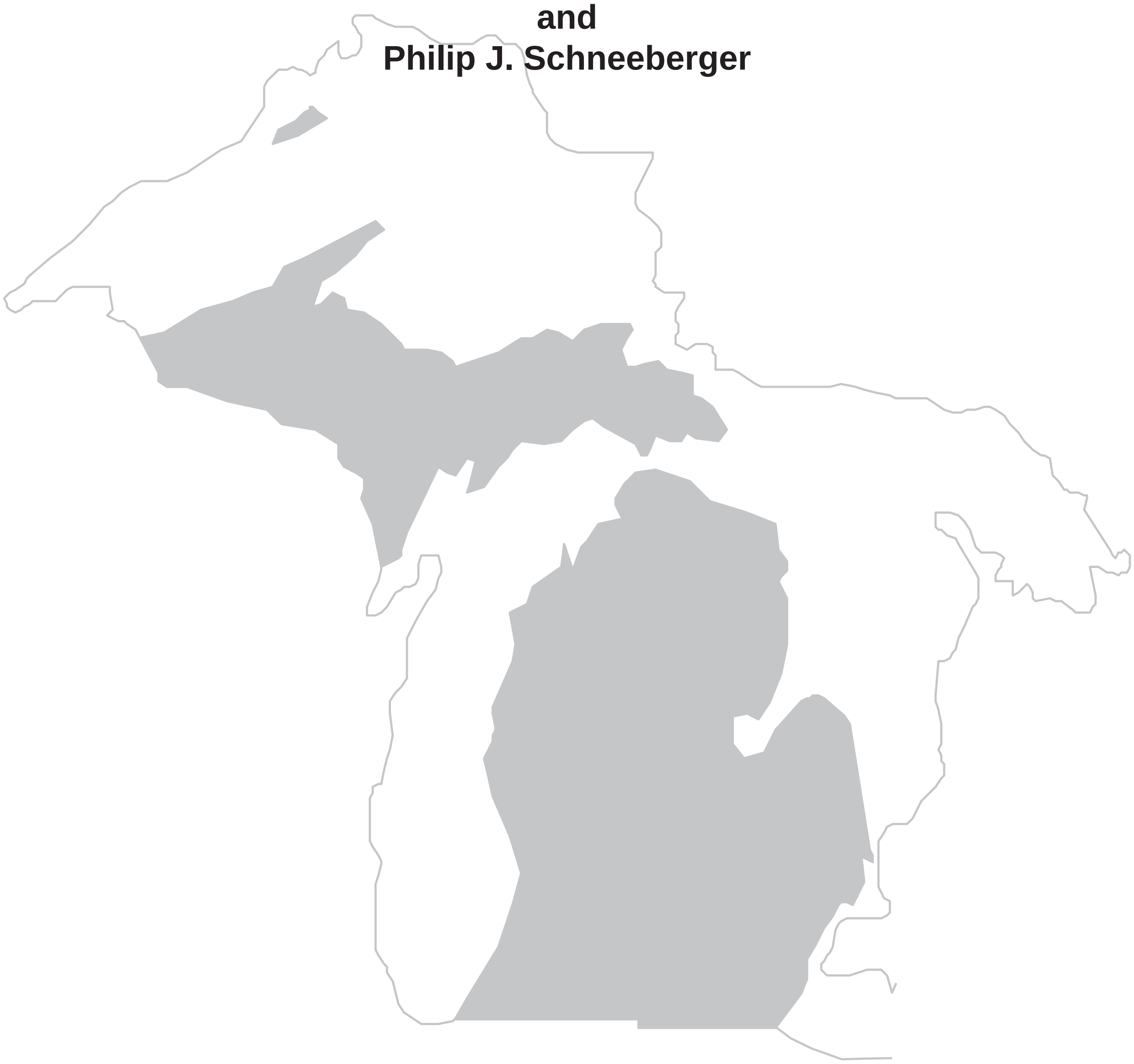

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Suggested Citation Format

Zorn, T. G., and P. J. Schneeberger. 2011. Habitat and fish community changes in the Michigan waters of Green Bay 1989–2005. Michigan Department of Natural Resources, Fisheries Research Report 2096, Lansing.

Michigan Department of Natural Resources
Fisheries Research Report 2096, 2011

Habitat and Fish Community Changes in the Michigan Waters of Green Bay 1989–2005

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Abstract.–The Michigan waters of Green Bay support the largest recreational fishery in Michigan's Upper Peninsula, with anglers targeting walleye *Sander vitreus* and yellow perch *Perca flavescens* most of the year. The need for data to support fisheries management led to initiation of trawl and gill net assessment surveys in Little Bay de Noc (LBdN) and Big Bay de Noc (BBdN) (collectively Bays de Noc or BDN) in 1988. Jaw-tagging studies to characterize walleye movement, exploitation, and survival started in the late 1980s and early 1990s for LBdN, BBdN, and the Cedar and Menominee rivers. From 1988 to 2005, summer water clarity increased 45% in LBdN and 19% in BBdN, and August and September surface water temperatures increased 16%. Assessment survey data for the period showed declines in yellow perch, trout-perch *Percopsis omiscomaycus*, rainbow smelt *Osmerus mordax*, spottail shiner *Notropis hudsonius*, and alewife *Alosa pseudoharengus*, but increases in brook stickleback *Culaea inconstans* and smallmouth bass *Micropterus dolomieu*, suggesting a decreased pelagic component in the fish community. Several of these species concurrently declined in the diets of walleye and yellow perch as well. Round gobies *Neogobius melanostomus* made their first appearance in Bays de Noc (BDN) assessment catches in 1998, and as of 2005, made up over 75% of trawl catches. Eurasian ruffe *Gymnocephalus cernuus* were first detected in 2004, and currently are at relatively low abundance levels. Walleye and yellow perch were a focus of our study. Data from assessment, tagging, and creel surveys indicated a much larger population of walleye in LBdN (compared to BBdN), with unstocked year classes being well-represented, and provided good evidence for natural reproduction. Age estimates of fish from surveys showed few walleyes representing nine unstocked year classes in BBdN, and no walleyes from unstocked years in Cedar River. However, 11 of 15 unstocked year classes of walleyes were represented in the Menominee River. Based on 1,946 angler reports of jaw-tagged walleyes, we estimated angler exploitation (adjusted for nonreporting) and walleye survival from 1997–2005 for our study populations as follows: 10.4% and 54% in LBdN; 8.1% and 67% in BBdN; 7.5% and 76% in Cedar River; and 11.8% and 59% in Menominee River. Over 90% of recaptures of walleyes tagged in LBdN, BBdN, and the Menominee River occurred within 20 km of spawning areas where tagging occurred. In contrast, 66% of walleyes tagged in and near the Cedar River and recaptured by anglers were more than 40 km from tagging sites. As our study progressed, walleyes tagged at sites in LBdN and Menominee River and later recaptured in spring and summer were generally caught further and further from tagging sites, and the proportional contribution of summer-caught walleyes to the LBdN fishery declined substantially. Both observations meshed with angler complaints, suggesting a shift in the fishery in response to changing biophysical conditions in LBdN. Abundances of age-0 and age-1 and older yellow perch reached their lowest levels in BDN during 2000–05. There was little correlation in yellow perch trends among BDN, southern Green Bay, and other Lake Michigan locations, and further analyses indicated a need for additional sampling effort to increase precision of abundance indices for BDN fishes. Growth and survival of yellow perch have remained fairly steady over the study period, and samples were consistently dominated by female fish. Open-water harvest and catch per angler effort data from sport creel surveys at LBdN, BBdN, Cedar River, and Menominee River areas generally showed increases for walleyes and declines for yellow perch from 1988 through 2005. Data for the LBdN ice fishery showed a decline for both species during this time. The dynamic nature of northern Green Bay, the importance of its aquatic communities and fisheries, and management issues (e.g., walleye rehabilitation, invasive species effects, cormorant-fish community interactions) justify the need for continued assessment effort. More intensive effort is needed in BDN to increase the accuracy and precision of abundance trends. Sampling should be expanded to adjacent areas to increase fish community assessment information for nearshore areas of Lake Michigan in Michigan's Upper Peninsula outside of BDN.

Introduction

Northern Green Bay (i.e., Michigan's portion of Green Bay) supports the largest recreational fishery in Michigan's Upper Peninsula (UP). Recreational angling effort in these waters, which averaged over 550,000 angler hours per year over the last two decades, is nearly equivalent to the 650,000 hours of summer effort estimated for US and Canadian waters of Lake Superior and more than three times higher than angling effort in Michigan waters of Lake Superior (Zorn 2005; Ebener and Schreiner 2007). Approximately 22% of Michigan's sportfishing effort on Lake Michigan during 2000–07 occurred in northern Green Bay (T. Kolb, Michigan Department of Natural Resources, personal communication). The northern Green Bay fisheries are clearly important to Michigan and Midwestern anglers and provide substantial socioeconomic benefits to the region.

Northern Green Bay anglers primarily target walleye *Sander vitreus* and yellow perch *Perca flavescens* in nearshore areas throughout most of the year, with some pursuing salmonids in spring and fall. Walleye populations consist of relatively discrete, rehabilitating stocks composed of both naturally-reproduced and stocked fish (Schneeberger 2000). Walleye rehabilitation efforts have occurred in these waters since 1969, with 40.4 million fry and 14.9 million fingerlings stocked through 2005 in Big Bay de Noc (BBdN), Little Bay de Noc (LBdN), Cedar River, and Stony Point (i.e., Lake Michigan about 13 km north of the Menominee River mouth) (Table 1). The contribution of hatchery fish to stock abundance is thought to vary among these four locations, but is not clearly understood. Yellow perch populations are sustained entirely by natural reproduction. In the late 1990s, angler catches of yellow perch in the bays de Noc (BDN) declined from levels in the previous decade. These declines were roughly concurrent with yellow perch declines elsewhere in Lake Michigan's main basin (Schneeberger 2000; Clapp and Dettmers 2004; Makauskas and Clapp 2008). Fishery assessment data were needed to help direct management of these percid stocks.

In addition to percid management issues, northern Green Bay has had a steady influx of invasive species, most of which were likely introduced through ship ballast water. Notable introductions of species into LBdN (and year we observed them) include the cladoceran *Bythotrephes cederstroemi* (1988), three-spine stickleback *Gasterosteus aculeatus* (1989), white perch *Morone americana* (1990), zebra mussel *Dreissenia polymorpha* (1993), and later, quagga mussel *Dreissenia bugensis*, round goby *Neogobius melanostomus* (1998), and Eurasian ruffe *Gymnocephalus cernuus* (2003). Monitoring was needed to document changes in the aquatic environment and fish community and to help direct future fishery management.

The importance of the fishery and fish stocks, the need for assessment data to support management, and the changing biophysical environment of northern Green Bay, especially in LBdN and BBdN, (referred to collectively as Bays de Noc or BDN) led to initiation of fishery assessment and tagging studies in the BDN in 1988 (Schneeberger 2000). The overall objectives of this report are: 1) to describe fish population trends for the BDN since 1989, as well as the current status of aquatic communities in the BDN, with emphasis on yellow perch and walleye; and 2) to characterize movement, exploitation, survival, and natural reproduction of walleye populations associated with LBdN, BBdN, and the Cedar and Menominee rivers. Data presented in this report were collected during 1997–2005, and analyzed and compared with information collected for 1989–96 by Schneeberger (2000).

Methods

Study Area

The waters of northern Green Bay cover an area of 277,537 ha in northwestern Lake Michigan. Field work for this study occurred in four areas of northern Green Bay namely, BDN and the Cedar and Menominee rivers (Figure 1). Assessment surveys focused on BDN, located in the northernmost portion of Green Bay (Figure 1). The two bays provide an interesting contrast. Little Bay de Noc is smaller at 16,100 ha compared to 37,711 ha for BBdN. An abrupt contour break along much of LBdN's length produces fairly distinct shallow (<3 m) and deeper (12 to 30 m) habitats. Except for its southeastern shoreline, BBdN is generally shallow (over half of its area < 9 m deep) with gentle contours throughout. Little Bay de Noc is fed by six rivers with high-gradient rapids that provide potential spawning habitat for walleye. These rivers are the Whitefish, Rapid, Tacoosh, Days, Escanaba, and Ford. The medium-sized Whitefish River (catchment area 794 km^2) likely supports the largest spawning run of walleye due to its: 1) connectivity throughout the lower half of its length; 2) natural flow and temperature regime; 3) many kilometers of high-quality rapids for spawning; and 4) extensive estuarine nursery habitat associated with its former role as a glacial outlet for Lake Superior. The larger Escanaba River (catchment area 2,381 km^2) is affected by a dam located 3 km upstream of its mouth. In contrast, major streams draining into BBdN (Ogontz, Sturgeon, Big Fishdam, and Little Fishdam rivers) are all predominantly sandy in their lower reaches, providing limited spawning habitat for walleye. However, rocky reefs potentially suitable for walleye spawning occur throughout BBdN (e.g., around St. Vital, Round, and Snake islands), and in LBdN (e.g., around the mouth of the Whitefish River and along the eastern shore south of Gladstone). Yellow perch spawn throughout both bays. The array of lake, bay, river, and estuarine conditions in the BDN provide habitat for many other species of fish as well (Table 2).

Walleye populations that make spawning migrations into the Cedar and Menominee rivers were also studied (Figure 1). The Cedar River is a medium-sized river (catchment area of 819 km^2) that is unfragmented for the lower two thirds of its length, with numerous rapids occurring to within about 1 km of the river mouth. Estuary habitat is limited as the river flows between breakwalls before emptying into Lake Michigan. The much larger Menominee River (catchment area of 10,496 km^2), which forms part of the Michigan-Wisconsin boundary, has considerable high-gradient rapids, but is impounded 4 km upstream of its mouth. However, a rapids complex extending 1 km downstream of this dam is used by spawning walleye. Estuary habitat is limited as the river has dropped its sediment load in upstream impoundments (rather than a Great Lakes estuary), and is largely confined by seawalls and breakwalls before entering Lake Michigan.

Data Collection

Sampling periods.–Various types of data were collected, compiled, and analyzed in this study. We summarized much of the 1989–2005 data into three periods to facilitate description of broad trends over the study. The three periods divide the data equally and roughly correspond to different ecological events: zebra mussel invasion (1989–93); transition (1994–99); and round goby invasion (2000–05). Statistical analyses were conducted using SPSS (2006) and tests were considered significant when $P \leq 0.05$.

Summer assessments.–Marquette Fisheries Research Station personnel collected monthly bottom trawl and gill-net samples from June through September 1997–2005 in BDN at the same locations and using identical methods to those of Schneeberger (2000) for collection of 1989–96 data. Netting stations in 1988 differed from those of later years, so 1988 fish collections were excluded from analysis. Weather condition, water clarity (Secchi disc depth), and water temperature profile data were collected at gill netting stations and trawling areas for each monthly sample. We examined temporal trends in water clarity and temperature using simple linear regression. The bottom trawl was a shrimp try net with a 3.7-m headrope, 19-mm square mesh body, and 6.4-mm square mesh cod end liner. Trawl hauls were of 10-min duration in waters 2.5–12 m deep, and generally followed bottom contours. Five trawl hauls were done per bay per month. Although specific stations were not established, trawling was conducted in the same general areas from month to month and year to year. Trawling transects varied among surveys as dictated by weather conditions, to ensure safe sampling with the relatively small (6 m long) survey boat used in this study. In Little Bay de Noc, trawling was concentrated in waters north of Saunders Point near the public access site at Kipling (Figure 1). In Big Bay de Noc, trawling was conducted mostly in Ogontz Bay.

Gill nets were 1.83-m deep and 18.3-m long, with 3.05-m panels of experimental monofilament stretch mesh measuring 25-, 38-, 51-, 64-, 76-, and 102-mm. Two 18.3-m gangs were tied together to provide replication of each mesh size for any overnight set. Gill net index stations were established at locations that were 3.1 m and 6.1 m deep in each of the BDN (Figure 1). Gill nets were set on the bottom parallel to shore at the appropriate depth contour. One overnight (~24 h) set occurred at each station per bay per month. In LBdN, the 3-m station was located near the east shore along a bank just north of Hunters Point and the 6-m station was located along the west shore just south of Saunders Point. In Big Bay de Noc, the 3-m station was located in Ogontz Bay between the public access site and St. Vital Island, and the 6-m station was between St. Vital Island and Indian Point. From the annual gill net and trawl CPUEs, we computed mean CPUEs and 95% confidence intervals by time period, location, and species for each gear type, and used non-overlapping confidence intervals to indicate a significant change. Trawl CPUE of age-0 yellow perch (fish < 89 mm) was used as an index of year-class strength, and gill-net CPUE of age-1 and older yellow perch (fish ≥ 89 mm) was used as an index of older perch for comparison with data from other Lake Michigan studies (e.g., Makauskas and Clapp 2008).

Fish captured in trawls and gill nets were examined in the field. We obtained total length, weight, sex, maturity, and diet data for representative numbers of each species caught in gill nets. Aging structures (scales or spines) were obtained from walleyes and yellow perch to assess age and growth. Fish stomach contents were examined in the field and food items were identified and counted. Fish prey were measured and identified to species when possible. Insects were identified to order or family, and zooplankton was considered a broad, inclusive category except that *Bythotrephes cederstroemi* was differentiated from other zooplankton. Many fish were measured but not examined internally, and others were only counted. Fish collected in trawls were usually measured and counted due to their small size (typically < 100 mm). Supplemental samples of fish were sporadically taken from 1997 to 2002 using seines and daytime boom shocking. Diet data were summarized as percentages and reported, but not statistically tested.

Trends in yellow perch growth and survival were assessed over time. We used mean length of age-3 female yellow perch to index changes in growth rates over the study period. We chose age-3 females because they were well represented in our data and were of a size that anglers will typically consider for harvest. We computed total annual mortality of yellow perch year classes using the "best" minimum-variance unbiased estimators of survival derived from coded age frequencies (Robson and Chapman 1961). To increase the sample size for these annual calculations, we pooled data for each year with the two subsequent years, and used the 3-year datasets to estimate total annual mortality and survival. Total annual mortality was calculated for data sets of age-3 to age-9 fish, but the lack of fish older than age-7 during 1993–96 may have affected mortality calculations from pooled data that included those years.

Sport fishery harvest and effort data were collected for Michigan waters of Green Bay through an on-site creel survey conducted annually by Michigan Department of Natural Resources (DNR) personnel (Federal Aid to Sport Fish Restoration, Grant F-53-R, Study 427). The waters and seasons surveyed varied by year, and targeted effort was not recorded. Harvest and effort data were summarized and reported, but not statistically tested. Age and length structure data were obtained from a representative sub-sample of angler-harvested fish as part of the creel survey. Significant changes in these parameters among periods or locations were indicated by non-overlapping confidence intervals (approximated by two times the standard error) about the estimated means.

Walleye tagging.–Individually-numbered monel bird leg bands were used to jaw-tag walleye captured during April and May when fish were concentrated for spawning. Boom shocking boats and trap nets (0.91 m high with 38-mm mesh) were used by survey crews to catch fish for tagging. Total length, sex, occurrence of lymphocystis disease, location, and date were recorded for each tagged fish. Tag number, length, sex, and location were noted for fish tagged in previous years that were recaptured during tagging operations. All tagged walleyes were of harvestable size (≥ 381 mm total length) so they would be available to sport anglers when the fishing season opened. In 2002, aging structures (dorsal spines) were collected from up to 20 tagged walleye per sex and 25-mm length group. Numbers of aging structures collected by location were: LBdN- 187; BBdN- 18; Cedar River- 180; and Menominee River- 215. Significant differences in length at age among populations were indicated by non-overlapping confidence intervals (approximated by two times the standard error) about the estimated means for age classes with at least 15 samples. Target numbers of fish to tag, as well as estimates of exploitation and survival rates were calculated for walleye using tag return data and formulae provided by Brownie et al. (1985).

Anglers catching tagged fish were asked to report the tag number, fish length, date, location of capture, and whether they kept or released the fish. In return, they received a form letter thanking them for their cooperation and providing them with information on their catch (i.e., number of days between the tag and capture dates, distance between the tag and capture sites, and estimated age and growth of their fish). We computed standardized tag return rates (i.e., number of tags returned per 100 tagged fish) to assess tag return rates for walleyes caught in summer (Wang et al. 2007).

Results

Water Clarity and Temperature

Analysis of standard physical data collected for each sampling effort showed significant changes in water clarity and summer temperature conditions in the BDN. Water clarity, as measured by June through September Secchi disc depth readings increased significantly ($P < 0.05$) between 1988 and 2005 in both bays (Figure 2). Using the significant regression equations, we estimated that summer water clarity increased 45% in LBdN (from 2.9 to 4.2 m) and 19% in BBdN (from 3.7 to 4.3 m) during 1988–2005. We also found a significant warming trend for 1988–2005 in the BDN based on surface water temperatures from August and September surveys (Figure 3). We saw no obvious difference in warming over time between bays. Using the regression equation for the pooled data, we estimated that August and September surface temperatures increased 15.5% (from 17.8 to 20.5ºC) for 1988–2005.

Fish Community Trends

Thirty species of fish were caught using trawls in BDN during 1997–2005 (Table 2). Most frequently collected species (in decreasing order) were yellow perch, round goby, johnny darter, trout-perch, brook stickleback, and smallmouth bass (Table 2). While annual CPUE values for species were sometimes quite variable, fairly clear patterns were evident when data were summarized over major time periods. Declines in yellow perch, trout-perch, rainbow smelt, and spottail shiner between the first and third periods were apparent, though not always significant, for both BDN (Tables 3 and 4). Brook stickleback and smallmouth bass were caught in trawls with greater frequency during the last decade in BBdN (Table 4). Brook stickleback CPUEs have also increased in LBdN, where they are caught less frequently than in BBdN (Appendix 1).

Thirty-four species of fish were collected from BDN using gill nets (Table 2). Species most commonly caught in the gill nets (in decreasing order of frequency) were yellow perch, walleye, alewife, spottail shiner, white sucker, northern pike, and smallmouth bass (Table 2]). Gill net CPUE trends for several species mirror those from the trawl data, namely declines in yellow perch, trout-perch, and spottail shiner (Tables 5 and 6). We also saw a notable decline in alewife CPUE during 2000–05 for both bays, as well as slight declines for northern pike in LBdN and white sucker in BBdN. Smallmouth bass catches have been higher during the last two periods in both bays, paralleling the trend for this species in the trawl data (Tables 5 and 6). Gill net CPUE data for the 2000–05 time period has also shown more frequent catches of freshwater drum in both BDN and gizzard shad in LBDN during (Appendix 2).

Two invasive fish species made their initial appearances in the BDN between 1997 and 2005. Round gobies first appeared in our LBdN trawl catches in 1998 (2002 for BBdN), and by 2005 they made up 77% and 82% of the annual trawl catches in LBdN and BBdN (Tables 3 and 4). Johnny darter CPUE declined in LBdN during 2000–05, coincident with the build-up of round goby populations (Table 3). Johnny darter CPUEs have remained relatively stable in BBdN, which was colonized later by round goby (Table 4). Eurasian ruffe was first detected in our trawl catches in both BDN during the summer of 2004, but their populations have not shown explosive growth like those of round goby.

Walleye Assessment Netting

Walleye populations in northern Green Bay represent a mix of stocked (LBdN strain) and naturally reproduced fish. Areas of Northern Green Bay were stocked with the following numbers of walleye fingerlings between 1997 and 2005: LBdN- 1,873,202; BBdN- 2,797,294; Cedar River- 457,927; and Stony Point- 354,177. The initiation of a study in 2004 to evaluate walleye reproduction in BDN and a change in walleye management for the Cedar and Menominee rivers resulted in a re-allocation of walleye among stocking sites (M. Herman, DNR Fisheries Division, personal communication). Comparing the 1997–2005 numbers of walleye fingerlings stocked with those for 1988–96, the following percent changes in stocking effort occurred: LBdN (-12%); BBdN (+65%); Cedar River (-59%); and Stony Point (-66%).

Assessment netting results indicated that the LBdN walleye population was considerably larger than that of BBdN. Average catch per unit effort (CPUE) for walleye in LBdN (1.7 walleye per 18 m gill net) was 5.4 times higher than that for BBdN for 1989–2005 (Tables 5 and 6). Examination of CPUE data showed no obvious trend during 1989–2005 in either bay. Gill net CPUEs for the 1989–93, 1994–99, and 2000–05 periods were 1.8, 1.5, and 1.8 walleyes per net night in LBdN and 0.4, 0.3, and 0.3 in BBdN (Tables 5 and 6). Average trawling CPUE for walleye in LBdN (0.24 fish per 10-minute tow) was roughly 50 times greater than that of BBdN (Appendix 1). Few walleyes were caught in our trawls during the 1989–2005 study period (92 walleyes in LBdN and 2 in BBdN).

However, higher catches in the early 1990s and the small size of walleye typically caught in our trawling (75% of fish were less than 254 mm) suggests that walleye reproductive success or survival of stocked walleye in LBdN was higher than in BBdN (Appendix 1).

Gill nets, trawls, boom shockers, and seines were used to capture walleyes for stomach content analysis. Sample sizes by time period for walleye diet composition ranged from 162 to 303 in LBdN, and from 26 to 168 in BBdN (Table 7). Empty stomachs were recorded for 25–50% of the walleyes examined.

Walleyes collected in field samples were mainly piscivorous during all time periods of the study (Table 7). Fish occurred in 78–100% of the stomachs having identifiable food items. Although most fish consumed by walleyes were digested past the point of being classified, twelve different species were recognizable, and their relative composition in diets varied by bay and by time period.

Alewife became increasingly common as food items for walleyes in LBdN, with occurrence rates growing from 9 to 27% over the three time periods. In BBdN, alewife occurred more frequently than any other species in walleye stomachs, though it was part of a greater diversity of fish species eaten during 2000–05 compared to earlier time periods. In contrast to the pattern for alewife, the dietary occurrence of rainbow smelt declined drastically from 19% to 1% over the three time periods in LBdN, and from 11% to 0% in BBdN. Round gobies first appeared in walleye diets between 2003 (LBdN) and 2005 (BBdN). Trout-perch were marginally important in LBdN walleye diets until they dropped out completely during 2000–05; trout-perch were never identified in BBdN walleye stomachs.

Insects were found in 13–18% of the LBdN walleyes during all time periods, but only during 2000–05 in 9% of the walleye in BBdN. Large burrowing mayflies (Ephemeroptera, *Hexagenia* spp.) composed the great majority of insects that were eaten. Apart from fish and insects, walleyes ate few other food items (Table 7).

Walleye Tagging

We tagged 24,877 walleyes in northern Green Bay between 1997 and 2005 (Table 8). Walleye were tagged at the north end of LBdN (N = 5,099), at various locations in BBdN (N = 2,618), in and near the Cedar River (N = 7,801), and in the Menominee River (N = 9,359) below the first dam. We processed 1,946 angler reports of tagged walleyes from northern Green Bay caught between 1997 and 2005. Estimated annual exploitation rates averaged for 1997–2005 (and for the entire tagging period) were 3.6% (3.8%) in LBdN, 2.8% (3.0%) in BBdN, 2.3% (2.8%) in Cedar River, and 3.2% (4.4%) in Menominee River (Table 8). Using a nonreporting adjustment factor of 2.7 derived for Lake Erie walleyes (Thomas and Haas 2005), we estimated mean annual exploitation of walleyes as 10.4% in LBdN, 8.1% in BBdN, 7.5% in Cedar River, and 11.8% in Menominee River. The exploitation rate of walleye declined in Menominee River after 1995, and has shown little obvious change in other study areas (Table 8).

Annual survival of walleye for 1997–2005 (and for the entire tagging period) were 54% (52%) in LBdN, 67% (65%) in BBdN, 76% (64%) in Cedar River, and 59% (50%) in Menominee River (Table 8). Examination of annual survival values suggests that walleye survival has generally increased in Cedar and Menominee rivers over time while showing little trend in the BDN.

Tag return data obtained from anglers for nearly 4,400 walleyes between 1988 and 2005 have revealed two distinct patterns of movement (Table 9). Walleye tagged in LBdN, BBdN, and the Menominee River show relatively little movement from tagging locations, with over 90% of tagged fish recaptured within 20 km of spawning areas where they were tagged (Table 9, Figure 4, Figure 5, Figure 6). In contrast, walleyes tagged in and near the Cedar River exhibited a bimodal movement pattern; only 31% were recaptured within 20 km of tagging sites and 66% were recaptured more than

40 km away (Figure 7). Fifty-one percent of tagged walleyes from Cedar River were recovered in and around the Menominee River, about 40 km away.

The distance of movements varied seasonally and among populations (Table 10). Walleyes recovered from BBdN typically were 3–8 km from tagging sites during all seasons. Average displacement of walleyes from Cedar River tagging sites was 9 km in fall, but 36–47 km during other seasons. Menominee River tagged walleyes were recovered nearest to river tagging sites in winter and spring (5.5 and 3.8 km away), but were further out in the Green Bay in summer and fall (mean displacements of 12.4 and 18.1 km). Walleyes tagged at sites near the north end of LBdN were recaptured fairly close in fall and winter (average displacements of 4.8 and 4.5 km), and ventured somewhat further from the inner bay in late spring and summer (9.3 and 8.7 km).

As our study progressed, walleyes tagged at sites in LBdN and Menominee River and later recaptured in spring and summer were generally caught further and further from tagging sites. Average displacements of walleyes caught during summer for the 1988–93, 1994–99, and 2000–05 time periods were 7.2, 10.4, and 20.1 km for LBdN-tagged walleyes and 1.0, 8.7, and 24.2 km for walleyes tagged in Menominee River. Similar trends were seen for these locations in spring (Table 10).

In addition to the change in summer displacement patterns, we also received fewer reports over time of tagged walleyes caught during summer (July 1 to September 30) in LBdN. Here, the average number of returns per 100 walleyes tagged declined over time as follows: 3.6 (1988–93), 2.8 (1994–99), and 1.2 (2000–05). There was no apparent trend in return rate of tagged walleye over time when looking at return rates for all months combined (Figure 8). As a result, the proportional contribution of summer-caught walleyes to the fishery declined substantially (Figure 8). Fewer data were available for examining such trends in BBdN, Cedar River, and Menominee River walleyes because tagging at these locations began in 1993. However, numbers of summer returns per 100 walleyes tagged in BBdN was higher in 2000–05 (3.6) than 1994–99 (2.0), though we have less confidence in the 2000–05 estimate because relatively few walleye were tagged during the latter period (972 vs. 6329). No obvious trends in summer return rates for fish tagged at Cedar and Menominee rivers were apparent, though a slight decline in return rates may have occurred in the Menominee fishery where return rates went from 1.8 (1993 only) to 1.4 (1994–99), and to 1.2 (2000–05).

Tendencies for walleye populations to exhibit fidelity to spawning site locations was assessed using data from walleyes that had been tagged during previous springs and were recaptured during subsequent tagging operations. Considering 1989–2005 data from all locations together, 96.4% of 4,054 recaptured walleyes returned to the same spawning area where they were originally tagged. Fidelity percentages varied only slightly among individual tagging sites, with highest percentages in Big Bay de Noc (99.6%; N = 1,121) and Little Bay de Noc (97.5%; N = 1,001) and somewhat lower percentages in Menominee River (94.3%; N = 1,003) and Cedar River (94.0%; N = 929). Walleyes that strayed from Big Bay de Noc were recaptured in Little Bay de Noc (3 fish), Menominee River (1 fish), and in Lake Michigan near Stony Point (1 fish). Most strays from Little Bay de Noc were recaptured in Cedar River (14 fish), followed by Big Bay de Noc (9 fish), and Menominee River (2 fish). Menominee River walleyes were subsequently recaptured in spawning runs at Cedar River (35 fish) and Little Bay de Noc (22 fish). Fish originally tagged in Cedar River strayed to Menominee River (55 fish), and Big Bay de Noc (1 fish).

Sex-specific, length-at-age for walleyes caught during spring tagging operations exhibited no apparent trends over the study period, so mean values were computed from data for all years (Table 11). No significant differences in mean length at age occurred among the walleye populations (Table 11).

Based on fish aged from tagging surveys and summer assessments, evidence of consistent natural reproduction is greatest in LBdN (Table 12). In LBdN, numbers of walleyes collected during assessment surveys that represent the seven unstocked years are comparable to numbers of walleyes assigned to year classes when stocking occurred. Except for the 1990 and 1992 year classes, very few aged walleyes from surveys in BBdN were assigned to the nine unstocked years (Table 12). No walleyes from the Cedar River samples could be attributed to years without stocking (Table 13). Eleven of 13 unstocked years were represented by naturally-reproduced walleyes in the Menominee River, including nine year classes of walleyes from before 1988 when stocking was initiated at Stony Point (Table 13). However, the numbers of walleyes representing unstocked year-classes were generally low compared to walleyes from stocked years.

Size structure of each walleye population (based on tagging data for males) appears to have shifted toward increased proportions of large fish, suggesting good survival of adult walleyes (Figure 9). Average size of males tagged between the 1988–93 and 2000–05 periods increased by 52, 78, 98, and 83 mm in LBdN, BBdN, Cedar River, and Menominee River. Notable changes in size structure in Cedar and Menominee rivers are coincident with reduced stocking during the latter time period. Increasing proportion of larger-sized fish suggests that relatively few small walleyes are recruiting (i.e., limited natural reproduction) and that hatchery fish may be major components of their walleye populations. The smallest increase in average size was for the LBdN population, which may consistently exhibit the most natural reproduction.

Yellow Perch Assessment Netting

Yellow perch abundance in northern Green Bay has fluctuated considerably over time. Abundance of age-1 and older yellow perch during the 2000–05 period fell to its lowest level in both BDN (Figure 10, Table 5, Table 6). The decline was most dramatic in LBdN where the average gill net CPUE was one third of its value during 1989–93 when the population was at its peak (Table 5). Densities of age-1 and older yellow perch in BBdN were somewhat low in 2000–05 but have fluctuated well within the range of values observed since 1989 (Figure 10). The correlation in gill net CPUEs between bays during 1989–2005 was low and not significant.

Yellow perch reproductive success has varied considerably from year to year, but was relatively low in both BDN during 2000–05 as indicated by numbers of age-0 fish in trawl catches (Figure 11). During this period, trawl CPUEs for yellow perch in LBdN were less than half of values from the previous periods, and in BBdN they were 8–10 times lower (Tables 3 and 4). Trawl CPUEs for age-0 yellow perch in BBdN during years when abundance was high were often several times higher than those in LBdN (Figure 11). There appear to be some commonalities between bays with strong reproduction happening at both locations in 1991, 1995, 1998, and to a lesser extent in 1990 and 2001 (Figure 11). Despite this, the correlation in annual trawl CPUEs between bays was modest ($r = 0.40$) and not statistically significant. Age-0 trawl CPUE was not a strong predictor of gill net CPUE for age-1 and older yellow perch the following year, as our best regressions using it explained at most only 8% of CPUEs in BBdN and 31% in LBdN.

Growth and survival of yellow perch in Little and Big bays de Noc seem to have changed little since 1989. Yellow perch growth has remained fairly steady over the study period as indicated by mean length of age-3 females (Table 14), but remains above the long-term average since 2001. Yellow perch in BBdN grew faster than fish in LBdN, with mean lengths of age-3 females being significantly different (186 vs. 170 mm) for 1988–2005. An average of 68% of yellow perch caught in summer gill nets were females, and no obvious temporal trend in the sex ratio was observed (Table 14). Total annual mortality of age-3 to age-9 yellow perch averaged 0.55 for 1989–2003, and showed no obvious trend over the period.

Yellow perch ate a wide range of food items in both bays de Noc (Table 15). Between 398 and 2,311 yellow perch stomachs were examined over each time period in each bay. Most yellow perch collected for diet analysis were caught in gill nets and trawls, but samples also came from boom shocking and seining. Empty stomachs were found in 15–26% of yellow perch.

Crustaceans were the most frequently occurring food category for yellow perch in both bays. *Bythotrephes cederstroemi* was by far the most commonly eaten crustacean during all three time periods in LBdN; it was prominent but less important in BBdN where amphipods were the largest contributor in this category. Crayfish were important dietary components considering their frequency of occurrence in yellow perch stomachs, and certainly also because of their size and caloric content. Frequency of occurrence of crayfish in yellow perch stomachs increased over time in both bays, but most notably in BBdN. Crayfish were more prominent in BBdN yellow perch diets during 2000–05 than for any other time period. Isopods represented a noteworthy food item that declined in frequency of occurrence over the three time periods in both bays.

Insects were another important food category for yellow perch, with Dipterans (mostly chironomidae) and Ephemeropterans (mostly *Hexagenia* spp.) as the dominant contributors. Caddisflies (Tricoptera) were a food item that decreased in frequency from the early to middle time period, then disappeared from diets during 2000–05 in both bays.

Although yellow perch ate small numbers of Pelecypodans in all time periods, their consumption shifted to zebra mussels, which first occurred in 1996 in both bays, and fingernail clams disappeared from yellow perch diets. Zebra mussels and fingernail clams were a very minor component of yellow perch diets in all time periods.

Yellow perch fed on a number of different fish species (Table 15). Of the fish that could be identified, trout-perch occurred with the highest frequency in LBdN yellow perch stomachs. Trout-perch were also present in BBdN diets, but there, alewife occurred most frequently overall. However, both trout-perch and alewife were absent from BBdN yellow perch stomachs during the 2000–05 time period. Johnny darters were consumed through all periods in BBdN, but dropped out of diets in LBdN during the third time period. Rainbow smelt dropped out earlier, and in both bays: after the first time period in BBdN and after the second time period in LBdN. Spottail shiners disappeared from diets as well, first in LBdN, then in BBdN. Round gobies were consumed beginning in 2002 in LBdN and in 2005 in BBdN. Yellow perch occasionally fed on walleye young-of-the year, and they were also somewhat cannibalistic.

Fishery (Creel)

Creel harvests and effort varied considerably from year to year within and across time periods (Appendices 3–6). Open-water creel data were consistently available from six different sites: LBdN, BBdN, Cedar River, Lake Michigan at Cedar River, Menominee River, and Lake Michigan at Menominee. Little Bay de Noc was the only site where ice fishing creel surveys were conducted during all three time periods. Harvest and catch-per-unit effort (CPUE) values were computed as averages of the annual estimates within each time period for comparisons in this report.

The ice fishery for walleyes in LBdN declined during 1988–2005. Average annual harvest of walleyes decreased by 46% between 1988–93 and 1994–99, from 6,399 to 3,484 fish per season (Figure 12). The decline continued an additional 52% to 1,679 fish per season during 2000–05. Ice fishery CPUEs diminished as well, from averages of 0.034 to 0.026 to 0.010 walleyes per hour during the three successive time periods (Figure 12).

In contrast, most open-water sport fisheries for walleye in northern Green Bay peaked during 1994–99. Average annual walleye harvests increased from 1988–93 to 1994–99 at all six sites. Lake Michigan walleye harvests continued to increase during 2000–05 at Cedar River and Menominee, but declined at all four other sites (Figure 13). In LBdN, average creel harvests were 25,029 walleyes per season during the first time period, climbed 49% to 37,284 fish per season in the middle time period, and tailed off to 27,719 fish per season during the third interval. The Menominee River fishery grew 142% from 8,799 to 21,304 walleyes per season during the first two time periods, then shrank to 15,326 walleyes per season during the third. Compared to LBdN and Menominee River, considerably fewer walleyes were caught in the BBdN open-water recreational fishery: an average of 2,422 during 1988–93, rising 33% to 3,226 during 1994–99, and dropping to 914 during 2000–05. The open-water walleye fishery in Lake Michigan at Menominee expanded 85% from 420 to 778 fish per season between the first and second time periods, then experienced an explosive increase of 505% to 4,705 walleyes per season from the second to the third time period. On a smaller scale yet more impressively, no walleyes were recorded from the Lake Michigan fishery at Cedar River until 1994–99 when an average of 36 fish per season were harvested, yet during 2000–05 the average annual harvest rocketed 4,553% to 1,675 walleyes per season.

Open-water CPUEs for walleyes followed patterns similar to those for harvests at the six creel survey sites. Average annual CPUEs were consistently highest in LBdN and Menominee River fisheries across all time periods (Figure 13). Estimates of CPUEs were considerably lower at the other four sites, though increases between the second and third time periods for Lake Michigan ports of Cedar River and Menominee were even more prominent than the increases for harvests at these two sites. The highest CPUE, 0.162 walleyes per hour, occurred during 1994–99 for Menominee River. Within the lower tier of creel sites, a CPUE of 0.064 walleyes per hour for Lake Michigan at Cedar River during 2000–05 was the maximum average estimate.

Harvest of yellow perch in the LBdN ice fishery declined from an average of 138,447 fish per season during 1988–93 to 58,077 fish per season during 1994–99, leveling off at 62,885 fish per season during 2000–05 (Figure 12). The overall decline from the first to the third time period was 54%. The drop in average CPUE for the LBdN yellow perch ice fishery fell from 0.66 fish per hour during 1988–93 to 0.45 and 0.34 fish per hour for the succeeding periods, an overall decline of 49%.

In open-water fisheries, yellow perch creel harvest declined over all three time periods at each of the six creel sites (Figure 14). Overall declines in open-water fisheries were substantial, ranging from 82% in LBdN to 99% for Lake Michigan at Cedar River. The relative magnitude of the fisheries differed by site. At LBdN, where the largest fishery occurred, an average of 94,770 yellow perch were caught in open-water fisheries during 1988–93, falling to 48,714 fish per season during 1994–99, and to 17,234 fish per season for 2000–05. Between the first and third time periods at the other sites, average open-water creel harvests declined from 67,842 to 1,939 in BBdN, from 13,007 to 127 for Lake Michigan at Cedar River, from 199 to 6 in Cedar River, from 25,073 to 4,176 for Lake Michigan at Menominee, and from 3,913 to 394 in Menominee River.

Estimates of open-water CPUEs for yellow perch declined consistently at all creel sites just as average harvests did (Figure 14). The highest average CPUE during the first time period was calculated as 0.80 fish/hour in BBdN, followed by 0.34 fish/hour in LBdN, 0.28 for Lake Michigan at Menominee, 0.26 for Lake Michigan at Cedar River, 0.03 in Menominee River, and 0.02 in Cedar River. By the third time period, average CPUEs dropped 97% to 0.06 in BBdN, 79% to 0.07 in LBdN, 97% to below 0.001 in Cedar River, 99% to 0.01 in Lake Michigan at Cedar River, 83% to 0.04 in Lake Michigan at Menominee, and 90% to 0.004 in Menominee River.

Beyond the six sites where collection of creel data was most consistent, notable harvests of yellow perch occurred by anglers fishing near Stony Point. Annual open-water harvests there were estimated as high as 27,737 fish, and the highest CPUE was 1.43 fish per hour.

Age and length structure of angler-harvested fish showed distinct changes over time in study waters (Table 16). Average length and age of walleyes caught by anglers increased substantially between early and later time blocks at BBdN, Cedar River, and Menominee River. In contrast, average length of walleyes caught in LBdN declined slightly, but significantly, between the 1989–93 and 2000–05 time periods, with no change in the average age of fish harvested. Average length of yellow perch caught declined significantly in BBdN and LBdN (by 35 and 15 mm) between these periods, with the average age of yellow perch harvested in LBdN being significantly lower in 2000–05, when compared to 1988–93. In contrast, average length of smallmouth bass harvested increased significantly at BBdN and LBdN between these periods, possibly owing to a 1995 increase in minimum size limit for smallmouth bass in Michigan waters of the Great Lakes. Average length of brown trout and splake caught by anglers generally increased over time at LBdN, Cedar River, and

Menominee River, though differences were often not statistically significant, in part due to declining sample sizes over time.

Discussion

Water Clarity and Temperature Changes

Our findings documented a shift in physical conditions in the BDN, and identified potentially related changes in their fish communities and fisheries. Increased water clarity resulting from zebra and quagga mussel colonization, is documented for other nearshore areas of the Great Lakes, such as Lake Ontario's Bay of Quinte (Chu et al. 2004). Increases in summer surface water temperatures have also been documented the Bay of Quinte since 1994 (Chu et al. 2004). Based on regression slopes, summer Secchi depth readings for the LBDN increased on average 0.076 m per year between 1988 and 2005, while August–September surface water temperatures in BDN increased an average of 0.16ºC per year.

We noted several changes in BDN fish communities concurrent with increased summer water clarity and water temperatures. Reductions in catches of some small planktivores (e.g., alewife and rainbow smelt) and pelagic invertivores (e.g., trout-perch and spottail shiner) in assessment nets may relate to conditions becoming less suitable for their foraging. Concurrent with these declines, we generally observed fewer rainbow smelt, trout-perch, and alewife in the diets of walleye and yellow perch during 2000–05 period (except for alewife in walleye stomachs in LBDN). Fielder et al. (2000) reported similar declines for alewife and rainbow smelt after zebra mussels invaded Saginaw Bay in Lake Huron. Slight increases in warmwater species (e.g., gizzard shad and freshwater drum) in gill net samples during recent years may also reflect more recent, warmer conditions. Increased abundance of warm-water, benthic-foraging smallmouth bass may also have been influenced by physical changes in the environment of the bays. A similar increase in smallmouth bass CPUE was apparent in spring trap-net surveys in western Lake Erie after it was colonized by zebra mussels (Thomas and Haas 2005). These changes seem indicative of a fish community shift from more pelagic, planktivorous, cool-warm species to one with a greater benthic component and more warmwater species. Mills et al. (2003) coined the term "benthification" to describe the increased importance of benthic food webs that results from increased water clarity due to nutrient reductions and dreissenid mussels.

Walleye behavior and the walleye sport fishery in LBdN also changed, apparently in response to the altered physical environment of the bay. Based on angler returns of tagged walleyes caught in LBdN during summer (July through September), we saw a trend toward fewer walleyes being caught, and a general movement of the population from the northern end of the bay in earlier years to the deeper, southern portion of the bay in later years, possibly in response to increased summer water clarity and temperatures. Our findings suggest that much of the population may no longer reside in the inner bay during summer. This concurs with anecdotal reports from anglers that the catch for the summer, small boat fishery for walleyes at the northern end of LBdN has declined substantially since the 1980s. The distance to locations where summer anglers caught walleyes tagged in the Menominee River has also increased over time. This may relate to changes in water quality similar to those in LBdN, though other factors may be involved, such as disproportional increases in tagged walleye reports from wider-ranging, tournament anglers. Unfortunately, the influence of tournament anglers on our findings cannot be distinguished from those of other anglers. Fish community assessment surveys are needed in the Menominee area of Green Bay to monitor changes in biophysical and fish community conditions.

Invasive Species

The past decade saw a continued invasion of the BDN by invasive fishes. Round goby were first observed in LBdN in 1998 and by 2002 they comprised 76% of fish caught in trawls numerically. They were first detected in BBdN in 2002, and by 2005 they made up 82% of the trawl catch. Some authors (e.g., Marsden and Jude 1995; Jude 1997) have suggested that round gobies may adversely affect native sculpin, darter, and minnow species. Based on our trawl data to date, effects of round gobies on abundance of native benthic fishes common in our trawl catch (e.g., johnny darter and brook stickleback) are not apparent. Round gobies occur in the summer diets of walleye and yellow perch in both bays, but are eaten at only modest levels and do not appear to be a preferred prey item during summer. However, this conclusion might change if a higher portion of fish consumed could be identified.

Populations of recently-established invasive species and resurging native species have the potential to substantially alter the BDN fish community. Eurasian ruffe was first observed in surveys of both BDN in 2004. We have not observed any ruffe in BBdN since the initial capture of one individual. Total numbers of ruffe caught during our summer assessments in LBdN were 3 in 2004 and 2 in 2005 (T. Zorn, unpublished data). Additional ruffe were collected in fall sampling for another study. Compared to the explosive growth of round goby numbers in LBdN, the ruffe population appears relatively stagnant and at an incidental level of abundance. The Eurasian ruffe has potential to compete with other fishes for food and space, and was hypothesized to be a potential threat to yellow perch populations, though this has not been clearly demonstrated (Czypinski et al. 2007). Likewise, resurging populations of the native double-crested cormorant *Phalacrocorax auritus* in northern Green Bay have the potential to significantly affect the fish community (Diana et al. 1997; Fielder 2008). Future monitoring is needed to describe effects of these species and future invaders on fish communities in northern Green Bay.

Contribution of Natural Reproduction and Stocking to Walleye Stocks

Walleye stocks in northern Green Bay are supported by a mix of naturally reproduced and stocked fish (Table 1). Schneider et al. (1991) noted that while “modest numbers of native fingerlings were collected off the mouth of the Whitefish River in 1988”, no strong signals of significant natural recruitment (e.g., an abrupt increase in the adult walleye stock or fishery) were observed. Schneeberger (2000) noted a strong naturally-produced year class in LBdN in 1991, and documented walleye year classes from nonstocked years that recruited to sport fisheries, assessment catches, and spawning stocks in LBdN.

Year class assignments from walleye samples for aging were used to assess the extent of natural reproduction of stocks before supplemental stocking occurred. Walleye samples for aging were first collected in 1988 from LBdN and in 1996 from BBdN, Cedar River, and Menominee River. In LBdN, no walleye were observed from year classes that pre-date the first years of stocking (1969 for fry and 1971 for fingerlings). Fry were initially stocked in 1969, and fingerlings were first stocked in 1971. We did not expect to see pre-1969 walleyes in our samples because they would have been quite old and unlikely to have survived to 1988 when our assessment surveys began. Existence of at least eight walleye year classes in the Menominee River from years prior to 1988 provides evidence that a naturally-reproducing population occurred in the river prior to initial walleye stocking. The near absence of walleyes from cohorts produced during years prior to when initial stocking occurred in BBdN and Cedar River (i.e., 1986 and 1988), suggests that walleye populations were scant to nonexistent in these waters prior to stocking.

Representation of unstocked year classes in the samples collected for aging can also provide insight into levels of natural reproduction. Though walleye in LBdN were stocked only in even-numbered years since 1991, age data from tagging and netting surveys indicates good representation of walleye year classes for the eight odd-numbered years between 1991 and 2005 when stocking did not occur. These findings indicate that walleye natural reproduction occurs in LBdN consistently from year to year, and at substantial levels (Table 12). To date, relatively few walleyes have been collected for the 2003 and 2004 year classes, but these fish were just reaching a size where they would be vulnerable to gill nets. In the Menominee River, walleyes from several old, naturally reproduced year classes were represented in 1999 and 2002 tagging surveys, and the naturally reproduced 1999 year class was evident in the 2002 survey. Naturally reproduced year classes from 1999, 2001, and 2003 were all well-represented in a 2006 survey of the river's spawning run (T. Zorn, unpublished data). Based on their ages, walleye in BBdN have been assigned to eight of nine unstocked year classes since 1990, though in numbers typically lower than those of stocked year classes (Table 12). Walleyes from the 2004 year class were likely too small to be vulnerable to our assessment nets. Exceptionally high numbers of walleyes assigned to the 1990 and 1992 year classes may reflect either strong year classes or mis-aged samples. Unstocked year classes were not represented in 2002 Cedar River tagging samples, (Table 13), but these year classes were observed in a 2005 survey of the river's spawning run (T. Zorn, unpublished data).

Changes in size structure of each walleye population between the 1988–93 and 2000–05 periods also seem indicative of the relative influences of stocking and natural reproduction (Figure 9). We focused on males because they are present during the bulk of the spawning period, and in LBdN, are not sorted and selected, as females are, by netting crews for concurrent egg-take operations. In all waters, the size distribution of male walleyes shifted to larger, older fish over time, reflecting a build-up of stocks and differing levels of recruitment of smaller, younger males to populations (via natural reproduction or stocking). We saw the smallest shift in size structure in LBdN where relatively strong reproduction and regular stockings combined to provide fairly steady infusions of young males into the population. The largest shift in size structure (98 mm difference between means) occurred in the Cedar River, which showed limited natural reproduction and was only stocked twice since 1998. Intermediate shifts occurred in BBdN (78 mm), which received regular and large infusions of hatchery walleye, and the Menominee River (83 mm), which exhibited some natural reproduction and received smaller, but regular stocking of hatchery walleyes.

Changes in size and age structure of harvested walleyes were similar to our findings from tagging data (Table 16). We saw little change in size or age structure of harvested walleyes in LBdN, where we suspect recruitment is highest. The largest shift in size and age structure of harvested walleyes occurred in the Cedar River and adjacent waters of Lake Michigan, while intermediate shifts occurred for fish harvested in BBdN and in the Menominee River and nearby waters of Lake Michigan. These findings were also consistent with size structure shifts observed from tagging data. Similarly, temporal shifts in size structure for angler caught brown trout and splake, and declining sample sizes over time, suggest that recruitment (i.e., survival of stocked fish) of fish to these populations has declined since the 1980s (Table 16).

Based on these data we hypothesize that natural reproduction of walleye seems to vary among populations with the most consistent and successful reproduction occurring in LBdN. Menominee River walleye showed consistent, but relatively lower levels of reproduction. Low levels of walleye reproduction probably occurred in BBdN and Cedar River populations, but we suspect these populations might become very small if stocking were discontinued. Further monitoring and an ongoing oxytetracycline (OTC) marking study will be used to further describe contributions of naturally-reproduced and hatchery-reared walleye to northern Green Bay walleye populations.

Walleye Exploitation, Survival, and Other Movements

Annual exploitation and survival of northern Green Bay walleye stocks is comparable to that of stocks in other Michigan waters (Table 17). Using a nonreporting adjustment factor of 2.7 derived for

Lake Erie walleyes (Thomas and Haas 2005), we estimated mean annual exploitation of walleyes as 10.4% in LBdN, 8.1% in BBdN, 7.5% in Cedar River, and 11.8% in Menominee River. In comparison, total exploitation of walleyes in Lake Erie for 1989–2003 ranged from 9% to 31% and averaged 18% (Thomas and Haas 2005), while annual adjusted exploitation of Saginaw Bay walleyes for 1992–2004 varied between 7% and 13%, averaging 8% (Fielder et al. 2005). Survival and exploitation of walleye populations in inland lakes varies considerably among water bodies (Table 17), but compared to these populations, northern Green Bay stocks were lightly to moderately exploited and had moderate to high annual survival (50% to 65%). Colby et al. (1994) suggest that annual survival of more than 50% is desirable for rehabilitation of walleye stocks.

Relatively high exploitation (and reduced survival) of Menominee River and LBdN stocks, relative to those in BBdN and Cedar River, may be due to their proximity to larger towns (Escanaba, Michigan; Menominee, Michigan; and Marinette, Wisconsin) where sportfishing effort is higher (Appendix 6). Both BBdN and Cedar River are over 50 km from larger towns. In addition, the larger size of these stocks might attract additional anglers from other regions. Lower survival of Menominee River and LBdN walleyes (compared to Cedar River and BBdN fish) results from an increased level of exploitation and other unknown factors. Annual survival of Menominee River walleyes is barely below the Colby et al. (1994) standard (>50%) for stock rehabilitation, while the other three stocks are above it. The shifting size structure of walleye populations in the four study areas (Figure 9) shows the relatively high survival, and demonstrates the varying contributions of hatchery- and naturally-reproduced fish.

Temporal trends in exploitation and annual survival of tagged walleye differed between the BDN and Cedar-Menominee river populations, with survival of the latter populations generally increasing over time. It’s possible that the rate of nonreporting of tagged fish by anglers changed over the study period. In contrast, survival estimates for walleyes in LBdN and BBdN showed no obvious trend over time, and were particularly stable in LBdN. From this, one might infer that nonreporting rates of anglers were fairly steady over the years. The importance of these stocks and fisheries (especially those in LBdN) warrant continued monitoring of walleye exploitation and survival at some level.

While most walleyes showed limited movement from tagging (typically spawning) locations in northern Green Bay waters, the distinct movement pattern of walleyes tagged in the Cedar River was noteworthy. Most walleyes tagged in or near the Cedar River were recaptured in or around the Menominee River or further south in Green Bay. Limited studies of current patterns for this portion of Green Bay suggest that counter-clockwise flows are typical during summer, though flows may periodically be disrupted by changes in prevailing winds (Miller and Saylor 1985; Beletsky et al. 2006). Walleye movements here may result from pursuit of prey fishes whose foraging movements are passively influenced by currents. Cedar River walleyes may eventually settle in southern Green Bay to take advantage of a warmer, potentially more productive, environment for foraging. When Menominee River walleyes stray from their spawning area, they more often venture further south into Green Bay, which also supports the hypothesis that prevailing currents might influence walleye and prey fish movements. Wang et al. (2007) hypothesized that walleye movements in Lake Erie might also be in response to migrating stocks of large forage fishes, the preferred food item for large walleye (Colby et al. 1979). High levels of walleye spawning site fidelity assessed over the entire data set were consistent with analyses reported earlier for 1988–96 data, as well as reported elsewhere and by others as cited in Schneeberger (2000).

Yellow Perch Population and Fishery Dynamics

Yellow perch trends in the BDN showed similarities with populations in southern (i.e., Wisconsin’s portion of) Green Bay and the main basin of Lake Michigan. Abundance of yearling and older yellow perch based on CPUEs in LBdN for 2000–05 were at low levels compared previous periods, and showed a pattern of decline similar to that observed in southern Green Bay (M. Mangan, Wisconsin Department of Natural Resources, unpublished data). Interestingly, data for southern Green Bay showed that high yellow perch abundances observed in the late 1980s and early 1990s were preceded by a period when assessment catches were only slightly higher than those we observed during the last decade. Thus, high perch abundances observed in LBdN from roughly 1989 to 1997 may represent an unusual population peak, with more recent abundance levels closer to typical. Data going back to the late 1970s on adult yellow perch abundance from southern Green Bay, as well as Illinois and Indiana waters of Lake Michigan, also identify the 1983–92 period as one of peak abundance (Makauskas and Clapp 2008).

Despite the above similarities, some notable differences among these populations cause us to question the accuracy of yellow perch trend data for BDN. For example, the lack of any notable decline in yellow perch in BBdN during the late 1990s, argues against temporal synchrony between yellow perch populations here and elsewhere in Green Bay and Lake Michigan. However, creel data for BDN show declining perch CPUEs over time in both bays, and corroborates assessment data from southern Green Bay. Looking at year class strength from age-0 yellow perch in trawl catches, we see some years when strong year classes were common throughout Green Bay (e.g., 1991 and 1998), some strong year classes common to both BDN (e.g., 1993 and 1995), but many more years with no apparent synchrony. For example, 2003 was the strongest year class in southern Green Bay since surveys began in 1980, but it hardly registered in BDN or elsewhere in Lake Michigan (Makauskas and Clapp 2008). Limited correspondence in trends between BDN and southern Green Bay (despite fair correspondence in trends among other Lake Michigan waters) suggests that either current levels of assessment effort are too low to accurately describe population trends, or that BBdN and LBdN are distinct from each other and other areas of Lake Michigan.

Unlike southern Lake Michigan surveys, we saw little change in the percent of yellow perch in our samples that were females. From 1989 to 2005 the percent of female yellow perch in our assessment samples remained steady, usually between 65–75% (Table 14). The percentage of females in southern Lake Michigan samples bottomed out at 10–20% in the mid-1990s, causing considerable concern among managers in regard to long-term sustainability of the stock (Makauskas and Clapp 2008). This, in combination with low stock abundance, resulted in reduced bag limits for sport-caught yellow perch in the main basin in several states and reduction of Wisconsin’s commercial perch fishery.

Management Implications and Future Direction

Our findings confirm that aquatic systems of northern Green Bay are indeed dynamic, with changes driven by physical and biological processes such as climate change and invasive species. Our data demonstrated that population dynamics of key species (e.g., yellow perch) show both similarities and differences with those of populations elsewhere in Lake Michigan. Thus, our ability to understand and manage fisheries in northern Green Bay is predicated on having habitat and fish assemblage data specific to these waters. In addition, effects of recently invading or growing populations of organisms (e.g., Eurasian ruffe, double-crested cormorant, round goby, Eurasian milfoil, and quagga mussels) on populations of important sport and forage fishes in northern Green Bay are still unknown. Actions to reduce double-crested cormorant populations, and their predation on the Lake Michigan fish community, are underway. More intensive assessment surveys are needed to document changes over time, evaluate effects of current management, and provide support for future management decisions.

Important sport fisheries for walleye occur throughout northern Green Bay and data are needed to describe population trends, levels of natural reproduction, contributions from stocked fish, and levels of harvest and exploitation. Our study documented significant natural reproduction for walleyes in portions of northern Green Bay, though uncertainty exists as to where natural reproduction is adequate to maintain self-sustaining populations. An ongoing evaluation of the contribution of stocked fish to BDN walleye populations via an oxytetracycline (OTC) marking study should help to address this uncertainty. Long-term assessments that index age-0 and age-1 walleyes would provide a useful measure of annual reproductive success. In addition, collection of age structure data from spawning walleyes in rivers that have not recently been stocked (e.g., Cedar River) could be used to further describe the contribution of nonstocked year classes to populations (spawning runs).

We described exploitation and survival of Green Bay walleye populations, and continue to jaw-tag walleyes in LBdN to index walleye exploitation and survival. The level of nonreporting of jaw-tagged walleyes by anglers is unknown for northern Green Bay, and we used a rate determined by Thomas and Haas (2005) for Lake Erie walleyes. This results in exploitation estimates that are 2.7 times higher than our tag return data indicate. Use of reward tag studies to estimate nonreporting rates for individual fisheries is documented for numerous Michigan waters (e.g., Table 17). We recommend such a study for northern Green Bay walleye fishery due to its importance to the region. Since tagging activities are ongoing, the primary need to accomplish this would be funds to pay anglers that report reward-tagged fish.

Future assessment work in northern Green Bay should employ additional survey effort. Given current catch variability, we estimated that our trawl and gill net efforts would have to increase by 4.4- and 1.7-fold to achieve 70% certainty that our mean CPUEs were within 25% of actual mean values at index stations (Zorn, unpublished data). The lack of synchrony in yellow perch population trends among BBdN, LBdN, and southern Green Bay, during a time when synchrony occurred between yellow perch harvests in southern and northern Green Bay and between population indices in southern Green Bay and Lake Michigan's main basin (Makauskas and Clapp 2008), also suggests sampling effort in northern Green Bay is insufficient. While we believe fish population trends presented here are roughly accurate, we have limited confidence in the magnitude of changes described. Also, we often pooled our yellow perch catch data between bays to conduct growth and survival analyses due to small sample sizes. Agency studies we cited for Lake Michigan, Saginaw Bay, and Lake Erie all used large survey vessels, larger trawls and gill nets, crews of four or more people, and employed more survey effort to collect larger samples of fish than was possible in this study. In comparison, our sampling typically involves two people and a 6-m long Jon boat. While obtaining a dedicated survey vessel and crew may not be feasible, we recommend that additional survey effort be deployed in BDN to provide a more robust and comprehensive picture of fish community trends. Such a sampling program would help to better address management questions (e.g., game- and nongame fish trends, walleye reproduction, effects of cormorants and cormorant control efforts on yellow perch and the fish community, effects of aquatic invasive species, global warming effects, etc.), and provide a sound information base for future management.

Except for our netting in the BDN, no long-term fish community assessments occur for nearshore areas of Lake Michigan in Michigan's Upper Peninsula. Expansion of the BDN nearshore assessments to other areas of northern Lake Michigan would help to fill this information gap. Investigation is needed to determine appropriate locations, gear, and level of sampling effort for such an initiative.

Acknowledgments

Karen Koval was critical for this project as she managed logistics of tagging and field surveys, as well as all stomach analysis, fish aging, and data entry. Marquette Fisheries Research Station staff that notably contributed to this project by assisting in field work and maintaining surveying equipment included Greg Kleaver, Kevin Rathbun, Dawn Dupras, Brandon Bastar, and Helen Morales. Personnel from DNR offices in Marquette, Escanaba, Crystal Falls, Baraga, and Newberry conducted tagging operations, and we appreciate their efforts, snacks, and good cheer. Wisconsin Department of Natural Resources provided additional help for the Menominee River walleye tagging. We thank all the anglers whose cooperation in reporting their tagged fish allowed us to describe these walleye populations. We greatly appreciate the diligence of several DNR employees that provided the bulk of our tag returns over the years: Bob Haas (internet tag returns), Betty Lynch and Chris Stage (Escanaba DNR office contacts), and Ron Sobay and Greg Sanville (Menominee and BDN creel clerks). Tracy Kolb summarized annual angler effort, harvest, and catch rates for waters of northern Green Bay. We are also grateful to personnel from USFWS Green Bay Fishery Resource Office (Rob Elliott) and Wisconsin Department of Natural Resources (Mike Donofrio, Matt Mangan, Justine Hasz, Rod Lange) that reported tagged fish from their surveys and from anglers. Input from Andrew Nuhfer and Darren Kramer helped improve this manuscript. Funding for this study was provided in part by the Federal Aid in Sport Fish Restoration Act.

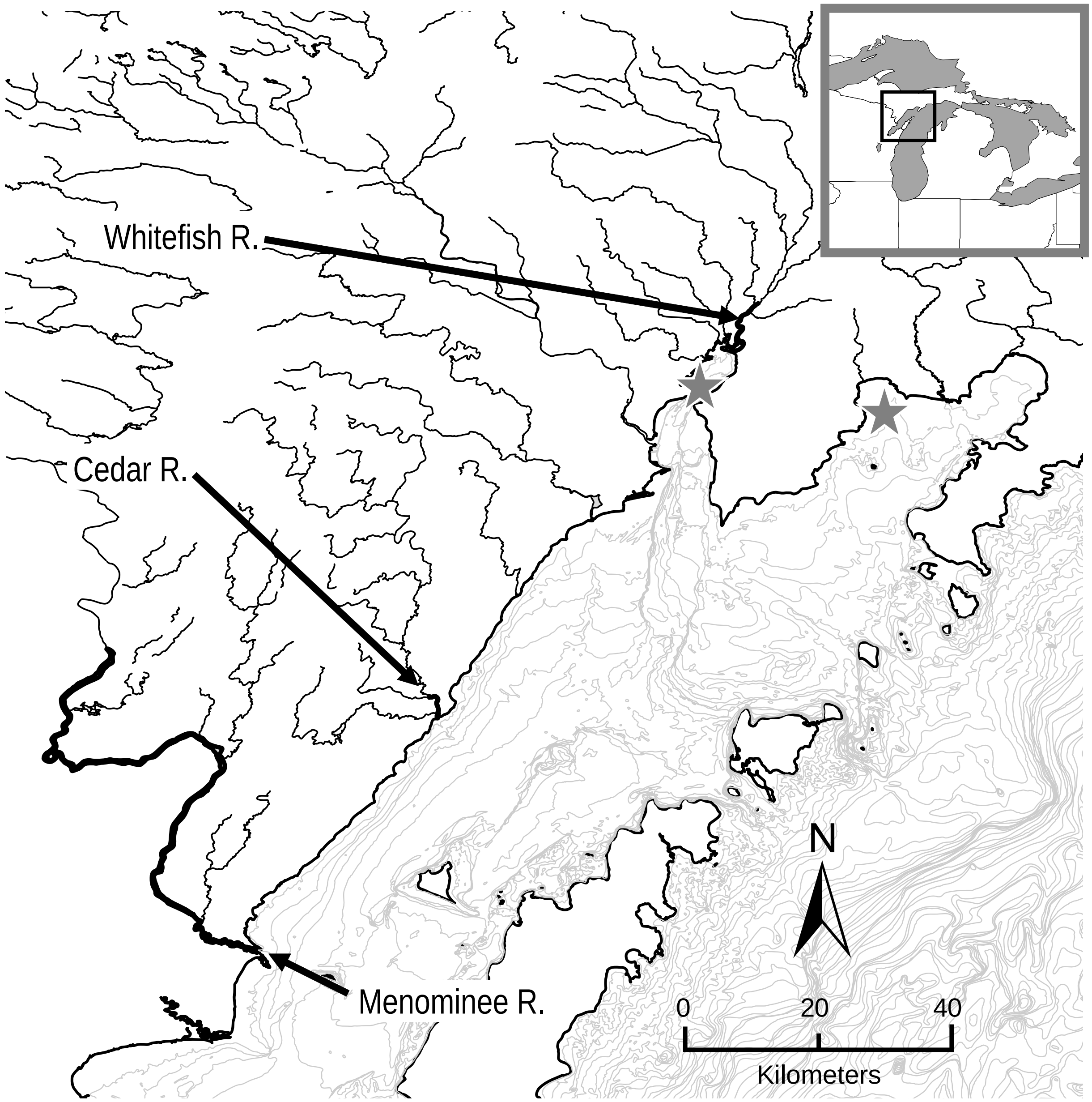


Figure 1.– Map of Green Bay showing assessment netting areas of Little and Big bays de Noc (western and eastern gray stars) and tagging locations (lower reaches and mouths Menominee, Cedar, and Whitefish rivers). Tagging occurred at several locations in Big Bay de Noc, but mostly in the vicinity of the eastern gray star.

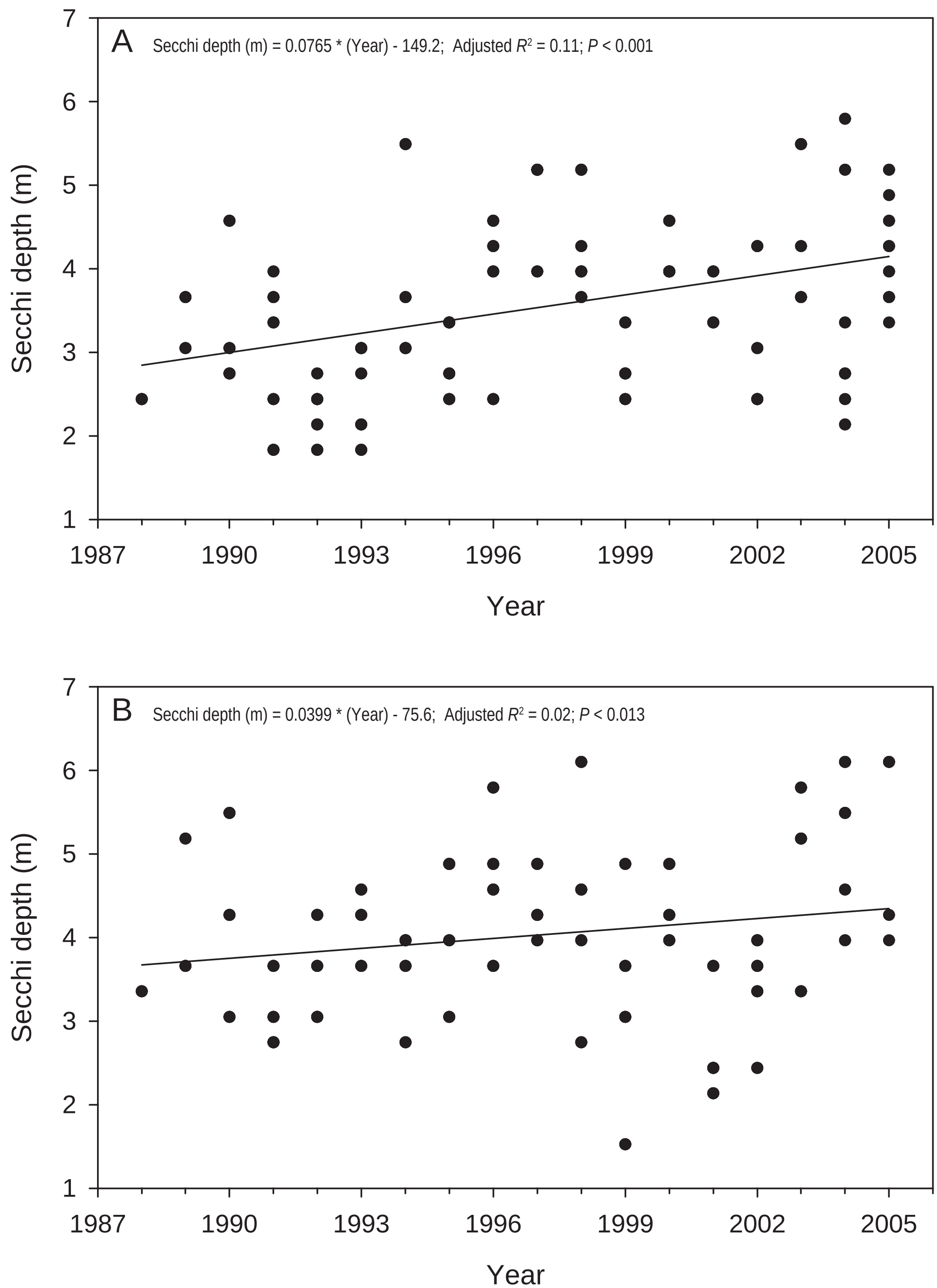


Figure 2.–Trends in secchi depths measured between June and September from 1988 to 2005 at the 20 ft netting locations in A) Little Bay de Noc and B) Big Bay de Noc. Both trends were significant at $P < 0.05$.

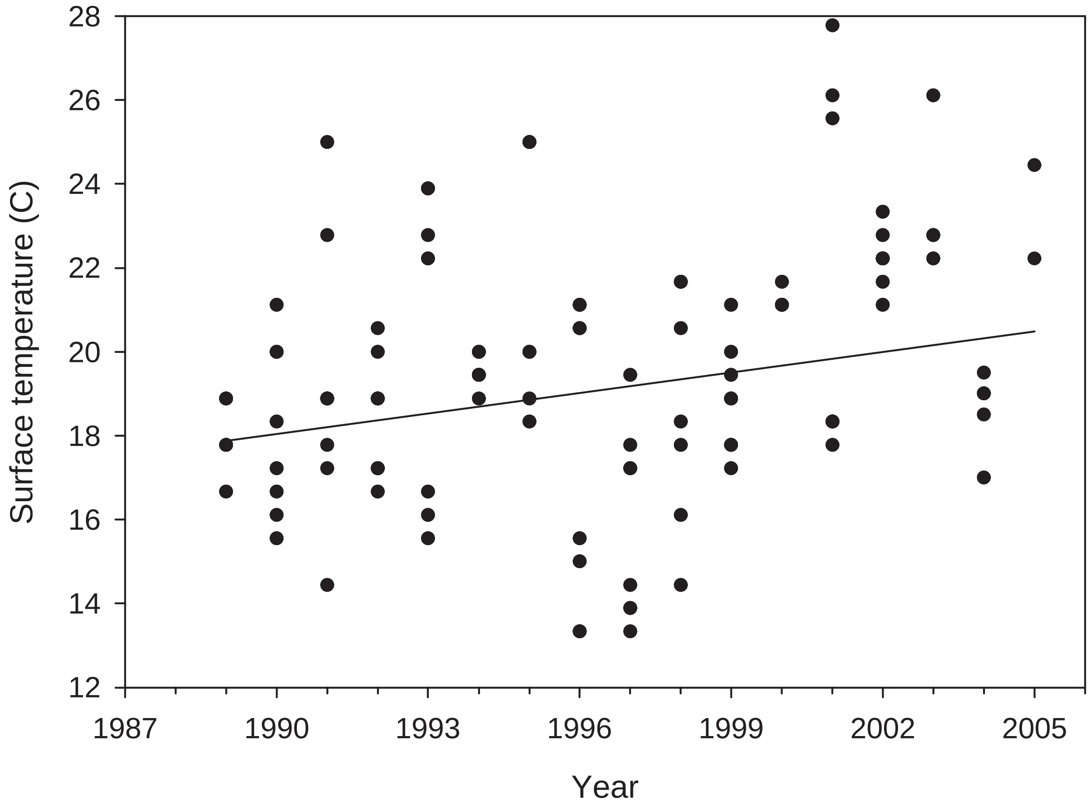


Figure 3.–August and September surface water temperatures at netting sites in Little and Big bays de Noc during 1988–2005. The linear regression describing the trend was: Surface temperature (°C) = 0.292·(Year) – 516.06; Adjusted $R^2 = 0.03$; $P < 0.003$.

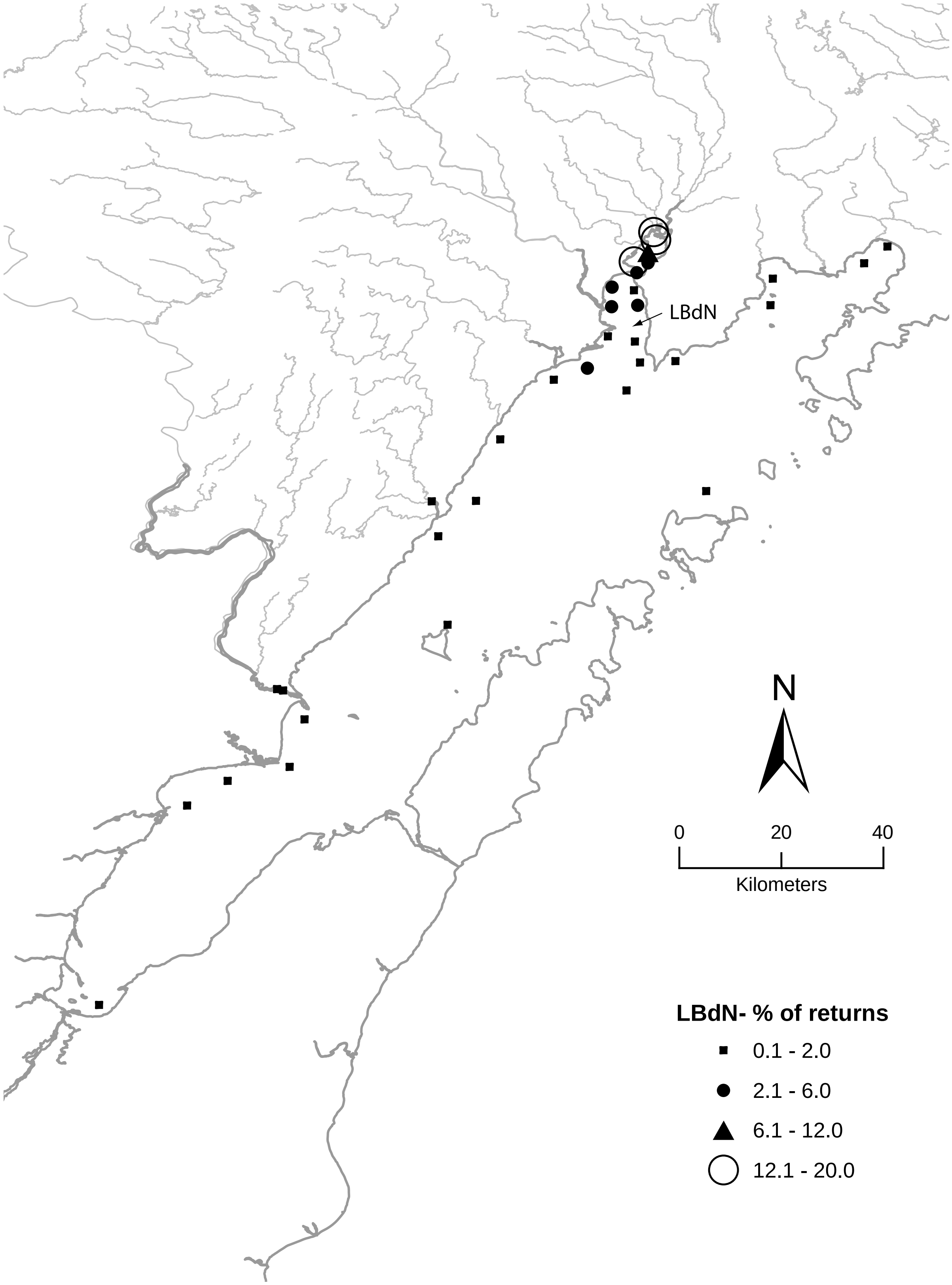


Figure 4.– Percent distribution of walleyes initially tagged in Little Bay de Noc that were recaptured during 1988–2005 (N = 1692).

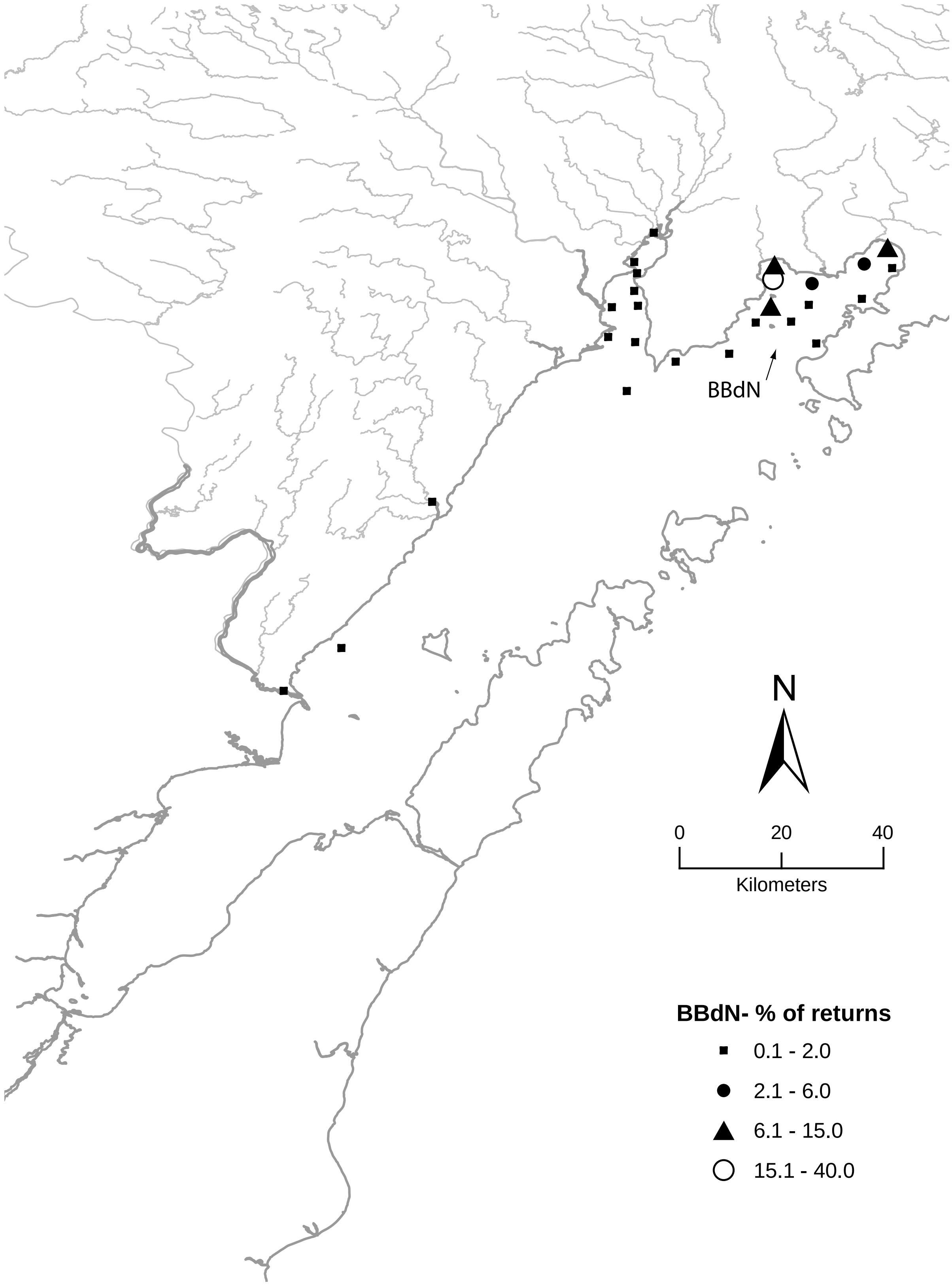


Figure 5.–Percent distribution of walleyes initially tagged in Big Bay de Noc that were recaptured during 1993–2005 (N = 480).

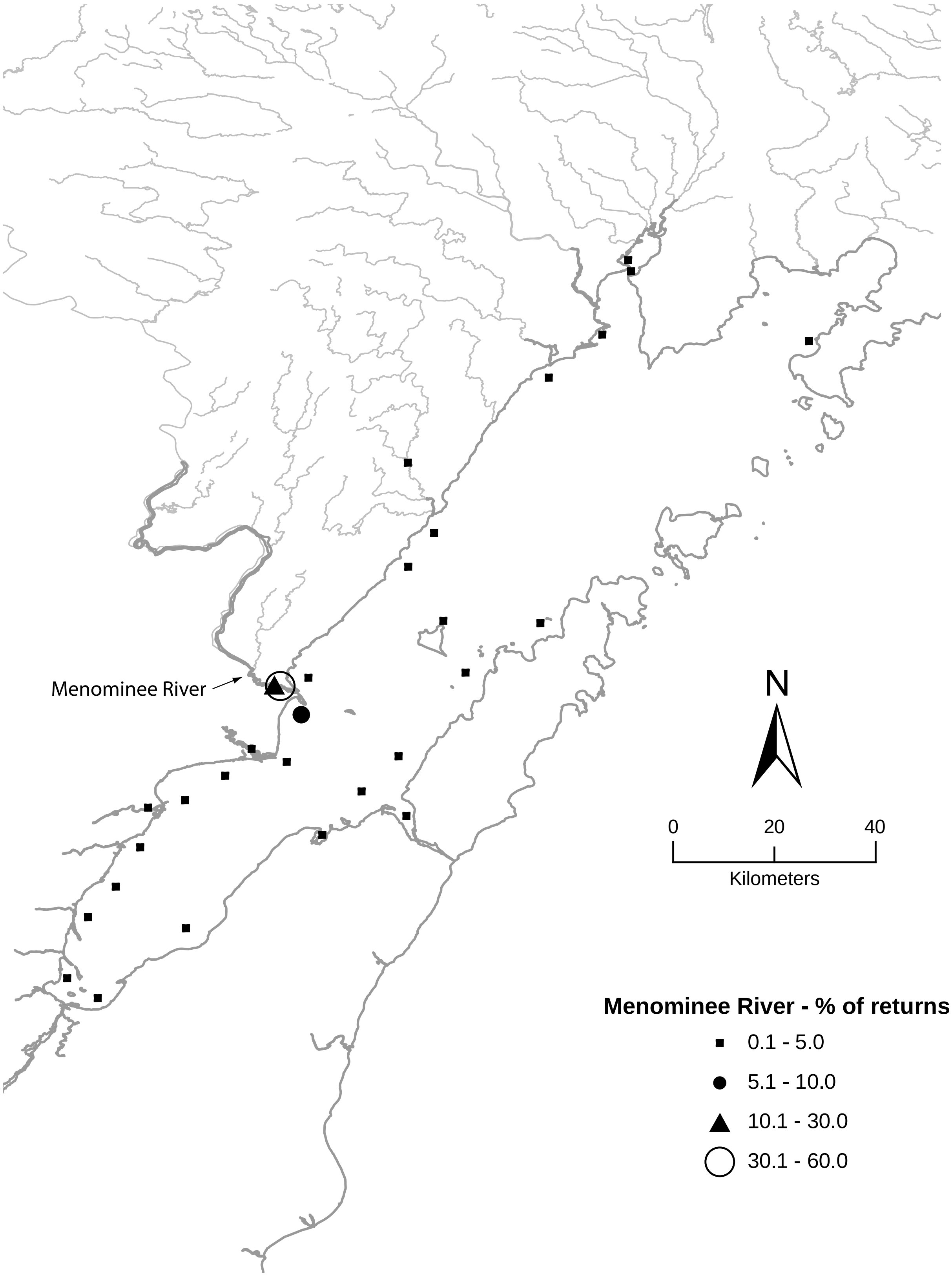


Figure 6.–Percent distribution of walleyes initially tagged in the Menominee River that were recaptured during 1993–2005 (N = 1,117).

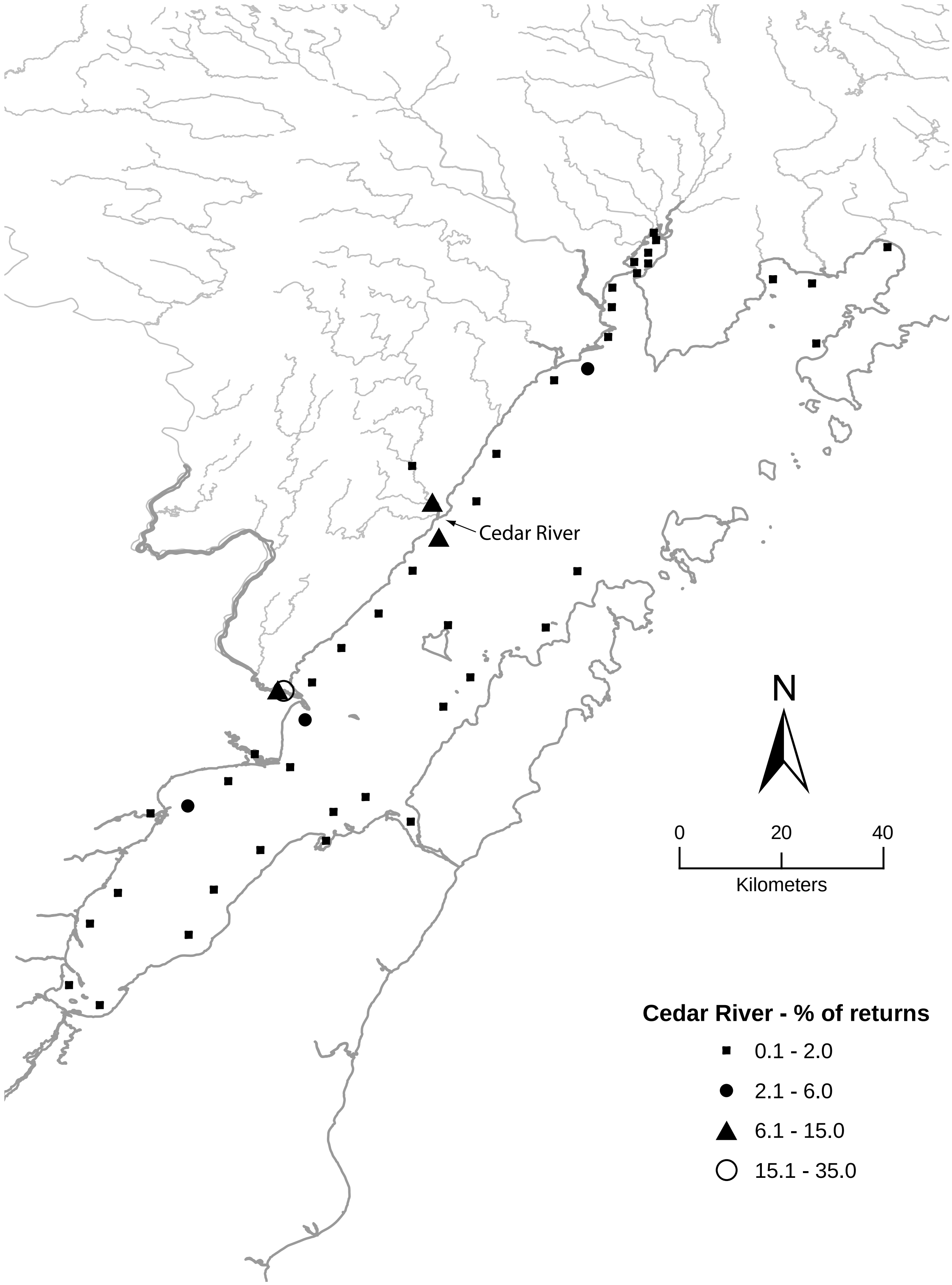


Figure 7.–Percent distribution of walleyes initially tagged in the Cedar River that were recaptured during 1993–2005 (N = 722).

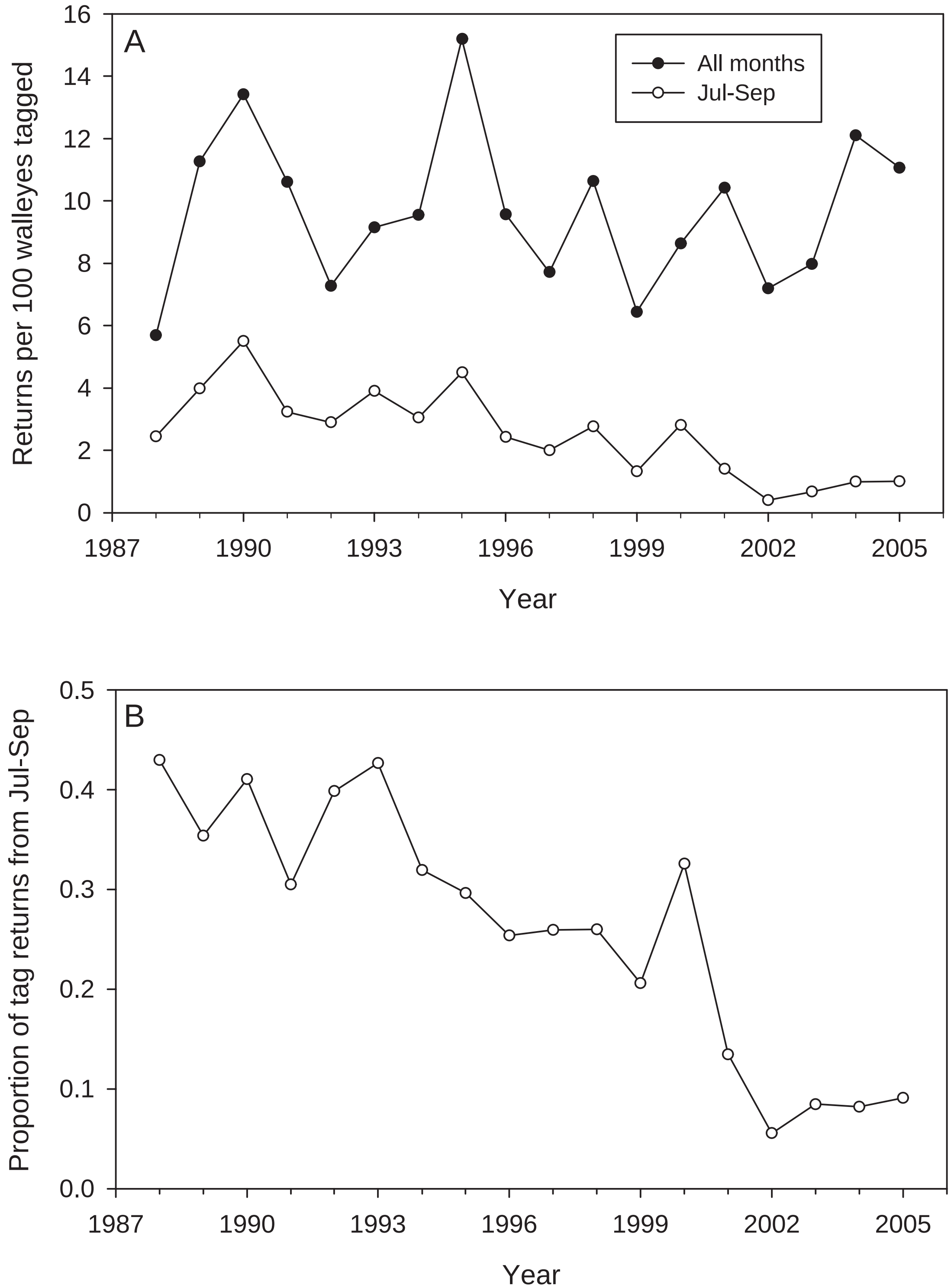
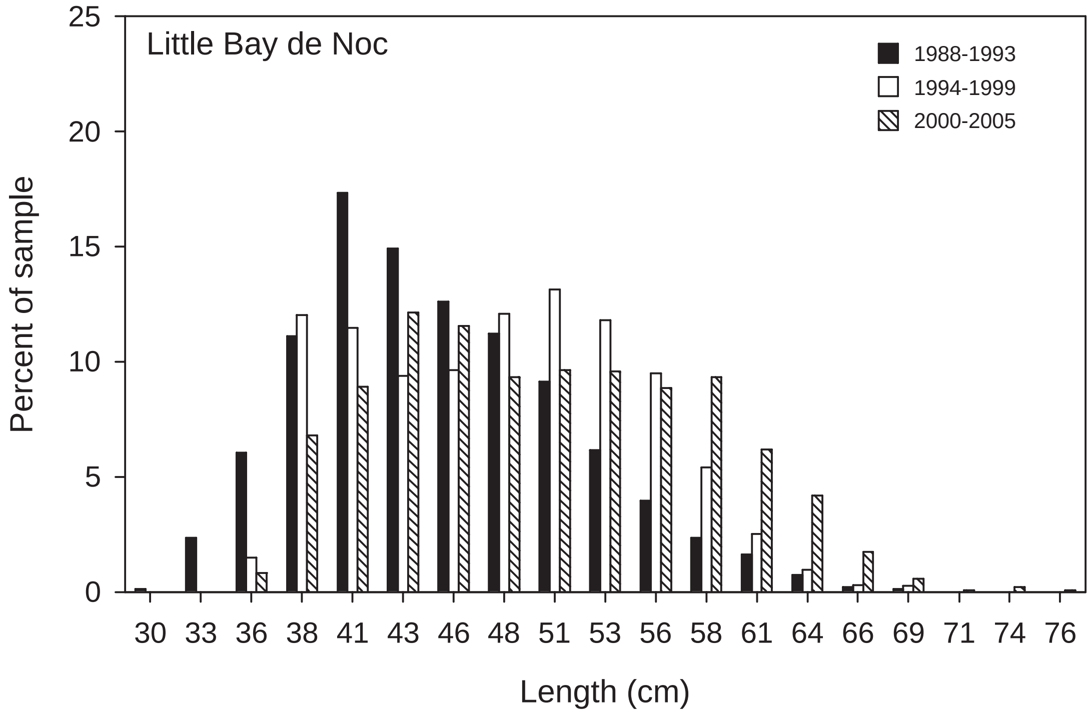


Figure 8.–Return rates of jaw-tagged walleyes in Little Bay de Noc during 1988–2005. A) Return rate (number of returns per 100 fish tagged) of jaw-tagged fish caught in all months vs. between July 1 and September 30. B) Proportion of jaw-tagged walleyes caught between July 1 and September 30.



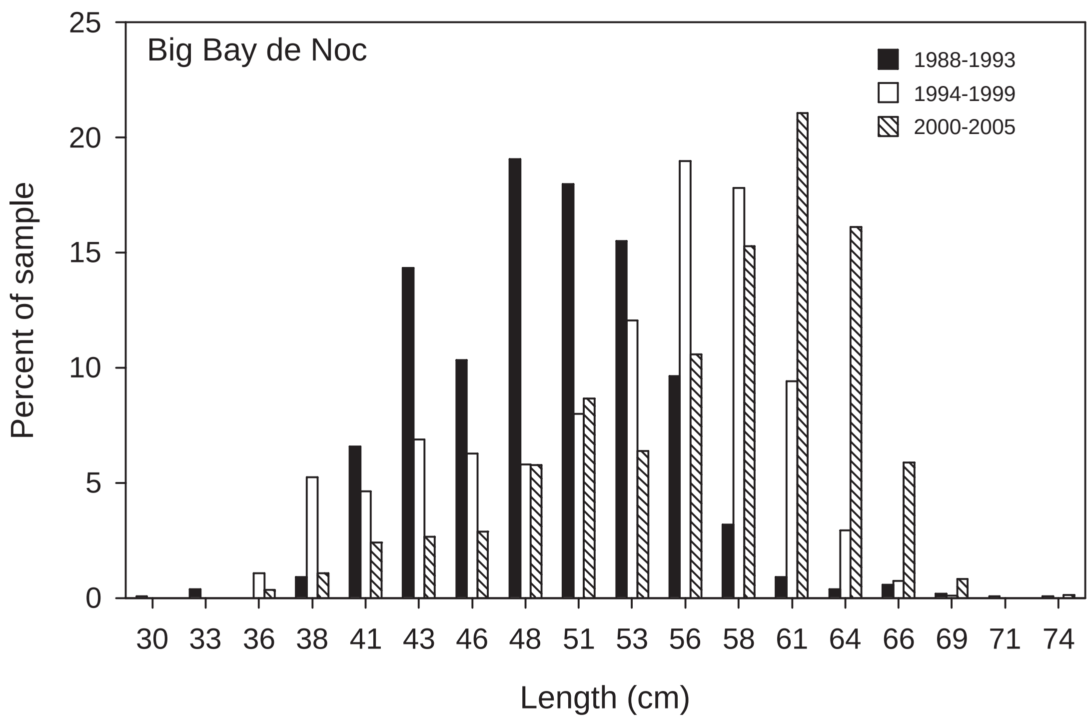


Figure 9.–Size frequency distribution of male walleyes tagged in spring at Little Bay de Noc, Big Bay de Noc, Cedar River, and Menominee River for three periods.

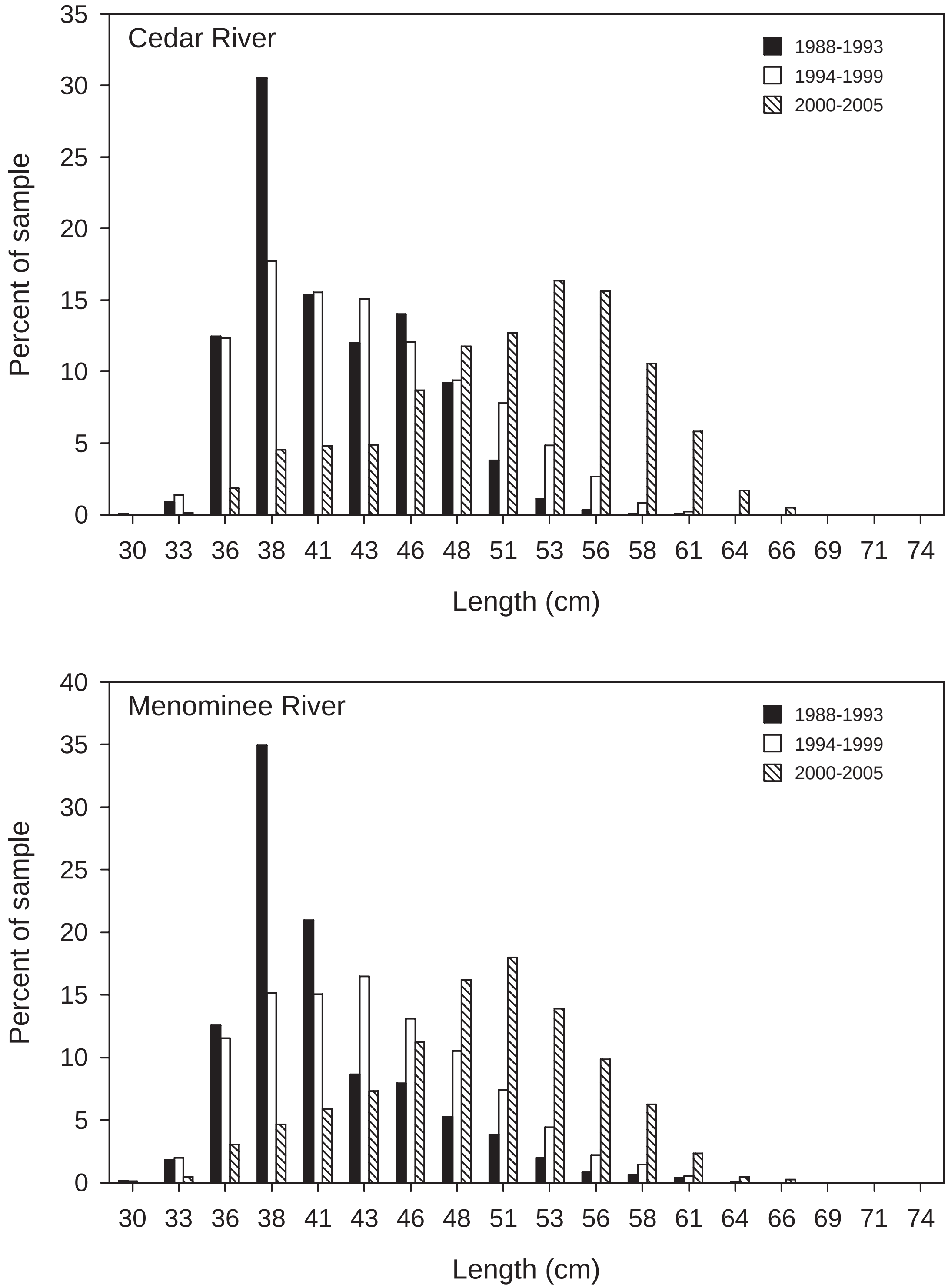


Figure 9.–Continued.

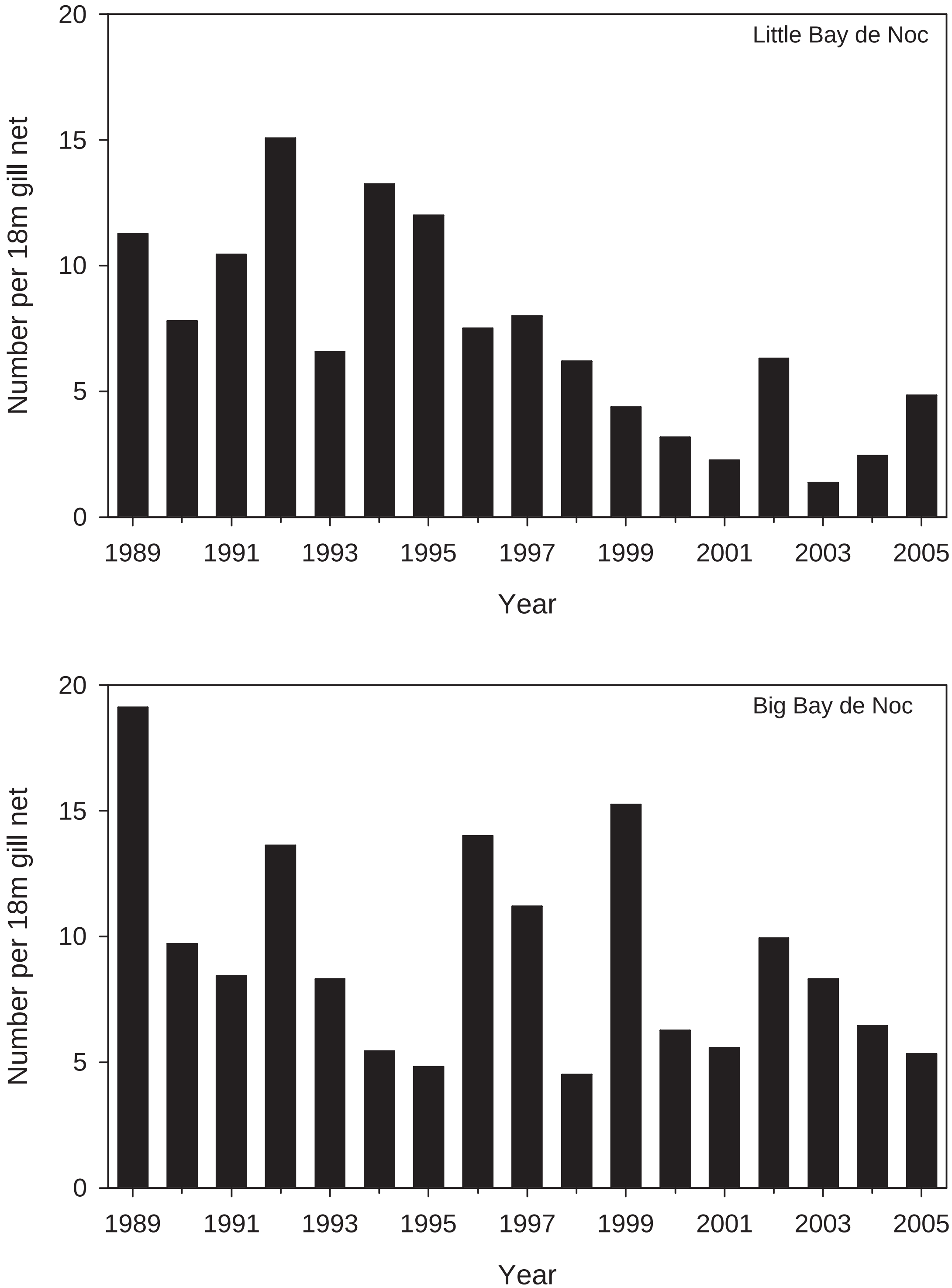


Figure 10.–Catch per unit effort of age-1 and older yellow perch from summer gill net surveys in Little and Big bays de Noc.

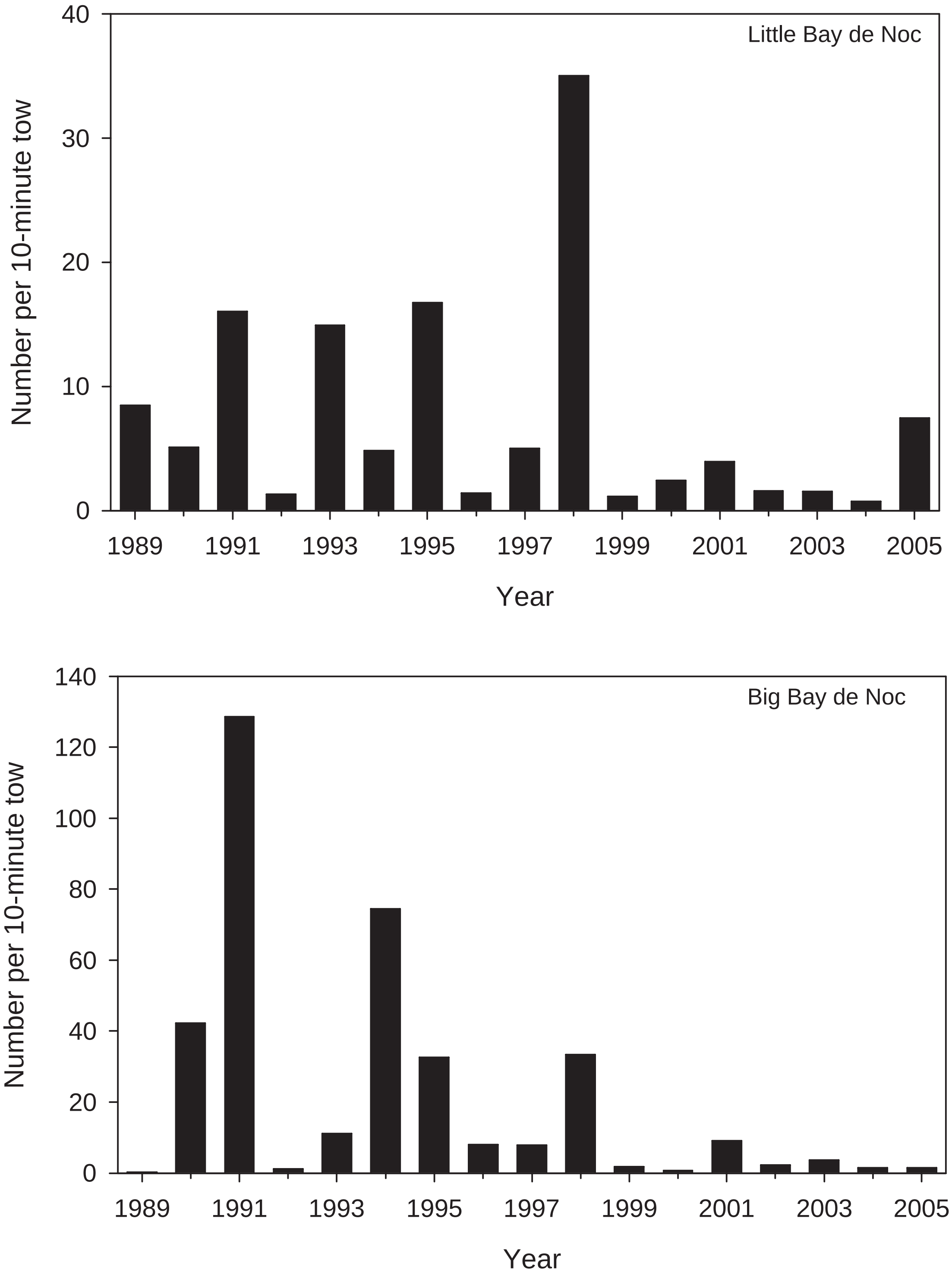


Figure 11.–Catch per unit effort of age-0 yellow perch from summer trawl surveys in Little and Big bays de Noc. Note the difference in scale on the y-axis.

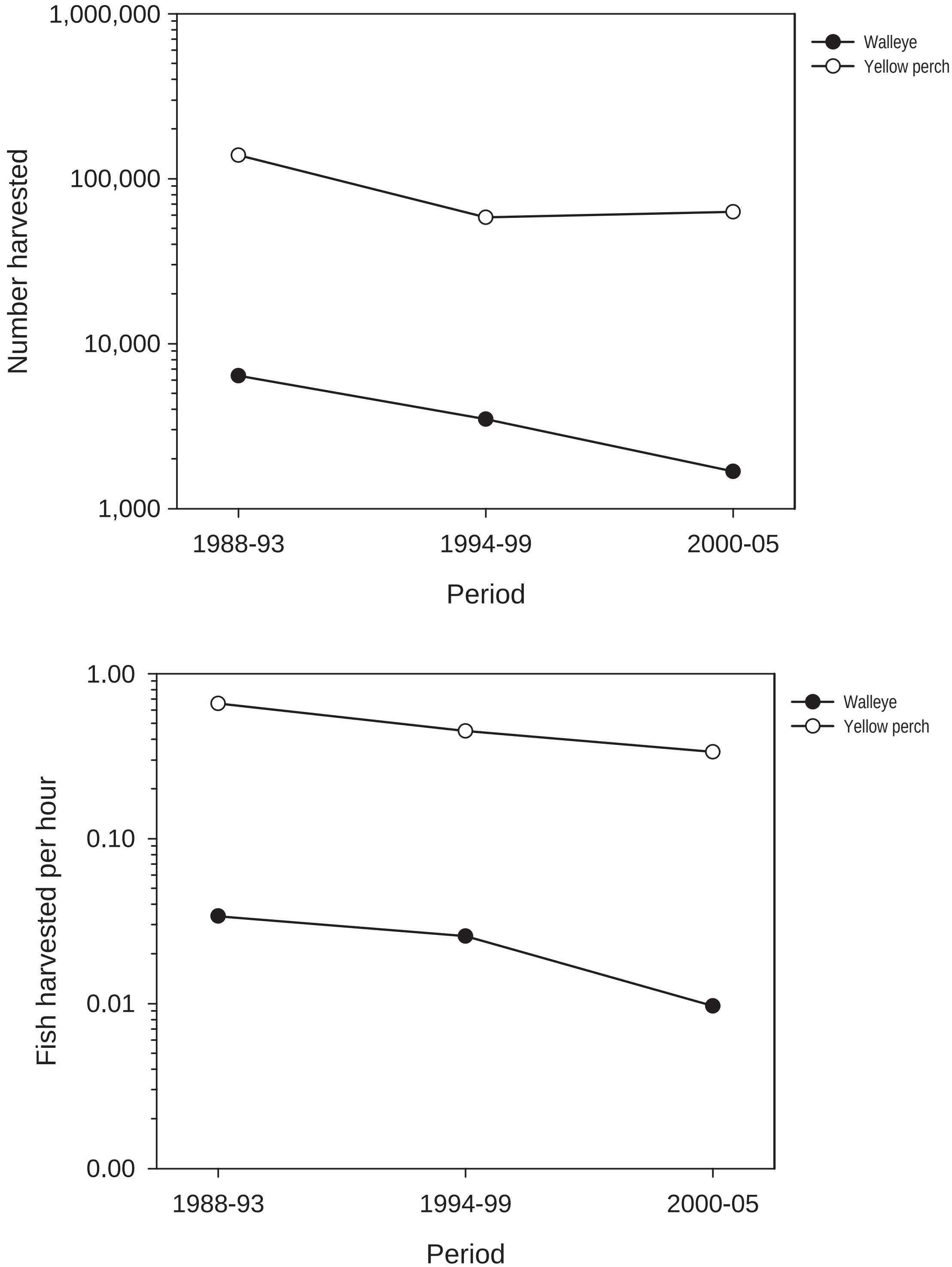


Figure 12.–Estimated harvest and catch per unit effort (fish harvested per hour) of walleyes and yellow perch in the Little Bay de Noc ice fishery by time period. Note that the y-axis scale is $\log_{10}$.

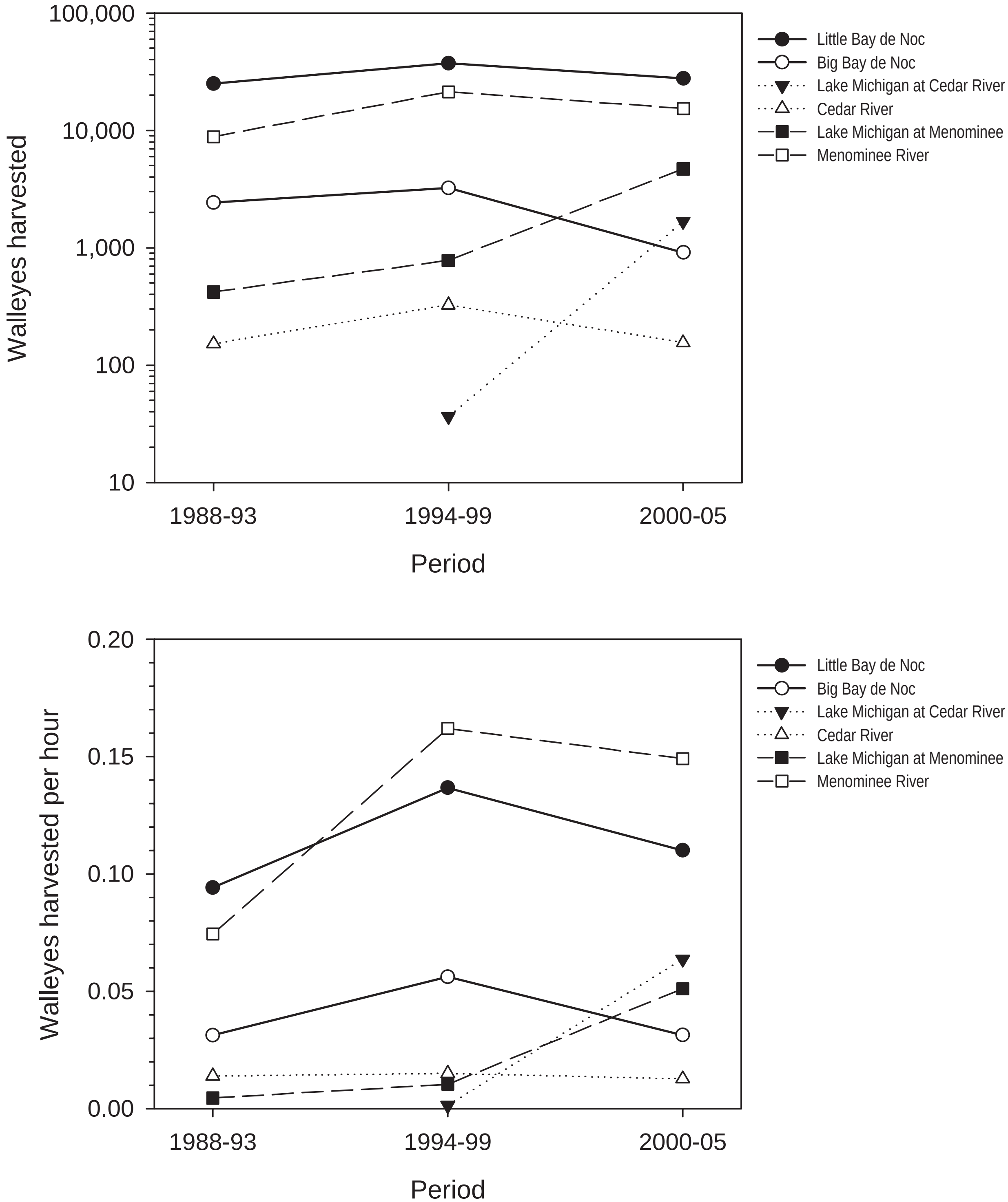


Figure 13.–Estimated harvest and catch per unit effort (fish harvested per hour) of walleyes from the open-water fishery for six locations in northern Green Bay. Note that the y-axis scale is $\log_{10}$. No walleyes were harvested at Cedar River (lake) for 1988–93.

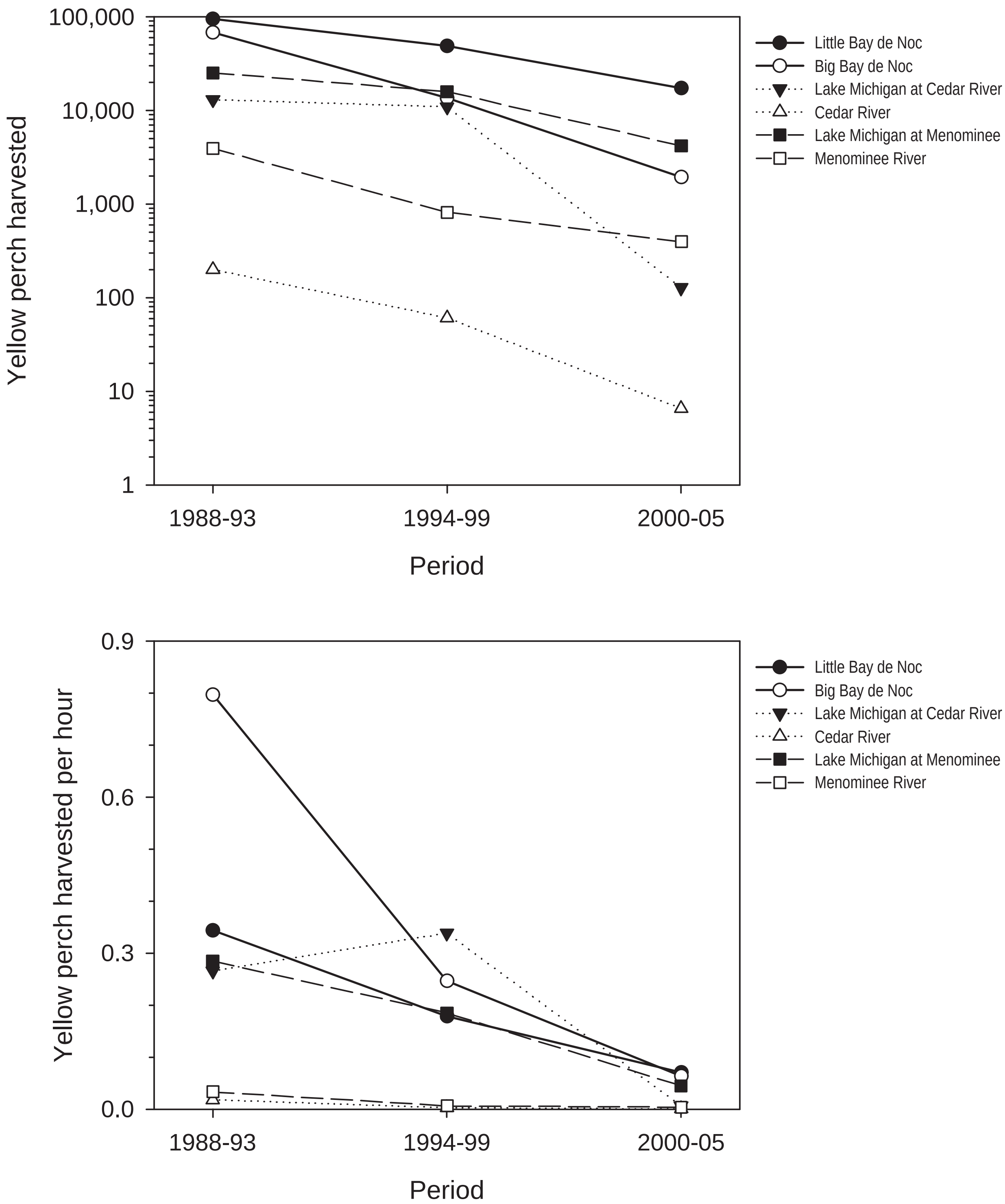


Figure 14.–Estimated harvest and catch per unit effort (fish harvested per hour) of yellow from the open-water fishery for six locations in northern Green Bay. Note that the y-axis scale is $\log_{10}$.

Table 1.–Numbers of walleye stocked by Michigan Department of Natural Resources Fisheries Division into Little Bay de Noc, Big Bay de Noc, Cedar River, and Stony Point (i.e., Lake Michigan about 13 km north of the Menominee River mouth) from 1969 to 2005. No fry were stocked at Stony Point.

	Little Bay de Noc		Big Bay de Noc		Cedar River		Stony Point
Year	Fingerlings	Fry	Fingerlings	Fry	Fingerlings	Fry	Fingerlings
1969		400,000					
1970							
1971	20,217		16,446	4,760,000			
1972	51,325	1,400,000					
1973	108,311			230,000			
1974	83,655		8,644				
1975	80,971			300,000			
1976	121,685			1,775,000			
1977	101,753		47,936				
1978	131,878						
1979	110,019						
1980	117,640	455,245					
1981	119,344	1,691,625				1,125,000	
1982	13,725	2,000,000				1,000,000	
1983	793,540	1,350,000				1,000,000	
1984	230,090	2,000,000					
1985	319,660	1,900,000					
1986	255,291	2,000,000	205,722	2,954,500			
1987	318,200	3,598,270	175,600				
1988	84,777		73,322		72,068		7,400
1989	278,076		217,507	2,775,000	96,727		
1990	505,941				157,757		92,797
1991	164		694,059		206,207		99,986
1992	426,471				32,770		166,563
1993			325,201		44,070		46,982
1994	263,508				217,162		307,145
1995			383,519		190,354		189,474
1996	560,558				96,161		123,569
1997			263,994		161,064		59,239
1998	652,288		169,212		100,767		128,471
1999			544,378	5,300,000			
2000	510,406			2,400,000	90,554		118,303
2001			463,052				
2002	141,283						25,773
2003			607,231				
2004	569,225				105,542		22,391
2005			749,427				
Totals	6,970,001	16,795,140	4,945,250	20,494,500	1,571,203	3,125,000	1,388,093

Table 2.–Total catch of fish by species from gill net (GN), seine (SN), and trawl (TR) surveys in bays de Noc, 1997–2005.

Family	Common name	Scientific name	GN	SN	TR	Total
Lepisosteidae	Longnose gar	*Lepisosteus osseus*	1			1
Clupeidae	Alewife	*Alosa pseudoharengus*	282	1	67	350
	Gizzard shad	*Dorosoma cepedianum*	14			14
Cyprinidae	Bluntnose minnow	*Pimephales notatus*		27	4	31
	Common carp	*Cyprinus carpio*	16		4	20
	Common shiner	*Notropis cornutus*	4	4		8
	Mimic shiner	*Notropis volucellus*		1	170	171
	Spottail shiner	*Notropis hudsonius*	158	154	202	514
Catostomidae	Golden redhorse	*Moxostoma crythrurum*	2			2
	Shorthead redhorse	*Moxosoma macrolepidtum*	1			1
	Silver redhorse	*Moxostoma anisurum*	1			1
	White sucker	*Catostomus commersoni*	141	834	130	1,105
Ictaluridae	Black bullhead	*Ameiurus melas*	4		1	5
	Brown bullhead	*Ameiurus nebulosus*	6		3	9
Esocidae	Northern pike	*Esox lucius*	133		3	136
Osmeridae	Rainbow smelt	*Osmerus mordax*	38		10	48
Salmonidae	Brook trout	*Salvelinus fontinalis*			16	16
	Chinook salmon	*Oncorhynchus tshawytscha*	1			1
	Coho salmon	*Oncorhynchus kisutch*	1			1
	Lake whitefish	*Coregonus clupeaformis*	1			1
	Splake	*Salvelinus namaycush x fontinalis*	5			5
Percopsidae	Trout-perch	*Percopsis omiscomaycus*	46		496	542
Lotidae	Burbot	*Lota lota*	3			3
Gasterosteidae	Brook stickleback	*Eucalia inconstans*	1		439	440
	Ninespine stickleback	*Pungitius pungitius*			3	3
	Threespine stickleback	*Gasterosteus aculeatus*			26	26
Cottidae	Mottled sculpin	*Cottus bairdi*			1	1
Centrarchidae	Bluegill	*Lepomis macrochirus*	1		14	15
	Largemouth bass	*Micropterus salmoides*	1		1	2
	Largemouth bass	*Micropterus salmoides*		1		1
	Pumpkinseed	*Lepomis gibbosus*	2	2	13	17
	Rock bass	*Ambloplites rupestris*	46	81	119	246
	Smallmouth bass	*Micropterus dolomieu*	108	1	338	447
Gobiidae	Round goby	*Neogobius melanostomus*	14		1,997	2,011
Moronidae	White bass	*Morone chrysops*	4			4
	White perch	*Morone americana*	47	164	1	212
Percidae	Iowa darter	*Etheostoma exile*			1	1
	Johnny darter	*Etheostoma nigrum*		8	630	638
	Logperch	*Percina caprodes*			6	6
	Ruffe	*Gymnocephalus cernuus*	3		4	7
	Sauger	*Sander canadensis*	2		1	3
	Walleye	*Sander vitreum*	303		18	321
	Yellow perch	*Perca flavescens*	1,753	146	3,032	4,931
Sciaenidae	Freshwater drum	*Aplodinotus grunniens*	7			7

Table 3.–Mean numerical catch per 10-minute trawl tow for most common species in Little Bay de Noc and number of tows (n). Mean values, with 95% confidence intervals (CI) below, occur for 1989–93, 1994–99, and 2000–05. Species are arranged in descending order based on abundance for the total time period.

Year	Yellow perch	Trout-perch	Round goby	Spottail shiner	Johnny darter	Rainbow smelt	White sucker	Rock bass	Others	n
1989	12.4	7.4	0.0	4.0	2.1	0.6	0.2	0.2	0.3	24
1990	13.1	15.0	0.0	3.5	1.0	0.1	0.2	0.8	1.3	22
1991	19.9	14.6	0.0	1.8	1.0	0.1	0.8	0.1	2.1	19
1992	4.4	11.8	0.0	1.0	7.5	0.5	0.1	1.3	0.9	20
1993	19.1	19.1	0.0	2.9	1.2	1.3	0.0	0.6	0.7	21
1994	6.5	15.7	0.0	0.7	2.2	2.1	0.9	0.1	1.9	20
1995	17.6	5.8	0.0	0.7	4.6	0.0	1.8	0.2	1.0	25
1996	1.7	0.2	0.0	0.1	1.3	0.1	0.1	0.2	0.1	20
1997	5.3	0.0	0.0	2.3	2.0	0.0	0.1	0.1	0.5	22
1998	37.0	8.1	0.2	1.2	0.6	0.2	3.0	0.3	0.6	27
1999	1.5	2.5	0.0	0.0	0.3	0.0	0.0	0.4	0.5	31
2000	3.0	0.8	0.6	2.4	0.1	0.3	0.0	0.1	0.1	20
2001	6.3	3.4	15.4	2.0	0.2	0.0	0.1	0.2	0.1	22
2002	1.9	0.2	10.7	0.1	0.4	0.0	0.0	0.3	0.6	20
2003	2.5	0.4	6.6	0.0	0.2	0.0	0.4	0.8	3.8	17
2004	3.7	4.9	12.0	0.5	0.2	0.0	0.6	0.5	0.2	20
2005	7.6	0.0	30.3	0.1	0.2	0.0	0.1	0.3	1.0	15
1989–93	13.8	13.6	0.0	2.6	2.6	0.5	0.2	0.6	1.1	
95% CI	7.8	5.4	0.0	1.5	3.4	0.6	0.4	0.6	0.8	
1994–99	11.6	5.4	0.0	0.8	1.8	0.4	1.0	0.2	0.7	
95% CI	14.5	6.3	0.1	0.9	1.7	0.9	1.2	0.1	0.7	
2000–05	4.2	1.6	12.6	0.8	0.2	0.0	0.2	0.4	1.0	
95% CI	2.4	2.1	10.6	1.1	0.1	0.1	0.2	0.3	1.5	
1989–2005	9.6	6.5	4.5	1.4	1.5	0.3	0.5	0.4	0.9	21.5

Table 4.–Mean numerical catch per 10-minute trawl tow for most common species in Big Bay de Noc and number of tows (n). Mean values, with 95% confidence intervals (CI) below, occur for 1989–93, 1994–99, and 2000–05. Species are arranged in descending order based on abundance for the total time period.

Year	Yellow perch	Johnny darter	Trout-perch	Spottail shiner	Round goby	Brook stickleback	Rainbow smelt	Smallmouth bass	Others	n
1989	0.8	0.8	2.2	0.5	0.0	0.0	6.0	0.0	1.5	24
1990	43.6	1.5	33.1	28.7	0.0	0.0	5.2	0.0	1.2	19
1991	128.9	1.2	0.5	0.7	0.0	0.0	0.8	0.1	0.6	20
1992	1.7	0.9	0.5	0.2	0.0	0.0	1.1	0.0	0.3	20
1993	11.4	11.9	14.4	3.4	0.0	0.1	2.5	0.1	0.3	19
1994	75.2	1.8	0.5	0.5	0.0	0.0	0.4	0.0	2.1	20
1995	33.5	4.5	0.0	1.4	0.0	1.9	0.0	0.6	7.3	22
1996	8.8	1.3	0.4	10.5	0.0	4.0	0.0	0.1	1.5	20
1997	7.9	2.9	0.0	0.4	0.0	0.2	0.0	4.4	0.6	16
1998	35.3	3.3	0.0	0.1	0.0	1.8	0.0	3.7	0.9	22
1999	3.1	3.4	0.0	0.0	0.0	2.1	0.0	1.2	8.8	21
2000	0.7	2.1	0.0	0.0	0.0	3.5	0.0	1.5	0.4	21
2001	11.5	3.8	0.0	0.1	0.0	6.2	0.0	3.8	0.2	22
2002	2.2	4.0	0.0	0.1	0.0	0.4	0.0	0.5	1.0	21
2003	3.7	2.0	0.0	0.1	1.1	1.6	0.0	0.2	2.4	20
2004	1.6	3.2	0.2	0.0	2.9	2.8	0.0	0.2	0.4	20
2005	1.5	2.4	0.0	0.0	37.1	2.1	0.0	1.4	0.5	15
1989–93	37.3	3.3	10.1	6.7	0.0	0.0	3.1	0.0	0.8	
95% CI	67.2	6.0	17.5	15.4	0.0	0.1	3.0	0.0	0.7	
1994–99	27.3	2.9	0.2	2.2	0.0	1.7	0.1	1.7	3.5	
95% CI	28.5	1.2	0.2	4.3	0.0	1.5	0.2	2.0	3.7	
2000–05	3.5	2.9	0.0	0.0	6.9	2.8	0.0	1.2	0.8	
95% CI	4.2	0.9	0.1	0.0	15.6	2.1	0.0	1.4	0.9	
1989–2005	21.8	3.0	3.0	2.7	2.4	1.6	0.9	1.0	1.8	20.1

Table 5.–Catch of most common species per net night using 18-m experimental mesh gill nets in Little Bay de Noc and number of lifts per year (n). Mean values, with 95% confidence intervals (CI) below, occur for 1989–93, 1994–99, and 2000–05. Species are arranged in descending order based on abundance for the total time period.

Year	Yellow perch	Alewife	Walleye	Northern pike	White sucker	Spottail shiner	Smallmouth bass	Rock bass	Trout-perch	Others	n
1989	11.3	4.4	1.4	0.6	0.8	0.3	0.2	0.4	0.3	0.3	20
1990	7.8	3.1	1.7	0.5	0.3	1.8	0.1	0.2	0.2	0.3	20
1991	10.4	4.1	2.5	0.6	1.0	0.8	0.6	0.4	0.7	1.3	21
1992	15.1	2.5	1.5	2.1	0.6	1.0	0.0	0.5	0.4	0.2	16
1993	6.6	4.0	2.1	1.6	0.3	0.5	0.0	0.5	0.6	0.1	16
1994	13.3	6.2	1.1	0.9	0.8	0.2	0.2	0.3	0.4	0.8	16
1995	12.0	7.1	1.4	0.7	0.8	0.9	0.9	0.3	0.2	0.8	16
1996	7.5	0.9	0.7	0.7	1.3	0.7	0.0	0.4	0.3	0.6	16
1997	8.0	1.6	2.1	1.7	0.6	0.1	0.0	0.3	0.3	0.8	16
1998	6.2	0.5	1.4	0.4	0.7	1.2	0.3	0.6	0.3	0.3	16
1999	4.4	0.8	2.4	1.6	0.6	0.3	1.4	0.3	0.6	1.0	16
2000	3.2	0.1	1.8	1.3	0.4	0.1	0.4	0.2	0.1	0.6	18
2001	2.3	0.3	2.0	0.2	0.9	0.1	0.2	0.3	0.4	1.1	16
2002	6.3	0.2	1.1	0.3	0.3	0.2	0.8	0.1	0.1	0.4	16
2003	1.4	0.0	1.8	0.4	0.9	0.0	0.5	0.3	0.1	0.3	16
2004	2.4	0.0	1.6	0.4	0.3	0.0	0.4	0.4	0.2	0.7	16
2005	4.8	1.8	2.5	0.1	0.8	0.0	0.3	0.1	0.1	0.4	12
1989–93	10.2	3.6	1.8	1.1	0.6	0.9	0.2	0.4	0.4	0.4	
95% CI	4.1	1.0	0.6	0.9	0.4	0.7	0.3	0.2	0.3	0.6	
1994–99	8.6	2.8	1.5	1.0	0.8	0.6	0.5	0.4	0.4	0.7	
95% CI	3.6	3.1	0.7	0.6	0.3	0.5	0.6	0.1	0.2	0.2	
2000–05	3.4	0.4	1.8	0.4	0.6	0.1	0.4	0.2	0.2	0.6	
95% CI	1.9	0.7	0.5	0.5	0.3	0.1	0.2	0.1	0.1	0.3	
1989–2005	7.2	2.2	1.7	0.8	0.7	0.5	0.4	0.3	0.3	0.6	16.6

Table 6.–Catch of most common species per net night using 18-m experimental mesh gill nets in Big Bay de Noc and number of lifts per year (n). Mean values, with 95% confidence intervals (CI) below, occur for 1989–93, 1994–99, and 2000–05. Species are arranged in descending order based on abundance for the total time period.

Year	Yellow perch	Alewife	Spottail shiner	White sucker	Trout-perch	Walleye	Northern pike	Smallmouth bass	Others	n
1989	19.1	4.1	1.1	0.9	0.1	1.0	0.2	0.0	0.3	18
1990	9.7	1.4	1.6	0.7	0.2	0.6	0.5	0.1	0.6	20
1991	8.4	4.6	2.6	0.6	1.6	0.1	0.4	0.2	0.0	14
1992	13.6	2.3	1.7	1.5	0.4	0.3	0.3	0.1	0.1	16
1993	8.3	4.0	1.9	0.6	0.6	0.1	0.3	0.1	0.1	16
1994	5.4	13.4	1.3	0.3	0.6	0.1	0.4	0.0	0.5	16
1995	4.8	8.7	2.0	0.2	2.7	0.3	0.1	0.1	0.3	16
1996	14.0	4.3	1.0	0.7	2.2	0.2	0.0	0.0	1.0	16
1997	11.2	5.3	0.9	0.6	0.1	0.6	0.2	1.1	0.4	16
1998	4.5	1.6	1.1	1.1	0.0	0.0	0.1	0.2	2.4	16
1999	15.3	0.8	3.1	0.4	0.0	0.4	0.5	0.2	0.6	16
2000	6.3	3.5	1.0	0.4	0.0	0.1	0.3	0.0	0.9	16
2001	5.6	0.1	0.9	0.3	0.0	0.3	0.1	0.1	0.6	16
2002	9.9	0.4	0.8	0.4	0.3	0.4	0.2	0.5	0.3	16
2003	8.3	1.0	0.2	0.2	0.0	0.4	0.3	0.3	0.4	16
2004	6.4	0.3	0.0	0.1	0.3	0.2	0.1	0.1	0.2	16
2005	5.3	0.0	0.0	0.2	0.1	0.3	0.1	0.1	0.5	12
1989–93	11.8	3.3	1.8	0.9	0.6	0.4	0.3	0.1	0.2	
95% CI	5.7	1.7	0.7	0.5	0.8	0.5	0.1	0.1	0.3	
1994–99	9.2	5.6	1.6	0.6	0.9	0.3	0.2	0.3	0.9	
95% CI	5.1	5.0	0.9	0.3	1.3	0.2	0.2	0.4	0.8	
2000–05	7.0	0.9	0.5	0.2	0.1	0.3	0.2	0.2	0.5	
95% CI	1.9	1.4	0.5	0.1	0.1	0.1	0.1	0.2	0.3	
1989–2005	9.2	3.3	1.2	0.5	0.5	0.3	0.2	0.2	0.5	16.0

Table 7.–Frequency of occurrence of diet items in walleye by time period and location. Numbers for food item categories show the percent of nonempty stomachs examined that contained a given food item. Percentages are not necessarily additive among or within categories because some stomachs contained multiple food items.

Parameter	Little Bay de Noc			Big Bay de Noc		
	1988–93	1994–99	2000–05	1988–93	1994–99	2000–05
Stomach summary						
Number examined	303	162	224	38	26	168
Number containing identifiable food items	182	83	105	18	15	76
Percent empty	37.3	43.2	25.0	50.0	42.3	48.2
Food item categories						
Crustacea						
Amphipod			1.0			
Bythotrephes	0.5					
Other (zooplankton)	0.5					
All Crustacea	1.1					
Insecta						
Diptera	3.8	1.2				
Ephemeroptera	13.7	16.9	13.3			5.3
Other (Odonata, Coleoptera, terrestrial)	1.6					5.3
All Insecta	18.1	18.1	13.3			9.2
Oligochaeta						
Worm	2.2					
Pisces						
Alewife	8.8	19.3	26.7	33.3	33.3	11.8
Centrarchids	3.8					
Johnny darter	3.3	1.2		5.6		2.6
Rainbow smelt	18.7	12.0	1.0	11.1	6.7	
Round goby			1.0			3.9
Spottail shiner		1.2	1.0			1.3
Trout-perch	0.5	1.2				
White sucker	2.2	3.6	1.0			1.3
Yellow perch	3.8	3.6	1.9			3.9
Other (Chinook salmon, bluntnose minnow, logperch, unidentified)	40.7	59.0	62.9	61.1	80.0	57.9
All Pisces	79.7	81.9	86.7	100.0	100.0	77.6

Table 8.–Numbers of fish tagged and estimates of recovery rate and annual survival (%) produced by the program "ESTIMATE" (Brownie 1985) during 1988–2005 for walleyes tagged in Big and Little bays de Noc and the Cedar and Menominee rivers.

Year	Number tagged	Recovery rate (%)	Standard error	Survival (%)	Standard error
			Little Bay de Noc		
1990	1,744	5.4	0.5	53.3	8.0
1991	1,886	4.0	0.4	49.5	7.7
1992	1,690	3.0	0.4	36.3	5.6
1993	1,563	4.2	0.5	37.8	5.7
1994	1,246	5.0	0.5	42.7	7.4
1995	711	4.3	0.6	59.6	11.8
1996	700	3.5	0.6	56.9	12.2
1997	700	3.2	0.5	34.8	7.7
1998	470	4.0	0.7	68.9	15.2
1999	530	2.6	0.5	52.9	11.3
2000	500	4.2	0.7	63.9	13.7
2001	500	3.7	0.7	91.4	23.2
2002	500	2.1	0.5	34.6	8.2
2003	893	4.7	0.6	58.5	12.6
2004	506	4.3	0.8	57.5	16.9
2005	500	3.4	0.7	26.6	10.0
Mean		3.8	0.1	51.6	1.6
			Big Bay de Noc		
1993	617	3.2	0.7	108.5	24.3
1994	1,458	2.3	0.4	26.3	5.1
1995	1,993	3.6	0.4	44.0	6.8
1996	1,324	2.9	0.4	66.6	12.0
1997	868	2.8	0.4	62.3	36.5
1998	77	1.8	1.0	55.4	33.9
1999	609	0.7	0.2	33.9	14.3
2000	92	2.5	1.0	71.6	48.3
2001	55	1.2	0.8	22.1	17.2
2002	20	6.9	3.9	92.8	52.8
2003	617	4.9	0.8	128.1	53.6
2004	280	1.3	0.5	–	–
Mean		3.0	0.4	64.7	7.0
			Cedar River		
1993	1,312	3.8	0.5	45.3	8.3
1994	1,500	4.8	0.5	38.1	7.5
1995	1,677	2.5	0.3	40.6	9.6
1996	445	2.5	0.6	48.6	11.9
1997	925	3.0	0.5	57.2	10.3
1998	1,290	2.0	0.3	72.7	11.7
1999	1,203	1.8	0.3	62.9	11.2
2000	748	2.4	0.4	60.2	11.0
2001	843	2.1	0.4	117.3	21.6
2002	1,057	2.0	0.3	32.1	6.1
2003	714	4.1	0.6	132.0	28.0
2004	1,021	1.3	0.3	–	–
Mean		2.8	0.1	64.3	3.0

Table 8.–Continued.

Year	Number tagged	Recovery rate (%)	Standard error	Survival (%)	Standard error
		Menominee River			
1993	1,280	7.3	0.7	23.1	4.7
1994	1,500	7.7	0.7	20.5	4.0
1995	1,879	5.3	0.5	41.2	8.1
1996	544	3.8	0.7	46.8	9.6
1997	1,758	4.1	0.4	38.5	6.2
1998	1,155	3.7	0.5	56.7	9.1
1999	1,503	2.7	0.4	47.8	7.3
2000	1,059	3.4	0.5	57.7	9.1
2001	983	3.7	0.5	71.7	12.3
2002	942	2.8	0.4	66.3	12.6
2003	959	3.3	0.5	74.9	17.9
2004	1,000	1.6	0.3	–	–
Mean		4.4	0.2	49.6	1.8

Table 9.–Frequency of movement distances for walleyes jaw-tagged during the spawning period at four locations in northern Green Bay. For example, 486 walleyes recaptured by anglers were 5 to 10 km from their tagging location in Little Bay de Noc.

Movement (km)	Little Bay de Noc	Big Bay de Noc	Cedar River	Menominee River
<5	1,050	356	192	983
5–10	486	93	12	68
11–15	68	48	37	11
16–20	183	18	1	17
21–25	54	1	12	25
26–30	12	7	6	5
31–35	1	2	3	20
36–40	0	5	285	10
41–45	2	4	114	14
46–50	2	6	13	0
51–55	3	2	22	7
56–60	1	0	26	0
61–65	3	1	7	9
66–70	4	0	15	8
71–75	0	0	18	5
76–80	1	0	1	2
81–85	0	0	0	0
86–90	0	0	4	0
91–95	0	1	3	2
96–100	3	0	0	1
101–105	6	0	7	0
>105	8	1	1	0

Table 10.–Mean and standard error (SE) of displacement (in km) of angler-caught walleyes from tagging locations by season and period. Number of observations = N. Seasons and associated months when walleyes were caught were: winter (January–March), spring (April–June); summer (July–September), and fall (October–December).

	Spring			Summer			Fall			Winter			All seasons		
Period	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE
Big Bay de Noc															
1988–93	48	7.4	2.6	27	3.9	1.8	0						75	6.1	1.8
1994–99	162	6.1	0.8	127	5.9	0.9	48	3.8	1.5	7	7.7	6.5	344	5.8	0.5
2000–05	55	7.4	2.0	50	7.4	1.8	8	6.5	5.5	10	8.8	4.3	123	7.4	1.2
All years	265	6.6	0.8	204	6.0	0.7	56	4.2	1.5	17	8.4	3.6	542	6.2	0.5
Cedar River															
1988–93	26	21.9	4.4	23	32.9	4.1	0						49	27.0	3.1
1994–99	250	36.0	1.2	88	40.0	2.5	2	50.4	7.2	2	43.2	0.0	342	37.2	1.1
2000–05	244	38.4	1.7	69	34.5	3.8	48	7.2	2.1	7	48.1	8.4	368	33.8	1.5
All years	520	36.4	1.0	180	37.0	2.0	50	8.9	2.4	9	47.0	6.5	759	34.9	0.9
Little Bay de Noc															
1988–93	393	5.1	0.5	427	7.2	0.4	176	4.2	0.4	129	4.2	0.3	1,125	5.7	0.2
1994–99	140	11.5	1.2	121	10.4	1.5	96	5.3	0.5	75	3.9	0.4	432	8.5	0.6
2000–05	151	18.4	3.2	39	20.1	4.3	67	5.7	0.7	61	6.1	1.1	318	13.6	1.6
All years	684	9.3	0.8	587	8.7	0.5	339	4.8	0.3	265	4.5	0.3	1,875	7.6	0.3
Menominee River															
1988–93	76	0.4	0.1	23	1.0	0.2	1	1.8			0.0	0.0	100	0.6	0.1
1994–99	450	2.4	0.4	120	8.7	1.7	12	8.1	7.3	14	1.5	0.3	596	3.8	0.5
2000–05	387	6.1	0.7	60	24.2	3.9	13	28.7	7.5	14	9.5	5.3	474	9.1	0.8
All years	913	3.8	0.4	203	12.4	1.6	26	18.1	5.3	28	5.5	2.7	1,170	5.7	0.4

Table 11.–Mean length at age (mm) of walleyes from samples collected during tagging operations in 1988, 1996, 1999, and 2002 at Little Bay de Noc, and in 1996, 1999, and 2002 at Big Bay de Noc, Menominee River, and Cedar River. SE is standard error of the mean and N is the number of fish aged.

	Little Bay de Noc			Big Bay de Noc			Menominee River			Cedar River		
Age	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE	N
Males												
2	362	18.4	5				370	8.8	8			
3	371	3.4	70	432		1	416	4.3	45	410	5.2	16
4	429	3.8	119	446	11.7	9	452	4.7	58	452	3.7	104
5	480	5.1	130	484	23.6	7	474	7.7	41	501	6.4	56
6	514	7.3	57	490	6.1	26	515	8.0	39	525	11.7	17
7	531	17.1	23	554	9.8	19	575	5.1	38	571	4.7	24
8	550	6.1	43	578	9.5	23	569	11.0	21	581	9.2	11
9	561	7.1	32	615	6.5	26	578	15.3	9	608	23.5	5
10	581	7.8	29	609	11.5	17	600	10.5	14	616	3.1	3
11	619	7.6	25	615	5.7	8	602	16.1	8	607	9.5	9
12	611	9.1	11	625	17.5	7	665	45.7	2	633	8.0	6
13	630	12.3	8	612	16.7	3	610	0.0	1	582		1
14	623	9.2	6				550	85.1	2	648		1
15	583	27.3	3				566	0.0	1			
16	668		1	632		1	645	0.0	1			
17	620	27.9	2									
18	554		1									
Females												
3				442		1	504	62.2	2	416	12.3	5
4	480		1				540	8.7	28	513	5.4	63
5	523	25.7	6	517	16.3	5	535	4.9	73	542	4.0	85
6	542	5.8	31	520	8.1	7	549	13.1	16	573	7.5	25
7	572	6.9	30	594	14.7	10	599	9.9	27	631	7.2	32
8	583	4.5	44	614	8.9	13	625	10.1	25	623	12.9	20
9	612	8.0	27	651	6.0	33	645	8.6	23	645	15.2	2
10	652	7.1	24	688	6.8	15	667	8.0	21	681	12.7	9
11	655	6.2	34	679	12.1	8	676	9.7	24	677	12.8	7
12	670	6.0	40	719	2.5	2	661	10.2	10	701	9.2	13
13	689	6.4	30	681		1	696	18.7	9	737	18.7	3
14	725	7.1	20				721	10.2	2	742		1
15	719	10.5	13				709	2.5	2			
16	738	11.0	6				681		1			
17	658	30.5	2									
18	732	14.7	4				635		1			
19							739		1			
20												
21												
22	709		1									

Table 12.–Year class assignments of walleye aged from tagging surveys in 1988, 1996, 1999, and 2002, and from annual summer assessment surveys during 1988–2005 in Little Bay de Noc and Big Bay de Noc. Aging structures are taken from 20 fish per 25 mm length group per sex on tagging surveys and from all walleyes captured during summer surveys. Unstocked years are shaded gray.

	Sample year								
	Little Bay de Noc					Big Bay de Noc			
Year class	1988	1996	1999	2002	1988–2005	1996	1999	2002	1988–2005
2004					1				
2003					4				
2002					8				1
2001					23				5
2000					26				
1999					16				4
1998				16	56			3	9
1997				18	30				3
1996			3	8	9			1	3
1995			42	4	18		3	1	8
1994			49	33	31		1		1
1993			22	10	12	2	4		2
1992		13	10	21	19	3	20	2	3
1991		25	17	21	40	11	15	5	2
1990		16	6	15	36	28	8	3	3
1989		7	8	8	30	8	16	2	2
1988		15	8	16	39	21	11		5
1987		30	17	12	56	51	4		14
1986	5	17	12	4	26	14	1	1	14
1985	67	17	4	1	16				2
1984	49	11	1		10	2			1
1983	45	6	1		4	1			
1982	42	4			1				
1981	32	1			2				
1980	22	2							
1979	13	3							
1978	7	5							
1977	13								
1976	8								
1975	12								
1974	2	1							
1973	2								

Table 13.–Year class assignments of walleye aged from tagging surveys in Cedar and Menominee rivers. Aging structures are taken from 20 fish per 25 mm group per sex. Year classes from unstocked years are bold and shaded gray.

	Sample year					
	Menominee River			Cedar River		
Year class	1996	1999	2002	1996	1999	2002
1999			14			
1998			40			62
1997			40			12
1996		4	14		13	7
1995		28	33		99	27
1994	8	27	11		77	16
1993	29	26	12	10	8	5
1992	18	15	17	15	5	10
1991	47	29	24	62	8	16
1990	15	12	3	28	1	19
1989	17	8	4	24	2	4
1988	6	5	2	7		2
1987	8	4		1		
1986	10	4	1			
1985	3					
1984	5	2				
1983	2	1				
1982	2					
1981	1					
1980						
1979						
1978	1					
1977	1					

Table 14.–Mean length of age-3 females (mm), percent female, and total annual mortality for yellow perch in Little and Big bays de Noc from summer gill net assessment data. Mean lengths at age-3 were calculated separately for Little Bay de Noc (LBdN) and Big Bay de Noc (BBdN), but percent female and total annual mortality were estimated using data from both bays. Total annual mortality of each year class was estimated using the "best" minimum–variance unbiased estimators of survival derived from coded age frequencies (Robson and Chapman 1961). Total annual mortality was estimated for age-3 to age-9 yellow perch, but estimates for years indicated by an asterisk (*) were based on age-3 to age-8 because no yellow perch older than age-7 were observed.

	Little Bay de Noc			Big Bay de Noc			Both bays, all ages		
Year	Mean	SE	N	Mean	SE	N	Percent female	N	Total annual mortality
1989	159	5	13	196	4	22	60	526	0.477
1990	154	3	16	177	9	17	60	344	0.482
1991	182	4	24	190	4	21	65	332	0.487
1992	176	6	14	169	7	10	47	431	0.596
1993	160	4	23	160	3	17	73	237	0.651*
1994	176	4	19	191	3	22	69	257	0.642*
1995	157	12	3	179	4	13	68	203	0.654*
1996	166	3	15	181	3	23	74	228	0.646*
1997	166	4	19	188	23	2	70	221	0.593
1998	171	7	8	152	2	4	65	169	0.550
1999	164	11	10	158	3	15	65	201	0.496
2000	164	8	13	187	8	14	73	152	0.495
2001	208	30	8	231	7	15	73	120	0.449
2002	166	6	5	229	6	4	64	204	0.505
2003	180	8	5	201	16	9	70	151	0.525
2004	188	5	11	207	11	2	83	106	
2005	160	4	6	195	4	17	74	101	
1988–2005	170	2	212	186	2	227	68	3,983	0.550

Table 15.–Frequency of occurrence of diet items in yellow perch by 6-year time period and location. Numbers for food item categories show the percent of nonempty stomachs examined that contained a given food item. Percentages are not necessarily additive among or within categories because some stomachs contained multiple food items.

	Little Bay de Noc			Big Bay de Noc		
Parameter	1988–93	1994–99	2000–05	1988–93	1994–99	2000–05
Stomach summary						
Number examined	2,311	1,043	398	1,474	906	578
Number containing identifiable food items	1,790	762	291	1,058	697	385
Percent empty	17.6	23.0	15.3	26.5	20.9	20.9
Food item categories						
Arachnoida						
Hydrachna	0.3			0.4		
Crustacea						
Amphipod	8.3	14.0	3.1	29.3	35.9	17.4
Bythotrephes	46.0	27.8	38.1	8.5	3.6	0.8
Crayfish	0.8	1.0	1.7	0.9	7.9	17.9
Daphnia	0.4					
Isopod	10.4	1.3	0.3	1.5	0.9	
Ostracod		0.1				
Other (zooplankton and unidentified crustacea)	16.8	11.8	14.1	22.9	20.5	1.6
All Crustacea	62.6	43.6	50.5	56.2	64.1	36.9
Gastropoda						
Snail	0.5	0.1		1.3	0.1	
Hirudinea						
Leech	3.7			0.1		
Insecta						
Coleoptera	0.1				0.1	
Diptera	18.0	19.9	4.1	24.6	14.1	3.1
Ephemeroptera	15.5	30.4	27.5	8.6	23.8	52.5
Hemiptera	1.0	2.6		2.8	1.0	0.3
Odonata	0.7			0.2	0.1	0.3
Tricoptera	7.0	2.8		4.8	2.0	
Other	1.0		1.0	0.2	0.3	0.8
All Insecta	37.6	49.0	32.6	36.5	37.0	55.3
Oligochaeta						
Worm	3.4	0.9	0.7	3.2		
Pelecypoda						
Clam	0.7	0.4		0.2		
Zebra mussel		0.5	0.3		0.3	0.3
Other (unidentified mussel)		0.3				
All Pelecypoda	0.7	1.2	0.3	0.2	0.3	0.3

Table 15.–Continued.

Parameter	Little Bay de Noc 1988–93	Little Bay de Noc 1994–99	Little Bay de Noc 2000–05	Big Bay de Noc 1988–93	Big Bay de Noc 1994–99	Big Bay de Noc 2000–05
Pisces						
Alewife	1.5	0.9	1.0	4.9	3.3	
Centrarchids	0.1			0.1		
Johnny darter	0.6	0.8		1.1	3.4	0.3
Mottled sculpin					0.3	
Rainbow smelt	0.5	0.4		0.2		
Round goby			1.4			0.5
Spottail shiner	0.2			0.2	0.4	
Sticklebacks				0.2	5.0	3.4
Trout-perch	1.1	8.5	0.7	2.4	1.9	
Walleye	0.1	0.1		0.2		
White sucker						0.3
Yellow perch	0.7	0.5		0.2		
Other[a]	9.2	11.3	18.9	9.3	11.8	13.5
All Pisces	12.9	21.4	21.6	18.0	22.2	16.9
Plant						
Pollen, seeds, plant material	0.9		1.0	1.1	1.6	3.1

[a] lake herring, freshwater drum, logperch, splake, largemouth bass, unidentified

Table 16.–Length and age of major game fishes harvested by anglers during four time periods in Big Bay de Noc (BBdN), Cedar River (CR), Little Bay de Noc (LBdN), and Menominee River (MR). Summaries for Cedar and Menominee rivers are based on fish caught in each river as well as adjacent waters of Lake Michigan. Time periods were 1983–88 (0), 1989–93 (1), 1994–99 (2), and 2000–05 (3). Summary statistics were number of samples, mean, standard error of the mean (SE), and standard deviation (S Dev). Data were not available for all combinations of species, area, and period. Data are arranged alphabetically by species.

		Total length (mm)				Age (years)			
Area	Period	N	Mean	SE	S Dev	N	Mean	SE	S Dev
Brown trout									
CR	0	240	489	4.3	67.2	240	2.8	0.1	0.8
CR	1	86	488	9.8	91.2	86	2.0	0.1	0.9
CR	2	16	546	30.7	123.0	16	2.4	0.2	0.9
CR	3	2	517	41.9	59.3	2	2.5	0.5	0.7
LBdN	0	12	449	28.7	99.6	12	2.2	0.2	0.8
LBdN	1	65	499	11.0	88.9	64	2.7	0.1	0.6
LBdN	2	37	483	12.9	78.6	37	2.4	0.1	0.6
LBdN	3	25	526	21.9	109.6	25	2.8	0.1	0.6
MR	0	582	527	4.2	101.5	582	2.7	0.0	1.1
MR	1	74	556	11.3	96.9	74	2.4	0.1	0.8
MR	2	31	583	25.4	141.3	31	2.4	0.3	1.4
MR	3	10	634	38.2	120.8	9	3.0	0.4	1.1
Chinook salmon									
BBdN	0	2	804	67.3	95.2	2	2.5	0.5	0.7
BBdN	1	32	692	33.1	187.2	32	2.7	0.2	1.3
CR	0	42	818	17.3	111.9	42	3.2	0.1	0.8
CR	1	43	570	20.2	132.3	43	2.2	0.2	1.0
CR	2	16	480	20.6	82.4	16	1.2	0.1	0.5
LBdN	0	127	764	13.6	153.8	127	2.8	0.1	1.0
LBdN	1	40	623	25.9	163.9	40	2.2	0.1	0.9
LBdN	2	3	456	25.8	44.6	3	1.3	0.3	0.6
LBdN	3	15	692	46.6	180.5	4	3.3	0.3	0.5
MR	0	563	703	7.4	174.7	563	2.4	0.0	1.1
MR	1	9	713	58.4	175.3	9	2.8	0.4	1.1
MR	2	8	466	9.3	26.4	8	1.0	0.0	0.0
MR	3	1	945			1	4.0		
Northern pike									
BBdN	0	11	686	39.4	130.6	11	5.2	0.5	1.7
BBdN	1	33	757	24.5	140.5	33	5.4	0.4	2.0
CR	0	20	631	22.9	102.4	20	4.3	0.3	1.4
CR	1	1	775			1	4.0		
LBdN	0	48	669	20.6	142.4	48	4.8	0.3	2.1
LBdN	1	105	651	9.7	98.9	105	4.5	0.1	1.5
LBdN	2	6	740	44.2	108.2	6	5.8	0.5	1.2
MR	0	21	696	25.7	117.6	21	4.6	0.4	1.7

Table 16.–Continued.

Area	Period	Total length (mm) N	Mean	SE	S Dev	Age (years) N	Mean	SE	S Dev
Rainbow trout									
CR	0	7	509	21.8	57.8	6	2.3	0.3	0.8
CR	1	2	566	2.5	3.6	2	2.0	0.0	0.0
CR	2	1	541			1	2.0		
LBdN	0	1	589			1	2.0		
LBdN	2	1	787			1	8.0		
LBdN	3	1	798						
MR	0	109	614	12.1	126.2	103	2.9	0.1	1.0
MR	1	6	643	38.6	94.5	6	3.8	0.4	1.0
MR	2	5	526	48.7	109.0	5	2.8	0.5	1.1
MR	3	4	601	71.6	143.1				
Smallmouth bass									
BBdN	0	65	358	6.2	50.0	65	5.4	0.2	1.4
BBdN	1	433	363	2.0	42.6	433	5.1	0.1	1.2
BBdN	2	173	387	3.3	43.7	173	5.9	0.1	1.5
BBdN	3	77	393	4.2	37.1	54	5.1	0.1	1.1
CR	0	164	336	3.9	49.8	164	4.7	0.1	1.3
CR	1	39	333	5.0	31.5	39	3.8	0.1	0.8
CR	3	2	425	31.8	44.9	2	6.5	0.5	0.7
LBdN	0	32	343	4.8	27.0	32	4.8	0.1	0.7
LBdN	1	33	354	6.7	38.5	33	4.4	0.2	1.1
LBdN	2	1	411						
LBdN	3	7	409	11.6	30.8	7	5.6	0.4	1.0
MR	0	27	338	12.6	65.6	27	4.6	0.4	2.3
MR	1	2	347	34.3	48.5	2	4.5	0.5	0.7
Splake									
CR	0	77	421	6.5	56.7	77	2.2	0.1	0.6
CR	1	25	523	12.0	60.2	25	3.1	0.1	0.5
CR	2	19	475	19.3	84.2	19	1.9	0.2	0.7
CR	3	3	608	21.1	36.5	3	3.3	0.3	0.6
LBdN	0	7	512	31.2	82.5	7	2.1	0.1	0.4
LBdN	1	107	416	6.9	71.4	107	2.2	0.0	0.4
LBdN	2	166	417	5.7	73.7	166	2.4	0.0	0.6
LBdN	3	53	543	13.6	98.9	46	2.5	0.1	0.6
MR	0	94	461	8.9	86.0	94	2.3	0.1	0.7
MR	1	4	525	50.5	100.9	4	3.3	0.5	1.0
MR	2	15	443	14.4	55.9	15	2.1	0.2	0.6
MR	3	1	551			1	3.0		

Table 16.–Continued.

Area	Period	Total length (mm)				Age (years)			
		N	Mean	SE	S Dev	N	Mean	SE	S Dev
Walleye									
BBdN	0	8	408	4.2	11.8	8	3.3	0.2	0.5
BBdN	1	266	471	4.0	64.7	266	4.7	0.1	1.9
BBdN	2	259	486	5.0	79.8	259	5.2	0.1	2.0
BBdN	3	55	556	12.3	91.5	46	7.0	0.4	2.6
CR	2	6	474	31.8	77.8	6	4.7	0.8	1.9
CR	3	25	604	15.3	76.5	25	8.6	0.6	2.9
LBdN	0	537	508	4.4	101.5	537	6.2	0.1	2.8
LBdN	1	1,017	485	2.7	85.3	1,017	5.4	0.1	2.4
LBdN	2	774	478	3.0	84.0	774	5.7	0.1	2.3
LBdN	3	783	470	2.9	80.3	602	5.6	0.1	2.3
MR	0	110	460	7.0	73.4	110	4.7	0.2	1.9
MR	1	3	374	13.6	23.6	3	3.0	0.6	1.0
MR	2	74	447	6.3	54.4	74	3.7	0.1	0.9
MR	3	29	546	13.0	70.2	29	6.2	0.3	1.8
Yellow perch									
BBdN	0	554	211	1.4	33.6	553	4.4	0.1	1.5
BBdN	1	726	220	1.4	36.9	726	4.4	0.1	1.6
BBdN	2	242	203	2.0	31.7	242	3.6	0.1	1.3
BBdN	3	28	185	5.6	29.9	4	3.8	0.6	1.3
CR	0	217	245	2.9	42.0	217	4.4	0.1	1.6
CR	1	55	255	6.2	45.9	55	4.7	0.2	1.4
CR	2	108	227	2.8	28.7	108	4.6	0.1	1.1
LBdN	0	506	205	1.9	41.8	506	4.3	0.1	1.3
LBdN	1	1,569	220	1.2	48.0	1,569	4.9	0.0	1.9
LBdN	2	1,334	216	1.2	43.2	1,335	4.7	0.0	1.6
LBdN	3	888	205	1.4	43.1	660	4.3	0.1	1.5
MR	0	874	221	1.4	41.7	873	4.7	0.1	1.7
MR	1	112	245	3.7	39.5	112	5.0	0.1	1.5
MR	2	218	220	2.3	33.5	218	4.3	0.1	1.5

Table 17.–Annual exploitation and survival rates of walleye populations in various Michigan waters. Method codes for estimating exploitation and survival are: A = reward tag returns and survival estimated from catch curve regression; B = tag returns adjusted upward by a factor of 2.7 due to nonreporting (Thomas and Haas 2000) and Brownie (1985) survival estimates; C = AD Model Builder catch-at-age model.

Water body	Annual exploitation (%)	Annual survival (%)	Method	Reference
Big and Little bays de Noc		35		Schneider and Crowe (1977)
Crooked and Pickerel Lks	16.3	49	A	Hanchin et al. (2005c)
Menominee R	11.8	49.6	B	This study
LBDN	10.4	51.6	B	This study
Houghton L	10.6	54	A	Clark et al. (2004)
Lake Erie	18.0	55	C	Thomas and Haas (2005)
Muskegon L	3.6	62	A	Hanchin et al. (2007b)
Burt L	9.0	62	A	Hanchin et al. (2005b)
Lake Leelanau	16.0	62	A	Hanchin et al. (2007a)
Michigamme Reservoir	29.3	63	A	Hanchin et al. (2005a)
Saginaw Bay	8.0	64	B	Fielder et al. (2005)
Cedar R	7.5	64.3	B	This study
BBDN	8.1	64.7	B	This study
Big Manistique	9.4	69	A	Hanchin et al. (2007)

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Approved by Tammy J. Newcomb

Appendix 1a.–Catch per 10-minute trawl tow for species in Little Bay de Noc not included in Table 3. Species sorted by total abundance in collections.

Year	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Walleye	0.083	0.818	1.947	0.200	0.191	0.450	0.000	0.050	0.000	0.222	0.000	0.000	0.095	0.200	0.177	0.100	0.000
Alewife	0.083	0.000	0.000	0.400	0.000	0.200	0.040	0.000	0.000	0.000	0.097	0.000	0.000	0.000	3.353	0.000	0.467
Logperch	0.167	0.409	0.105	0.200	0.048	0.950	0.160	0.000	0.182	0.074	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Brook stickleback	0.000	0.000	0.000	0.000	0.000	0.000	0.120	0.000	0.000	0.000	0.194	0.000	0.000	0.200	0.000	0.050	0.400
Smallmouth bass	0.000	0.046	0.053	0.000	0.143	0.050	0.320	0.000	0.091	0.074	0.065	0.000	0.000	0.050	0.059	0.000	0.000
Pumpkinseed	0.000	0.000	0.000	0.000	0.000	0.100	0.040	0.000	0.000	0.000	0.065	0.000	0.000	0.050	0.118	0.000	0.000
Bluegill	0.000	0.000	0.000	0.000	0.048	0.000	0.000	0.000	0.091	0.111	0.000	0.000	0.048	0.000	0.000	0.000	0.000
Largemouth bass	0.000	0.000	0.000	0.000	0.143	0.000	0.080	0.000	0.000	0.000	0.032	0.000	0.000	0.000	0.000	0.000	0.000
White perch	0.000	0.000	0.000	0.000	0.000	0.000	0.200	0.000	0.000	0.000	0.000	0.050	0.000	0.000	0.000	0.000	0.000
Northern pike	0.000	0.000	0.000	0.000	0.000	0.000	0.080	0.000	0.000	0.037	0.000	0.000	0.000	0.050	0.000	0.000	0.067
Mottled sculpin	0.000	0.000	0.000	0.000	0.048	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Bluntnose minnow	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.091	0.000	0.000	0.000	0.000	0.000	0.059	0.000	0.000
Eurasian ruffe	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.050	0.067
Black crappie	0.000	0.046	0.000	0.000	0.000	0.050	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Burbot	0.000	0.000	0.000	0.050	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Lake herring	0.000	0.000	0.000	0.000	0.000	0.050	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Brown bullhead	0.000	0.000	0.000	0.050	0.000	0.000	0.000	0.000	0.000	0.000	0.032	0.000	0.000	0.000	0.000	0.000	0.000
Golden redhorse	0.000	0.000	0.000	0.000	0.048	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ninespine stickleback	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Carp	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.037	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sauger	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.037	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Appendix 1b.–Catch per 10-minute trawl tow for species in Big Bay de Noc not included in Table 4. Species sorted by total abundance in collections.

Year	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Mimic shiner	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	8.095	0.000	0.000	0.000	0.000	0.000	0.000
Threespine stickleback	1.125	0.368	0.100	0.300	0.263	1.550	0.818	0.700	0.313	0.364	0.286	0.000	0.000	0.000	0.100	0.250	0.000
Lake whitefish	0.000	0.000	0.000	0.000	0.000	0.000	6.273	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Rock bass	0.000	0.105	0.050	0.000	0.000	0.000	0.091	0.050	0.063	0.364	0.000	0.000	0.046	0.857	0.950	0.000	0.467
White sucker	0.042	0.421	0.250	0.000	0.000	0.000	0.000	0.300	0.063	0.091	0.143	0.333	0.091	0.048	0.400	0.050	0.000
Ninespine stickleback	0.083	0.000	0.000	0.000	0.000	0.350	0.000	0.000	0.063	0.000	0.095	0.000	0.000	0.000	0.000	0.000	0.000
Bluegill	0.000	0.053	0.000	0.000	0.000	0.050	0.000	0.200	0.000	0.046	0.000	0.000	0.000	0.000	0.350	0.000	0.000
Alewife	0.208	0.053	0.050	0.000	0.000	0.050	0.046	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Unidentified fish	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.350	0.000	0.000
Pumpkinseed	0.000	0.000	0.000	0.000	0.000	0.000	0.046	0.000	0.000	0.000	0.000	0.000	0.000	0.143	0.100	0.000	0.000
Bluntnose minnow	0.000	0.158	0.050	0.000	0.000	0.000	0.000	0.000	0.063	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Carp	0.000	0.053	0.050	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.095	0.000	0.046	0.000	0.000	0.000	0.000
Brown bullhead	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.063	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.067
Walleye	0.000	0.000	0.000	0.000	0.053	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.050	0.000	0.000
Burbot	0.000	0.000	0.000	0.000	0.000	0.050	0.000	0.050	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Northern pike	0.000	0.000	0.050	0.000	0.000	0.050	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Eurasian ruffe	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.050	0.050	0.000
Black bullhead	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.048	0.000	0.000	0.000	0.000	0.000	0.000
Mottled sculpin	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.048	0.000	0.000	0.000	0.000	0.000
Sculpin spp.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.048	0.000	0.000	0.000	0.000	0.000	0.000
Iowa darter	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.046	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Appendix 2a.–Gill net catch per net night for species not included in Table 5. Species sorted by total abundance in Little Bay de Noc collections.

Year	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
White perch	0.000	0.050	0.000	0.188	0.000	0.188	0.375	0.313	0.250	0.000	0.250	0.389	0.563	0.125	0.000	0.000	0.000
Gizzard shad	0.100	0.100	0.143	0.000	0.000	0.000	0.063	0.063	0.125	0.125	0.063	0.000	0.063	0.125	0.188	0.063	0.000
Splake	0.000	0.000	0.000	0.000	0.000	0.438	0.125	0.063	0.125	0.063	0.000	0.056	0.063	0.000	0.000	0.000	0.000
White bass	0.000	0.000	0.571	0.000	0.000	0.000	0.000	0.063	0.000	0.000	0.250	0.000	0.000	0.000	0.000	0.000	0.000
Round goby	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.111	0.250	0.125	0.000	0.188	0.167
Redhorse spp.	0.000	0.050	0.095	0.000	0.000	0.000	0.000	0.000	0.063	0.000	0.000	0.000	0.000	0.000	0.000	0.063	0.000
Carp	0.000	0.000	0.000	0.000	0.000	0.000	0.063	0.000	0.000	0.000	0.063	0.000	0.063	0.000	0.000	0.125	0.083
Brown bullhead	0.050	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.063	0.000	0.000	0.000	0.000	0.000	0.000
Golden redhorse	0.100	0.000	0.095	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.056	0.063	0.000	0.000	0.000	0.000
Chinook salmon	0.050	0.050	0.000	0.000	0.000	0.063	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sauger	0.000	0.000	0.143	0.000	0.000	0.000	0.000	0.000	0.063	0.063	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Brown trout	0.000	0.000	0.000	0.000	0.000	0.063	0.000	0.063	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Eurasian ruffe	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.125	0.083
Shorthead redhorse	0.000	0.000	0.048	0.000	0.063	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.083
Pumpkinseed	0.000	0.000	0.190	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Common shiner	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.188	0.000	0.000	0.000	0.000	0.000	0.000
Logperch	0.000	0.000	0.000	0.000	0.000	0.000	0.188	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Freshwater drum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.063	0.125	0.000
Burbot	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.063	0.063	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Rainbow smelt	0.000	0.050	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.063	0.000	0.000	0.000	0.000	0.000	0.000
Silver redhorse	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.063	0.000	0.000
Largemouth bass	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.063	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Brook stickleback	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.063	0.000	0.000	0.000	0.000	0.000	0.000
Brook trout	0.000	0.000	0.000	0.000	0.063	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Channel catfish	0.000	0.000	0.048	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Appendix 2b.–Gill net catch per net night for species not included in Table 6. Species sorted by total abundance in Big Bay de Noc collections.

Year	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Rainbow smelt	0.222	0.100	0.000	0.000	0.000	0.063	0.000	0.000	0.000	2.313	0.000	0.000	0.000	0.000	0.000	0.000	0.000
White perch	0.111	0.000	0.000	0.000	0.000	0.000	0.000	0.625	0.063	0.000	0.375	0.250	0.438	0.188	0.000	0.000	0.000
Carp	0.000	0.150	0.000	0.000	0.000	0.063	0.125	0.063	0.063	0.000	0.063	0.125	0.063	0.063	0.188	0.063	0.083
Brown bullhead	0.000	0.050	0.000	0.063	0.000	0.125	0.000	0.250	0.063	0.000	0.063	0.000	0.063	0.000	0.000	0.063	0.083
Rock bass	0.000	0.000	0.000	0.000	0.000	0.063	0.000	0.000	0.000	0.063	0.063	0.125	0.000	0.063	0.000	0.063	0.000
Gizzard shad	0.000	0.000	0.000	0.000	0.000	0.000	0.125	0.000	0.063	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.083
Freshwater drum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.063	0.000	0.000	0.000	0.063	0.000	0.167
Longnose gar	0.000	0.050	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.083
Black bullhead	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.250	0.000	0.000	0.000	0.000	0.000
Longnose sucker	0.000	0.000	0.000	0.000	0.063	0.188	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Common shiner	0.000	0.150	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.063	0.000	0.000	0.000	0.000	0.000
Pumpkinseed	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.063	0.000	0.000	0.000	0.000	0.063	0.000	0.000
Redhorse spp.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.125	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Burbot	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.063	0.000	0.000	0.000	0.000	0.000
Chinook salmon	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.063	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Lake whitefish	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.063	0.000	0.000
Splake	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.063	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Round goby	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.063	0.000	0.000
Coho salmon	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.063	0.000	0.000	0.000	0.000	0.000
Round whitefish	0.000	0.050	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Appendix 3.–Walleye and yellow perch harvest and nontargeted effort for the ice fishery of northern Green Bay. Creel estimates for the 1988 and 1989 ice fishery at Big Bay de Noc were: yellow perch harvest—60,677 and 11,541; walleye harvest—0 and 0; effort—32,619 and 13,357 hours.

	Lake Michigan at Menominee			Menominee River			Little Bay de Noc		
Year	Walleye	Yellow perch	Effort (hrs)	Walleye	Yellow perch	Effort (hrs)	Walleye	Yellow perch	Effort (hrs)
1988							7,747	65,290	133,107
1989							6,062	87,083	182,963
1990							9,448	176,068	195,210
1991							5,225	215,532	221,355
1992							4,635	249,804	257,559
1993							5,275	36,902	256,842
1994	16	36,228	45,656	272	29	1,658	2,703	28,711	156,394
1995	0	1,086	4,226	280	99	7,144	6,611	30,464	129,064
1996	107	30,527	43,292	156	36	6,261	3,908	33,543	121,690
1997									
1998	28	517	3,138	292	0	10,876	1,156	94,263	90,409
1999	25	2,354	14,431	278	0	7,367	3,041	103,405	203,341
2000	812	376	17,108	561	88	14,572	1,151	107,688	256,218
2001	0	7,886	18,586	19	44	7,368	2,507	71,019	249,431
2002				5	0	3,222	2,087	58,094	136,738
2003	0	221	4,373	93	0	5,402	1,396	66,352	174,867
2004	0	0	455	0	0	3,412	1,627	42,304	166,480
2005							1,307	31,853	125,675
2006	0	18	92	133	683	6,132	477	103,265	122,810
Averages									
1988–93							6,399	138,447	207,839
1994–99	35	14,142	22,149	256	33	6,661	3,484	58,077	140,180
2000–05	203	2,121	10,131	136	26	6,795	1,679	62,885	184,902
1988–2005	110	8,799	16,807	196	30	6,728	3,876	88,140	179,844

Appendix 4.–Open water harvest of walleye from creel census sites in northern Green Bay.

Year	Lake Michigan at Menominee	Menominee River	Stony Point	Lake Michigan at Cedar River	Cedar River	Little Bay de Noc	Big Bay de Noc	All locations
1988	35			0		12,534	1,168	13,737
1989	192			0		30,483	5,292	35,967
1990						31,017	2,408	33,425
1991						41,405	3,013	44,418
1992						17,704	906	18,610
1993	1,034	8,799	0	0	152	17,031	1,746	28,762
1994	108							108
1995	433	9,154	34	38	189	67,297	5,518	82,663
1996	107	11,685	0	35	399	56,270	1,960	70,456
1997	887	37,322	0	0	233	22,535	2,976	63,954
1998	1,384	26,503	0	6	658	19,769	4,245	52,566
1999	1,746	21,859	0	103	147	20,548	1,432	45,834
2000	1,560	8,477		954	23	30,769	902	42,686
2001	10,432	32,358	0	1,705	253	37,952	720	83,420
2002	3,456	11,681	0	3,353	101	35,958	1,657	56,207
2003	3,373	8,787	0	687	245	15,088	1,212	29,390
2004						33,436	704	34,140
2005						13,109	289	13,398
2006	5,856	14,348	100	272	4	11,164	1,064	32,807
Averages								
1988–93	420	8,799	0	0	152	25,029	2,422	29,153
1994–99	778	21,305	7	36	325	37,284	3,226	52,597
2000–05	4,705	15,326	0	1,675	156	27,719	914	43,207
1988–2005	1,904	17,663	4	573	240	29,583	2,126	41,652

Appendix 5.–Open water harvest of yellow perch from creel census sites in northern Green Bay.

Year	Lake Michigan at Menominee	Menominee River	Stony Point	Lake Michigan at Cedar River	Cedar River	Little Bay de Noc	Big Bay de Noc	All locations
1988	34,634			14,470		60,504	87,719	197,327
1989	27,104			7,998		95,468	61,809	192,379
1990						112,798	69,439	182,237
1991						191,480	143,214	334,694
1992						90,500	32,499	122,999
1993	13,481	3,913	7,708	16,552	199	17,872	12,371	72,096
1994	2,889							2,889
1995	15,131	480	22,693	8,465	94	54,794	24,087	125,744
1996	56,741	108	27,737	34,159	84	111,604	29,463	259,896
1997	5,932	1,460	556	3,188	98	25,856	6,521	43,612
1998	6,986	1,081	0	1,789	0	20,776	2,532	33,164
1999	7,102	940	2,542	6,948	27	30,540	5,260	53,361
2000	3,073	1,135		223	15	35,184	153	39,783
2001	9,172	441	0	269	0	16,962	186	27,031
2002	2,952	0	0	9	11	14,531	242	17,746
2003	1,506	0	0	7	0	6,922	22	8,457
2004						10,271	125	10,396
2005						19,537	10,904	30,441
2006	15,628	39	0	0	0	23,356	2,796	41,819
Averages								
1988–93	25,073	3,913	7,708	13,007	199	94,770	67,842	183,622
1994–99	15,797	814	10,706	10,910	61	48,714	13,573	86,444
2000–05	4,176	394	0	127	7	17,234	1,939	22,309
1988–2005	14,362	956	6,804	7,840	53	53,859	28,620	97,458

Appendix 6.–Hours of nontargeted sportfishing effort during open-water season at creel census sites in northern Green Bay.

Year	Lake Michigan at Menominee	Menominee River	Stony Point	Lake Michigan at Cedar River	Cedar River	Little Bay de Noc	Big Bay de Noc	All locations
1988	84,298			69,038		164,094	62,678	380,108
1989	53,780			59,389		215,969	71,374	400,512
1990						315,781	72,112	387,893
1991						377,620	154,782	532,402
1992						243,172	64,254	307,426
1993	109,789	118,324	11,822	36,634	10,988	254,097	63,716	605,370
1994	64,893							64,893
1995	45,492	105,393	15,891	31,555	20,815	348,890	72,834	640,870
1996	92,116	114,629	22,022	34,752	26,855	241,015	46,615	578,004
1997	88,282	140,957	10,960	34,368	22,589	263,290	58,085	618,531
1998	77,716	146,185	10,598	32,442	20,198	271,696	57,219	616,053
1999	80,386	125,345	4,056	23,796	18,146	208,252	38,072	498,052
2000	98,215	98,593		16,973	11,900	287,854	18,548	532,082
2001	93,301	123,696	1,690	28,504	14,306	218,940	25,866	506,303
2002	87,529	75,676	2,939	30,538	13,213	286,013	36,998	532,905
2003	91,292	93,086	537	23,769	10,567	230,104	37,215	486,571
2004						292,169	28,244	320,413
2005						176,356	30,773	207,130
2006	119,870	93,566	4,702	48,071	11,906	150,718	29,643	458,476
Averages								
1988–93	82,622	118,324			10,988	261,789	81,486	435,619
1994–99	74,814	126,502	12,705	31,382	21,721	266,628	54,565	502,734
2000–05	92,584	97,763	1,722	24,946	12,496	248,573	29,607	430,901
1988–2005	82,084	114,188	8,946	35,147	16,958	258,548	55,258	456,418